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-: HAND WRITTEN NOTES:-

OF

CIVIL ENGINEERING

(1)

-: SUBJECT:-

ENVIRONMENTAL

ENGINEERING

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(2)

Environment :- The environment consists of atmosphere, hydrosphere, lithosphere in which sustainable resources of the earth are contained.

The light ^{sustaining} resources of the earth are contained.

Atmosphere contains gaseous composition, hydrosphere contains water composition and lithosphere contains solid composition.

(3)

Ecology is the relationship b/w living organisms with their surrounding environment. The ecological balance is required for sustainable development.

The role of environmental engineer is to design, construct and operating treatment facilities for water, air, solid waste.

- Steps in design of water supply scheme for a town

- (i) Assessment of future population during design period and assessment of total water demand.
- (ii) To search for the source of water supply.
- (iii) To study water quality parameter.
- (iv) Design of water treatment units.
- (v) Design of water carriage system.
- (vi) Design of distribution reservoir and distribution network.

① Water Demand and Population Forecasting :-

The total water demand consists of following 6 component

- Domestic water demand - According to manual of water supply of Govt of India it should be b/w 135 lpcd to 225 lpcd. Which is nearly 50 to 60% of total water demand. It is generally taken as 135 lpcd for low income group and 200 lpcd for high income group.
- Industrial water demand :- It is generally taken as 50 lpcd however it depends upon type of industry and number of industrial units in the city.

Type of industry ④

Sugar "

Water demand

1 to 2 KL per tonne of crushed sugarcane

80 to 200 KL/Ton of sugar

200 to 1000 KL/Ton of sugar
40 to 50 KL/vehicle

40 to 50 KL/Ton of leather

1 to 2 KL/Tonne of crude oil

Fertilizer "

Pulp and paper (max 1000)

Automobile "

Leather

Petroleum refining

- Institutional and commercial water demand :- On an average ~~200~~²⁰ lpcd is considered sufficient but in highly commercial cities it is as high as 50 lpcd.

Commercial unit

Water demand

45 lpcd

45 to 135 lpcd

180 lpcd

350 to 450 lpcd

15 lpcd

Office

School

Hotel

Hospitals

Cinemas/Halls

- iv) Demand for public uses: It includes maintenance of parks, gardens, roads etc. This demand is 5% of total demand.
- (v) Fire demand: This quantity is very small for big city. For population more than 50 lakh fire demands may be less than 1/lpcd but at the time of breakout of fire this water should be available suddenly.
- Guidelines for the fire demand
 - (i) The minimum water pressure available at the fire hydrant should be 1 to 1.5 kg/cm² and must be maintained for 4 to 5 hrs. (R)
 - (ii) 3 jets should be thrown simultaneously: one on burning body and 2 on adjacent bodies.
 - (iii) Discharge of each stream should be about 1100 ltr/min per minute.
 - (iv) No. of fire jets required depend on the size of population and is given by $F = 2.8NP$
 $P \rightarrow$ Population in thousands.
 If population is 40,000 then $P = 40$
 - (v) The rate of water demand for fire depends on population and can be computed using following empirical formula

① Kuichling formula $Q = 3182\sqrt{P}$

$P =$ in thousands.

$P = 5000$ then $P = 5$

$Q = 1136 \text{ ltr/min}$

Freeman Formula $Q = 1136 \left(\frac{P}{10} + 10 \right)$

$Q = 1136 \text{ ltr/min}$ $P = \text{thousand}$

National board formula

(American insurance Association formula)

(a) For high valued commercial cities population $< 2\text{ lakh}$

$$Q = 4637 \sqrt{P} (1 - 0.01 \sqrt{P})$$

(b) For high valued commercial cities population $> 2\text{ lakh}$

$$Q = 54600 \text{ l/min. and extra provision second and third fire.}$$

For residential cities

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Small buildings. $Q = 2200 \text{ ltr/min}$

High buildings. $Q = 4500 \text{ ltr/min}$

High valued apartments = $Q = 7650 \text{ ltr/min}$

- Boston Formula $Q = 5663 \sqrt{P}$

(c) Water Demand For losses and theft

On an average 15% of total demand may be provided for losses and theft which is nearly 55 lpcd.

Total max^m water demand It is the sum of above 6 demands. and IS code permits for India total max^m demand of 335 lpcd.

Domestic Demand : 200 lpcd

Industrial " 50 lpcd

Commercial " 20 lpcd

Public " 10 lpcd

Waste & theft " 55 lpcd

Fire < 1 "

Total $\approx 335 \text{ lpcd}$

Note: → The total water demand depends on size of population and for the design of water supply scheme for a given population size following guidelines may be adopted.

| Size of Population | Total water demand |
|-----------------------|--------------------|
| < 50,000 | 110 to 150 lpcd |
| 50,000 to 2,00,000 | 150 to 240 lpcd |
| 2,00,000 to 10,00,000 | 240 to 300 lpcd |
| > 10,00,000 | 300 to 335 lpcd |

(7)

Factors affecting water demand :-

- (i) Size of population → (ii) Climatic conditions
- (iii) For industrial and commercial activities
- (iv) Habits of people.
- (v) Quality of water supply.
- (vi) Pressure available in distribution system
- (vii) Development of sewage facilities.
- (viii) Cost of water

Variation in water demand:-

Smaller towns have more variation

- (i) Max^m monthly consumption → 1.28 times ~~the~~ average monthly consumption
 - (ii) Max^m weekly consumption → 1.48 times average weekly.
 - (iii) Max^m daily consumption → 1.8 time average daily comp.
 - (iv) Max^m hourly consumption peak demand → 2.7 time of average hourly consumption
- It is also equal to 1.5 times max^m daily hourly consumption.

Goodrich formula to compute \max^m / peak demand

$$P = 1.8 (t)^{-0.1}$$

$$P = \frac{\text{max}^m \text{ demand}}{\text{Avg demand}} \quad \textcircled{8}$$

t = time in days

t = 1 for max^m daily

$t = \frac{1}{24}$ for max^m hourly

"GRII manual of water supply recommended peak factor b/w 2.5 to 3.0 depending upon population size".

"Coincident Draft" It is the max^m of

① Max^m daily demand & fire demand

② Max^m hourly demand. —

Design periods of water supply unit →

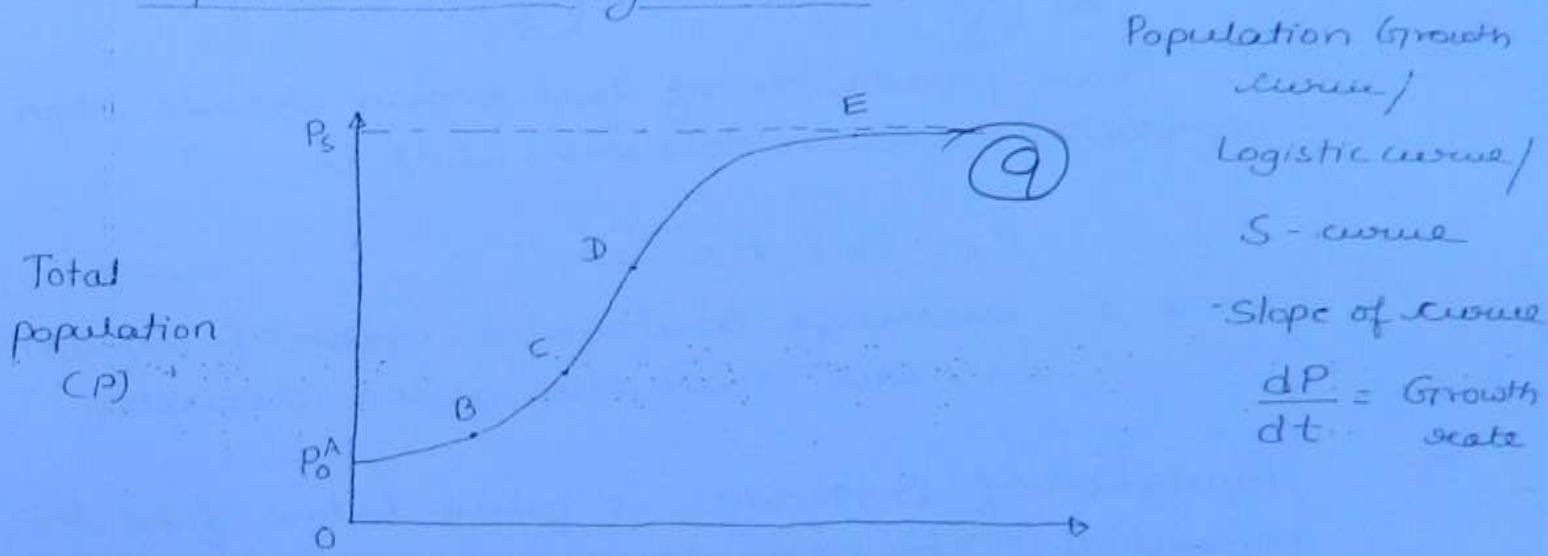
| Water treatment unit | Design Discharge | Design period |
|-----------------------------------|--|---------------|
| Dams and reservoirs | Average annual demand | 50 yrs |
| Wells and tube wells | Max ^m daily demand | 30-50 yrs |
| Main supply pipes (water main) | " | 30 yrs |
| Water treatment units | " | 15 yrs |
| Overhead tank, service reservoir | To care of hourly fluctuation, fire demand, Breakdown storage. | |

Distribution networks

Peck demand/
Max^m hourly demand

30 yrs.

Population Forecasting methods :-



Time / Decade →

In AB → $\frac{dP}{dt} \propto P$ → increasing growth rate

in BCD → $\frac{dP}{dt} = \text{const}$ → High growth rate

in DE → $\frac{dP}{dt} \propto (P_s - P)$ → Decreasing Growth rate.
 P_s = saturation value.

Methods of population forecasting

- (i) Arithmetic increase method
- (ii) Geometric increase method
- (iii) Incremental increase method
- (iv) Decreasing rate of growth method
- (v) Graphical extension method
- (vi) Graphical comparison method
- (vii) Zoning or master plan method
- (viii) Ratio or co-relation method
- (ix) Logistic curve method or Verhulst method

① Arithmetic increase method \Rightarrow This method assumed that population increases at a constant rate.

$$\frac{dP}{dt} = \text{constant} \quad (16)$$

If P_0 is population of last known decade then population after n decades will be

$$P_n = P_0 + n\bar{x}$$

where \bar{x} = average arithmetic mean of population increase over the given decades.

Ex. Population of 5 decades is given below find the population in the year 2040 using arithmetic increase method.

| Year | Population | Increase in population x |
|----------------------|------------|--------------------------------------|
| 1970 | 25,000 | - |
| 1980 | 28,000 | 3,000 |
| 1990 | 31,000 | 3,000 |
| 2000 | 42,000 | 8,000 |
| 2010 2010 | 47,000 | 5,000 |
| | | $\bar{x} = \frac{22,000}{4} = 5,500$ |

$$P_{2040} = P_0 + n\bar{x}$$

$$= 47,000 + 3 \times 5,500$$

$$P_{2040} = 63,500$$

② Geometric Increase method / Uniform increase method
Compounding rate method

Geometric Increase method

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But since geometric average is always less than arithmetic average hence for all practical approach conservative approach

Example Population of 5 decades of a town is given in the table using geometric increase method find population in year 2040.

| Year | Pop ⁿ | % Growth rate |
|------|------------------|---------------|
| 1970 | 25,000 | 12% |
| 1980 | 28,000 | 21.43% |
| 1990 | 34,000 | 23.53% |
| 2000 | 42,000 | 11.90% |
| 2010 | 47,000 | |

$$g = (g_1, g_2, g_3, g_4)^{\frac{1}{4}}$$

$$= (12 \times 21.43 \times 23.53 \times 11.90)^{\frac{1}{4}}$$

$$= 16.38\%$$

$$P_n = P_0 \left[1 + \frac{g}{100} \right]^n$$

$$P_{2040} = 47,000 \left[1 + \frac{16.38}{100} \right]^3 \quad (D)$$

$$P_{2040} = 74,1087$$

(3) Incremental increase method

This is also called method of varying increment. This method combines both arithmetic and geometric average method and this method is used when growth is not constant.

Population after n decades as given as:-

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$$

where \bar{x} = Average increase in population of known decades.

\bar{y} = Average of incremental increase of the known decades.

Note:- Geometric increase method gives high results which is suitable for cities growing with fast rate such as new cities whereas arithmetic increase method gives low result which is suitable for cities growing with slow rate such as old cities however incremental increase method gives moderate results which can be used for new and old cities both.

x. Find the population in the year 2040 using incremental increase method.

| Year | Pop ⁿ | Increase | Incremental Increase |
|------|------------------|------------------------------|----------------------------|
| 1970 | 25,000 | | |
| 1980 | 28,000 | 3000 | (13) |
| 1990 | 34,000 | 6000 | 3000 |
| 2000 | 42,000 | 8000 | -3000 |
| 2010 | 49,000 | 5000 | |
| | | $\bar{x} = \frac{22,000}{4}$ | $\bar{x} = \frac{2000}{3}$ |
| | | = 5,500 | |

$$P_0 = 47,000 + 3 \times 5,500 + \frac{3(3+1)}{2} \times \frac{2000}{3}$$

$$P_{2040} = 67,500$$

The results of this method are moderate b/w arithmetic average method and geometric average method.

(i) Decreasing Growth rate method:

If population is reaching towards saturation and growth rate is decreasing then this method is suitable. In this method average decrease in the % increase is calculated and then subtracted from the last % increase computation are made for each successive year.

- (i) Find % increase in population for each decade
- (ii) and workout decrease in % increase in each decade and find average % decrease say r' .
- (iii) The population of next decade from the last known decade is given as

$$P_t = P_0 + \left(\frac{r_0 - r'}{100} \right) P_0$$

where P_0 = Population of last known decade.

R_0 = Growth rate of last decade

α' = Average decrease in growth rate.

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Population after 2 decades from the last known decade is given as

$$P_2 = P_1 + \frac{(R_0 - 2\alpha')}{100} P_1$$

Example The census record of a particular town is shown in table. Estimate the population for the year 2020 by decreasing growth rate method.

| Year | Population | % increase ^(*) | Decrease in % G.R. |
|------|------------|---------------------------|--------------------|
| 1960 | 55,500 | | |
| 1970 | 63,700 | 14.77% | |
| 1980 | 71,300 | 11.93% | - 2.84% |
| 1990 | 79,500 | 11.50% | - 0.43% |

R_0 = G.R. of last known census = 11.50%.

α' = Avg. decrease in G.R. = $\frac{2.84 + 0.43}{2} = 1.635\%$

$$P_{2020} = P_{1990} + \left(\frac{R_0 - 3\alpha'}{100} \right) P_{1990}$$

$$P_1 = P_{1990} = 79,500 + \left(\frac{11.5 - 1.635}{100} \right) \times 79500$$

$$P_{1990} = 87,343$$

$$P_{2020} = 87,343 + \left(\frac{11.5 - 2 \times 1.635}{100} \right) \times 87343$$

$$P_{2020} = 94531$$

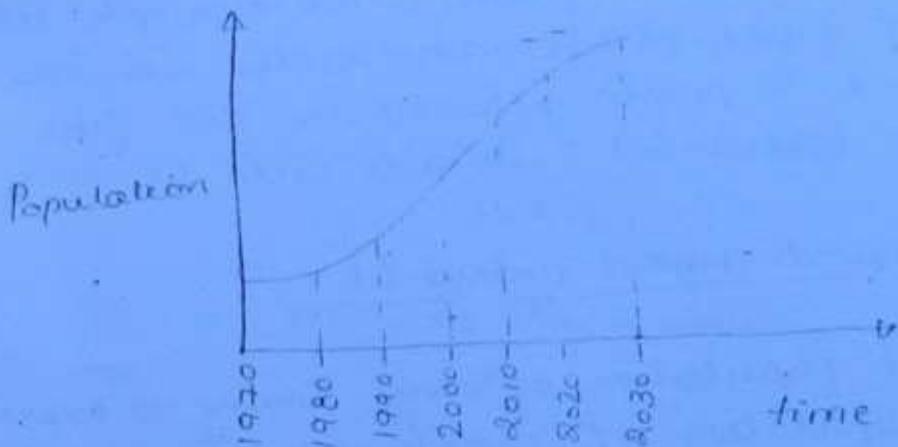
$$P_{2030} = 94531 + \left(\frac{11.5 - 3 \times 1.635}{100} \right) \times 94531$$

$$P_{2030} = 1,00,165 \text{ Ans.}$$

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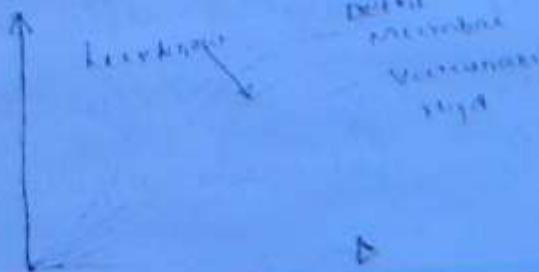
- ⑤ Graphical extension method or simple graphical method :-

A graph is plotted b/w population and time for available data and the curve is smoothly extended for the desired year. For example let population is desired in the year 2030 and let population data are known for the last 50 years 1970 - 2010.



This method is suitable when past record is available for long duration and extension is required for small duration.

- ⑥ Comparison: Graphical method :-
Cities of similar condition and characteristics are selected which have grown in similar fashion in the past and their graphs are plotted. The mean graph from available data may be used for required city.



here let required population of Lucknow for year 2040. Growth of Lucknow is from 2010 to 2030 will be similar to i.e. which is avg. of growth of

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① Delhi - 1940 to 1970

Mumbai - 1930 to 1960

Varanasi - 1980 to 2010

Hyd. - 1970 to 2000

④ Master plan or Zoning method :-

Generally in metropolitan cities growth is controlled by development authorities in a planned manner only those extension are allowed which are proposed in master plan. For example let n = number of flats will be constructed in next 1 decade and 4 people allowed in one flat then population added in 2 decades will be 16n.

⑤ Ratio or apportionment method :-

In this method population of any town is expressed as a % of population of whole country and by taking the average growth rate of country population may be projected.

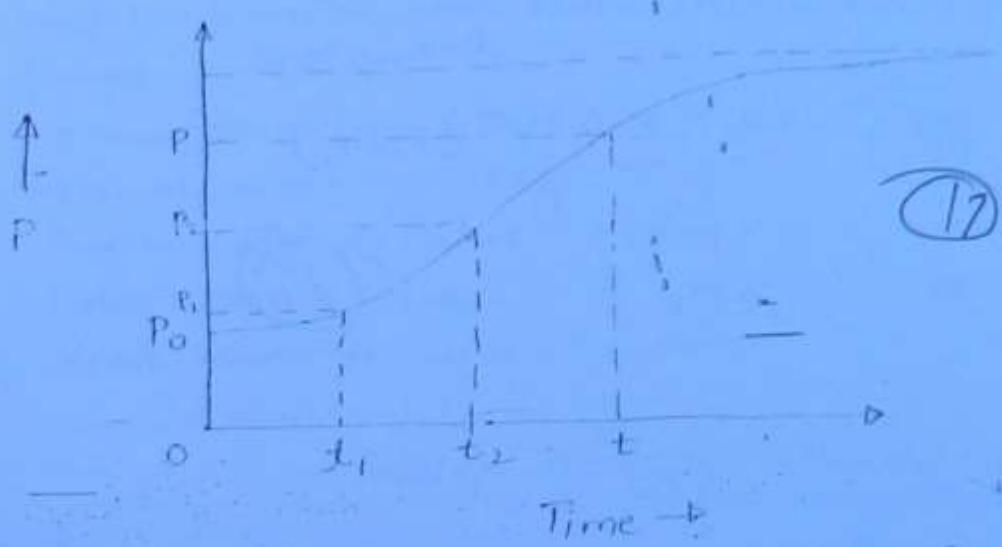
⑥ Logistic Curve method or Verhulst's method :-

Let P_0 Population at the beginning of census record.

P_t Population after time t , years.

P_s Population after time t_s years

P_s Saturation population



Then population after any time from the start is given as

$$P = \frac{P_S}{1 + m \log_e^{-1} (n t)}$$

$$P_S = \frac{2 P_0 P_1 P_2 - P_1^2 (P_0 + P_2)}{P_0 + P_2 - P_1}$$

$$m = \frac{P_S - P_0}{P_0} = \text{const}$$

$$n = \frac{1}{t_1} \log_e \left[\frac{P_0 (P_S - P_1)}{P_1 (P_S - P_0)} \right]$$

Example 2: In two periods of each 20 years a city has grown from 30,000 to 1,70,000 and then to 3,00,000. Determine

- (i) Saturation population
- (ii) Equation of Logistic curve
- (iii) Population after 60 years from the start

$$P_0 = 30,000$$

$$P_2 = 3,00,000$$

$$P_1 = 1,70,000$$

$$t_1 = 30 \text{ years}$$

$$t_2 = 40 \text{ years}$$

$$t = 60 \text{ years}$$

$$\textcircled{1} \quad P_S = \frac{2P_0 P_1 P_2 - P_1^2 (P_0 + P_2)}{P_0 P_2 - P_1^2}$$

$$P_S = 3,26,000$$

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$$\textcircled{2} \quad m = \frac{P_S - P_0}{P_0}$$

$$= \frac{3,26,000 - 30,000}{30,000} = 9.87$$

$$n = \frac{1}{30} \log_e \left[\frac{30,000 (3,26,000 - 1,70,000)}{1,70,000 (3,26,000 - 30,000)} \right]$$

$$= 0.119$$

$$P = \frac{3,26,000}{1 + 9.87 \log_e^{-1} (-0.119 t)}$$

$$\textcircled{3} \quad \text{If } t = 60 \text{ years}$$

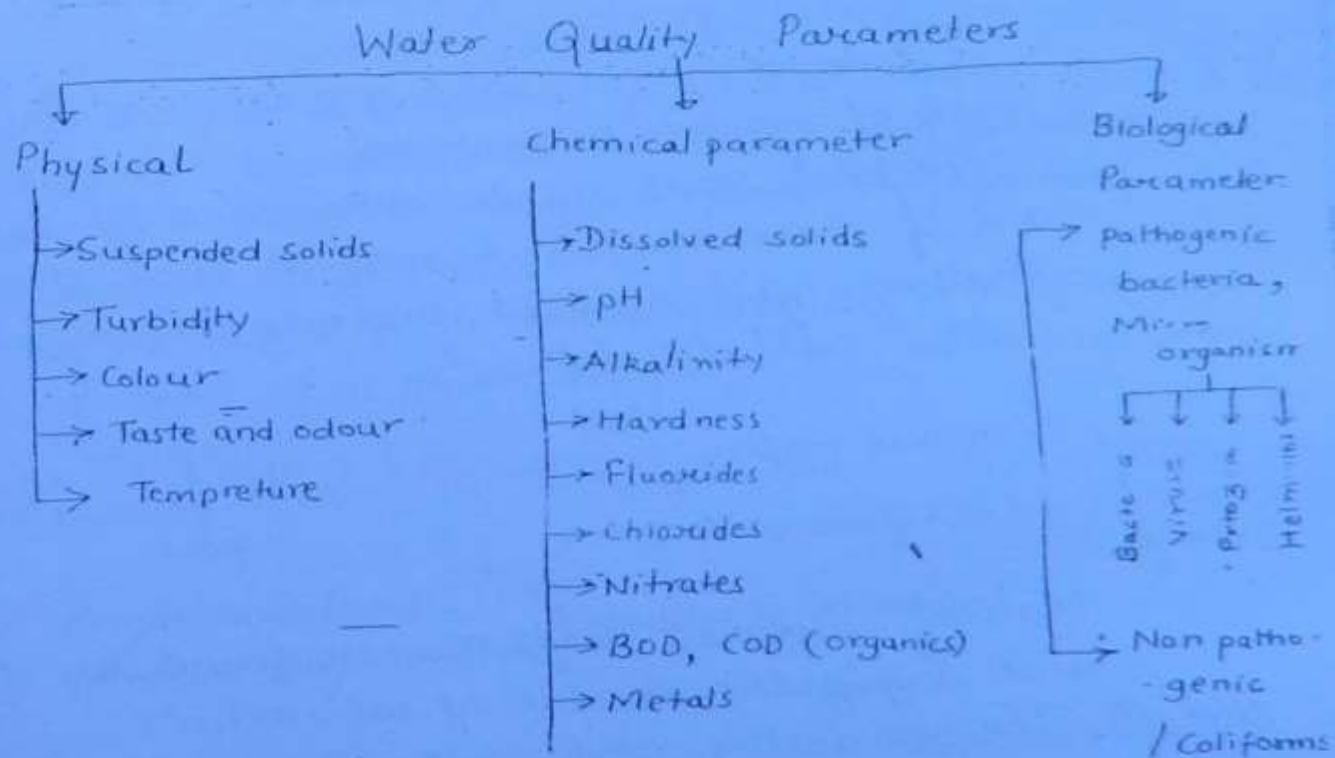
$$P = \frac{3,26,000}{1 + 9.87 \log_e^{-1} (-0.119 \times 60)}$$

$$P = 3,23,000$$

Water sources and their distribution in earth surface

- (i) Oceans - 97.3%
- (ii) Ice and Glaciers - 2.14%
- (iii) Ground water - 0.61%
- (iv) Fresh water in Lakes - 0.007%
- (v) Saline water in lakes - 0.008%
- (vi) Fresh water in river - 0.0001%

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① Physical parameters

Suspended solids Total solids may be present in the form of

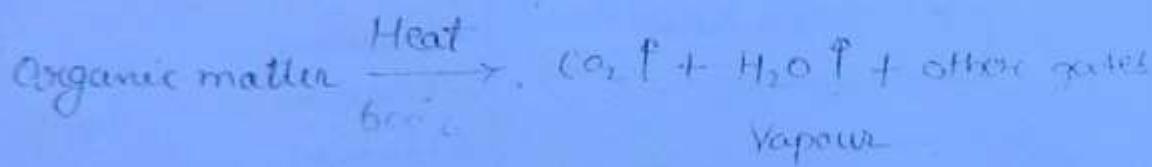
- (i) Suspended solids - 10^{-1} to 10^{-3} mm size
- (ii) Colloidal solids - 10^{-3} to 10^{-6} mm size
- (iii) Dissolved solids - $< 10^{-6}$ mm size

Suspended } — Dispersed solids
Colloidal }

- * Suspended solids may consist of inorganic and organic content like silts, clays, immisible liquids like oil and greases, plant fibers and algae etc.
- * These are undesirable because (20)
 - (i) These make water aesthetically displeasing
 - (ii) They are biologically active may cause of growth of disease producing micro-organism
 - (iii) These may attract or absorb chemical and biological agents.

Measurement is done by gravimetric test involving mass of residues measurement.

The total solids can be determined by evaporation, and if dried mass is burned at 600°C . then organic matters will oxidised and only inorganic matter will be left.



Mass of suspended solids can be found by filtration, and drying the residue at 105° to 110°C .

Note - ① The permissible total solids (Dissolved + suspended).
 $\leq 500 \text{ ppm (mg/L)}$ for drinking water

and in no case it should be greater $> 2000 \text{ ppm}$.

② Permissible limit of suspended solid is 30 mg/L for drinking water according to environmental protection agency EEA.

(2) Turbidity → Turbidity is measure of the extent to which light is either absorbed or scattered by suspended material in water. It is not direct measure of quantity of suspended solids. Mostly turbidity is due to colloidal materials like clay, silts, rock fragments, metal oxides, vegetation fibres and microorganisms.

(2) Due to presence of turbidity there is interference in light penetration which affects photo synthesis. And disinfection of turbid water is difficult because suspended solids may partially seal site sealed the organims from disinfection.

Measurement of turbidity

It is measured photochromatically by determining the % of light of a given intensity i.e. either absorbed or scattered

Measuring Devices (i) Turbidity Rod

(ii) Jackson Turbidity Rector } from principle

(iii) Baylis turbidometer } scattering principle.

(iv) Modern Nephelometer

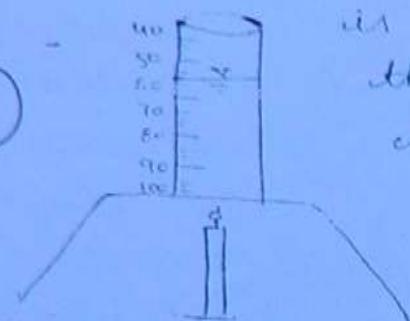
(i) Turbidity rod: Turbidity rod with platinum needle is inserted inside the water and the depth at which platinum needle just becomes invisible gives the turbidity in mg/ltr. or ppm.

* The turbidity is expressed in standard unit called TTU. (Jackson turbidity unit) which is based absorption principle.

* One TTU is equivalent to turbidity produced by 1 mg of fine silica (SiO_2) dissolved in one ltr of distilled water.

(2r) Jackson Turbidimeter - A burning candle is placed below a Jackson turbidimeter and turbidity is determined by measuring the depth of water when decapping candle is just invisible from the top.

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Longer the visibility lesser is the turbidity.

Turbidity of 25 FTU or more is detectable by this device.

(22) 10.8 cm path is equivalent to 200 FTU and 25 20.5 cm path is equivalent to 100 FTU.

Baylis Turbidimeter and Nephrometer - These are based on colour matching technique i.e. on scattering principle in this method small turbidity less than 1 unit can also be measured. Hence can be used for domestic water supply.

Since it is based on scattering principle hence turbidity caused by dark substances which absorb light rather than reflect should be measured by absorption technique.

In this method standard unit is FTU or NTU (Formazin turbidity unit).

1 FTU = Turbidity produced by 1 mg of formazine polymer dissolved in one ltr of distilled water.

Note for drinking water permissible limit of turbidity is 5 to 10 FTU but it should be as less as 1 FTU.

T_{ON} is computed for cold water because change in temperature may change odour.

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③ Temperature :- Temperature affected chemical and biological activities if temperature increases by 10° biological activities are doubled desirable temp for drinking water is 10°C and in no case should be more than 25°C.

By increasing temp solubility of dissolved gases decreases. At 20°C DO (Dissolved oxygen) in water is nearly 9.2 mg/ltr. If DO falls below 4 mg/ltr then water species may die such as fishes, crabs, lobsters.

Thermal shock :- If hot water powerplants and automobile industry effluent from discharged in natural streams then due to rise of temp DO may fall below 4 ppm which may lead in death of water species such an stage is called thermal shock.

CHEMICAL WATER Quality Parameters

Total Dissolved Solids

④ Dissolved Solids :- Dissolved substances may be organic or inorganic. Inorganic may be minerals, inorganic gases

where as organic may be plant fibers, organic gases, organic chemicals

TDS are often determined by measuring electrical conductivity of water using ohionic water tester.

- The ability of water to conduct electricity.

③ Colour :- Colour is due to either suspended matter or dissolved matters. Colour caused by suspended matter is called apparent colour which can be removed by filtration. Whereas colour caused by dissolved solid is called true colour which is due to dissolved mineral, metals and gases. Measurement of Colour :- It is done by colour matching techniques. True colour is measured on Burgess scale by Nessler's tube. 24

The standard unit of colour is TCU (true colour unit) 1TCU is equivalent to colour produced by 1 mg of platinum cobalt in the form of chloro platinic ions mixed in one ml of distilled water. (It gives yellowish brown colour).

Note - The colour testing must be done within 72 hrs of collection of sample otherwise biological activity may alter the colour.

The permissible limit of colour for drinking water is 5 ppm and in no case > 20 ppm.

④ Taste and odour :- Odour and taste are expressed by threshold odour number it represents dilution ratio at which odour can not be detected. TON cannot be less than one.

$$TON = \frac{A+B}{A} = \frac{\text{Vol. of diluted sample}}{\text{Vol. of undiluted sample}}$$

A = Volume of water sample undiluted

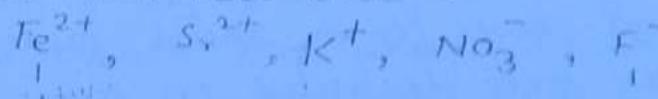
B = Volume of distilled water required to be added to remove the odour.

The permissible limit for drinking water is 1 TON and in no case it should be more than 1.

is known as specific conductance which is known as ionic strength of water which can be used by measure Stone bridge method.

Major sources of TDS in water are Na^+ , Ca^{2+} , Mg^{2+} , HCO_3^- , SO_4^{2-} , Cl^- .

Minor sources are



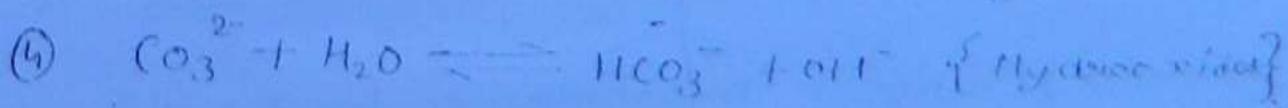
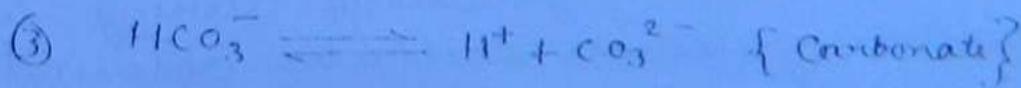
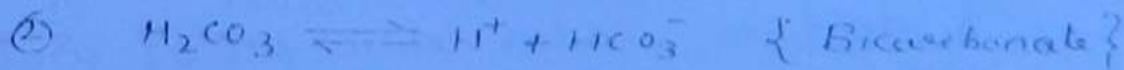
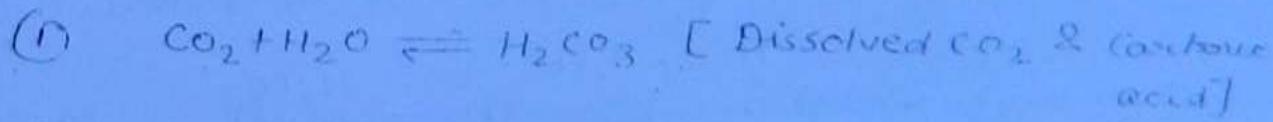
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Alkalinity :- It is defined as the quantity of ions in water that will react to neutralise hydrogen ion. It means it's ability of water to neutralise acids.

Major compound causing alkalinity are CO_3^{2-} , HCO_3^- , OH^-
bicarbonate caustic alkalinity carbonate

Minor compounds are HSO_3^- , H_2BO_3^- , HPO_4^{2-} , H_2PO_4^- & HS^-

For purpose of computation alkalinity caused by minor compound is neglected. The alkalinity in water comes due to minerals or due to atmospheric CO_2 mixed in water or due to microbial decomposition of organic compound.



The fourth reaction is a weak reaction but if algae present in water then reaction may take place.

Due to consumption of carbonate. Alage may produce OH^- ion which may cause high pH 9 to 10.

If pH is found less than 9 than usually OH^- may not present. (26)

The cation (Ca_2^+) may combine alkalinity of water and may form solid precipitate of CaCO_3 which may get deposited on pipe surface and may cause encrustation in pipe.

(Tuberculation)

Note 2* If water is acidic then there will be corrosion action. Aq.

Measurement of Alkalinity

Measurement is done by titration of water with an acid. The alkalinity is expressed in mg/l as CaCO_3 . If 0.02 N H_2SO_4 is used as titrant then 1 ml of acid will neutralise 1 mg of alkalinity expressed as CaCO_3 .



If acid is added then pH of water falls and pH is recorded gradually during titration then following curve will be obtained.



The affinity of OH^- ions to react with H^+ ion is maximum followed by affinity of CO_3^{2-} and of the last HCO_3^- .

If pH falls from original level to 8.3 then all the hydroxyl ion and $\frac{1}{2} \text{CO}_3^{2-}$ ions are neutralised when pH falls from 8.3 to 4.5 then remaining half of carbonate ions and bicarbonate ions are neutralised.

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Let P = Amount of Acid req. to reach pH from original level to 8.3.

M = Amount of acid $\overset{\text{req. to fall}}{\text{req. pH}}$ from original level to 4.5.

Conclusion \Rightarrow

If $P=M \Rightarrow$

alkalinity is due to OH^- ions.

If $P=\frac{M}{2} \Rightarrow$ It means there is carbonate alkalinity

If $P=0$ and $M \neq 0 \Rightarrow$ Hence there is bicarbonate alkalinity

If $P=0$ and $M=0$ No alkalinity

If $P < \frac{M}{2}$ Bicarbonate and carbonate ions are predominant

If $P > \frac{M}{2}$ OH^- ion and CO_3^{2-} are predominant.

Note : P Mol wt. of a compound = Sum of atomic wt (g/mol)

$$\begin{aligned} \text{CaCO}_3 &= 40 + 12 + 3 \times 16 = 100 \text{ gm} \\ \text{H}_2\text{SO}_4 &= 1 \times 2 + 32 + 16 \times 4 = 98 \text{ gm} \\ \text{NaCl} &= 23 + 35 \\ \text{NaOH} &= 23 + 16 + 1 = 40 \text{ gm} \end{aligned}$$

(ii) equivalent weight = $\frac{\text{Mol. wt.}}{\text{Valency}}$ (28)

$$\text{Equiv. wt. of CaCO}_3 = \frac{100}{2} = 50 \text{ gm}$$

$$\text{H}_2\text{SO}_4 = \frac{98}{2} = 49 \text{ gm}$$

$$\text{NaOH} = \frac{40}{1} = 40 \text{ gm}$$

(iii) 1 Mole = Mol. wt. of compound

1 Mole of CaCO₃ = 100 gms. CaCO₃

1 mole of H₂SO₄ = 98 gms. H₂SO₄

1 Mole of NaOH = 40 gms. NaOH

(iv) Concentration = $\frac{M}{L}$ (mole/liter).

If 1 mole of CaCO₃ is present in 1lit of water
then con' is 1M/L of CaCO₃.

It means 100 gms of CaCO₃ is present in 1 lit of
dil. water = 1M/L

If 1gm of CaCO₃ is present in 1lit then con'
 $= \left(\frac{1}{100}\right) \text{ M/L}$

$\therefore = 0.01 \text{ M CaCO}_3$

No. of Moles = $\frac{\text{Wt. in gms}}{\text{Mol. wt. in gms}}$

If 490 gm of H_2SO_4 is present in water then

$$\text{conc. is } \frac{490}{98} M/L$$

(29)

$$= 5 M/L$$

If 490 mg of H_2SO_4 is present conc. is

$$= 0.005 M/L$$

$$= 0.005 M H_2SO_4$$

1 gm eqv. wt. = Eqv. wt. of compound in gm

1 gm eqv. of $CaCO_3$ = 50 gm of $CaCO_3$

" " " " H_2SO_4 = 49 gm " H_2SO_4

" " " " NaOH = 40 gm of NaOH

1N = No. of gm eq. present in 1 lit. of water

$$\text{Ex. } 490 \text{ mg of } H_2SO_4 = \frac{490 \times 10^{-3}}{49} = 0.01 \text{ gm eq.}$$

If 490 mg of H_2SO_4 is present in 1 lit. of water

$$\text{then } \text{Conc. is } = 0.01 N H_2SO_4$$

If 980 mg of H_2SO_4 is present in 1 lit. of water then conc. is $= 0.02 N H_2SO_4$

1M = 1N if Valency is 1

1Mole/lit = 1 gm eq/l of NaOH

1M = 1N of NaOH

If valency } 1M = 2N

$$\text{is 2. } \quad 0.01M = 0.02N$$

$$1M = 3N \} \text{ If Valency is 3}$$

1 gm eqv. of OH^- is equal to 1 gm eqv of carbonate ions (CaCO_3)

(B)

Note:- If x gm eqv. of OH^- ions and y gm eqv. of carbonate ions and z gm eqv. of bicarbonate ions are present than total alkalinity is equal to $(x+y+z)$ gm eqv. of CaCO_3

$$1 \text{ gm eqv. of } \text{OH}^- \text{ ions} = 1 \text{ gm of } \text{CaCO}_3$$

$$1 \text{ gm eqv. of } \text{CO}_3^{2-} = 1 \text{ gm of } \text{CaCO}_3$$

$$1 \text{ gm eqv. of } \text{HCO}_3^- = 1 \text{ gm of } \text{CaCO}_3$$

The total alkalinity in terms of weight of CaCO_3 = $(x+y+z)$

Usually alkalinity is represented in mg/ltr as CaCO_3 .

Ques.

A sample of water contains 210 gm of CO_3^{2-} , 122 gms of HCO_3^- and 68 gms of OH^- . Find total alkalinity in the same water expressed as CaCO_3 .

$$\begin{aligned} \text{gm eqv. of } \text{CaCO}_3 &= \frac{\text{wt. of } \text{CO}_3^{2-}}{\text{Eqv. wt. of } \text{CO}_3^{2-}} \\ &= \frac{210}{30} = 7 \text{ gm eqv. (x)} \end{aligned}$$

$$\begin{aligned} \text{gm eqv. of } \text{HCO}_3^- &= \frac{\text{wt. of } \text{HCO}_3^- \text{ in gms}}{\text{Eqv. wt. of } \text{HCO}_3^-} = \frac{122}{61} \\ &= 2 \text{ gm eqv. (y)} \end{aligned}$$

$$\text{gm eqv. of } \text{OH}^- = \frac{68}{17} = 4 \text{ gm eqv. (z)}$$

$$\begin{aligned} \text{Total alkalinity} &= 7+2+4 = 13 \text{ gm eqv. of} \\ &\quad \text{CaCO}_3 \end{aligned}$$

$$\text{wt. of } \text{CaCO}_3 = 13 \times 50 = 650 \text{ gms}$$

Ques A 200ml. of sample of water has initial pH of 10. 30 ml. of 0.02 N H_2SO_4 is required to titrate the sample to fall pH to 4.5. If OH^- conⁿ is 5 mg/ltr as CaCO_3 and 11 ml. of 0.02 N is consumed to reach from original to 7.02504

8.3. Then find

(31)

- (i) Caustic Alkalinity OH^-
- (ii) Carbonate "
- Expressed as CaCO_3 .

Ans.

200ml. of sample of water
1 ml. of 0.02 N H_2SO_4 neutralises 1 mg. of alkalinity as CaCO_3 .

30ml. of 0.02 N H_2SO_4 will " 30 mg. of alkalinity as CaCO_3 .

It means 30 mg. alkalinity as CaCO_3 is present in 200ml of water

$$\text{Total alkalinity per ltr of water} = \frac{30 \times 1000}{200}$$

$$= 150 \text{ mg/ltr.}$$

as CaCO_3

$$\text{OH}^- \text{ alkalinity as } \text{CaCO}_3 = 5 \text{ mg/ltr}$$

$$\text{CO}_3^{2-} \text{ alkalinity as } \text{CaCO}_3 + \text{HCO}_3^- \text{ alk. as } \text{CaCO}_3$$

$$= 150 - 5$$

$$= 145 \text{ mg/ltr}$$

200 ml of sample of water

(32)

OH^- alkalinity present in 1 lit = 5 mg/L as CaCO_3

$$\text{ " } \quad \text{ " } \quad 200 \text{ mL of water} = \frac{5}{1000} \times 200$$

$$= 1 \text{ mg per 200 mL of water}$$

It means 1 ml of $0.02 \text{ NH}_2\text{SO}_4$ will be used to neutralise 1 mg of OH^- as CaCO_3 .

Hence $0.02 \text{ NH}_2\text{SO}_4$ used to neutralise CO_3^{2-} + HCO_3^- as CaCO_3 = $30 - 1 = 29 \text{ mL}$

11 ml of $0.02 \text{ NH}_2\text{SO}_4$ is used for $\text{OH}^- + \frac{1}{2} \text{ CO}_3^{2-} = 11 \text{ mL}$

$$\Rightarrow \frac{1}{2} \text{ CO}_3^{2-} = 11 - 1 = 10$$

$$\text{CO}_3^{2-} = 20 \text{ mL}$$

CO_3^{2-} ion conc. as CaCO_3 in lit of water

$$= \frac{20}{200} \times 1000$$

$$= 100 \text{ mg/L}$$

as CaCO_3

$$\text{HCO}_3^- = 150 - 100 - 5 = 45 \text{ mg/L as CaCO}_3$$

Date - 2007

(3) pH of water

It represents the presence of H^+ ion concentration
pH is given as

$$pH = -\log_{10}(H^+) \quad (33)$$

H^+ Hydrogen ion concentration in Mole / ltr.

It is measured by potentiometer or colour matching
indicators. Indicators used are

- Methyl orange (Acidic indicator)
- phenophthalein red (Basic ")

For drinking water permissible pH is 7 to 8.5 but
it should not be less than 6.5 and not greater
than 9.2.

(4) Hardness It is defined as concentration of ~~valent~~
valent cations present in water solution. Hard-
ness cation will react with anions in the water
to form solid precipitate.

Note:- The multi valent cations may be Ca^{2+} , Mg^{2+} ,
 Al^{3+} , Fe^{2+} , Mn^{2+} , Sr^{2+}
but mostly calcium and magnesium ions are
predominant.

Hardness may be classified in 2 parts.

(i) Carbonate hardness
(CO_3^{2-})

(ii) Bicarbonate
Noncarbonate hardness
(Cl^- , SO_4^{2-} , NO_3^-)

or

Temporary Hardness

↓

Carbonate and HCO_3^-

or

Ca^{2+} and Mg^{2+}

(other negel)

Permanent Hardness

↓

Cl^- , SO_4^{2-} & NO_3^-

of Ca^{2+} & Mg^{2+}

(if other multi Valant negel)

Hard water prevents formation of foam or leather increase laundry expences.

Hard water also cause incrustation in pipe and boiler. Hence boiler feed water should be free of hardness. Usually hardness is not harmful to digestive system but the taste is rankish.

(B4)

however excess presence of magnesium sulphate has laxative effect.

Calcium hardness does not cause any health hazard.

Temporary hardness can be removed by boiling or adding lime and permanent hardness can be removed by lime soda method and

Hardness is expressed as CaCO_3 eqv. of Ca^{2+} , Mg^{2+} and other multi valent

There are 3 methods to determine hardness

- (i) Vaseline mtd (EDTA mtd)
- (ii) Clark's Mtd
- (iii) Hennig's mtd

In rosanate method hardness in water is determined by titration with rosanate solution.

EDTA is used with cresochrome black T as indicator. 0.01M EDTA is used for 1ml of titrant to neutralise 1mg of hardness expressed as CaCO_3 .

Total hardness is equal to

$$T.H. = \text{gm eqv of } \text{Ca}^{2+} + \text{gm eqv of } \text{Mg}^{2+}$$

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T.H. = $\left[\text{gm eqv. of } \text{Ca}^{2+} + \text{gm eqv. of } \text{Mg}^{2+} + \text{gm eqv. of other multi-valent ions} \right] \times \text{Eqw. of eqv.}$

(35)

T.H. as CaCO_3 in gms.

$$\begin{aligned} \text{T.H. in mg/ltr} &= \left[\frac{\text{conc. of } \text{Ca}^{2+}}{\text{in mg/L}} + \frac{\text{conc. of } \text{Mg}^{2+}}{\text{in mg/L}} \right. \\ \text{as } \text{CaCO}_3 &\quad \left. + \frac{\text{conc. of other compd.}}{\text{in mg/L}} \right] \times \frac{\text{eqw. wt of that compd.}}{\text{mg/L}} \end{aligned}$$

If other than Ca^{2+} , Mg^{2+} ions are neglected then

$$\text{T.H.} = \left[\frac{\text{Ca}^{2+} \text{ conc. in mg/L}}{20} + \frac{\text{Mg}^{2+} \text{ in mg/L}}{12} \right] \times 50$$

mg/ltr as CaCO_3

Comparative study b/w alkalinity and hardness.
 Alkalinity causing compds | Hardness causing compds

CaCO_3 , MgCO_3 , Na_2CO_3

CaCO_3 , MgCO_3 {
 $\text{Ca(HCO}_3)_2$, $\text{Mg(HCO}_3)_2$ }

$\text{Ca(HCO}_3)_2$, $\text{Mg(HCO}_3)_2$, NaHCO_3

CaCl_2 , MgCl_2 }

Ca(OH)_2 , Mg(OH)_2 , NaOH

CaSO_4 , MgSO_4 }

Caustic alkali
Negligible
alkalinity

Collective only on
very high pH.

$\text{Ca(NO}_3)_2$, $\text{Mg(NO}_3)_2$

N.C.H.



usually caustic alkalinity is negligible in water and if permanent hardness is present then salts such as chloride, sulphate and nitrate of Ca and Mg react with sodium carbonate and bicarbonate

to convert them into Ca^{2+} and Mg^{2+} salt hence sodium alkalinity will be present only when permanent hardness is absent. under such condition carbonate Hardness = T.H.

Case-I If permanent hardness is present then $\text{T.H} > \text{C.H.}$
and $\text{C.H.} = \text{Alkalinity.}$

Case-II If permanent hardness is absent $\text{T.H.} = \text{C.H.}$
 $\text{Alkalinity} > \text{C.H.}$

$$\text{From case-I} \quad \frac{\text{Permanent Hardness}}{\text{N.C.H.}} = \frac{\text{T.H.} - \text{Alkalinity}}{\text{C.H.}}$$

Hardness is expressed as mg/ltr. of CaCO_3 or ppm or may be expressed in terms of degree of hardness.

1 British degree of hardness = 14.25 mg/ltr. and

1 French " " " : 10 mg/ltr of CaCO_3

Hardness in mg/ltr

Type of water

0 to 55

Soft

55 to 100

Slightly Hard

100 to 200

Moderate Hard

200 to 500

Very Hard.

(37)

Note: For drinking water desirable hardness is 75 to 115 ppm.

If it is less than 200 ppm there will be no effect on health hazard.

Ques. Results of water sample analysis are tabulated below. Find total hardness of water expressed as mg/ltr of CaCO_3

(a) 44.8

(b) 89.5

(c) 177

(d) 358

| Cations | Concentration in mg/ltr | eqn. wt. |
|------------------|----------------------------|----------|
| Na^+ | 40 | 23 |
| Mg^{2+} | 10 | 12.2 |
| Ca^{2+} | 55 | 20 |
| K^+ | 2 | 39 |

$$T.H. = \left[\frac{\text{Ca}^{2+} \text{ in mg/ltr}}{20} + \frac{\text{Mg}^{2+} \text{ in mg/ltr}}{12.2} \right] \times 50$$

$$T.H. = \left[\frac{55}{20} + \frac{10}{12.2} \right] \times 50 = 179 \text{ mg/ltr of } \text{CaCO}_3$$

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Ques 10 A Water contains following dissolved ions with their atomic wt. shown in figure.

| Cations | Con' in mg/L | Atm. wt. |
|-------------------------------|--------------|----------|
| Na ⁺ | 56 | 23 |
| Ca ²⁺ | 40 | 40 |
| Mg ²⁺ | 30 | (38) |
| Al ³⁺ | 3 | 27 |
| HCO ₃ ⁻ | 190 | 61 |
| Cl ⁻ | 165 | 35.5 |

pH of water is 7.

Ques ① The total hardness of sample in mg/L as CaCO₃ is

- (a) 484 (b) 450 (c) 225 (d) 242

Ques ② N. C. H. of the sample is in mol/L as CaCO₃

- (a) 225 (b) 156 (c) 86 (d) 0

① Total hardness = $\left[\frac{\text{Ca}^{2+} \text{con}^n \text{in mg/L}}{40} + \frac{\text{Mg}^{2+} \text{in mg/L}}{12} + \frac{\text{Al}^{3+} \text{in g}}{9} \right]$

$$\left(\frac{40}{20} + \frac{30}{12} + \frac{3}{9} \right) \times 50$$

$$= 242$$

Not given

② Alkalinity is caused by CO₃²⁻, HCO₃⁻ & OH⁻

OH⁻ 10⁻⁷ Negligible.

hence alkalinity is caused by bicarbonates.

$$\text{Alkalinity as } \text{CaCO}_3 = \frac{[\text{HCO}_3^-] \text{ in mg/L}}{\text{Eq. wt of HCO}_3^-} \times \text{Eq. wt of CaCO}_3$$

$$(39) = \frac{190}{61} \times 50 \\ = 156 \text{ mg/L}$$

$$\text{NCH} = \text{TH} - \text{ALK} \\ = 242 - 156$$

$$\text{NCH} = 86$$

Grade 2007 Alk. and hardness of water sample are 250 mg/l and 350 mg/l as CaCO_3 respectively. The water has

- (a) 350 mg/ltr carbonate hardness & 0 N.C.H.
- (b) 250 mg/ltr C.H. & 0 N.C.H.
- (c) 250 " " & 350 N.C.H.
- [x 50] (d) 250 " C.H & 100 mg/ltr N.C.H.

Grade 2009 Common Data Question

Following chemical compounds reported from a source.

| Compounds | Cone ⁿ in milli eqv./Ltr |
|--------------------|-------------------------------------|
| Cl^- | 15 |
| SO_4^{2-} | 15 |
| CO_3^{2-} | 05 |
| HCO_3^- | 30 |
| Ca^{2+} | 12 ✓ |
| Mg^{2+} | 18 ✓ |

Hardness

pH: 8.5

Ques. 1 T.H. in mg/litre due to CaCO_3 is ^(a) 15,000
 (b) 2000 (c) 3000 (d) 5,000

Ques. 2 Alkalinity present in water 40

- (a) 250 (b) 1500 ~~(c) 1150~~ (d) 5,000

$$\text{Total alk.} = \text{CO}_3^{2-} + \text{HCO}_3^{-} + \text{OH}^-$$

$$= \text{gm eqv. of } \text{CO}_3^{2-} + \text{gm eqv. of } \text{HCO}_3^{-} + \text{gm eqv.}$$

of OH⁻

$$= \text{gm eqv. of } \text{CaCO}_3$$

$$= (m\text{eqv}/L + m\text{eqv}/L + m\text{eqv}/L) = \text{meqv. of}$$

CaCO_3

$$= (25 + 30 + 0) \times 50 = 35 \times 50 = 1750 \text{ mg/litre}$$

$$\text{OH}^- = 10^{-5.5} \text{ M/L}$$

$$= 10^{-5.5} \text{ gm eqv./L}$$

$$= 10^{-5.5} \times 10^3 \text{ mg eqv./L} \quad (\text{Negligible})$$

Rate 2010 Concentrations obtained for Ground water sample having pH = 8.1 are as follows.

| ion | con ⁿ (mg/litre) | pH value |
|------------------|-----------------------------|----------|
| Ca^{2+} | 100 | 40 |
| Mg^{2+} | 6 | 24 |
| Na^+ | 15 | 23 |
| HCO_3^- | 250 | 61 |

SO_4^{2-}

45

96

 Cl^-

39

35.5

(41)

Ques.

Total hardness in mg/ltr as CaCO_3 present in above water is

- (a) 205 (b) 250 (c) 275 (d) 308

Ques.

C-H. in mg/ltr as CaCO_3 is

- (a) 205 (b) 250 (c) 275 (d) 289

Ans.

$$\text{ALK} = \left[\frac{[\text{CO}_3^{2-}]}{\text{Eqwt.}} + \frac{(\text{HCO}_3^-) \text{ mg/ltr}}{\text{Eqv. wt.}} \right] \times 50$$

$$= \frac{250}{61} \times 50 = 205 \text{ mg/ltr}$$

$$\text{T.H.} = \left[\frac{\text{Ca}^{2+}}{20} + \frac{\text{Mg}^{2+}}{12} \right] \times 50$$

$$= 275$$

$$\text{N.C.H.} = \text{T.H.} - \text{ALK.}$$

$$= 275 - 205$$

$$= 70$$

$$\text{CH.} = \text{ALK} - 205$$

42

(7)

Fluorides :-

- Fluorides are essential for healthy teeth. Permissible limit is $(1\text{--}1.5)$ mg/ltr.
- * If fluorides is less than 1 mg/ltr, then it will cause more than 1.5 mg/ltr then it will cause fluorosis or discolouration of teeth.
- * When fluorides is more than 5 mg/ltr then it may cause deformation of bones which is called bone fluorosis.

43

(8)

Phosphorous :- It is neither toxic nor harmful but it is indicator of future pollution of natural bodies. It facilitates rapid growth of aquatic plant like algae which may pollute water in natural streams. Phosphorous also interferes with chemical coagulation.

(9)

Iron and Magenes (Fe & Mn). Excess iron causes hard-bad taste, discolouration of clothes and incrustation of pipe due to formation of encrustation. It should not be more than 0.3 mg/ltr in drinking water.

Excess presence of Mn also causes discolouration of clothes and its permissible limit 0.05 mg/ltr.

Fe & Mn are generally found in water which is deficient in oxygen, such as underground water.

(10)

Copper (Cu) :- Its excess presence affects lungs and respiratory organ. If copper sulphate is more than 250 mg/ltr, then it may cause laxative effect.

Permissible limit 0.05 to 1.5 mg/ltr.

Permissible limit of sulphur - 200 mg/Ltr

Toxic metals : Arsenic, Barium, Cadmium, Chromium, Lead, Mercury and Silver are toxic and hazardous those enter in human body through food chain. Arsenic is poisonous and it should not be more than 0.2 mg/Ltr.

Phenolic substances are also harmful and should not more 0.001 mg/Ltr.

(44)

Dissolved Gases : (i) CH_4 - It is explosive in nature and causes green house effect

- (ii) H_2S + It produces bad smell.
- (iii) CO_2 → Its presence indicates biological activities.
It imparts bad taste and makes water more corrosive
- (iv) O_2 + O_2 is required for respiration of water species and in no case it should less 4 mg/Ltr

Nutrients : Helps in growth of plant ex carbon, Nitrogen, phosphorus

Presence of organics : There are two types of organics

- (i) Biodegradable → These are utilised as food by microorganisms ex. - starch, fats, protein, Alcohols, Acids, Aldehydes and esters. The utilisation of dissolved organic is either through oxidation process or through reduction process and oxidation may be aerobic or anaerobic.

Usually aerobic reaction gives stable product and the amount of O_2 consumed during microbial utilization called BOD. BOD in drinking water should be nil.

Non Biodegradable organics are: tannic acid, cellulose, tannic acid, phenols, detergent compounds and industrial waste.

COD is measure of biodegradable and non biodegradable organics hence non biodegradable organics are represented by

$$= \text{COD} - \text{BOD}_{\text{u}}$$

OR

$$\Rightarrow \text{COD} - \text{TOC}$$



Type of aquatic plants

- (i) Spermatophyta → Waterweeds
- (ii) Bryophyta → Mosses
- (iii) Pteridophyta → Ferns & horsetails.
- (iv) Thallophyta → algae + photosynthesis plants

Aquatic Animals.

- (i) Vertebrates → Fish and Amphibian
- (ii) Mollusca → Snails, slugs and limpets.
- (iii) Arthropoda → Insects, spiders, Slugs, Worms → Rotifera & thread worms.
- (iv) Metozoa → Polyzoa and hydra
- (v) Protzoa → E. Histolytica
↳ Entamoeba

Biological Characteristics

Those microorganism which are harmful for human and animals are called pathogens these are capable of infecting and transmitting the diseases to human being they are not native to aquatic system but

usually require an animal host for their growth and reproduction. They can be transported by water and air. The water born pathogen includes bacteria, viruses, protista and helminth.

(iii) Bacteria :- Usually these may be rod shape but may be also spherical or spiral. These are single celled microorganisms which is simplest form of life they synthesize protoplasm from surrounding environment.

Rod shaped bacteria are called - bacilli

Spherical shaped are called - Cocci

Spiral shaped - Spirocha.

Diseases caused by bacteria

Diseases

Typhoid Fever

Cholera

Bacillary Dysentery

Lepto spiroasis

Bacteria

Salmonella typhi

Vibrio - comma / Vibrio - Cholera

Shiga bacillus

Lepto spiral - Weil's Disease

(iv) Virus :- Smallest biological structure which is known to contain all genetic information necessary for their own reproduction. These can be seen only by microscope.

Diseases

Polio

Jaundices / Hepatitis

Diarrhoea

Virus

Polio

Hepatitis

Cito - Pathogen

iii) Protozoa : These are unicellular organisms which have complex functional activity as compared to bacteria and viruses. Biological infection is usually characterized by gastro intestinal disorders.

If drinking water is contaminated by sewage, then protozoal infection is common.

| Disease | Protozoa |
|-----------------|-------------------------------|
| Ambic Dysentery | <i>Entamoebia Histolytica</i> |
| Giardiasis | <i>Giardia-Lambia</i> |

(47)

iv) Helminth : These are also called parasitic worm. These involve two or more animal host one of which may human or ^{animal} which will contain helminth. *Oncocentasis* \rightarrow *Dracunculus medinensis*

Measurement of Pathogens

Indirectly pathogens are determined by measurement of coliforms. Since coliform survive longer than survival of pathogen hence if in drinking water there is no presence of coliform, then there will be no presence of pathogens. Coliforms are harmless aerobic microorganisms which are found in intestine of all warm blooded animals. Common coliforms are $\underline{\text{B-COLI}} \text{ & E-COLI}$.

Methods to measure coliform

- Membrane filter technique
- Test tube method (Most probable number method)
- Coliform index

Membrane filter Technique : - It is ^{most} commonly used by environmental engineer to find coliform bacteria.

In this test water sample is filtered through a membrane the pores of which do not exceed 0.45 μ micrometer. Coliform bacteria are retained on the filter and then bacteria are placed on a selective media called M- Endow Medium.

Which promotes growth of only coliform and not other species. Usually after 24 hrs. at suitable incubated temperature coliform grows into visible size which may be counted manually and results are represented as no. of coliform per 100 ml of water. For drinking water not more 1 coliform colony should be present per 100 ml of water.

Test tube method or most probable number method 48

It is generally preferred by micro biologist. The water sample is mixed with lactos. and sample is incubated at 37°C. for 48 hours. Sample is kept in 15 tubes (5 tubes of 10 ml, 5 tubes of 1 ml, 5 tubes of 0.1 ml)

After 48 hrs. tubes are tested for presence of CO_2 and acids which indicates the presence of coliform bacteria and results are referred with Standard Statistical table given by Mecardi which can be used to find most probable no of BCOL per 100 ml of water most probable no represents bacterial density which is most likely to be present.

Example :-

| Sample size | No. of +ve test | No. of -ve test | Total no. of test tubes |
|-------------|-----------------|-----------------|-------------------------|
| 10 ml. | 4 | 1 | 5 |
| 1 ml. | 2 | 3 | 5 |
| 0.1 ml. | 1 | 4 | 5 |

+ve. test combination = 4-2-1 ,

Referring to mcardi table MPN is 26 per 100ml
Vol. of water .

(49)

WATER PURIFICATION SYSTEM

Water treatment units :-

Purpose of water treatment

(80)

- (i) To remove colour, turbidity, dissolved solids, suspended solids.
- (ii) To remove diseases producing micro organisms.
- (iii) To remove objectionable taste and odour
- (iv) " excess hardness and salinity
- (v) " toxic metal and dissolved gases

Method of treatment will depend upon the quality of raw water, presence of pollutant and desired quality of water.

Water treatment units :-

- (i) Screening → Removal of floating object. Coverage area provided at intake points.
- (ii) Aeration → Removal of Dissolved gases, iron and Mn upto some extent.
- (iii) Sedimentation or clarification → Removal of suspended impurities, silts, sands and other fine suspended particles and some of bacteria.
- (iv) Filtration → Most important operation of water purification. It removes suspended impurities, colloidal impurities, micro organisms etc.
- (v) Disinfection → Removal of pathogenic microorganisms.
- (vi) Softening → Removal of hardness
- (vii) Deflocculation → Removal of Fe and Mn chemically.
- (viii) Desalination → Removal of excess salts.

(x) Fluoridation & defluoridation → Addition of fluorine in deficient condition & defluoridation is removal of excess fluorine.

(xi) Adsorption units → Treatment with activated carbon. It is to remove suspended impurities.

(xi)

Types of water treatment :

Case-I When source of water provides clear water with low turbidity and free from taste and odour and no excess presence of metals and minerals. Under such condition plain chlorination is done i.e. Raw water → Chlorination → Supply

Case-II Treatment plant for treating hard ground

Raw water → Aeration → Softening → Flocculation
Sedimentation
Supply → Disinfection → Filtration

Case-III Treatment of Turbid surface water with organics

Rawwater → Screening → Prechlorination →
Aeration & Flocculation
Sedimentation

Supply → MSC. → Disinfected
treatment
(If required)
Absorption → Filtration

(Treatment with
Activated carbon)

Screening

Screens.

Coarse screen
or

Rock Screen

(SD)

Fine screen
or

(mesh) wire screen

Coarse screens are in the form of bars of 25mm size spaced at 75 to 100 mm. c/c.

Screens are kept inclined at 45 to 60° with horizontal so that it helps in trapping reduces flow velocity by providing increased flow area.

Fine screens are in the form of wire mesh with opening less than 10mm size. Since

fine screens get clogged frequently hence head loss increases therefore they are not preferred instead for removal of fine floating particles sedimentation is preferred.

Aeration → Air is mixed in water to create self renewing interfaces b/w air and water. Aeration helps in removal of

- (1) Bad taste and odour caused by dissolved gases and organic compounds.
- (2) It increases DO content in water
- (3) Reduces corrosive property of water by removal of CO_2
- (4) Removes partly Fe & Mn.
- (5) Helps in increasing biological activities hence early completion of oxidation and some of bacteria may
- (6). Removal of volatile liquids such as phenols, humic acids

Types of aerators

- ① Gravity aerators & Trickling beds, Steps, Inclined apron with ripples.
- Slat tray aerator (Most commonly used)
- Gravel bed aerator
- ② Spray towers or nozzles :- Efficient in removal of CO_2 and H_2S (97%)
- ③ Air diffusers :- A compressed air is introduced in this method but this method is not efficient in removal of CO_2 .

Limitations of Aeration

(33)

- ① Not very efficient in removal of taste and odour caused by non volatile substances like oil and algae, greases.
- ② Not efficient in removal of taste and odour caused by chemical such as due to industrial waste.
- ③ Fe & Mn can be precipitated only when organic matter are not present.
- ④ Possibility of Air born contamination :-

Sedimentation

Sedimentation is removal of suspended particles by gravitational settling. Sedimentation tanks are designed to reduce velocity of flow so as to reduce turbulence. Sedimentation is based on Stokes law.

- ① Plain sedimentation (Type I sedimentation) It is called decanting settling where no coagulant was added.

Coagulation sedimentation (Type-2 settling).

Classification

Chemicals are added to form flocs of suspended and colloidal substances.

Types of sedimentation tank

(54)

Quiescent type (Bull & porous type)

Continuous type

①

Quiescent type :- Tank is filled with incoming waste and if allowed to rest for detention period.

Generally 24 hrs. detention period is provided and 6 to 12 hrs are required for sludge removal (cleaning the tank) therefore total cyclic operation need 30 to 36 hrs. hence of minimum of 3 tanks are required to maintain constant supply.

Tank are designed to treat maximum daily demand - 1.8 times average daily demand.

These are obsolete now a days.

②

Continuous flow type :- The aim of design is to achieve ideal condition of equal velocity at all points. Depending on type of flow there may be of following three types

(i)

Horizontal Flow tanks - These are rectangular

(2)

Spiral or Radial flow - Circular

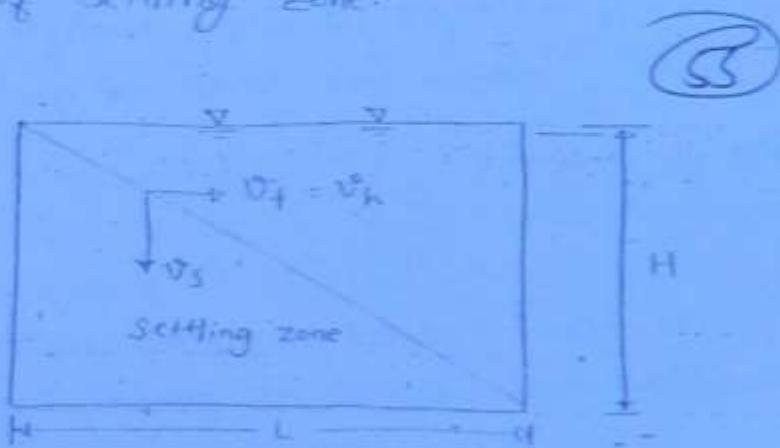
(3)

Vertical flow Hoffer bottom tank

Horizontal Flow rectangular sedimentation tank

Assumptions (i) Settling of particle is same as in case,

- of quiescent type of equal depth
- (i) The flow is horizontal and steady and settling velocity is uniform.
 - (ii) The "cone" of suspended particles is same at all vertical c/s.
 - (iii) Particles are removed when they reach at the bottom of settling zone.



Let $t = \text{Detention time} = \frac{L}{V_f} = \frac{V}{Q} = \frac{(B \times L \times H)}{Q}$

for zero
angular

$$t = \frac{H}{V_s} \quad \text{hence}$$

V_s = settling Velocity of particle which enters at the top surface at the entry point and reaches to bottom surface of settling zone at exit point

$$\boxed{\frac{V_f}{V_s} = \frac{L}{H}}$$

It means those particles which will settle with velocity $V_s > V_f$ will be 100% removed but if settling velocity of particle is less than V_s will be fractionally removed because

particles entering at lower depth may be removed.
If particles have settling velocity smaller than v_s then % removal is given by

$$\% \text{ removal} = \left[\frac{v_s'}{v_s} \right] \times 100 \quad (6)$$

Let

h : Height at which particles enter ($h \leq H$) which are removed and have velocity v_s'

then

$$\left[\frac{v_s'}{v_s} = \frac{h}{H} \right]$$

Note $\circledast v_s$ is also called overflow rate or surface overflow rate which is given by $\frac{Q}{BH} = v_s$

Surface overflow rate is a design property of sedimentation tank.

$$v_s' = \left[v_f = \frac{Q}{BH} \right]$$

② The settling velocity of particle having diameter d' can be computed using stoke's law

$$v_s' = \frac{g (\rho_s - \rho_w) d^2}{18 \mu}$$

$$v_s' = \frac{g (C_{s_s} - 1) d^2}{18 \nu}$$

Design Parameters

- (i) Retention time 4 to 8 hrs for plain sedimentation
 2 to 4 hrs, coagulation & sedimentation

It is theoretical time required by a particle to pass from entry to exit or time required for settling a particle from top to bottom with velocity v_s or it is the time required to fill the tank.

$$t = \frac{L}{v_s} = \frac{H}{v_s} = \frac{V}{Q} \text{ - volume } \quad (52)$$

$$t = \frac{BLH}{Q} \quad \text{for rectangular}$$

$$\frac{D^2(0.011D + 0.785H)}{Q} \quad \text{for circular}$$

(ii) Overflow rate ($v_s = \frac{Q}{BL}$)

$$v_s = \frac{500 \text{ to } 750 \text{ l/hr/m}^2}{\text{or}} \quad \left. \begin{array}{l} \text{Plain sedimentation} \\ \text{12,000 to 18,000 l/day/m}^2 \end{array} \right\} \text{sludge}$$

$$v_s = \frac{1000 \text{ to } 1250 \text{ l hr/m}^2}{\text{or}} \quad \left. \begin{array}{l} \text{coagulation and} \\ \text{flocculation} \\ 24,000 \text{ to } 30,000 \text{ ltr/day/m}^2 \end{array} \right\} \text{slurry}$$

(iii) Horizontal flow velocity ($v_f = \frac{Q}{BH}$)

It is in the range of 0.15 to 0.9 m/minute and usually taken as 0.3 m/minute.

(iv) Flowing through period (\bar{T})

\bar{T} is the average time required for a batch of water to pass through the settling tank. Since the central portion of water has short circuiting effect hence $\bar{T} < T$

(vi) Displacement efficiency :- It is defined as ratio of flowing through period to detention period. Generally its value is 0.25 to 0.50 but it is desirable to keep displacement efficiency more than 0.3.

(vii) Tank dimensions :- Width (B) : 8 to 12 m. (± 12)
Length (L) : 4B
Depth (H) : 3 to 4.5 m. ($\pm 1.8m$)
 $\pm 6m$

(58)

Sludge Zone :- If sludge is mechanically removed continuously by scraper then no extra provision for sludge zone is required but if sludge is removed manually, periodically then 0.8 to 1.2 m sludge storage is required.

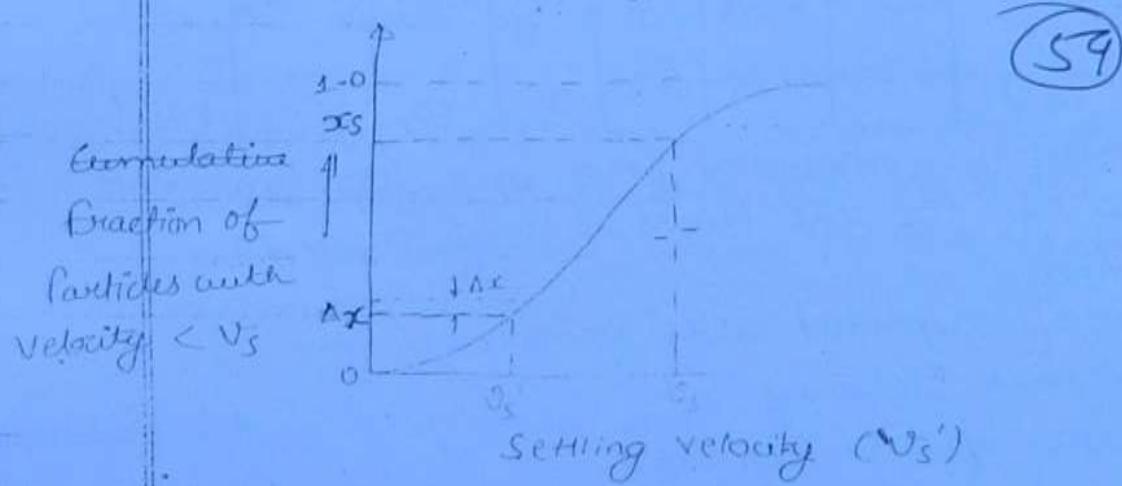
Circular tank :- These may have radial or spiral free surface zones at the centre and move radially outward. At the circumference over is provided in circular tank velocity of water continuously decrease from centre towards circumference. Overflow weir of V-notch is provided to reduce short circuiting and to ensure smooth drop of water.

Hoffer bottom tank with vertical flow :- Water enters through centrally placed inlet pipe and is deflected towards by the deflector box. Water flows vertically downward. The sludge settles at the bottom of hoffer from where it is removed with the help of sludge pipe connected to pump.

Determination of settling tank efficiency in horizontal flow tank (Size, weight composition analysis). Efficiency of a sedimentation basin indicates % removal of suspended matter at a given overflow rate (V_s).

These particles which settle with velocity $V_s \geq V_s'$ will be fully removed and those particles which have velocity $V_s' < V_s$ will be fractionally removed.

The efficiency can be determined by using cumulative frequency curve.



The overall removal of particles in sedimentation tank in fraction is given as

$$R = (1 - x_s) + \sum_i \frac{V_s'}{V_s} \cdot \Delta x$$

x_s = Fraction of particles which have velocity $\leq V_s$
It means $(1 - x_s)$ is fraction of those particles which have settling velocity $> V_s$.

$\sum_i \frac{V_s'}{V_s} \cdot \Delta x$ is fraction of particles removed having velocity $V_s' (< V_s)$

Δx is fraction of particles having velocity $V_s' (< V_s)$

Settling efficiency may be reduced by

- ① Eddy currents.
- ② Surface currents. (68)
- ③ Vertical convection currents.
- ④ Draining current (cold water sinks below hot water).

Example 3: A water sample having particle size distribution of sediments is shown below

| Size (mm) | 0-1 | 0-2 | 0-3 | 0-4 | 0-5 | 0-60 | 0-70 |
|------------------------|-----|------|------|------|------|------|--------------|
| % particles present | 10% | 20% | 15% | 5% | 30% | 20% | 7% |
| v_s' (mm/sec) | 0.2 | 0.25 | 0.30 | 0.35 | 0.40 | 0.50 | $\sqrt{0.5}$ |
| | | | | | | | |

Total solids in suspended form are 1000 gms and overflow rate of the tank is 0.35 mm/sec.

Then find

(i) Weight of suspended solids removed in gm.

(ii) Settling tank efficiency in %.

Solution Fraction of S.S. Removed

$$R = (1 - x_s) + \sum \frac{v_s'}{v_s} \Delta x$$

x_s : Fraction of particles with $v_s' < v_s$

$$= 0.1 + 0.20 + 0.15$$

$$\therefore 0.45 < \sqrt{0.5}$$

$$(1 - x_s) - 0.55 \geq \sqrt{0.5}$$

$$\sum \frac{v_s'}{v_s} \times \Delta x = \frac{0.20 \times 0.10}{0.35} + \frac{0.25 \times 0.20}{0.35}$$

$$1 - \frac{0.30 \times 0.45}{0.55} = 0.328$$

$$\% \text{ removal} = \left(C_i - x_s \right) + E \frac{V_s!}{V_i} \times A_r \times 100$$

(6)

$$(0.554 - 0.318) \times 100$$

$$= 34.2\%$$

$$\text{Weight of suspended solids removed} = 1000 \times 0.342 \\ = 342 \text{ gm}$$

Ques

2 ML/day is passing through a sedimentation tank which is 6m wide, 15m long and having water depth of 3m. Find

- (i) Detention time
- (ii) Average horizontal flow velocity
- (iii) Overflow rate and weight of dry suspended solids removed per day if conc' of suspended solids in influent water is 60 mg/ltr and tank efficiency is 70%.

Solution :- t = detention time $t = \frac{LBH}{Q} = 8$

$$Q = 2 \text{ MLD} \\ = \frac{2 \times 10^6 \times 10^{-6}}{24} \text{ m}^3/\text{hr} \\ = 83.33 \text{ m}^3/\text{hr}$$

$$t = \frac{6 \times 15 \times 3 \times 84 \times 0.7 \times 60}{2 \times 10^6 \times 10^{-6}}$$

$$t = 11664 \text{ sec.}$$

$$t = 3.24 \text{ hrs.}$$

horizontal flow velocity

$$V_f = \frac{Q}{B \cdot H} = \frac{83.33}{6 \times 3} \text{ m/sec.} \\ = 0.72 \text{ cm/sec.}$$

Surface velocity

$$v_s = \frac{Q}{B \cdot L} = \frac{83.33 \times 10^{-6}}{6 \times 15} \text{ m/sec.}$$

Overflow rate

$$= 0.001 \text{ l/sec/m}^2$$

Total weight of S.S. entering tank per day

$$= 60 \text{ mg} \times 2 \times 10^6 \times 10^{-6} = 120 \text{ kg/day}$$

% removal = 70%

(62)

wt of suspended solids removed = 120×0.7

$$= 84 \text{ kg/day}$$

Ques. A circular sedimentation tank filled standard sludge ^{mechanical} removal equipment is to handle 3.5 MLD of raw water. If detention period of tank is 5 hrs and depth of tank is 3m. Find the dia of the tank.

Solution

$$\text{Volume of circular tank } V = D^2 (0.011D + 0.785H)$$

= Quantity of water to be treated in
detention time

$$3.5 \times 10^3 \times \frac{3.5 \times 10^6}{24} \times 5 = 729.16 \text{ m}^3$$

$$729.16 = D^2 (0.011D + 0.785 \times 3)$$

$$D = 16.94 \text{ m}$$

Ques. In a continuous flow settling tank having depth 2.5m and $L = 60 \text{ m}$. What velocity of water will be permitted for effective removal of 0.025 mm particles having specific gravity 2.65 and ν of water $0.01 \text{ cm}^2/\text{sec}$ at 25°C .
For effective removal $v_s > v_c$.

$$0_c - v_s = g(t_h - t) d^2$$

(25)

$$v_s = 9.81(2.65 - 1)(0.025 \times 10^{-3})^2 = 1.8 \times 0.01 \times 10^{-3}$$

$$V_s = 5.62 \times 10^{-4} \text{ m/sec}$$

$$\frac{V_f}{V_s} = \frac{L}{H}$$

(63)

$$V_f = \frac{60 \times 5.62 \times 10^{-4}}{2.5} = 0.0135 \text{ m/sec}$$

$$V_f = 1.35 \text{ cm/sec.}$$

Type 2 Sedimentation

It is also called classification or sedimentation with coagulation. Coagulants are added to neutralise the negative protective charge on colloidal particle and allow them to coagulate. The coagulant should remove following impurities.

- (i) Fragments of vegetation matter and plants.
- (ii) Organic colouring matters.
- (iii) Fine minerals present in colloidal form.
- (iv) Bacteria and other microorganisms.
- (v) Dissolved organic compound added from sewage.

Factors affecting Coagulation :-

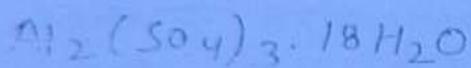
- ① Type of coagulant
- ② Quantity or Dose of coagulant
- ③ Characteristics of water
- ④ Type and Quantity of suspended matter
- ⑤ Temperature
- ⑥ pH of water
- ⑦ Time and method of mixing

Coagulants dissolved in water are thoroughly mixed and

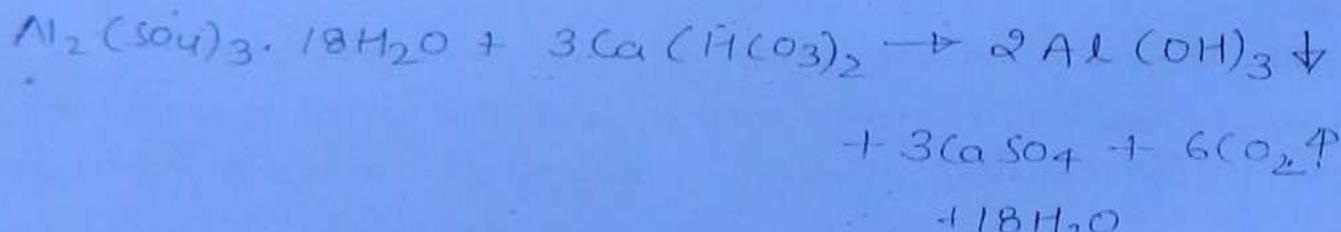
a thick gelatinous precipitate known as floc is formed. Aluminium and ferrous ions having +ve charge attract negative charge colloidal particles of clay and turbidity. Commonly used coagulants. (64)

- ① Alum
- ② Ferrous sulphate (copperas) CuSO_4
- ③ Chlorinated copperas
- ④ Sodium aluminate $\text{AlP}_2\text{O}_7 \cdot \text{Na}_2\text{HPO}_4$
- ⑤ Magnesium carbonate
- ⑥ Polyelectrolytes

Alum :- It is also called aluminium sulphate.



- Alum reacts with $\text{Ca(HCO}_3\text{)}_2$ to form Al(OH)_3 which is a precipitate



Addition of Alum produces CO_2 which forms carbonic acid which decreases pH and hence corrosiveness is increased. Addition of ^{Alum} lime imparts permanent hardness because it converts bicarbonate into sulphate. Alum is effective only in pH range of 6.5 to 8.5 therefore in order to increase the pH Alkali may be required such like Ca(OH)_2 or Soda.

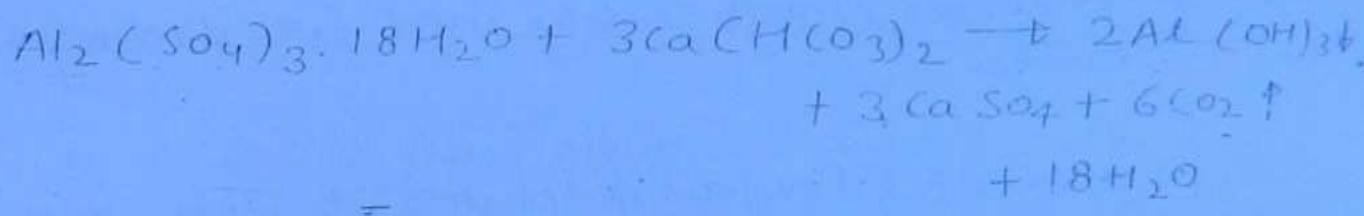
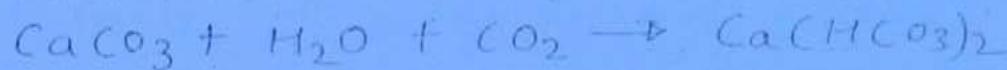
$\text{Al}_2(\text{SO}_4)_3$ to raise the pH.

The dose of alum 10 to 30 mg/ltr and on an avg. 17 mg/ltr is usually provided.

Alum is cheaper and flocs formed are stable but disadvantage is that huge quantity of sludge is produced.

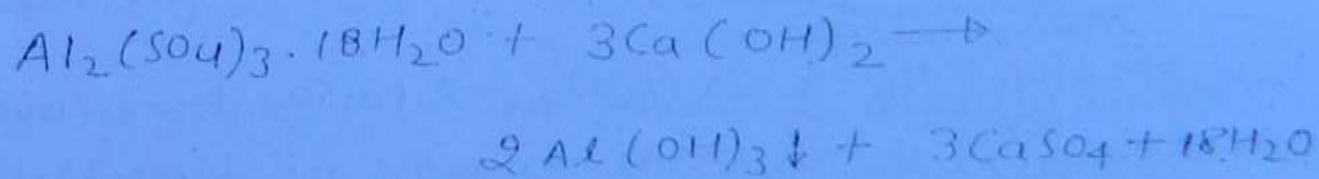
If quick lime (CaO) is added to increase the pH, then following reaction will take place.

(65)



From above reactions it is clear that 1 mole of alum require 3 moles of CaO for alkaliing.

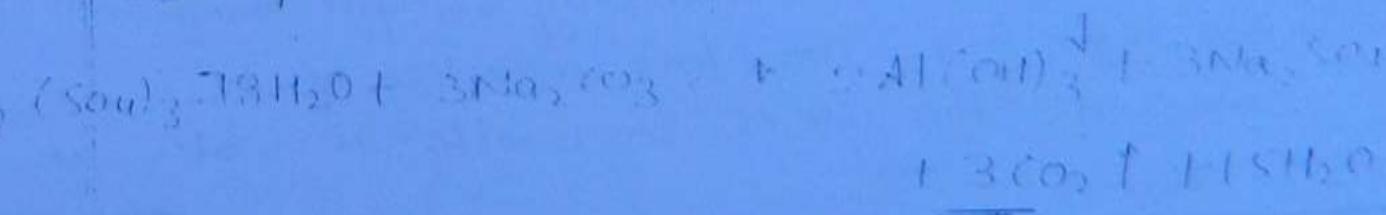
If hydrated lime is added, then following reaction will take place



It means 1 mole of alum produce 2 moles of

$\text{Al}_2(\text{OH})_3$ precipitate

If soda is added then following reaction will take place.



From above reactions it is clear that 1 mole of alum (666 gm) produces 2 moles of $\text{Al}(\text{OH})_3$ ($2 \times 78 = 156$ gm). Hence 1 gm of Alum will produce $\frac{156}{666}$ gm of dry sludge
 (66)
 $= 0.234$ gm of $\text{Al}(\text{OH})_3$

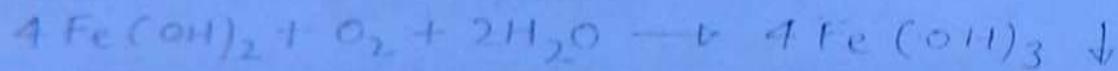
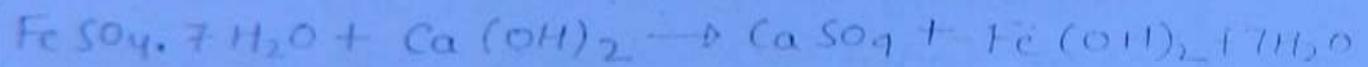
When flocs are formed then impurities are caught / trapped hence total sludge weight will include weight of impurities + weight of $\text{Al}(\text{OH})_3$ precipitate.

Note - i) Alum is most widely used for treating raw water.

Copperas (Ferrous sulphates) \rightarrow These are used with lime in order to increase the pH.



when Copperas is added in water with lime, then ~~solid~~ precipitate of Fe(OH)_3 is formed.

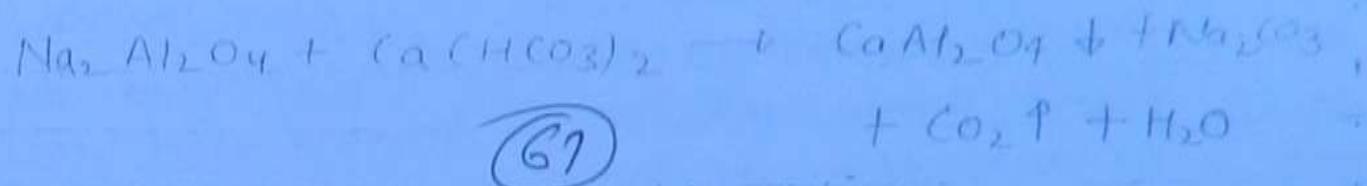


It means 1 mole of ferrous sulphate produces 1 mole of Fe(OH)_3 precipitate.

Pearl salts are active only in pH range of more than 8-5. Therefore addition of lime is essential. The use of Pearl salts in water is

water and gives precipitate of calcium aluminate. Since it removes permanent hardness hence it is often used treating boiler feed water.

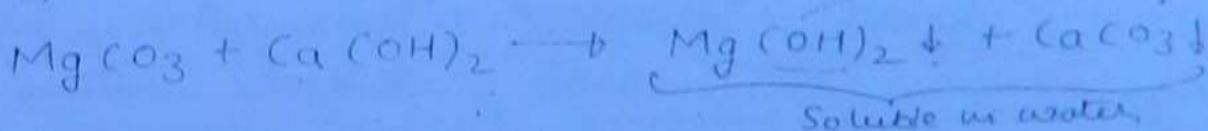
It works in pH range of 6 to 8.5.



Note :- It is weaker than Alum.

Magnesium Carbonate with lime.

Further, magnesium carbonate is used with lime.



hence Sludge produced in the form of slurry which is difficult to remove because it is broken hence this is not commonly used.

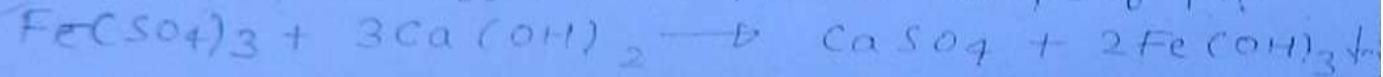
Poly electrolytes:- These are high molecular weight water soluble polymers. These work on wide pH range but are costly hence not preferred.

Page

limited because it maintains high pH beyond the permissible limit of drinking water. Moreover ironisation problem in pipe increases. Dose of ferrous sulphate is also 10 to 30 mg/ltr.

(68)

Chlorinated copperas : When chlorine is added with ferrous sulphate, then ferric sulphate and ferric chloride is formed and resulting combination of these 2 is called chlorinated copperas. The ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$) is active in pH range 4 to 7 and at pH more than 9. While as ferric chloride is active in the pH range (FeCl_3) 5.5 to 6.5 and at pH over 8.5. Hence resulting combination is effective in wide range of pH.

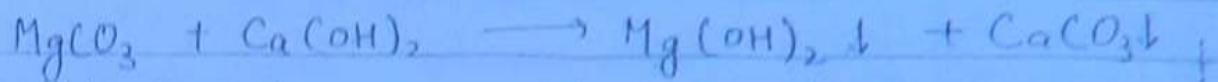


Note ① Iron salts are more commonly used in treating sewage water.

- ② Iron salts produce $\text{Fe}(\text{OH})_3$ which cause tuberculation in pipes hence produces bad taste and odour. Therefore not preferred for treating drinking water.
- ③ Iron salt produce heavy floc and also time required for floc formation is less.

Sodium Aluminate ($\text{Na}_2\text{Al}_5\text{O}_4$)

It reacts with permanent hardness present in



Hence it is not commonly used.

(69)

Poly electrolytes :-

These are high molecular wt

- water soluble polymers. These work on wide pH range but are costly hence not preferred

Methods of feeding Coagulants :-

Dry feeding :- It is simple and requires less space for working and it is cheaper but its control is difficult and mixing is not very effective.

Wet feeding :- The solution of coagulant of required strength is prepared and mixed with water slightly through mixture in this method there is better control of quantity.

Mixing devices :-

Centrifugal Pump :- In most of cases centrifugal pump is used to raise the water to the settling tank & coagulants may also be added in suction line of water which will be mixed with

8. Compacted air agitation (O = 100%)
 9. Mixing basin with baffle walls
 10. Mixing basin with mechanical devices \therefore It is used
 in most of the modern water treatment plant. The mechanism is called Flash Mixer which contain paddles which are operated by power driven motor. The intensity of mixing is dependent upon temporal mean velocity gradient (G_T). The turbulence and mixing is based on the rate of power input. Generally Flash mixer has speed of 400 to 1400 rpm & detention time of 30 to 60 sec.

The temporal mean velocity gradient is defined as the rate of change of velocity per unit distance normal to the section.

The dimension of G_T = m/sec/m = sec⁻¹

$$G_T = \sqrt{\frac{P}{\rho V}}$$

Where P = Power Input required in watt/m³/hr of flow (1 = 3)

V = Volumetric flow in m³/hr

V = Q/t to which power is applied for mixing

$$Q \times t$$

| | | |
|-------|--|----------------------------------|
| μ | dynamic viscosity coeff. / (N.s/m ²) | absolute viscosity coeff. / (cP) |
|-------|--|----------------------------------|

Flocculation :- It is the process to initiating formation of flocs. Flocculation is a slow mixing process in which colloids are brought together to form flocs. The rate of flocculation is dependent upon several factors such as concentration of turbidity, type of coagulant, Temporal mean velocity gradient etc.

If temporal mean velocity gradient (G_f) is combined with detention time or displacement time then non dimensional parameter is formed called conjunction opportunity.

$$C.O. = \frac{G_f \times t}{\text{detention time}} = \frac{G_f \times t}{\text{sec}^{-1} \times \text{sec}} = 1$$

$$= \sqrt{\frac{P}{\mu V} \times \frac{V}{Q}}$$

$$C.O. = \frac{P V}{\mu Q}$$

Power induction flow
Water flow
also called detention
flow

Flow : Power Induction flow = $\frac{PV}{\mu Q}$

If G_f is large & t is short then small and dense flocs are formed which subsequently together to form large flocs which can be removed easily.

Note 2: If Q is small & t is long then lighter flocs are created.

Note 3: Q is recommended $\geq 300 \text{ sec}^{-1}$ and t is recommended $\leq 60 \text{ sec}$.

(72)

Ques: A water treatment plant is required to process $28800 \text{ m}^3/\text{day}$ of raw water. The rapid mixing tank imparts a velocity gradient of 900 sec^{-1} to mix/blend 35 mg/l of alum with the flow for a detention time 2 min . If $\rho = 1000 \text{ kg/m}^3$, $\eta = 2 \times 10^{-6} \text{ m}^2/\text{sec}$ then find power input in watts required for rapid mixing -

- a) 32.4 W b) 36 W c) 32.4 W d) 32400 W

$$G_t = 900 \text{ sec}^{-1}$$

$$t = 2 \text{ min} = 120 \text{ sec}$$

$$Q = \frac{28800}{24 \times 60} = 0.333$$

$$V = G_t \times t$$

$$V = 0.333 \times 120$$

$$V = 40 \text{ m}^3$$

$$\mu = \rho \cdot \eta = 1 \times 10^{-3} \text{ N-s/m}^2$$

$$P = G_t^2 V \mu$$

$$= (900)^2 \times 40 \times 1 \times 10^{-3}$$

$$= 32400 \text{ Watt}$$

Filtration

(73)

In Filtration the turbidity, colloidal metals, non settleable metal, some insoluble metals, organic comp^d, micro organisms are removed.

Following are the 4 operations during filtration.

Mechanical straining

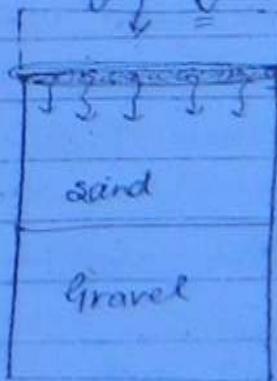
Sedimentation

biological action

electrolytic action

1. Mechanical straining :- Impurities are trapped in sand surface. It is a kind of screening which takes place at the surface of sand.

2. Sedimentation :- The particles which are finer than the voids may also removed by filtration b/c such particles stick stick to already settled gelatinous mass.



3 Biological action :- A layer of sticky particulate organic matter, silica clay, etc., 74 bacterial sludge is formed at top surface of filter medium which is called dirty skin or SCHMUTZDECKE which may contain bacteria, protozoa and Helminths also.

The organic matter become food & microbe consumer hence biological activities takes place sometimes bacteria destroy each other to maintain bacterial balance.

* Electrolytic Action :- The particulate matter may be removed by electrostatic exchange. The charge on filter medium neutralizes the charge on flocs. During the process of back wash the electrostatically neutral material is removed & charge on filter medium is regenerated.

Classification / Types of filters :-

- 1 Slow sand filter
- 2 Rapid sand filter / Rapid gravity filter
- 3 Pressure filter

1 Slow sand filter :- Generally there are unrigid rectangular basin with Q/B ratio 1.5 to 3. The treatment reqd. for such water plain sedimentation without coagulation.

→ The filter medium consists of sand having size 0.2 to 0.4 mm & coefficient of uniformity b/f_w 3 to 5 & total depth of slow sand filter 90-110 cm 75

→ Below the sand is a gravel base is provided having particle size 3-6.5 mm of thickness of gravel base of 30-75 cm.

→ The top 10-15 cm depth of sand is usually finer than the lower part which is retaining the impurities. The area of each filter unit ranges b/f_w 100 to 200 m^2 having its size of the order of $30m \times 60m$.

→ The filtration rate is small of the order of 100 to 200 $l/t/hr/m^2$ is the

→ The design period of filter is 10-15 yrs if design discharge is taken as $\max_{\text{daily demand}}$

→ Freshly clean filter have low head loss of the order of 10-15 cm only but with the passage of time head loss increase hence to maintain const. discharge - telescopic tube is adjacent.

→ The slow sand filters are very efficient in removal of bacteria & removal upto 98-99% bacterial content & suspended solid.

The water is prechlorinated then effluent may be upto 99.9%. There may be some turbidity upto 50 ppm.

(76)

The cleaning of filter is done once in 1 to 3 months in which 1.5 to 3 cm layer is scrapped and washed manually. Amount of water required for cleaning is 0.2 - 0.6 filtered water of a day.

Since these are very efficient they are suitable for smaller (discharge reqd less) treatment plant where low colour, low turbidity & low bacterial turbidity is reqd but hence these require a large area hence uneconomical for large public supply. For large public supply rapid sand filter is used.

The no. of filters bed required depends on total filter area but usually one filter bed is provided at standby.

Guidelines to adopt no. of filter beds :-

area

$\leq 20 \text{ m}^2$

20 - 250

250 - 650

650 - 1200

> 1200

no. of filter beds
, running, standby

2 (1 + 1)

3 (2 + 1)

4 (3 + 1)

5 (4 + 1)

6 (5 + 1)

Design a slow sand filter for following data

Popn \rightarrow 50,000

(77)

per capita water demand - 150 l/ped

maxm daily demand - 1.8 avg. daily demand

rate of filtration - 180 lt/hr/m².

design 6 beds of filter assuming 1 bed will be kept at stand by.

$$\text{avg. daily demand} = 150 \times 50,000 \\ = 7,500,000$$

$$\text{maxm daily demand} = 1.8 \times 7,500,000 \\ = 13.5 \times 10^6 \text{ l/day.}$$

$$\text{design discharge in l/hr} = \frac{13.5 \times 10^6}{24}$$

$$= 562,500 \text{ lt/hr.}$$

$$\text{Total filter area reqd} = \frac{562,500}{180} = 3,125 \text{ m}^2$$

$$\text{no of opn filter bed} = 5$$

$$\therefore \text{area of each opn filter bed} = \frac{3,125}{5}$$

$$= 625$$

$$\therefore B = 2$$

$$\text{area} = 2B \times B = 2B^2 = 625$$

$$B = 17.67 \text{ m}$$

$$L = 35.35 \text{ m}$$

Rapid sand filter :-

(78)

- The water to be treated must be coagulated & sedimented. The filter media is sand having size b/w 0.35 to 0.60 m & uniformity Coff changes $b/w = 1.3$ to 1.7. The depth of sand is about 75 cm.
- The sand is laid at decreasing increasing size from top to bottom.
- Below the sand gravel base is provided having size 3m to 40 mm & its depth is 60 - 90 cm.
- The size of each filter unit is smaller b/c filtration rate is more the area of a filter bed will be 10 to 80 m^2 & size of each filter unit may be 10.5 m to 8 m.

Rate of filtration - $3000 \text{ lit/hr/m}^2 - 6000 \text{ lit/h}$
(30 times of slow sand filter).

These are washed mechanically through backwashing either using water & compressed air. Backwashing is done at every 1 to 3 days to amount of water reqd for back washing 1 to 5% filtered water of a day can't usually 30 min time is reqd for back washing hence if back washing is done the filter runs for $23\frac{1}{2}$ hrs.

→ These are less efficient in removal of bacteria (80 - 90%) but are highly efficient in removal of colour. These may remove 35-40 ppm turbidity.

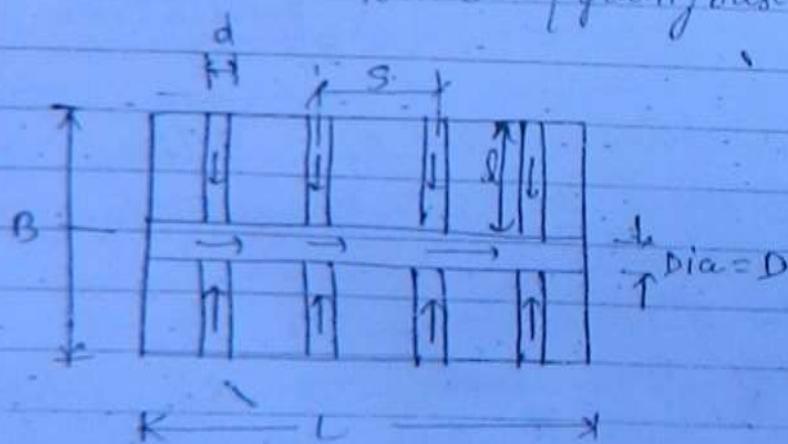
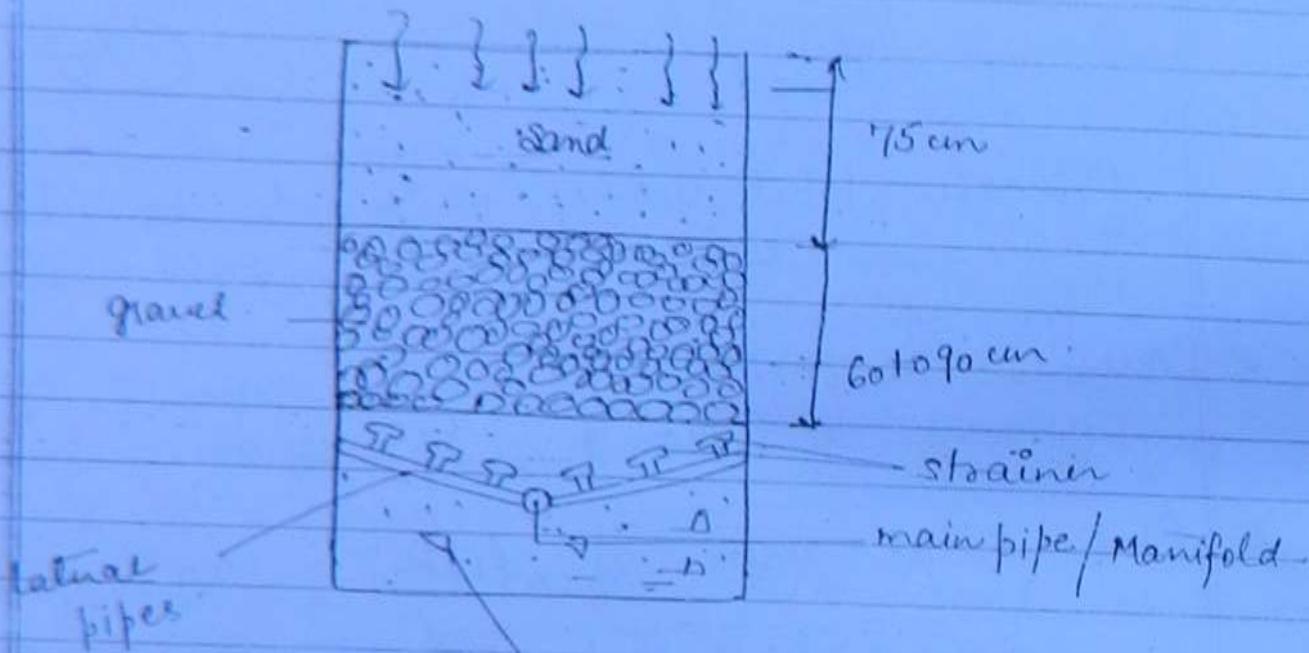
(79)

Design steps :-

1. Estimate total vol. of water to be filtered per day which is equal to \max^m probt daily demand for poplⁿ.
2. Assume suitable filtration rate (if not given in range of 3000 - 6000 ltr/hr/m²)
3. Find total area of filter reqd
 $= \frac{\text{Vol. of water to be filtered}}{\text{filtration rate (ltr/hr/m}^2)}$
4. Find the total no. of filter reqd for opn having area of each filter b/w 10 to 80 m².
If no. of filters unit is 4-5 then provide a standby unit but no. of filters unit may also be worked out by Morrel & Wallace formula
- no. of filter units = $1.22 \sqrt{Q}$
Q → ml/day.
- Design each filter unit to be rectangular having L/B ratio b/w 1.5 to 3.

Design of under drainage system of
Rapid gravity filter (Back washing system)

(80)



$$il = \left(\frac{B}{2} - \frac{D}{2} \right) \quad (D = \text{Dia of manifold})$$

$s = 10 \text{ cm to } 30 \text{ cm}$ (known to us).

- no of laterals on one side = $\frac{\text{length}}{\text{spacing}}$

$$= \frac{L}{s}$$

Total no. of lateral on both side = $\frac{A_L}{S}$

(81)

Stips:-

The laterals are of two types

- a) Pipes having perforations of whole size (6-30 mm)
- b) Pipes having strainers. Generally perforated type suggest high velocity for cleaning hence strainer type is preferred.
2. The total c/s area of perforations / strainers should be abt 0.2% of total filter area and the c/s area of laterals should be 3-4 times c/s area of perforations. Area of lateral may be taken 2 times of the perforation area when dia of perforation is 13mm & it should be taken 4 times when dia is 6mm.
3. The c/s area of main pipe should be abt 2 times the c/s area of all laterals.

The ratio of length to dia of each lateral should not be more than 60

$$\frac{l}{d} \leq 60$$

The spacing of laterals should be kept 10-30 cm/c

The maxⁿ permissible velocity in manifold to provide adequate backwashing but to

prevent up flow of sand. is 1.8 to 2.9 m

Note:-

The rate of application of wash water & settling velocity of smallest particles to be retained in filter to avoid boiling of sand.

(82)

Note-2

If V_b is backwash velocity or up flow velocity & V_t is terminal settling velocity then

$$\left[\left(\frac{V_b}{V_t} \right)^{0.22} = n \right]$$

where n = porosity of sand / porous media filter

V_t can be found by

$$\left[V_t^2 = \frac{4}{3} \left(\sigma_s - 1 \right) g \cdot d \right]_{C_D}$$

Where C_D = drag coeff.

σ_s = sp. gr. of solids.

g = gravity

d = dia of settling particle or dia of particle

Note-3

When backwashing is done to expand porous bed / sand hydrostatically then head loss occurs. loss of head is given as -

$$\therefore \left[h_1 = (\sigma_s - 1)(1-n)L \right]$$

where $l = \text{length} / \text{thickness of effective porous media / sand}$
 $\eta = \text{porosity}$ (83)

In rapid gravity filter the permissible head loss is 2.5 - 3.5 m & permissible re head is 0.8 - 1.2 m.

Ques: Design the dimensions of a set of rapid gravity filters (2 filters) for treating water reqd for 50,000 popn. The water demand is 180 lpcd and max^m demand is 1.8 times of avg daily demand assume filtration rate 5000 ltr/hr/m² & assume 30 min time is lost in backwashing in 5% of filtered water is reqd for back washing

$$\text{Total max^m daily demand} = 1.8 \times 50000 \lambda 180 \text{ l/day}$$

$$\begin{aligned} \text{Total water reqd to be filtered per day} &= 1.05 \times 1.8 \times 50000 \\ &\quad \downarrow \\ &\quad \text{account for backwash water} \\ &= 17.01 \times 10^6 \text{ l/day.} \end{aligned}$$

~~$$\begin{aligned} \text{Total water to be filtered per hr} &= 17.01 \times 10^6 \text{ l/hr} \\ &\quad \frac{23.5}{3.5 \text{ hrs}} \\ &= 723829.7 \text{ l/hr} \end{aligned}$$~~

$$\text{filter area reqd} = \frac{723829.7 \text{ m}^2}{5000} = 144.76 \text{ m}^2$$

There are two filter beds.

(84) area of each = $\frac{144.76}{2} = 72.38$

assume $L:B = 1.5$

$$A = 1.5 B^2 = 72.38$$

$$B = 6.94 \text{ m}$$

$$L = 10.92 \text{ m.}$$

Ques Design R.G. Filter for 4 MLD of water supply.
Assume filter rate 5000 lphr/m^2 , amount of back washing 4% of filtered water & time lost in back washing 30 min. And (1) no. of filter bed & size of each filter (2) Manifold lateral drainage system.

assume $s = 15 \text{ cm}$

Total water reqd to be filtered per day =
including backwash water

$$\frac{1.04 \times 4 \times 10^6}{4.16 \times 10^6} \text{ m}^3$$

$$\text{water to be filtered per hour} = \frac{4.16 \times 10^6}{23.5}$$

$$\sqrt{F} = 0.177 \times 10^6 \text{ l/hr.}$$

$$\text{No. of filter units} \approx 1.22 \sqrt{Q}$$

$$= 1.22 \sqrt{4.16}$$

$$= 2.488 \quad (\text{2 no. of filter})$$

$$\text{total area of filter reqd} = \frac{0.177 \times 10^6}{5000}$$

$$= 35.4 \text{ m}^2$$

$$\text{area of each filter} = \frac{35.4}{2}$$

$$= 17.7 \text{ m}^2$$

(8)

$$\text{assum } l/B = 1.5$$

$$1.5 B^2 = 17.7$$

$$B = 3.43 \text{ m}$$

$$L = 5.15 \text{ m}$$

under drainage system

$$\text{area of perforations} = 0.2\% \text{ of filter area}$$

$$= \frac{0.2}{100} \times 17.7$$

$$0.0354 \text{ m}^2$$

let us adopt 13mm size of perforation

$$\begin{aligned} \text{area of laterals} &= 2 \times \text{area of perfor} \\ &= 2 \times 0.0354 \\ &= 0.0708 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{area of main pipe (manifold)} &= 2 \times 0.0708 \\ &= 0.1416 \text{ m}^2 \end{aligned}$$

dia of main pipe \rightarrow

$$\frac{\pi D^2}{4} = 0.1416$$

$$D = 0.424 \text{ m} = 42 \text{ cm}$$

$$\text{Length of lateral} = \frac{B}{2} - \frac{D}{2}$$

$$L = 3.43 - \frac{0.42}{2}$$

$$l = 1.505 \text{ m}$$

$$\text{no. of laterals each side) } n = \frac{l}{s} = \frac{5.15 \times 100}{15} \text{ cm}$$

$$(86) = 34.33 \approx 35$$

$$\text{Total no. of laterals} = 2 \times 35 = 70$$

$$\text{area of all laterals} = 0.0708 \text{ m}^2$$

$$\text{area of each lateral} = 0.001 \text{ m}^2$$

$$= 2 \times 0.035 = 0.070$$

$$\text{area of manifold} = 2 \times \text{area of lateral}$$
$$= 2 \times 0.070$$
$$0.14 \text{ m}^2$$

$$\frac{\pi d^2}{4} = 0.001$$

$$d = 0.035 \text{ m}$$

$$= 3.5 \text{ cm}$$

$$\frac{l}{d} = \frac{1.505}{3.5} = 0.43 = 43 \text{ cm} \neq 60$$

OK

It means no. of filter units = 2

$$\text{size of each filter} = \frac{3.43}{3} \times 5.15$$

$$\text{no. of lateral pipe} = 35 + 35 = 70$$

$$\text{dia of lateral} = 3.5 \text{ cm}$$

$$s = 15 \text{ cm } \%$$

$$\text{size of perforation} = 13 \text{ mm}$$

$$\frac{l}{d} = 1.505 \text{ m}$$

$$d = 7.2 \text{ cm}$$

$$L = 5.15 \text{ m}$$

Ques. No. 4

Rapid Sand Filter is to be provided in water treatment plant to process the water for a town with population of 275000. The water demand is 200 lpcd. The rate of filter is $15 \text{ m}^3/\text{hr}$. Allow 5% of filtered water for back washing & 30 min period for back washing. determine the no. of filterbed required including 1 filter in standby.

(87)

Assume area of each filter $10 \text{ m} \times 4 \text{ m}$.
also compute the upflow velocity & head loss to expand the porous bed to length of 0.66 m
assume $n = 0.5$ (porosity).

$$q_s = 0.5$$

$$d = 0.6 \text{ mm}$$

$$C_d = 25.02$$

$$\lambda = 0.1013 \times 10^{-5} \text{ m}^2/\text{sec}$$

$$\text{Total water req'd to be filtered per day} = 1.8 \times 275000 \times \frac{\text{hr}}{24 \times 1.05} \\ \text{including back washing.}$$

23.5

$$= 4.42 \times 10^6 \text{ lit/hr}$$

$$= 4.42 \times 10^3 \text{ m}^3/\text{hr}$$

$$\text{Total area of filter req'd} = \frac{4.42 \times 10^3}{15}$$

$$= 294.89 \text{ m}^2$$

$$\text{no. of operational filters} = \frac{294.89}{10 \times 4}$$

$$= 7.36 \text{ n.s}$$

$$\text{So Total no. of filter} = 8 + 1 - \text{standby} \\ = 9$$

$$V_t^2 = \frac{4}{3} (C_s - 1) g \cdot d$$

$$\textcircled{88} = \frac{\frac{4}{3} (2.5 - 1) 9.81 \times 0.6 \times 10^{-3}}{25.02}$$

$$V_t^2 = 0.47 \times 10^{-3}$$

$$V_t = 0.022 \text{ m/s}$$

$$\left(\frac{V_b}{V_t}\right)^{0.22} = n$$

$$\left(\frac{V_b}{0.022}\right)^{0.22} = 0.5$$

$$V_b = 9.4 \times 10^{-4} \text{ m/sec}$$

$$h_L = (C_s - 1)(1 - n)L \\ = (2.5 - 1)(1 - 0.5) 0.66$$

$$h_L = 0.495 \text{ m}$$

 **filter Troubles** : — The problems in filter
— arise due to either ~~in~~ probe
design or poor openⁿ. Following are the
troubles

1. cracking & clogging of filtered bed
2. formations of mud balls
3. Air binding
4. Sand incrustation
5. Jetting or sand boils
6. Sand leakage

Cracking & clogging of filter bed :-

(89)

It is :-

caused by accumulation of solids on the top surface of the filter media. There is compression & shrinkage of soft vegetalinous - grains which may cracks. The cracks are more prominent near wall junction. Due to cracks dirty matter may pass with the water hence efficiency may reduced. To minimise cracking - proper back washing is sugd.

Formation of mud balls :- When turbid flocs combined with sand & other binders near the top of filter then mud balls are formed. These are formed due to insufficient washing sand grains. It reduces the filter rate. It can be avoided by adequate back washing to surface washing.

Air binding :- When water percolates then it loses its head which further increases with time when h/t is high p/r in water becomes -ve & when it falls below vapour pr then air gets separated from the water which produces bubbles - which trapped on the pore hence air locks are cracked and filter rate is reduced.

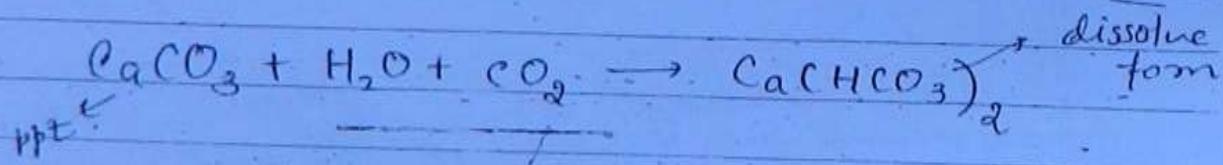
The problem of air binding is more

When \rightarrow temp. of water is high
growth of algae have seen
water is super saturated with
excessive head loss -

(90)

Air binding can be minimising by air
head loss or excessive +ve head by
providing extra over filter bed
control of algae growth by adding C₆
avoiding heating of water
avoiding supersaturation with air

Sand Incrustation : — When sticky gelatinous
materials combine with
sand due to crystallisation of CaCO₃
then eff size of sand is increased.
This prob. can be minimized by
carbonating the influent water or by
adding sodium hexa meta phosphate to
keep CaCO₃ in dissolved state.



boiling or Sand boils : — During back wash
under high head sand
may start coming up & condⁿ of
quick sand may be revealed. It may
be minimise by surface or air
wash. It may be eliminated by using

coarse garnet layer or ilminite layer b/w
sand & gravel. (9)

Sand leakage:- Th. d/w movement of sand and
escape of finer particulate may
occur due to improper grading or when
gravel is displaced by backwashing. It
may be minimised by well grading
or by using coarse garnet layer b/w
sand & gravel.

PRESSURE FILTER:- It is a kind of
rapid sand filter which is
enclosed in a container and water passes
under pres. The pres. may vary from 3-7
kg/cm² which may be developed by
pumping. These may be horizontal or
vertical type.

Design Specification:

Dia of tank - 9 - 9.5 m

length / height - 9.5 = 8 m

Filter rate - 6000 - 15000 lit/hr/m²

which is 2.5 times of rapid
sand filter.

Filter material - sand followed by gravel

It is often used for swimming pool water
& also for softening industry.

Double Filtration OR Roughning Filter:-

(q2)

To increase the filtration rate through a slow sand filter without compromising the quality we use rapid sand filter before the slow sand filter this process is called double filtration and rapid sand filter is used called roughning filter or scrubber.

Disinfection

Disinfection means killing of pathogenic bacteria whereas
sterilisation means killing of pathogenic & non-pathogenic
bacteria both.

(1)

Disinfectants either destroy or inactivate microorganisms
by following four mechanism:-

1. Damage of cell wall of microorganism
2. Alteration of cell permeability
3. Changing the nature of cell protoplasm
4. Inactivating the enzyme system which is responsible for metabolism

Methods of disinfection :-

Minor methods :-

1. Boiling : It is the best method which removes 100% bacteria and other micro-organisms. This is adopted by individuals but not suitable for mass public supply.

2. Treatment with excess lime :- Lime increases pH and when pH is more than 11 then it removes 99 - 100 % bacteria. Generally it is used for boiler feed water b/c it reduces hardness. The necessary dose of lime (CaO) is to do so. Its excess lime can be removed by carbonation of the water.

5 Treatment with silver ion / electrocatalytic process

(94)

Metallic silver ion have strong killing action. These require in contact killing period of 15 min to 3 hrs. A DC supply voltage may be required of the order of 1.5 volt to produce silver ion. This method is costly.

4 Treatment with iodine & Bromine :-

It may be used for army troops & by private plants.

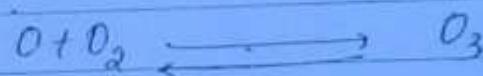
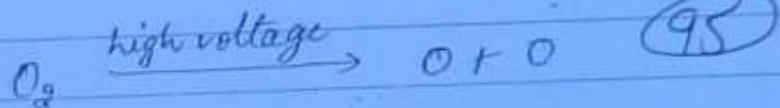
5 Treatment with UV light :- This mtd is efficient mtd of sterilisation. UV rays are generated using mercury vapour lamp. Blue green region of spectrum is more destructive (2000 \AA to 3000 \AA).

This mtd is also costly and is often adopted for treating surgical water & swimming-pool water.

6 Treatment with KMnO_4 : (Pink Powder) :-

It is commonly adopted for open wells in rural area. It can kill bacteria and can oxidised bed taste producing organic matters. If pink colour disappear quickly then it indicates oxidation & presence of organic matter. Its small dose i.e. 2 mg/lit may be sufficient.

7. Ozone :- It is a powerful oxidising agent & it can be produced in a high voltage electrical field from oxygen. Since it is highly unstable hence it should be produced at sight. Ozonised water is tasteless & no residue is left & also no colour is produced.



(Q)

Since residual O_3 is not left hence for prevention of future contamination a small quantity of chlorine is added.

This method is adopted in Europe and was first in Chandigarh in India. Since it is costly hence it has limited use in India.

Chlorine dioxide (ClO_2) :- It's properties are similar to O_3 .

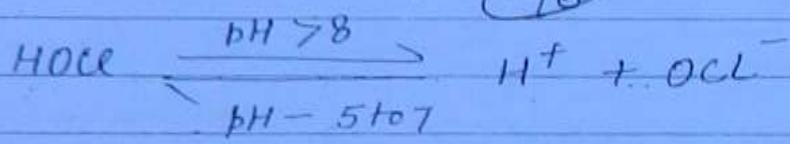
It doesn't form chloroforms & chloramines. It is effective in oxidising phenolic compd. It is also unstable hence it should be produced at site sight.

Major Method :-

1. Chlorination :- When chlorine is added in H_2O it forms hypochlorous acid (HOCl).

of hypochlorite ion (OCl^-). If pH is less than 5 then cl does not react & it remains as elemental cl. which is not effective in killing bacteria. If pH = 5 to 7 then mostly HOCl is found which is most effective in killing bacteria. (80 times more active than OCl^- ions).

If pH > 8 then mostly OCl^- ions are formed.



It means for most effective killing action of cl pH of water should be b/w 5 to 7.

factors Affecting disinfection :-

1. Form of chlorine
2. pH
3. concentration of cl
4. Type of micro.
5. Temp.
6. contact time

1. Forms of chlorine :- cl may be applied to the water in any of the following forms

- a) bleaching powder (hypochlorite or perchlorate)
- b) chloramines (cl + NH_3)

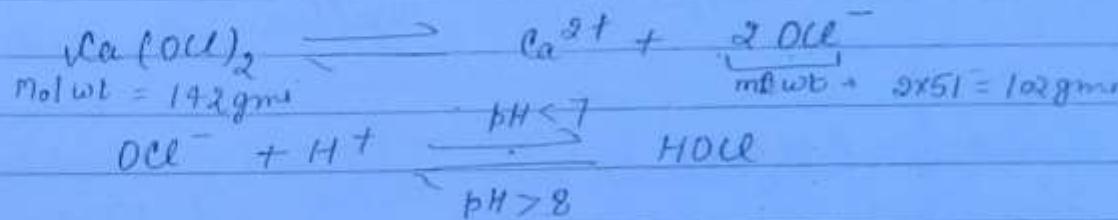
c) free Cl (either liquid or gaseous)

d) chlorine dioxide (ClO_2)

e) chlorine Tablets

(91)

vii) Bleaching Powder :- It contains 30 - 33% Cl contents whereas perchlorine also contains 60 - 70 % of available Cl



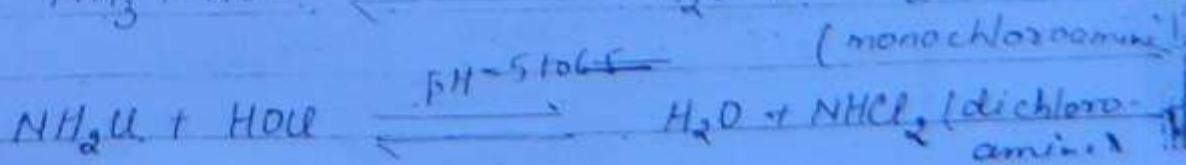
This process is also called hypochlorination.

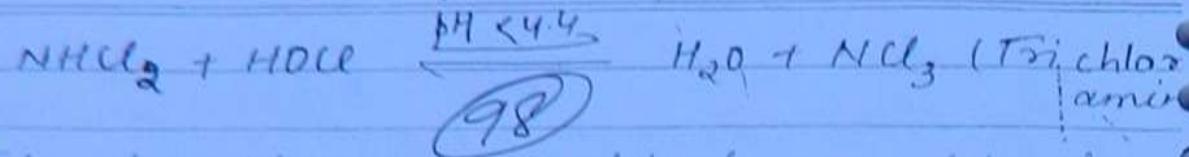
$$1 \text{ gm of bleaching powder produces} = \frac{102}{142}$$

$$= 0.718 \text{ gm of Hypochlorite ions}$$

viii) Since bleaching powder increases pH hence its use is restricted to swimming pools only.

Chloroamines :- NH_3 is added just before of addition of Cl. Usually 1 part of NH_3 & 4.5 parts of Cl are added.





Type of chloramine depends on pH of water if $\text{pH} < 4.4$ then trichloramine is formed which has no disinfection property. Most commonly formed compound is NHCl_2 .

$\text{NH}_3 + \text{HOCl}$ together is called combined chlorine.

c) Free chlorine :- either it may be applied in gaseous or liquid form. It is 2.48 times more heavier than air.

one vol. of liquid chlorine gives 462 vol. of gaseous chlorine.

When chlorine gas is subjected to pres. of 1 kg/cm² then it gets converted into liquid.

The solubility of chlorine depends upon

→ organic matter

→ pH value

→ Amount of CO_2 % present in water

→ temp.

→ contact period

The free available chlorine after 10 min. of contact time should be of the order of 0.2 mg/l

d) Chlorine dioxide (ClO_2) :- It is unstable and is produced from sodium chlorite (NaClO_2)



It is 2.5 times more active than free cl.

• It may also be used when phenolic compounds are present. (99)

If pH = 8 to 10 it may also removes organic matters since it is unstable hence it is difficult to prevent future contamination.

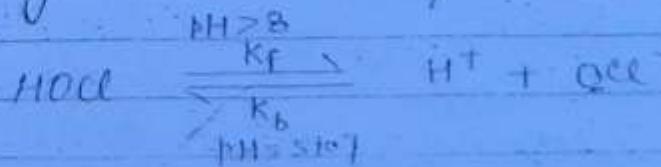
e) Chlorine Tablets :- A single tablet of 0.5 gm is sufficient for 20 lit of water. It is used by -

chlorine demand :- It is the diff b/w applied cl & residual cl at the end of specified contact period

$$\text{Chlorine demand} = \text{Applied chlorine} - \text{Residual chlorine}$$

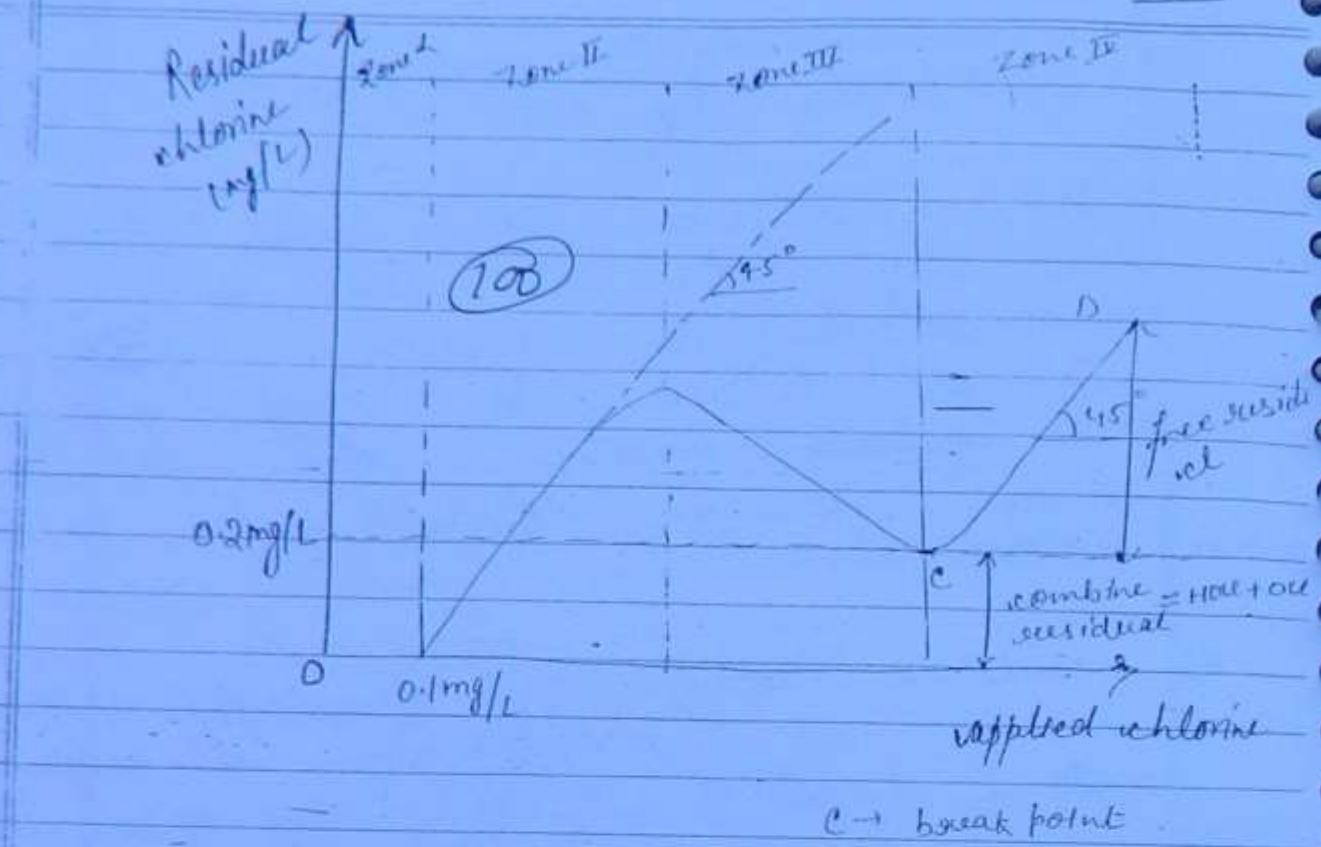
Water is satisfactorily disinfected if residual cl is of the order of 0.2 mg/l

Disinfecting action of cl :-



$$K_f = \frac{[\text{H}^+] [\text{OCl}^-]}{[\text{HOCl}]}, \quad K_b = \frac{[\text{HOCl}]}{[\text{H}^+] [\text{OCl}^-]}$$

concentration is in mol/l lit



Zone I :- The consumption of cl in zone I due to oxidation of Fe, Mn, & NO_2 (nitrite)

Zone II :- A small consumption is due to formation of chloro organic compounds & chloramines & also activation of killing

Zone II & B Actual oxidation of organic comp starts and bad taste appears whereas at C oxidation is completed & bad taste disappears :-

Zone IV :- There is no consupⁿ of cl in Zone IV
If cl is added in Zone IV then it is called superchlorination stage 2 entire cl remains as free residual cl.

Note:- If Cl_2 is added in distilled water then Cl_2 curve will start from origin & entire added Cl_2 will remain as residual Cl_2 .

Types of Chlorination :-

(10)

- 1 Plain chlorination :-
- 2 Pre chlorination
- 3 Post chlorination
- 4 Double chlorination / Multiple chlorination
- 5 Brake pt. chlorination
- 6 Super chlorination
- 7 Dechlorination.

1 Plain chlorination :- Cl_2 is applied to the raw water & no other treatment is provided. It kills & checks the growth of weeds, algae, m.o. & organic matters. It is suitable when turbidity less than $20 - 30 \text{ mg/l}$.

2 Prechlorination :- Cl_2 is applied before sedimentation. It helps in reducing amount of coagulants and also oxidises organic matters therefore reduces bacterial load of filter hence increases life of filter. It controls algae & planton growth also removes taste & odour. If cysts of *Cryptosporidium* are present then high dose with higher concentration is reqd.

Postchlorination :- It's std process to apply it after sedimentation / filtration.

(102)

Double chlorination :- Pre & Post chlorination both are applied. This is used when raw water contains large amount of bacterial life or organic matters.

Breakpt chlorination :- It removes taste & odour, Mn & Fe & leaves desired residual cl for future disinfection.

At 1st kill bacteria then oxidises organic compound.

Break pt is that pt at which all the added cl appears as free residual cl. It represents completion stage of disinfection. Free residual cl remains in water in the form of hypochlorous acid or hypochloride ion or combination of both depending upon the pH of water. At pH < 5 it may remain as elemental cl.

Super chlorination :- If cl is added beyond break pt then it is called super chlorination. It is used for removal of high concn of organic matters, cystes of E histolyticus & for prevention of future contamination.

Dechlorination :- It is the process of removal of excess of Chlorine.

It is done either byeration or by using chemicals such as Sodium Thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$), Sodium metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$), Sodium sulphite (Na_2SC_3), Potassium permanganate (KMnO_4), Sodium bisulphite (NaHSO_3), activated carbon, sulphur dioxide.

Testing of residual chlorine Methods :- 103

- 1. Ortho Tolidene Test
- 2. Starch Iodide Test
- 3. Chlorotest Test
- 4. DPD Test

Chlorine gas used for disinfection combines with water to form HOCl. The HOCl dissociates to form OCl^- ions.

$$K = 2.7 \times 10^{-8}$$



The equilibrium is governed by pH. The sum of HOCl & OCl^- is called free chlorine residual. HOCl is 90% & remaining is OCl^- in free d then pH of water should be -

- (a) 4.8 (b) 6.6 (c) 7.5 (d) 9.5



pH (5 to 7) only one option - (b)

$$K = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$2.7 \times 10^{-8} = \frac{[H^+] \times 1}{9}$$

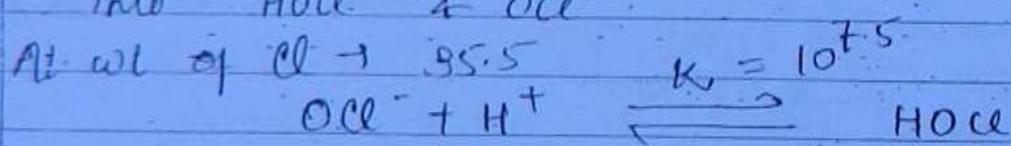
(104)

$$H^+ = 2.43 \times 10^{-7}$$

$$\begin{aligned} pH &= -\log_{10} H^+ \\ &= -\log_{10} [2.43 \times 10^{-7}] \\ &= 7 - \log_{10} 2.43 \\ &= 6.6 \end{aligned}$$

Ques. - cl gas 8 mg/l was Cl₂ was added to drinking water if free cl residual was measured as 2 mg/l as Cl₂ & pH was measured as 7.5. what is the concn of OCl⁻ ions in the water.

Assuming Cl₂ gas is completely converted into HOCl & OCl⁻.



$$\begin{aligned} \text{free residual cl} &= 2 \text{ mg/l of } Cl_2 \\ &= 2 \times 10^{-3} \text{ gm/l of } Cl_2 \\ &= \frac{2 \times 10^{-3}}{2 \times 35.5} = 2.816 \times 10^{-5} \text{ mole/lit} \end{aligned}$$

$$[HOCl] + [OCl^-] = 2.816 \times 10^{-5} \text{ mole/lit}$$

$$\text{pH} = 7.5$$

$$H^+ = 10^{-7.5}$$

$$K = \frac{[\text{HOCl}]}{[\text{H}^+][\text{OCl}^-]} \quad (65)$$

$$10^{7.5} = \frac{[\text{HOCl}]}{10^{-7.5} [\text{OCl}^-]} =$$

$$\frac{[\text{HOCl}]}{[\text{OCl}^-]} = 10^{7.5} \times 10^{7.5}$$

$$[\text{HOCl}] = [\text{OCl}^-]$$

$$[\text{OCl}^-] \text{ and } [\text{HOCl}] = 50\%$$

maxima frequency

621

$$[\text{OCl}^-] = \frac{2.816 \times 10^{-5}}{2} = 1.408 \times 10^{-5} \text{ mol/l}$$

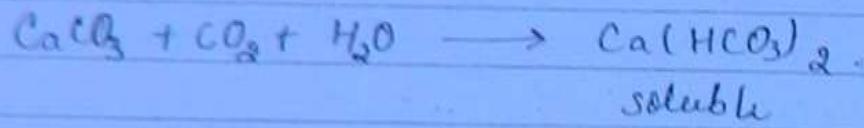
Water Softening :-

Removal of temporary hardness :-

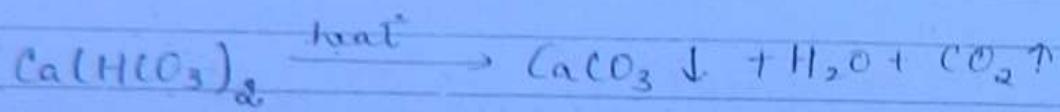
METHODS :-

TOC

- (1) Boiling :- usually CaCO_3 gets dissolved in water if Cl_2 is present.



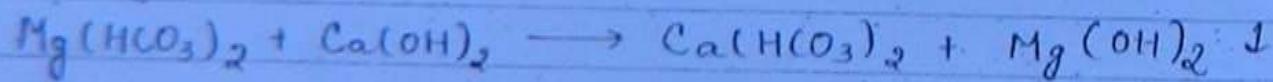
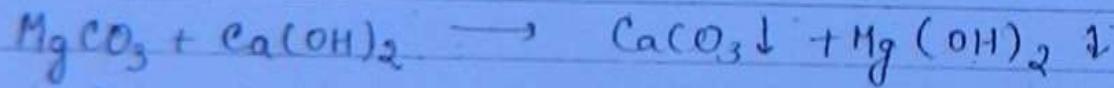
When water is boiled then



CaCO_3 can be sedimented out in settling tank

(2) Magnesium carbonate & bicarbonate cannot be removed by boiling b/c these are soluble in H_2O hence lime addition is reqd.

- (2) Addition of lime :-



1 mole of MgCO_3 requires 1 mole of lime but 1 mole of $\text{Mg(HCO}_3)_2$ requires 2 mole of lime.

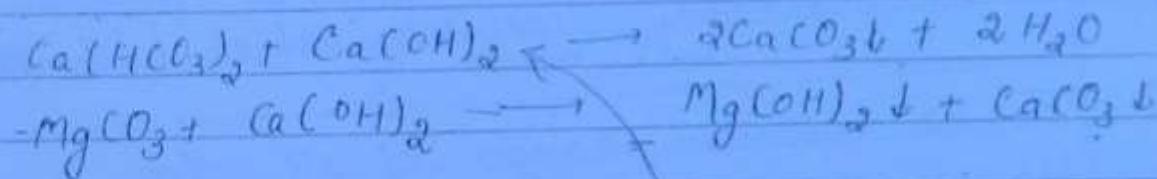
Removal of permanent hardness :-

Methods :-

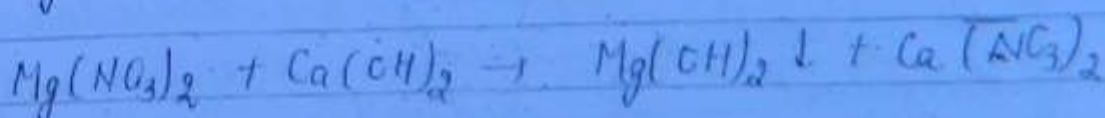
(107)

- (1) Lime Soda Method
- (2) Base exchange method / Zeolite Method
- (3) Demineralisation process

(1) Lime Soda Method :-



Hence lime removes temp hardness

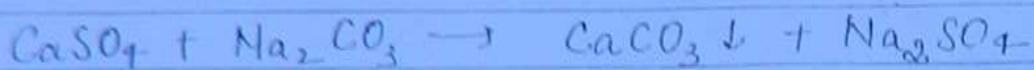
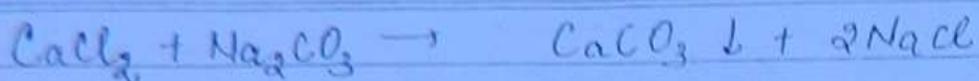


It means lime converts mg hardness into
ca hardness hence Soda is required to
remove ca hardness (permanent)

number of maximum metal
Sodium is singular

classmate

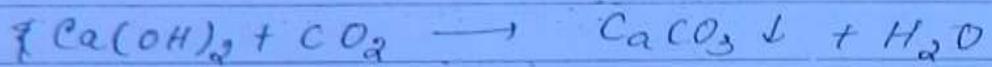
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(108)

Note-1 Lime converts noncarbonate hardness of Mg into noncarbonate hardness of Ca.

Note-2 Lime helps in removal of CO_2



which prevents corrosive action (CO_2 elimination)

Note - The optimum range of pH for ppt of CaCO_3 is 9 to 9.5 and for ppt of $\text{Mg}(\text{OH})_2$ is 11. Therefore excess lime may be reqd to be added & excess lime may be removed by carbonation.



Note- If lime to soda is added with alum i.e softening + coagulation is combined then demand of coagulant is reduced.

Note:- Lime soda process increases alkalinity hence reduces corrosive action & it also helps in removal of Fe & Mn.

Note:- In this process there is large quantity of sludge produce if lime soda is added with alum then sludge will contain following compound. The dry sludge will have wt of following compound

(109)

wt of Al(OH)_3 (Product of alum)

wt of $\text{Ca(OH)}_2 \} \text{ Product of lime soda process}$
 $\text{Mg(OH)}_2 \}$

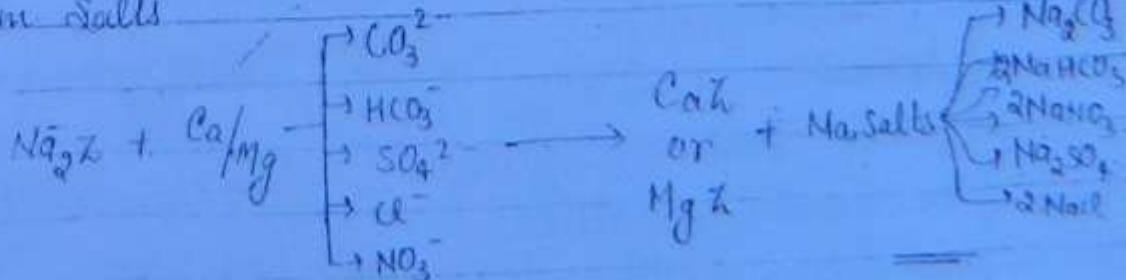
wt of suspended solid removes (Product of sedimentation)

wt of activated carbon which may be added for removal of excess lime

(2) Zeolite Method :- Zeolites are natural materials whereas zeolines are synthetic material. Zeolites are made of salts, clays, silicates of sodium & aluminium having general formula as $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot n\text{SiO}_2 \cdot y\text{H}_2\text{O}$ ($n \geq 2, y \geq 2$)

Sodium Zeolite - Z = $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot n\text{SiO}_2 \cdot y\text{H}_2\text{O}$

Sodium Zeolite when reacts with Ca or Mg salts they produce CaZ or MgZ and Sodium Salts



Z is regenerated by treating CaZ or MgZ with 5 to 10% Brønchin Solution (NaCl)



(10)

Note:- Zeolyte & seines have excellent property of exchanging their cations. These resemble with sand filter in which filtrate medium is zeolyte rather than sand.

Zeolyte are green hence often called green sand whereas synthetic seines are white which is called permuntit which is manufactured using clay, felspar, kaolin, soda.

Advantages of Zeolyte Method:-

1. No sludge produced
2. zero hardness can be achieved
3. Running & Maintenance cost is less
4. no problem of incrustation in pipes

Disadvantages

- 1) If Fe & Mn are present then both iron zeolyte & Magnese zeolyte are formed which cannot be regenerated into Sodium zeolyte hence process becomes costlier.

2) It leaves NaHCO_3 in H_2O which develops foams in H_2O especially in boilers.

3) Not suitable for turbid water. (III)

(3) Demineralization :- This process removes minerals from H_2O & it is suitable when hardness is to be precisely controlled of desired quantity. The demineralized water is also called ionised water.

Treatment With ACTIVATED CARBON

Activated carbon is form having absorptive property which attracts impurities such as gases, liquids, fine solids and it is used to remove taste and odour.

Activated carbon is produced by burning (charring) the wood at 500°C in a close vessel.

The activated carbon is available in the market either in granular or in the powder form or in the name of MARCO & NUCAR.

It can also remove phenolic substances. It is added either before or after the coagulation but before filtration. The best way is to add partly before sedimentation & partly after sedimentation, this is ~~not~~ not true.

Advantage of activated Carbon coagulation

If it is added before, then it helps in coagulation

(112)

It reduces the coliform.

It removes taste, colour, colour caused by iron, Mn & phenols.

It's over dose not harmful.

Treatment with Copper Sulphate ($CuSO_4 \cdot 7H_2O$)

It helps removal of colour, taste & odour and it is used to kill weed & check growth of algae. If often applied in crop reservoirs and lakes.

Desalination (Removal of Suspended Solids)

① Reverse Osmosis / -

Distillation / -

Electrodialysis /

Biozinc process /

Solar Distillation /

Fluoridation - If fluorine presence in H_2O is less than

more then fluorine may be added by adding following compound:

1. Sodium fluorides
2. Sodium Silicofluoride
3. Hydrosilicofluoride

(113)

Defluoridation

If fluorine presence more than 1.5 mg/l then excess fluorine may be removed by following mtd.

1. Adding activated alumina
2. Natgonda technique
3. Reverse osmosis
4. Adding flower
5. Adding Bone charcoal
6. activated carbon
7. ion exchange mtd
8. Tricalciumphosphate
9. Adding lime

DISTRIBUTION SYSTEM

classmate

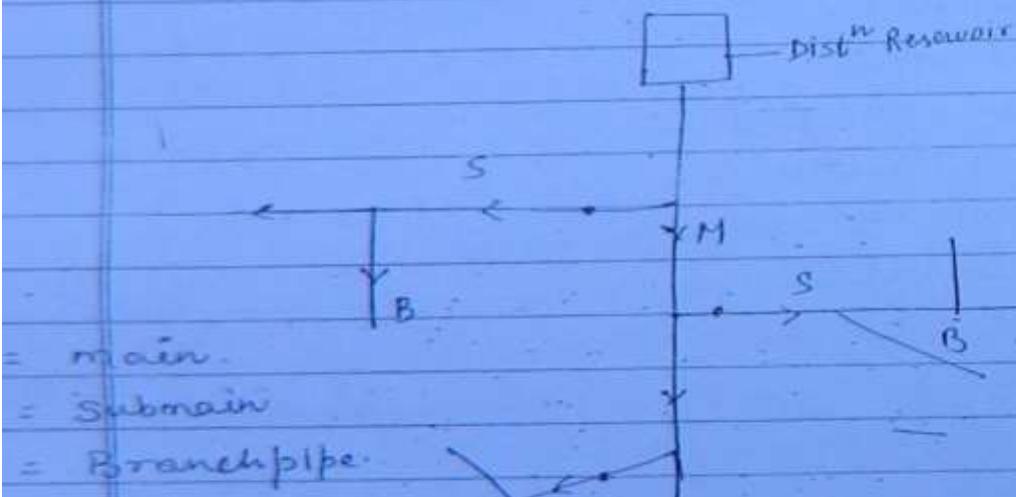
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The treated water is to be supplied to individual house. The layout of the distribution network depends upon social pattern of city and may be of the following 4 types:-

- 1 Dead end system
- 2 Grid iron system
- 3 Ring system
- 4 Radial system

(114)

1. Dead end System:-



= main

= Submain

= Branch pipe

(Tree System)

It follows network of roads and it is suitable for their scattered & town which has irregularity (half-hazard).

Advantages :-

Easy computation
less no. of cut off valves
shorter pipe length
cheap & simple

(T.S)

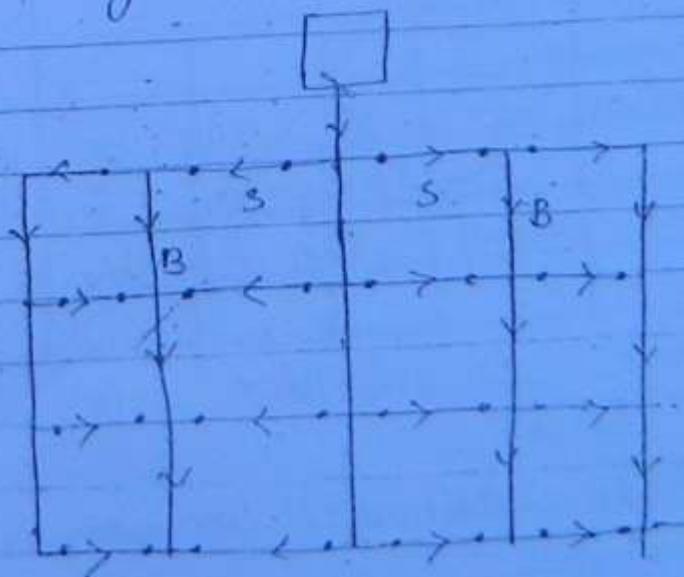
Disadvantages : - ① There is only one route of supply hence if it is damaged then entire off supply is affected.

② there are many dead ends where water will be stagnated which may get polluted.

③ Difficult to get additional water during fire break down

④ P.R. keeps on decreasing towards dead end

2. Grid iron System :-



It is suitable for well planned city having grid iron road pattern.

Advantages:-

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- ① There are more than 1 paths of flow hence friction lesser and pipe size get reduced.
- ② In case of repair only small area is affected.
- ③ Dead ends are eliminated hence due to continuous flow hence there is no stagnation & poll.
- ④ During fire more water can be drawn from alternative sources.

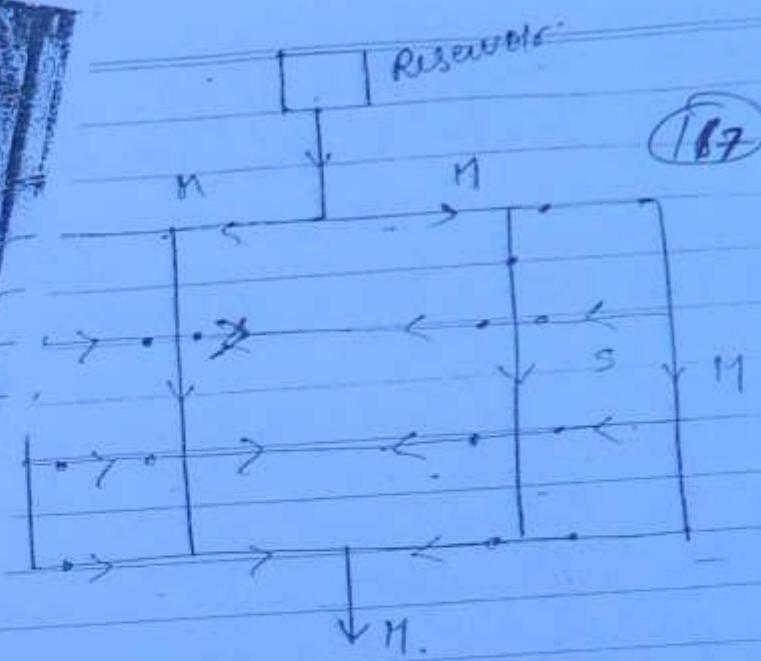
Disadvantages:-

- ① More length of pipe.
- ② Larger no. of ~~fit~~ valves
- ③ more costly

8 Ring System:- It may be circular or rectangular in which main pipes runs along the periphery.

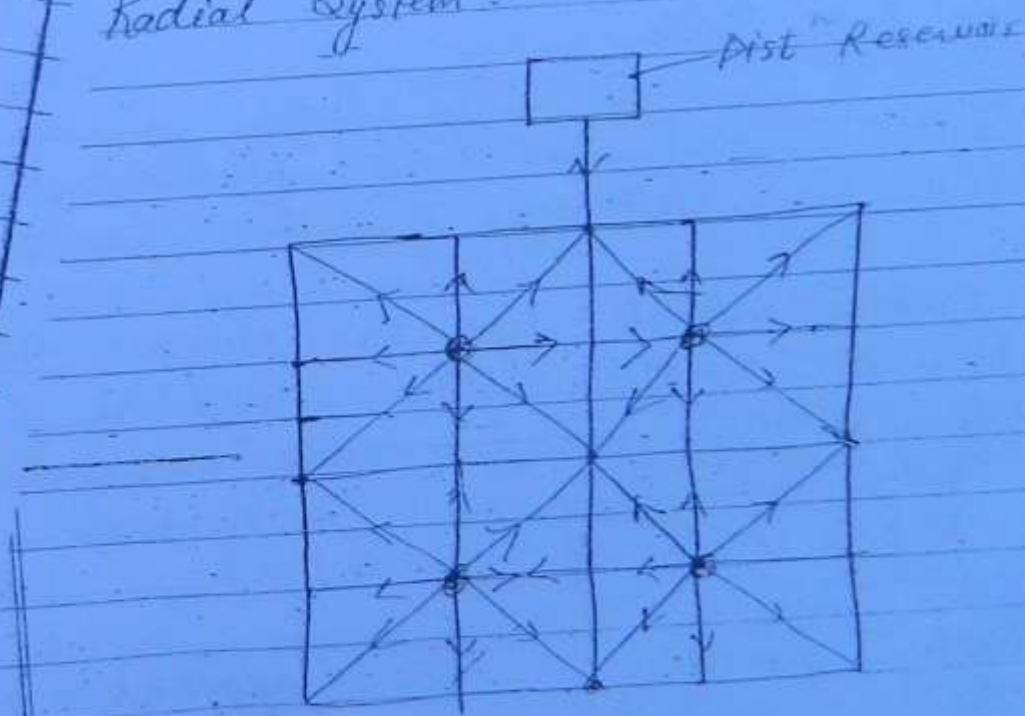
City area is divided into circular or radial blocks.

It is suitable for well planned cities.



If Disads are similar to grid system

Radial System :-



If roads are radial then water is stored in the dist reservoirs / tanks & distributed through radially laid pipes.

This mtd. maintains high pr & efficient water distribution

(118)

Analysis of pn in distribution system :-

Methods :-

1. Hardy Cross Method
2. Equivalent Pipe Mtd.
3. Circle mtd.
4. Graphical Mtd.
5. Pitometer Mtd
6. Electric Network analyser mtd

1. Hardy cross Method.

It involves trial and error approach.
it is based on following 2. rules.

- (a) On each separate pipe or element there will be a relation b/w head loss & discharge given as

$$h_f = k \cdot Q^n \quad \text{no 1. 85}$$

- (b) At each junction the algebraic sum of the quantity of water entering and leaving the junction is zero.

$$\Sigma Q = 0$$

m) In any closed loop or path, the algebraic sum of headloss in the individual element is zero.

$$\sum H_i = 0$$

(119)

Type of Water Supply System:-

- ① Continuous System \rightarrow water supplied 24 hrs.
- ② Intermittent System \rightarrow water is supplied during fixed hrs.
for eg. - 6 am to 8 am
9 pm to 8 pm.

The intermittent system has drawbacks as

- Lack of water during fire breakdown
- During non-supply hrs there is stagnation hence chance of contamination.
- Greater size of pipe reqd
- Need of domestic storage

Q. Determination of Storage Capacity of Distribution reservoir:

The total capacity consist of following. 3 storage

- ① Balancing Storage
- ② Breakdown storage } emergency storage
- ③ Fire storage } w: 25% of total capacity

$$V = \text{Bal. cap} + \text{emergency cap}$$

$$= \text{Bal cap} + 0.25V$$

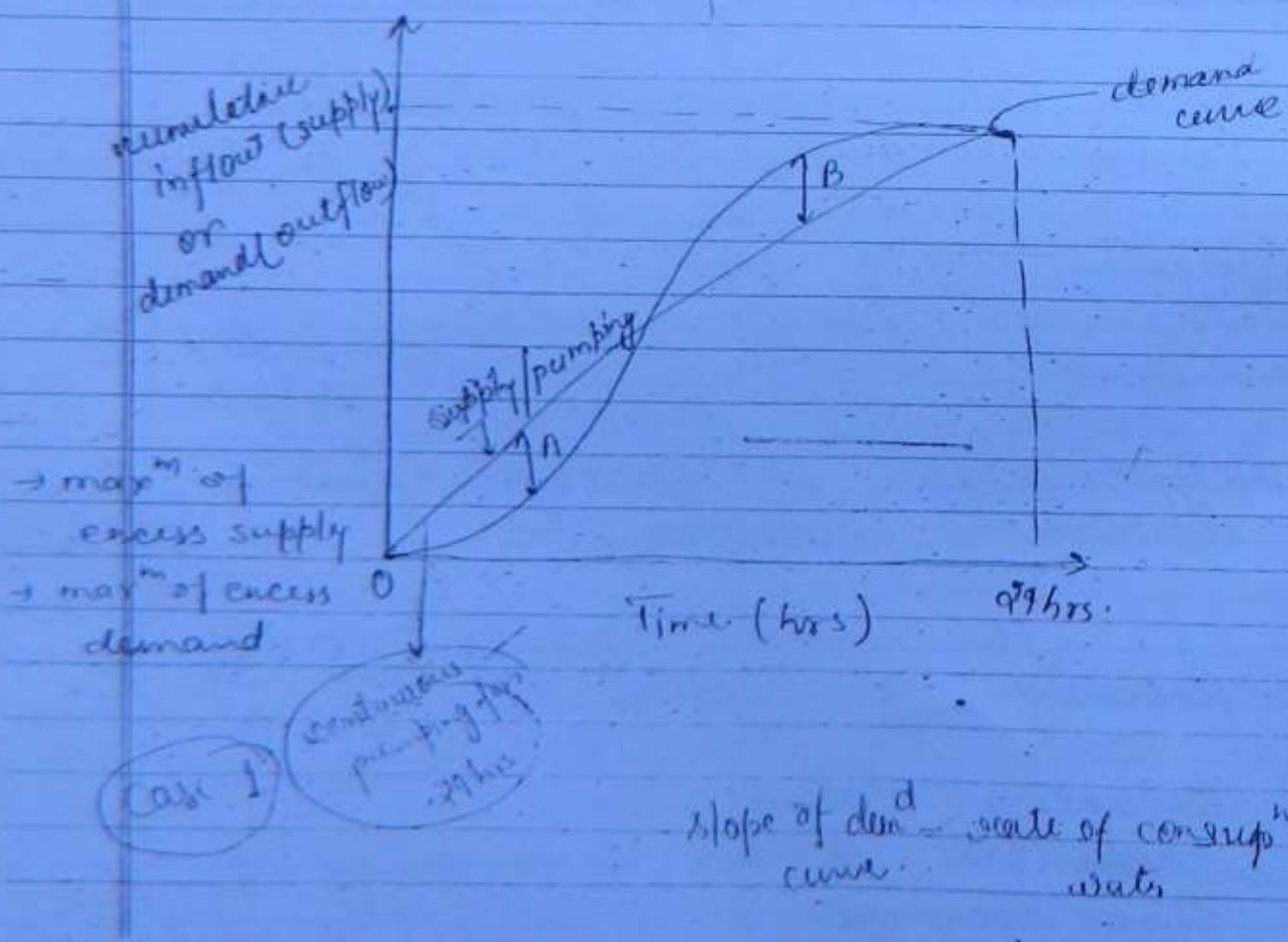
~~Ques~~ Determination of balancing storage :-

Methods :-

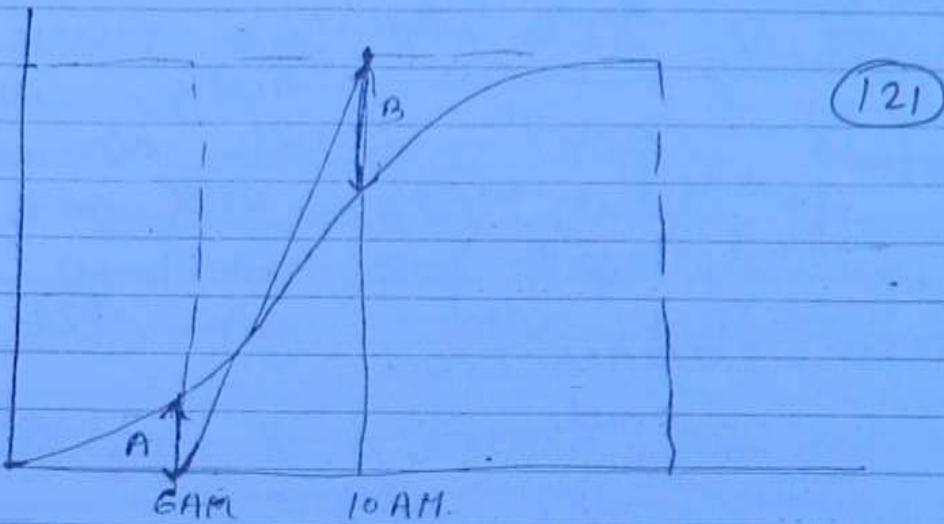
(No)

- ① Mass curve Mtd.
- ② Analytical Mtd

① Mass curve Mtd :- Mass curve is a plot of accumulated inflow - v/s time or cumulated outflow Vs time



Balancing storage = A + B ...

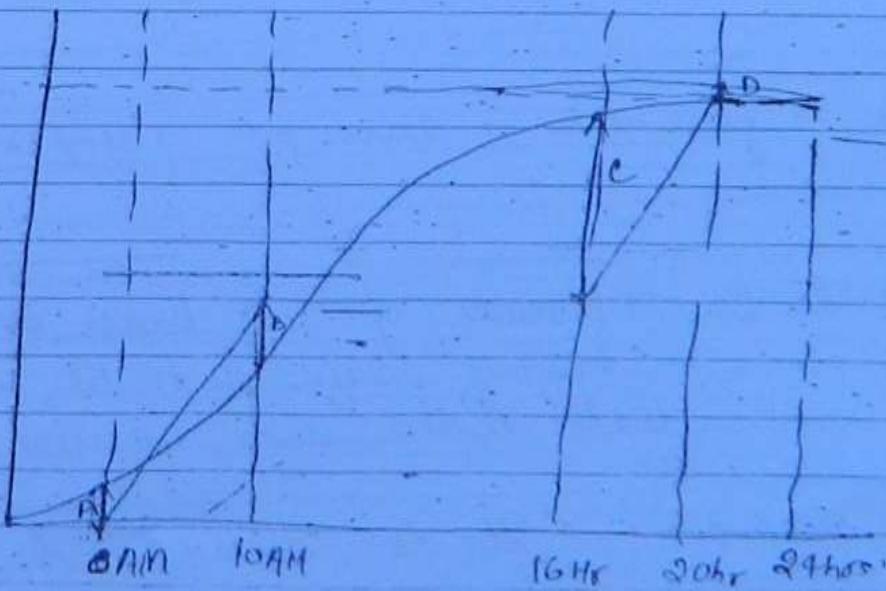


case (2) pumping has one morning 6 AM to 10 AM

A \rightarrow excess demand (max) -

i B \rightarrow max. excess supply

$$\text{Bal. cap} = A + B$$

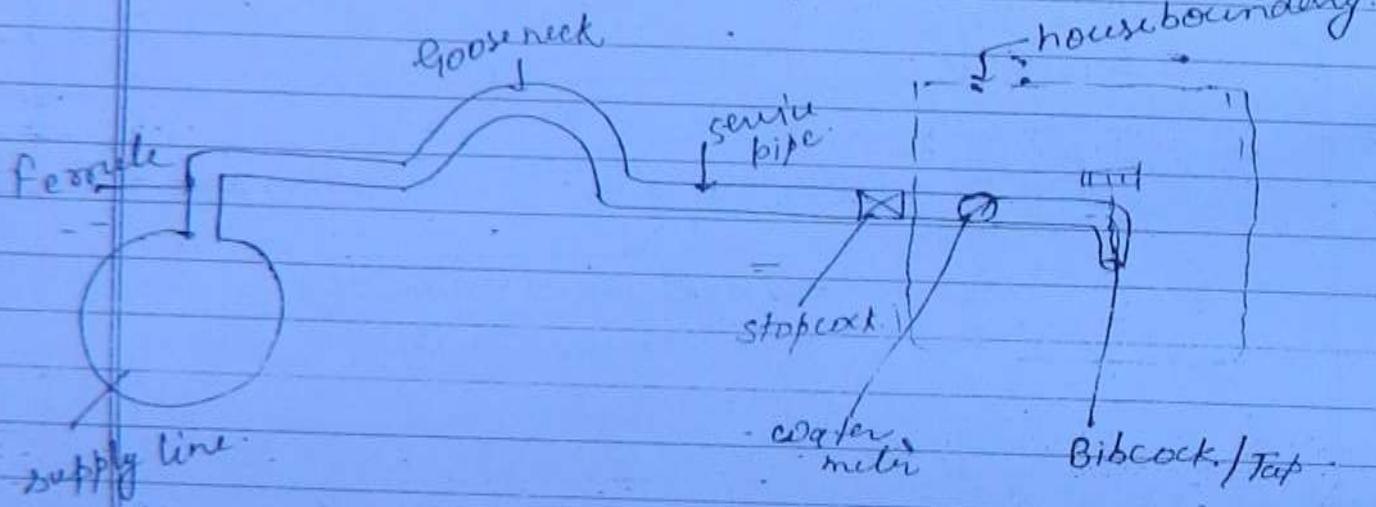


case 3 pumping is done in two shift but tank is not full in single shift

② Analytical Mtd :- In this mtd, cumulative hourly demand & cumulative supply are tabulated for all 24 hrs. And hourly excess demand & hourly excess supply is computed. The sum of \max^m excess demand & \max^m excess supply will give bal. cap.

(122)

HOUSE CONNECTION :-



Ferrule \rightarrow gooseneck \rightarrow service pipe \rightarrow stopcock \rightarrow water main
bibcock

1. Ferrule :- made of iron brass or gun metal having size 10 to 15 mm connects water main to service pipe.

2. Goose Neck :- It is curved & made of lead having ast length 75cm. It connects service pipe with the ferrule. It is provided for

to absorb shocks & disturbances.

(123)

Service Pipe : made of Galvanised iron having size less than 50 mm dia.

Stop cock : Provided before water meter at entry line of house used to stop flow during repair work & for other purposes.

Water meter : To record & measure the quantity of water.

Bib cocks : To control the flow.

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- (1) Basic term of sanitary engg
- (2) System of sewage
- (3) Type of sewer / conduits
- (4) Calculation of sewage discharge & Storm discharge
- (5) Sewage Characteristic
- (6) Treatment of sewage.
- (7) Disposal of sewage.
- (8) Air pollution
- (9) Solid waste management
- (10) Ecological system

(125)

Basic term in Sanitary Engg.

(126)

- (1) Refuse :- All the waste that is generated in the form of Solid + Semi-Solid + Liquid form.
- (2) Garbage :- Dry form of waste of refuse
Organic in nature i.e., vegetable matter, fruit peeling, biodegradable, putrified.
- (3) Rubbish :- Dry form of waste i.e. waste paper, pieces of card board, office waste, rest towards water
(Inorganic in nature). (Combustible).
- (4) Sewage :- All the waste generated from the domestic and industrial process in the form of liquidized state. (99.9% Liquid form)
Dark in colour, foulsmell, remaining in solids)
- (5) Sutage :- It is the waste in the liquid form generated from kitchens, bathrooms, household utilities.
→ Less foul in nature
→ light greyish.
- (6) Storm water :- It is the runoff that is coming from all the roads, building sites and other catchment areas.
- (7) Sewer :- It is the pipeline or conduit which carries "sewage".
- (8) Dry weather flow :- It is the normal flow that is occurring in any season.
- (9) Sewage system :- Collection and conveyance of sewage & Disposal of it through sewers.

Sewage System

- Collects, Transports, disposes - sewage

(i) Separate system

(ii) Combined "

(iii) Partially Separate system

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(i) Separate system is designed in the areas of uneven rainfall distribution.

* Separate system is adopted in hilly areas.

* Above system is suitable where deeper excavation is not possible.

* Sewage and storm water is carried out in separate pipe line.

(2) Combined system : In combined system sewage and storm water is collected and carried out in the same pipe line.

* This system is adopted where there is even rainfall distribution.

* The above system is suitable in the plane areas where deeper excavation is possible.

* In combined system, as the sewage and storm water is collected in one conduit, It is easy to provide a larger c/s of pipe line in the congested areas. i.e. metro polition cities.

(3) In this system the pipe lines are designed for the entire sewage and a part of the storm water.

(*) Generally there are two sewage carriage system

(i) Conventional system.

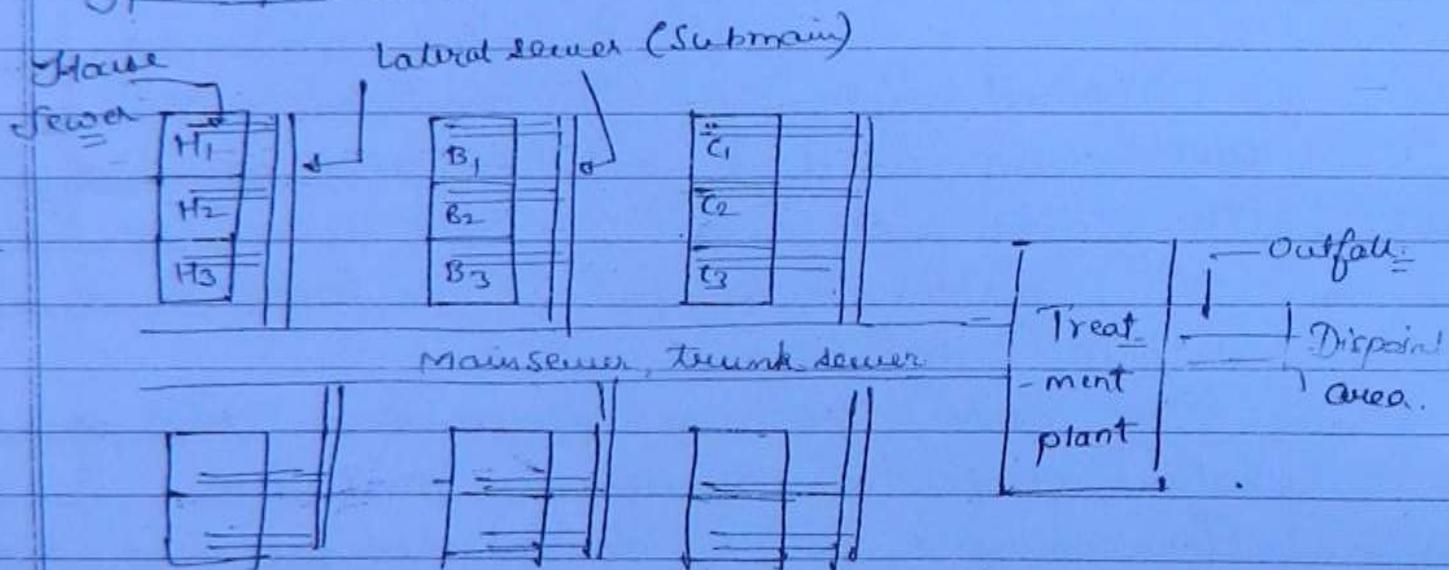
(ii) Water carriage system.

In conventional system all the sewage is collected from all the sources and it is dumped in the outskirts of the city and disposed off carefully.

- * In water carriage system water is used as a medium for the safe transportation of sewage & pipelines are laid down below the ground level, sewage is treated properly and safely it is disposed of.

(128)

Type of Sewers



- (i) House Sewer
- (ii) Lateral (Submain) Sewer
- (iii) Main (trunk) Sewer
- (iv) Outfall sewer

House Sewer - The waste in the form of sewage is collected from the house hold and immediately disposed off into lateral sewer. The pipe line which carries sewage from the house to lateral sewer is known as house sewer.

Lateral or Submain Sewer - The conduit or pipeline which carries all the sewage from the house sewer and linking it to the main sewer.

(F29)

(3) The main sewer conveys all the waste upto the treatment plant by collecting the sewage from all the lateral sewers.

(4). The section of the pipe line which carries the sewage from the treatment plan to the disposal area is known as outfall sewer.

* Sewer pipe designed for $\frac{1}{2}$ or $\frac{3}{4}$ full.

* Sewage Treatment plant should be located in low lying area and outskirts of the city.

Design Discharge of Sewage

Population of the city = P

per capita consumption of water = $x \text{ l/pd}$

Total drinking water supply = px

litres/day

Sewage generated from a city need not be equal to the water supply.

The sewage discharge is equal to 75 to 80% of drinking water supply.

$$q = (75\% \text{ to } 80\% \cdot px)$$

Design sewage discharge can be calculated based upon flow condition.

Maximum daily sewage flow rate = $2q$

q = Average sewage flow.

Maximum hourly flow is 1.5 times that of max^m daily flow rate.

$$= 1.5(2q) \quad \textcircled{P30}$$

$$= 3q$$

The sewer pipeline should be checked for min^m flow rate so that silting should not occur.

The minimum daily sewage flow rate is $\frac{2}{3}$ of q .

Minimum hourly sewage flow rate $\frac{1}{2}$ min^m daily sewage flow rate.

$$= \frac{1}{2} \times \frac{2}{3} q =$$

$$= \frac{1}{3} q \quad (\text{One third of average flow rate}).$$

Always sewage system is designed max^m hourly sewage flow rate ($3q$) and checked for min^m hourly sewage flow rate.

Design period:-

- Treatment plant = 30 years
- Trunk sewer = 15 - 20 year
- Pumping system = 5 - 10 year

average value of K is taken as

$$K = \frac{K_1 A_1 + K_2 A_2 + \dots + K_n A_n}{A_1 + A_2 + \dots + A_n}$$

(131)

Storm water calculations :-

Runoff from the building areas, road sides and other catchment area.

(132)

Runoff = Rainfall - Losses.

Storm discharge is calculated by Rational formula

$$Q_p = \frac{K P_c A}{36} = m^3/\text{sec.}$$

where K = Runoff Coefficient.

0.9 to 1.0 (for the impervious areas
pavement).

For Garden / Grass = 0.15

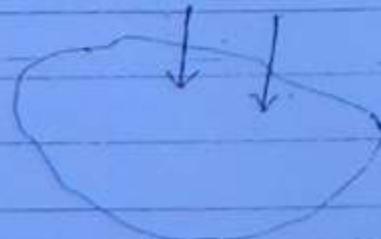
P_c = Critical rainfall intensity. (cm/hr).

A = Catchment area in "Hectare" ($1\text{Ha} = 100 \times 100 \frac{\text{m}}{\text{m}}$).

⇒ Critical rainfall intensity

Q_p = Storm water discharge, in $\text{m}^3/\text{sec.}$

↓ is defined as the maximum runoff obtained in the catchment area during time of concentration (t_c).



Time of concentration is defined as the period during which main runoff is contributed to catchment area. which is equal to

$$t_c = t_e + t_f$$

$$t_i = \left(0.885 \frac{L^3}{H} \right)^{0.385}$$

H = height (full height)

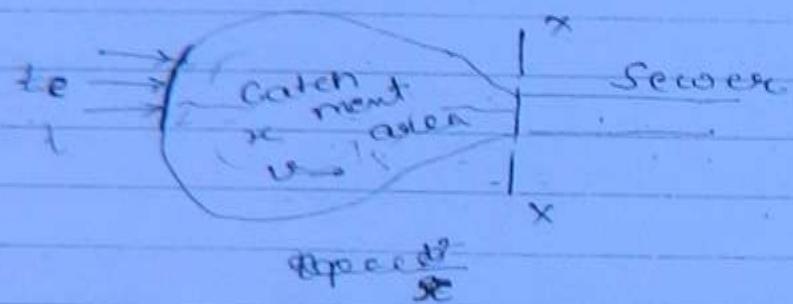
(133)

where t_e = time of entry (critical rainfall duration)

t_f = time of flow.

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Time of entry is defined as time taken by the runoff to enter in the catchment area.



Time of flow is defined as the time taken by the farthest drop of runoff to enter into the inlet section of the sewer.

$t_e \Rightarrow$ The units of t_e, t_f, t_c in minutes.

If time of concentration b/w 5 to 20 minute

$$P_c = \frac{75}{t_c + 10} \text{ cm/hr}$$

If $t_c \Rightarrow 20 - 100$ minute

$$P_c = \frac{100}{t_c + 20} \text{ cm/hr}$$

Empirical formula

$> 400 \text{ ha}$ Southern India

Dickan's formula (North India)

$$C_p = C_d A^{3/4}$$



Englis formula - Old Bombay state of India

$$Q_p = 123\sqrt{A}$$

Kawab Jung Bahadur formula - derived from
hydrated deccan catchment

wedge or Burge's formula -

$$Q_p = 19.6 \frac{A}{L^{4/3}}$$

(135)

Catchment A = Area - in Km²

C_d : Coefficient depends upon Geological
Aug value of terrain and other factors
 $C_d = 11.5$ like runoff coefficient.

(b) Ryve's formula (South India)

$C_d = 6.8$

$$Q_p = C_d A^{2/3}$$

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Note: Sewage system is designed for the sewage discharge and storm water put together in a combined system.

Total design discharge = Sewage discharge
+ Storm water
Discharge

Question The city has a population of 1 Lakh with water supply rate of 200 lpcd. Assuming 75% of water supply reaches the sewer, the DWF in m³/sec is

$$P = \text{Population} = 1,00,000$$

$$x = 200 \text{ lpcd}$$

$$\text{Total drinking water supply} = 10^5 \times 200 \text{ l/day}$$

$$q = \frac{75 \times 200 \times 10^5}{24 \times 3600} = \frac{75 \times 200 \times 10^5}{12 \times 18 \times 6} = \frac{125,000 \times 10^3}{72} = 17,222 \text{ m}^3/\text{sec}$$

$$q = 0.17 \text{ m}^3/\text{sec.}$$

For a residential area has 50 ha of land. assume critical rainfall intensity as 1 cm/hr

runoff coefficient as 0.80, calculate storm discharge in cumecs

Soln

$$Q_p = \frac{K \cdot P_c A}{36}$$

(137)

$$Q_p = \frac{0.8 \times 1 \times 50}{36} = 1.11 \text{ m}^3/\text{sec.}$$

Question A city with a population of 5 lakhs has an area of 100 ha. Rate of water supply is 200 lpsd. and average runoff coefficient for the entire area is 0.5. Time of concentration is 5 min. Assume 80% of water supply reaches sewer. DWF and storm water flow for the sewer line for the above data and also calculate the discharge for which a combined sewer system is to be designed.

Ans:

$$P = \text{Population} = 500,000$$

$$\text{per capita consumption } x = 200 \text{ lpsd.}$$

$$\text{Total drinking water supply} = Px =$$

$$5,00,000 \times 200 \text{ lts/day}$$

80% of water of sewage

$$= \frac{80}{100} \times 5 \times 10^5 \text{ lts/day}$$

$$\text{DWF} = q = 0.926 \text{ m}^3/\text{sec.}$$

Average daily flow

Storm water 'Q_p'

$$Q_p = \frac{K \cdot P_c A}{36}$$

$t_c = 5 \text{ min}$

$$K = 0.5, A = 150 \text{ ha}, P_C = \frac{100}{t_c + 20}$$

$$= \frac{100}{50 + 20} = 1.43 \text{ cm/h}$$

$$Q_p = \frac{0.5 \times 1.43 \times 100}{36} = 1.98 \text{ m}^3/\text{sec}$$

(38)

(iii) System is designed for = Sewage + Storm water

$$= -3q + Q_p$$

$$= 3 \times 0.926 + 1.98$$

$$\text{Design Discharge} = 4.77 \text{ m}^3/\text{sec}$$

CS

Question Design the section of a combined circular sewer for full flow from the data given below.

Area to be served = 150 ha.

Population of locality = 50,000

Max^{permissible} permissible velocity = 3.2 m/sec

Time of entry = 5 min.

" of. flow = 20 min.

Rate of water supply = $\frac{270}{2000} \text{lpcd}$.

Runoff coefficient = 0.45

Assuming 75% of water supply converts into sewage.

Ans

Pop

Total drinking water supply = $P.p = 50,000 \times 27$

75% of drinking water as sewage, $\frac{75}{100} \times \frac{50,000 \times 27}{1000 \times 9.4}$

76

$q = 0.17 \text{ m}^3/\text{sec}$.

(ii) Storm water $Q_p = \frac{k P_c A}{36}$

(139)

$$= \frac{0.45 \times P_c \times 150}{36}$$

$$= \frac{0.45 \times 2.22 \times 150}{36}$$

$$= 4.16 \text{ m}^3/\text{sec.}$$

$$P_c = \frac{100}{(t_c + 20)}$$

$$P_c = \frac{100}{25+20}$$

$$P_c = 2.22 \text{ cm/hr}$$

(iii) Total design discharge = $3q + Q_p$

$$= 3 \times 0.117 + 4.16$$

$$= 4.51 \text{ m}^3/\text{sec.}$$

Assuming "d" = dia of circular sec.

$$Q = AY$$

$$4.51 = \frac{\pi}{4} \times d^2 \times 3.2 \quad [\because v = 3.2 \text{ m/sec}]$$

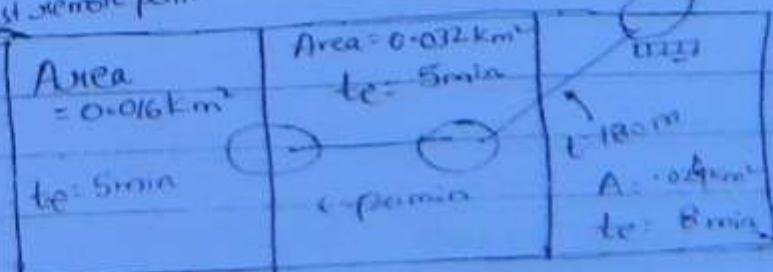
$$d = 1.34 \text{ m}$$

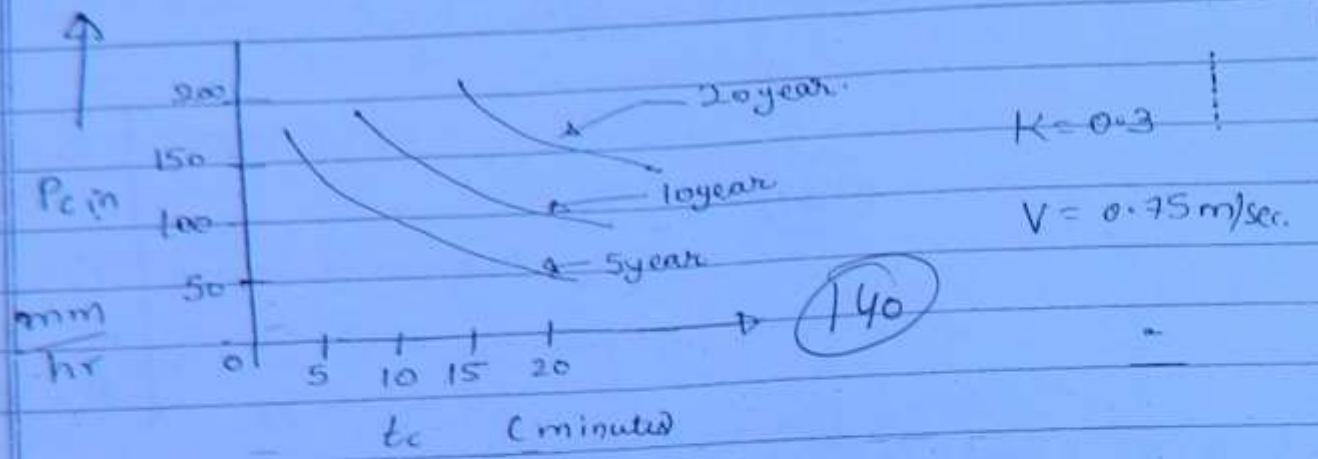
IES

Que.

Length of lines in a drainage area and inlet tank are marked in the figure given below. Find the time of concentration for catchment and ^{storm} discharge by taking k_s as 0.3 and velocity of flow in the sewer as 0.75 m/sec. Assume frequency of design rainfall as 5 years from the graph given below.

Most remote point





Time of concentrations of area $A_1 = t_{c_1} + t_f$,

$$t_{c_1} = 5 + \frac{12.0 + 180}{0.75}$$

$$t_{c_1} = 11.67 \text{ min}$$

$$t_{c_2} = 5 + \frac{180}{0.75} = 9 \text{ min}$$

$$t_{c_3} = 8 \text{ min}$$

maxⁿ t_c will be taken = 11.67 min

$$P_c = 100 \text{ mm/hr} \quad (\text{From above graph}).$$

$$Q_p = \frac{K P_c A}{36}$$

$$= \frac{0.3 \times 100 \times 7.2}{36 \times 10}$$

$$Q_p = 0.6 \text{ m}^3/\text{sec.}$$

$$A_1 = \frac{0.016 \times (1000)^2}{10,000}$$

$$A = 1.6 \text{ ha}$$

$$\text{Total area } A = A_1 + A_2 + A_3$$

$$= 0.016 + 0.032 + 0.024$$

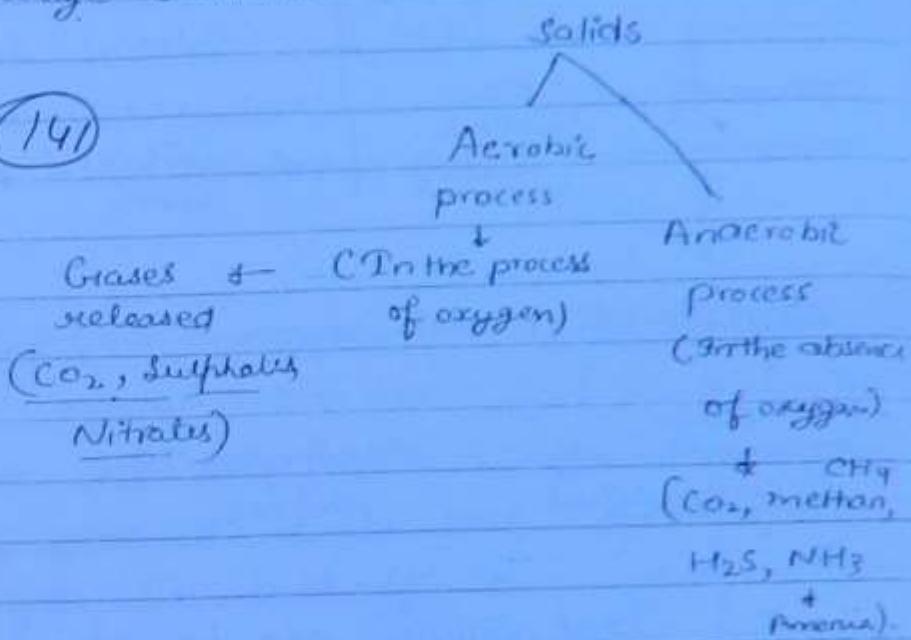
$$= 0.072 \text{ km}^2$$

$$A = 7.2 \text{ ha}$$

Sewage Characteristic

→ Sewage contains 99.9% water, remaining

(14)



- ① Physical parameter ② Chemical parameter
- ③ Biological parameter

① Physical Parameter.

(1) Turbidity → Because of presence of sand, silt, grit type of particles and solids.

(2) Colour - Fresh sewage greyish / light - foul smell
↓
Septic - black in colour / Dark → foul smell

(3) Temperature → If temperature increases in sewage D.O gets reduced hence effect following

(ii) Biological activity

(500 - 1000 mg/l)

Total Solids

on
their
Nature

(iii) Dissolved gases.

Suspended Solids $\rightarrow > 1 \mu$ Colloidal Solids $\rightarrow 1 \text{ to } 10^{-3} \mu$ Dissolved Solids $\rightarrow < 10^{-3} \mu$
better

Organic 45%, Inorganic 55%.

do not undergo
decomposition
undergo decomposition.

142

- * Total solids can be checked by evaporation test i.e. Sewage ^{sample} taken in a container is subjected to process of evaporation, residue left after evaporation is amount of total solids. (103° to 105°)
- * Suspended Solids \rightarrow can be found by subjecting the sewage sample to the process of filtration of 1μ size filter. The particles which are residues on filter paper = quantity of suspended solids.
(Total Solids = Suspended solids + Dissolved solids)
- * Dissolved Solid can be found difference b/w total solids and suspended solids
- * Suspended Solid can be classified as volatile solid and fixed solid.
↓
evaporable.

Page No. :
Date: / /

Volatile solid can be found by keeping suspended sample of sewage sample in a muffle furnace at 550°C . for 20 minute.

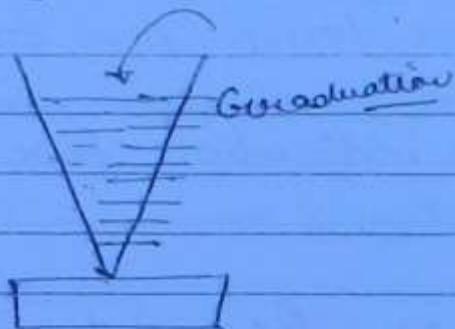
organic

(143)

The matter which was burnt in muffle furnace
— Volatile solids and remaining solids are known as fixed solids.

$$\text{Fixed Solids} = \text{Suspended Solids} - \text{Volatile}$$

* Settatable solids \Rightarrow can be found in the laboratory by the imhoff (wood) cone test. By keeping sewage sample in imhoff cone for a period of 2 hr, from the graduated markings present on the cone we can get directly settatable solid.



Ph of the sewage sample \Rightarrow Fresh sewage

appears to be ~~water~~ light grey colour and possey ph of 7.2 - 7.5 (Alkaline in nature).

As the time passes sewage become septic in nature and it becomes acidic in nature. To prevent the acidity of the sewage lime should be added.

Dissolved Oxygen 'O₂' → For the freshness of the sewage DO content should be more. The permissible value of DO after removing toxic elements from the sewage sample is above 4.2 mg/l or ppm. As temp increases DO quantity reduces.

- * DO can be found by the Winkler's method.
- * DO levels variation causes the biological activity and Dissolved gases. 144

Biological Oxygen Demand (Biochemical)

(BOD) It is the amount of O₂ or demand of oxygen that is required for Biological decomposition of biological degradable matter at a specified temp. for specific duration of time.

- * BOD is an indication for the presence of organic matter.

Eutrophication → As we dump the sewage containing high BOD into the fresh water body, as time passes the accumulation of organic matter will be and there will be high BOD after some time increase in level of organic matter the fresh water becomes absolute, this phenomena is known as eutrophication.

- BOD is reported at 20°C for a period of 5 days ($\text{BOD}_{5,20^{\circ}\text{C}}$)
- BOD takes care of only biologically active organic matter
- Biologically active organic matter
- Biologically Inactive organic matter
- $\therefore \text{COD} > \text{BOD}$

(145)

COD (Chemical oxygen demand)

The amt. of Oxygen or demand of oxygen i.e required for the chemical decomposition of organic matter is called COD.

COD can be tested by chemical reagent potassium di chromate ($\text{K}_2\text{Cr}_2\text{O}_7$) & potassium permanganate (KMnO_4). COD takes care of both biologically active organic matter. For the COD 2 to 3 hour duration of time is enough but BOD takes several days.

Theoretically oxygen demand (TOD)

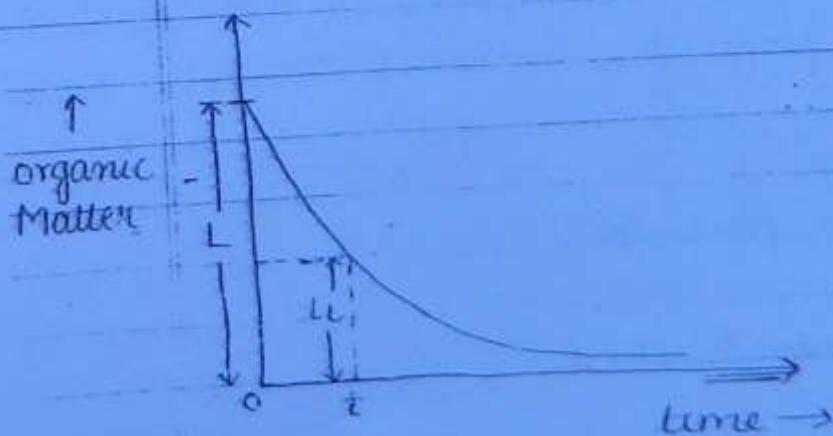
It is the amount of oxygen required for the decomposition of organic matter calculated from the chemical reaction theoretically.



$\text{TOD} > \text{COD} > \text{BOD}$

BOD calculation -

time \uparrow $\xrightarrow[\text{oxidation}]{\text{em}} \text{Organic Matter} \downarrow \rightarrow \text{BOD} \downarrow$



: Consumed oxygen = 1-L

The rate of decomposition of organic matter w.r.t time is directly proportional to amt. of organic matter at any time

$$\frac{dL_t}{dt} \propto -L_t$$

$$\frac{dL_t}{dt} = -k L_t$$

$$\frac{dL_t}{dt} + k L_t = 0 \quad \text{--- (i)}$$

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$$\text{Soln of above eqn} \quad \log_e(L_t) = -kt + C \quad \text{--- (ii)}$$

$$\text{at } t=0 \Rightarrow L_t = L$$

$$\log_e L = C$$

putting the value of C in eqn (ii) we get

$$\log_e(L_t) = -kt + \log_e L$$

$$\log_e\left(\frac{L_t}{L}\right) = -kt$$

$$\frac{L_t}{L} = e^{-kt}$$

$$L_t = L e^{-kt}$$

$$\text{BOD at any time } t = L - L_t = \text{BOD}_t$$

$$\Rightarrow L - L e^{-kt}$$

$$\Rightarrow L(1 - e^{-kt})$$

The rate of decomposition of organic matter at any time is directly proportional to amt. of organic matter present at that time (-ve sign indicates as time passes the decrease in the organic matter)

$$\text{BOD}_{t, T^\circ C} = L(1 - e^{k_1 t}) = L(1 - 10^{-k_2 t})$$

Where k_1 = Rate constant at a particular temp $T^\circ C$

$$k_{10} = 0.23 \text{ per day}$$

k_2 = Deoxygenation rate constant

$$K_{D_T} = \frac{K_T}{2.3} \text{ per day}$$

$$K_{D_{20^\circ C}} = \frac{0.23}{2.3} = 0.1 \text{ per day}$$

$$K_{T^\circ C} = K_{20^\circ C} (1.047)^{T_{20^\circ C}}$$

$T \rightarrow$ temp at ${}^{\circ}C$ rate constant is required

$$\text{Similarly } K_{D_{T^\circ C}} = K_{D_{20^\circ C}} (1.047)^{T_{20^\circ C}}$$

$$\text{base 10} = K_D$$

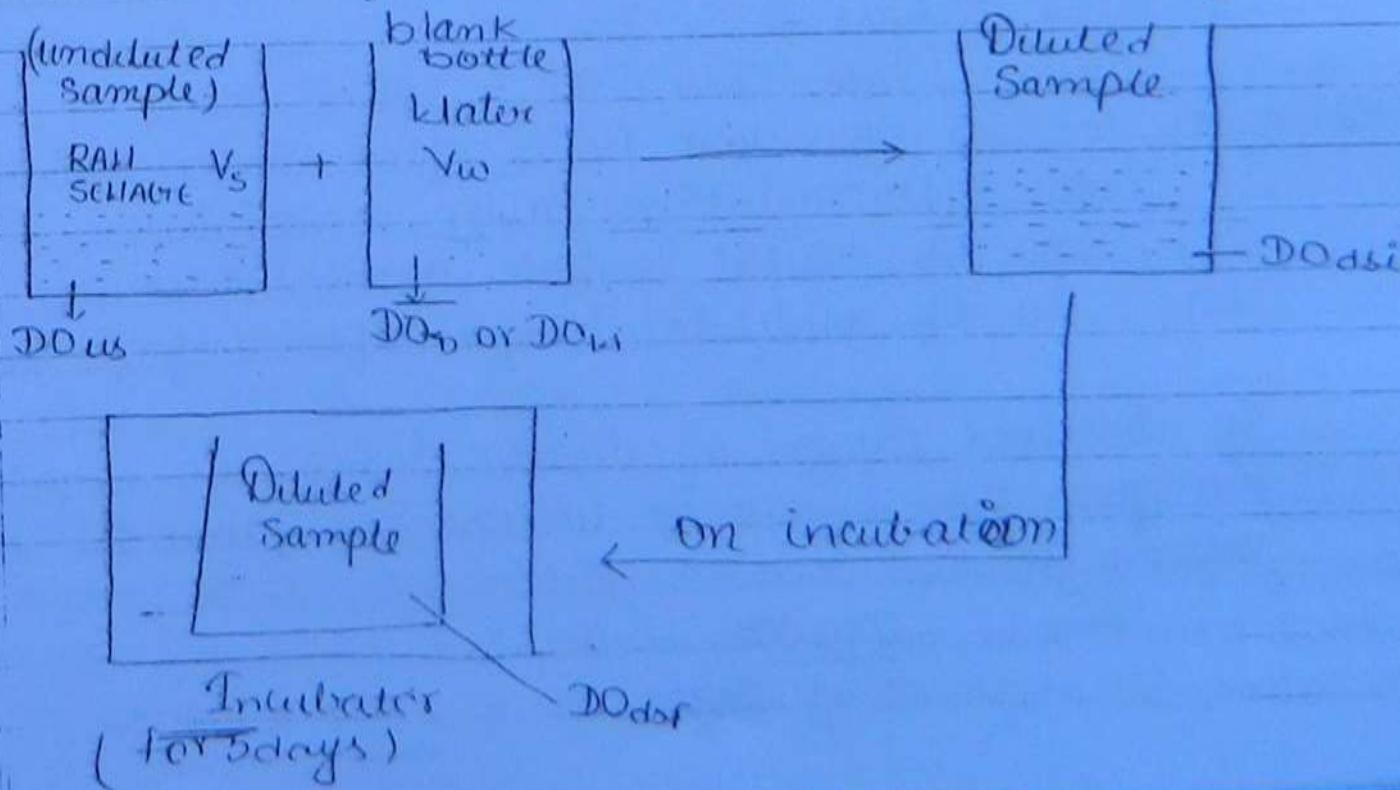
$$\text{base e} = k$$

$L \rightarrow$ represents initial or ultimate BOD (BOD_u)

$BOD_{5, 20^\circ C} = 68\%$ of organic matter decompose
 $\&$ at 20 days = 95-99% decomposition occurs.

$$BOD_5 \text{ (5 days)} = \frac{1}{3} BOD_u$$

Procedure to find out BOD in the laboratory.



1. Let a raw sewage sample is tested for the BOD. The volume of raw sewage is V_s & its DO is DO_{us}
2. Let the water used for the dilution process having a volume of V_w & its DO is DO_b or DO_u .
3. After dilution the dissolved oxygen of diluted sample is DO_{dsi} (Before Incubation)
4. Keep the diluted sample in the incubator for a period of 5 days & its DO is calculated after incubation i.e. DO_{dai}

$$BOD_{5 \text{ } ^\circ C} = (DO_{dsi} - DO_{dai}) DF \quad (148)$$

$= (\text{Initial DO} - \text{final DO}) \text{ Dilution factor}$

Where,

$$\text{dilution factor} = \frac{100}{x} \quad (\text{If x.l. of } \text{SO}_4^{\text{-}} \text{ is added then})$$

$$DF = \frac{V_s + V_w}{V_s} \quad V_s = \text{Vol. of Sewage}$$

V_w = Vol. of dilution water

NOTE If the water other than distilled water is used then the above formula reduces to

$$BOD = (DO_b - DO_f) DF - (DO_b - DO_s)$$

where DO_b = DO of blank bottle after water remained in the bottle after dilution (after incubation)

DO_f = DO of diluted sample after incubation

DO_s = DO of undiluted sample after before incubation

If dissolved oxygen of diluted sample i.e initial DO is not given then it will be worked out from the known volume of V_s & V_w & from DO_s & DO_u

$$DO_i = \frac{DO_s V_s + DO_u V_w}{V_s + V_w}$$

A waste water sample having 5 days 30°C BOD is 110 mg/litre.

Calculate the 5 day BOD at 20°C Assuming $K_{D,20^\circ\text{C}} = 0.1$ per day

$$\text{BOD}_{5,30^\circ\text{C}} = 110 \text{ mg/litre}$$

$$L(1 - e^{-Kt})$$

$$L(1 - 10^{-K_{30^\circ\text{C}} t}) = 110$$

$$K_{D,T} = K_{D,20^\circ\text{C}} e^{(1.047)^{T_{20^\circ\text{C}}}}$$

$$K_{D,30^\circ\text{C}} = 0.1 (1.047)^{30-20}$$

$$= 0.15 \text{ per day}$$

$$\Rightarrow L(1 - 10^{-0.15 \times 5})$$

$$L = 131.29 \text{ mg/l}$$

$$\text{BOD}_{20^\circ\text{C}, 5} = L(1 - 10^{-K_{D,20^\circ\text{C}} t})$$

$$= 131.29 (1 - 10^{-0.1 \times 5})$$

$$= 89.71 \text{ mg/litre}$$

149

Ques 6
Date

Go determine the BOD of a waste water sample 5, 10 & 15 ml of waste water were dilute to 300ml and incubated at 20°C in the BOD bottle for 5 days. The results were as follows. Based on the data the avg. BOD for the 5 days of the waste water

| S.NO | Vol of waste water | Initial DO | DO after 5 days | Dilution factor | BOD 5days |
|------|--------------------|------------|-----------------|-----------------|-----------|
| 1 | 5 ml | 9.2 | 6.9 | 60 | 13.8 |
| 2 | 10 ml | 9.1 | 4.4 | 30 | 14.1 |
| 3 | 50 ml | 8.4 | 0 | 6 | 50.4 |

Soln

$$V_s + V_w = 300 \text{ ml}$$

$$\text{Avg BOD at 5 days} = 109.8 \text{ mg/l}$$

Ans 2011

Determine the ultimate BOD of a waste water sample it was subjected to the BOD determination as follows. 6 ml of waste water containing no dissolved oxygen was mixed to 294 ml water containing 8.6 mg/l of DO. After Incubation at

at 20°C for 5 days. The DO of NW was 5.4 mg/litre. The BOD rate constant to the base e $K_{20^{\circ}\text{C}} = 0.25$ per day.

Sol $V_s = 6\text{ ml} \quad \text{DO} \geq 0$

$$V_w = 294\text{ ml} \quad \text{DO} \geq 8.6\text{ mg/l}$$

$$\text{Dilution factor } \frac{6+294}{6} = 50$$

After Incubation DO = 5.4 mg/litre

$$\text{DO}_i = \frac{6 \times 0 + 294 \times 8.6}{6+294}$$

$$= 12.8 - 8.428$$

$$\text{BOD} = \frac{(8.428 - 5.4)}{50}$$

$$= 151.4\text{ mg/l}$$

$$151.4 = L(1 - e^{-K_{20^{\circ}\text{C}} t})$$

Initial BOD I = 212.19 mg/l

150

Ques. For a BOD test using 5% of dilution of the sample (15 ml of sample & 285 ml of dilution water) DO values for the sample & dilution water blank bottle after 5 days incubation at 20°C were given as 3.8 mg/l & 8.8 mg/l. DO originally present in the undiluted sample was 0.80 mg/l. The 5 days 20°C BOD of the sample is

$$\text{Dilution factor} = \frac{100}{5} = 20$$

$$\begin{aligned} \text{BOD}_f &= (\text{DO}_b - \text{DO}_f) \text{DF} - (\text{DO}_b - \text{DO}_s) \\ (8.8 - 3.8) \cdot 20 &= (8.8 - 0.80) \\ &= 92\text{ mg/litre} \end{aligned}$$

Ques. The 5 day BOD of a waste water sample is obtained as 190 mg/litre $\therefore k = 0.01/\text{hr}$. The ultimate BOD of the sample in mg/l will be

$$\text{Sol:- BOD} = L(1 - e^{-Kt})$$

$$190 = L(1 - e^{0.01 \times 15})$$

$$1 = 271.89 \text{ mg/l}$$

date 2010

Ques If the BOD of a waste water sample after 3 days is 75 mg/l & the rate constant (base e) is 0.345 /day. The amt. of BOD remaining in the given sample after 10 days is

$$\text{BOD}_{3\text{days}} = L(1 - e^{-K_T t})$$

$$75 = L \times 0.644$$

$$L = 116.32 \text{ mg/l}$$

$$\text{BOD}_{10\text{days}} = L(1 - e^{-K_T t})$$

$$= 112.63 \text{ mg/l}$$

(157)

Remaining BOD = 3.7 mg/litre

date 2009

Ques A portion of waste water sample was subjected to standard BOD test (5-days 20°C). The BOD value after 5 days was found 180 mg/litre. The rate constant (base e) at 20°C is 0.18 per day. The rate constant at other temp. may be estimated by $K_{T^{\circ}\text{C}} = K_{20^{\circ}\text{C}} (1.047)^{T-20}$. The temp. at which portion of the sample should be tested to exert the same BOD in 2.5 days is

$$\text{BOD}_{5, 20^{\circ}\text{C}} = 180 \text{ mg/l}$$

$$K = 0.18 \text{ per day}$$

$$180 = L = 303.32 \text{ mg/l}$$

$$\text{BOD}_{2.5, T^{\circ}\text{C}} = L(1 - e^{-K_{T^{\circ}\text{C}} \times 2.5})$$

$$180 = L(1 - e^{-K_{T^{\circ}\text{C}} \times 2.5})$$

$$1 - e^{-K_{T^{\circ}\text{C}} \times 2.5} = 0.593 \Rightarrow K_{T^{\circ}\text{C}} = 0.36$$

$$K_{T^{\circ}\text{C}} = K_{20^{\circ}\text{C}} (1.047)^{T-20}$$

$$0.36 = 0.18 (1.047)^{T-20}$$

$$T = 35.09^{\circ}\text{C}$$

Ques: If BOD for the 3 days of a waste water is 75 mg/l & $k = 0.015$ per day, what is the ultimate BOD
 Ans: $75 = L(1 - e^{-k \cdot t})$
 $L = 1104.45 \text{ mg/litre}$

(152)

The following observations were made on a 4 l dilution of waste water DO of diluted water used for dilution is 3 mg/l. DO of diluted sample after 5 days incubation = 0.8 mg/l. DO of original sample 0.6 mg/l. Calculate the BOD of sample after 5 days & ultimate BOD of the two sample $k_D = 0.1 \text{ /day}$

$$\text{Ans: } D.F. = \frac{DO_i - 25}{4} = \frac{96 + 4}{4} = \frac{V_s + V_w}{V_w} \quad V_s = 4 \\ V_w = 96$$

$$\text{BOD} = (3 - 0.8) \times 25 = (3 - 0.6)$$

$$\text{BOD} = 52.6$$

$$\text{BOD} = L(1 - 10^{\frac{-k_D \cdot t}{5}})$$

$$52.6 = L(1 - 10^{-1 \times 5})$$

$$L = 76.92 \text{ mg/l}$$

$$\text{or } DO_i = DO_s V_s + DO_w \times V_w = \frac{0.6 \times 4}{4 + 96} + \frac{3 \times 96}{100} = 2.9$$

$$\begin{aligned} \text{BOD} &= (DO_i - DO_f) D.F. \\ &= (2.9 - 0.8) \times 25 \\ &= 52.6 \text{ mg/l} \end{aligned}$$

Ques Data from an unseeded domestic waste water BOD test are 5ml of waste in 300 ml of water. Initial DO is 7.8 & final DO after days 4 & 3. $k = 0.1 \text{ per day}$. Calculate BOD & initial BOD.

$$\text{BOD} = (7.8 - 4.3) 60$$

$$\text{BOD} = 210 \text{ mg/litre}$$

$$\text{Ans: } 210 = L(1 - e^{-0.1 \times 5})$$

$$\text{Ultimate: } L = 533.71 \text{ mg/l}$$

$$\left[D.F. = \frac{300 - 60}{5} \right]$$

105-2005

Ques.

The 5 days BOD at 20°C of a given sample is 450 mg/litre. Calculate the estimate BOD at 35°C. Given that K_D at 20°C = 1 per day

$$K_{D_{35^{\circ}C}} = K_{D_{20^{\circ}C}} (1.04)^{35-20}$$

$$= 1.99$$

$$BOD_{20^{\circ}C} = L (1 - e^{-0.1 \times 5})$$

$$450 = L \times 0.684$$

$$L = 658.11 \text{ mg/l}$$

(153)

$$BOD_{5\ 35^{\circ}C} = L (1 - e^{-1.99 \times 5})$$

$$= 658.11 (1 - e^{-1.99 \times 5})$$

$$BOD_{5\ 35^{\circ}C} = 591.54 \text{ mg/litre (initial BOD)}$$

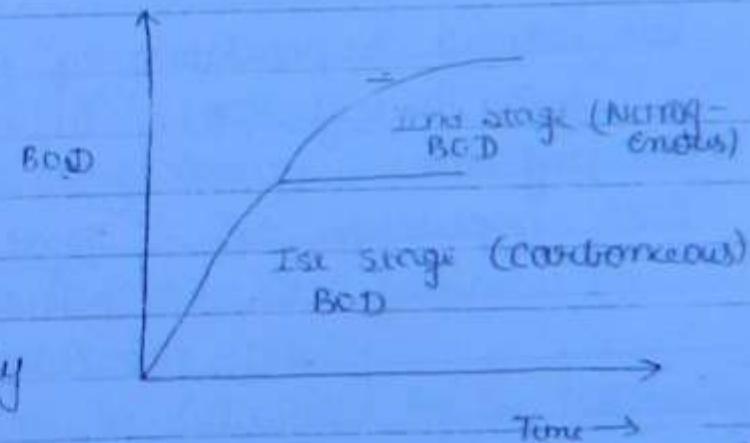
BOD - Types

→ BOD is of two type

(i) 1st stage BOD

(ii) 2nd stage BOD

→ Q.B.T. of BOD is of
Carbonaceous matter only



BOD_u Ratio = 0.92 to 1.0 (sewage in Biodegradable type)

COD

$\frac{BOD_5}{COD} = 0.63 \text{ to } 0.68$ (sewage is said to have containing
biodegradable ~~waste~~ waste)

population equivalent = Total BOD produced by the Industry
per day of a city

BOD produced by an individual
— per day

Standard BOD produced by an individual per day = 0.08 kg

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Relative Stability

It is defined as Ratio of oxygen i.e. present in the effluent to the amt. of the oxygen req. for the decomposition of carbonaceous matter i.e. 1st stage BOD

Relative stability can be given by following eqn depending on the temp level

$$(i) 100 \left(1 - 0.794^{\frac{t_{20^\circ C}}{t_{37^\circ C}}}\right)$$

$$(ii) 100 \left(1 - 0.604^{\frac{t_{20^\circ C}}{t_{37^\circ C}}}\right)$$

Where $t_{20^\circ C}$ = No. of days req. for the decomposition of carbonaceous matter at $20^\circ C$

$t_{37^\circ C}$ - No. of days req. for the decomposition of carbonaceous matter at $37^\circ C$

Ques Calculate the population eq^v of a city given that (i) avg. sewage from the city 95×10^6 lit/day (ii) The avg 5 day BOD is 300 mg/litre

$$\text{Soln population eq}^v = \frac{\text{Total BOD contributed to city per day}}{\text{Individual BOD per day}}$$
$$= \frac{95 \times 10^6 \text{ lit} \times 300 \times 10^{-3} \times 10^{-3} \text{ kg}}{\text{day litre}}$$
$$= 0.08 \text{ kg}$$
$$= 356250$$

The period of incubation is 10 days at $20^\circ C$, then the % of relative stability of the sewage sample is

$$\text{Soln } 100 \left(1 - 0.794^{\frac{t_{20^\circ C}}{10}}\right)$$

$$100 \left(1 - 0.794^{10}\right)$$

$$= 70.04\%$$

Ques Find out the BOD of a waste water containing 300 mg/l of ketone of chemical formula $\text{CH}_3\text{COC}_2\text{H}_5$. The oxidation eqn is given by



(15)

$$12 + 3 \times 1 + 12 + 16 + 24 + 5 + \frac{11 \times 2 \times 16}{2}$$
$$72 + 176$$

92 mg \rightarrow 176 mg of oxygen

$$300 \text{ mg} \rightarrow ?$$
$$= \frac{176}{72} \times 300 = 733.3 \text{ mg/l}$$

Design of Sewer

Designed for the $\frac{1}{2}$ or $\frac{3}{4}$ full

- Should have the self cleaning velocity in order to prevent silting / sedimentation
- Sewage pipes should be lay down at a particular gradient so that the flow occurs under gravity.
- Velocity in the sewer can be calculated by the following formula

(a) Chezy equation

$$V = C \sqrt{R S} \quad V = C \sqrt{RS}$$

C \rightarrow Chezy's constant

R \rightarrow Hydraulic Mean depth $= \frac{A}{P}$ $\frac{\text{Wetted area}}{\text{Wetted perimeter}}$

S \rightarrow Gradient or slope at c sewer in place

V \rightarrow Velocity of flow for sewage

(ii) Manning's equation

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

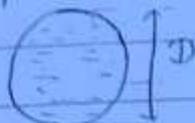
n = Manning's coefficient

156

There are 3 condition in sewage pipe line to be maintained -

(i) Full flow condition

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



full

(ii) Half flow condition

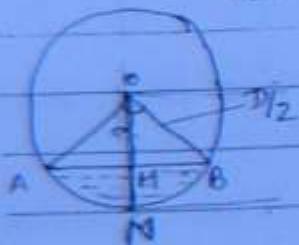
$$R = \frac{A}{P} = \frac{\frac{1}{2} \frac{\pi D^2}{4}}{\frac{\pi D}{2}} = \frac{D}{4}$$



(iii) Partially flow condition

$$MN = ON - OH$$

$$\frac{D}{2} - \frac{D \cos \alpha}{2}$$



$$MN = \frac{D}{2} \left(1 - \cos \frac{\alpha}{2} \right)$$

$$A \Rightarrow 360^\circ \rightarrow A \left(\frac{\pi D^2}{4} \right)$$

$$\alpha^\circ \rightarrow ?$$

$$= \frac{\pi D^2}{4} \times \frac{\alpha}{360^\circ}$$

$$\text{Wetted area } A = \frac{1}{360^\circ} A \times \alpha - \frac{1}{2} \frac{D \cos \alpha}{2} \left(\frac{D \sin \frac{\alpha}{2}}{2} + \frac{D \sin \frac{\alpha}{2}}{2} \right)$$

$$= \frac{A \times \alpha}{360^\circ} - \frac{D^2}{4} \cos \frac{\alpha}{2} \sin \frac{\alpha}{2}$$

$$P = \pi D$$

$$\frac{360^\circ}{\alpha^\circ} \rightarrow \frac{P}{?}$$

$$= \frac{P \times \alpha}{360^\circ}$$

Wetted perimeter p

(157)

NOTE - These are known as hydraulic characteristics of a sewer

Ques A 20 cm dia of sewer is lay at a slope of 0.004 & is designed to carry a discharge at a depth of 10cm & Manning $n = 0.014$, then find out the design discharge.

Soln It is condition of Half flow

$$R = \frac{D}{4} = \frac{20}{4} = 5 \text{ cm}$$

$$V = \frac{n}{1} R^{2/3} S^{1/2}$$

$$0.014 \times (5)^{2/3} (0.004)^{1/2}$$

$$V = 13.209 \text{ cm/sec}$$

$$Q = AV = \frac{\pi D^2}{4} \times 13.209$$

$$Q = 4149.84 \text{ cm}^3/\text{sec}$$

Ques The slope of a 1m diameter concrete sewer laid at 1 in 1000. It develops a velocity of 1 m/sec. When flowing full, the velocity of flow of sewer when it is flowing half full will be

$$\frac{V_1}{V_2} = \frac{R_1^{2/3} S_1^{1/2}}{R_2^{2/3} S_2^{1/2}}$$

$$\frac{1}{V_2} = \frac{(1)^{2/3} (1/1000)^{1/2}}{\left(\frac{1}{2}\right)^{2/3} \left(\frac{1}{1000}\right)^{1/2}}$$

$$V_2 = 1 \text{ m/sec}$$

Ques A 20 cm dia sewer on a slope of 1 in 500 is running full calculate of rate of flow in sewer. Given $n = 0.00012$.

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$= \frac{1}{0.00012} \left(\frac{20}{4}\right)^{2/3} \left(\frac{1}{500}\right)^{1/2}$$

(158)

$$V = 0.50 \text{ m/sec}$$

$$Q = AV$$

$$Q = 0.015 \text{ m}^3/\text{sec}$$

DTE - $BOD_{5, 20^\circ C}$ of Municipal unster water = 100 to 500 mg/L

$\rightarrow COD > BOD_u$

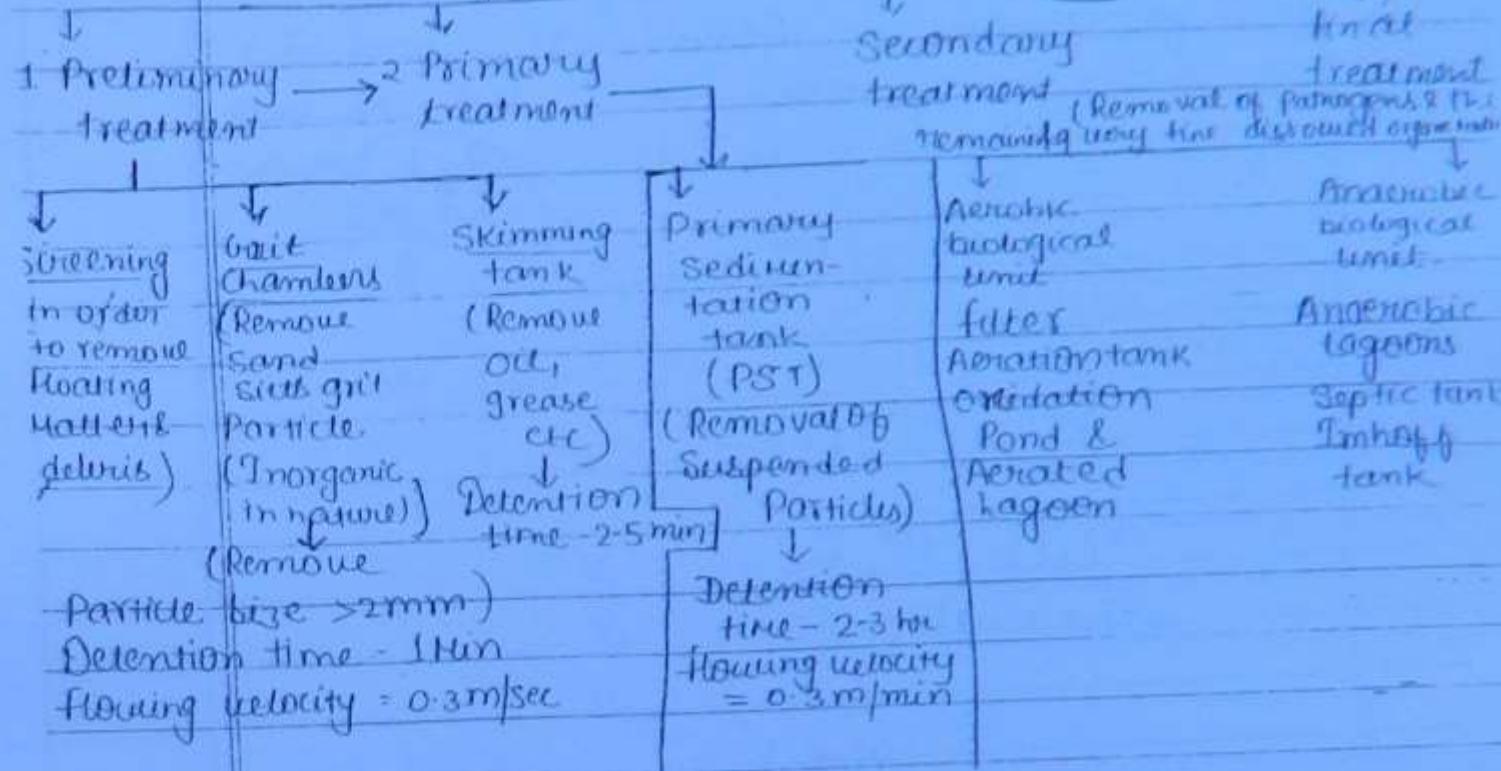
$COD - BOD_u$ = Non biodegradable organics

$\frac{BOD}{COD} \rightarrow$ considered to be an imp factor in water

$$\frac{TOC}{water treatment} = 2.66$$

Sewage treatment

159.



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Q. The slope of a 1m dia concrete sewer laid 1 in 1000, it develops a velocity of 1 m/s when flow is full, the velocity of flow of the sewer when it is flowing half full will be

$$V_1 = \frac{1}{n} (R_1)^{2/3} (S_1)^{1/2}$$

(161)

half-flow

$$V_2 = \frac{1}{n} (R_2)^{2/3} (S_2)^{1/2}$$

$$\frac{V_1}{V_2} = \frac{(D/4)^{2/3} (S_1)^{1/2}}{(D/4)^{2/3} (S_1)^{1/2}}$$

$$V_1 = V_2 \\ = 1 \text{ m/s}$$

Q. A 12cm dia sewer with a slope of +1 in 500 is running full. calculate the rate of flow in sewer given that $n = 0.42$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$V = \frac{1}{0.42} \left(\frac{0.12}{4}\right)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

$$V = 0.089 \text{ m/s}$$

$$Q = \frac{\pi}{4} (0.12)^2 \times 0.089$$

$$Q = 0.015 \text{ m}^3/\text{sec}$$

Waste Treatment :-

- (a) Preliminary treatment
- |
 - (b) Primary treatment
 - (c) Secondary treatment
 - (d) Final treatment
 - (e) Disposal

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Preliminary Treatment :-

- (1) Screening → floating matter & Debris
 - (2) Grit chamber → remove sand, silt, grit particles (inorganic in nature)
 - (3) Skimming tank → Oil, greases etc.
- ↓ ↓
- Detention time remove particle size $> 2\text{ mm}$
- 2-5 min Detention time = 1 minute
- Flowing velocity $\rightarrow 0.3\text{ m/sec}$

Primary Treatment \rightarrow Primary sedimentation tank

↓

removal of suspended particles

↓

2-3 hours detention time

flowing velocity = 0.3 m/min .

Secondary Treatment \rightarrow Waste treatment effluent coming from the primary sedimentation tank is treated aerobically or anaerobically to get the clearer effluents.

In absence of oxygen in primary sedimentation tank, this process of mining is called **sudging**.

PAGE NO.

DATE :

Secondary treatment

(763)

Aerobic treatment

(presence of O_2)

- (1) Trickling filter (TF)
- (2) Activated sludge process (ASP)
- (3) Oxidation ponds
- (4) Aerobic tanks
5. Aerated lagoon

Anaerobic treatment

(absence of O_2)

- (1) Sludge digestion tank
- (2) Septic tanks
- (3) Imhoff tanks
- (4) Anaerobic lagoon

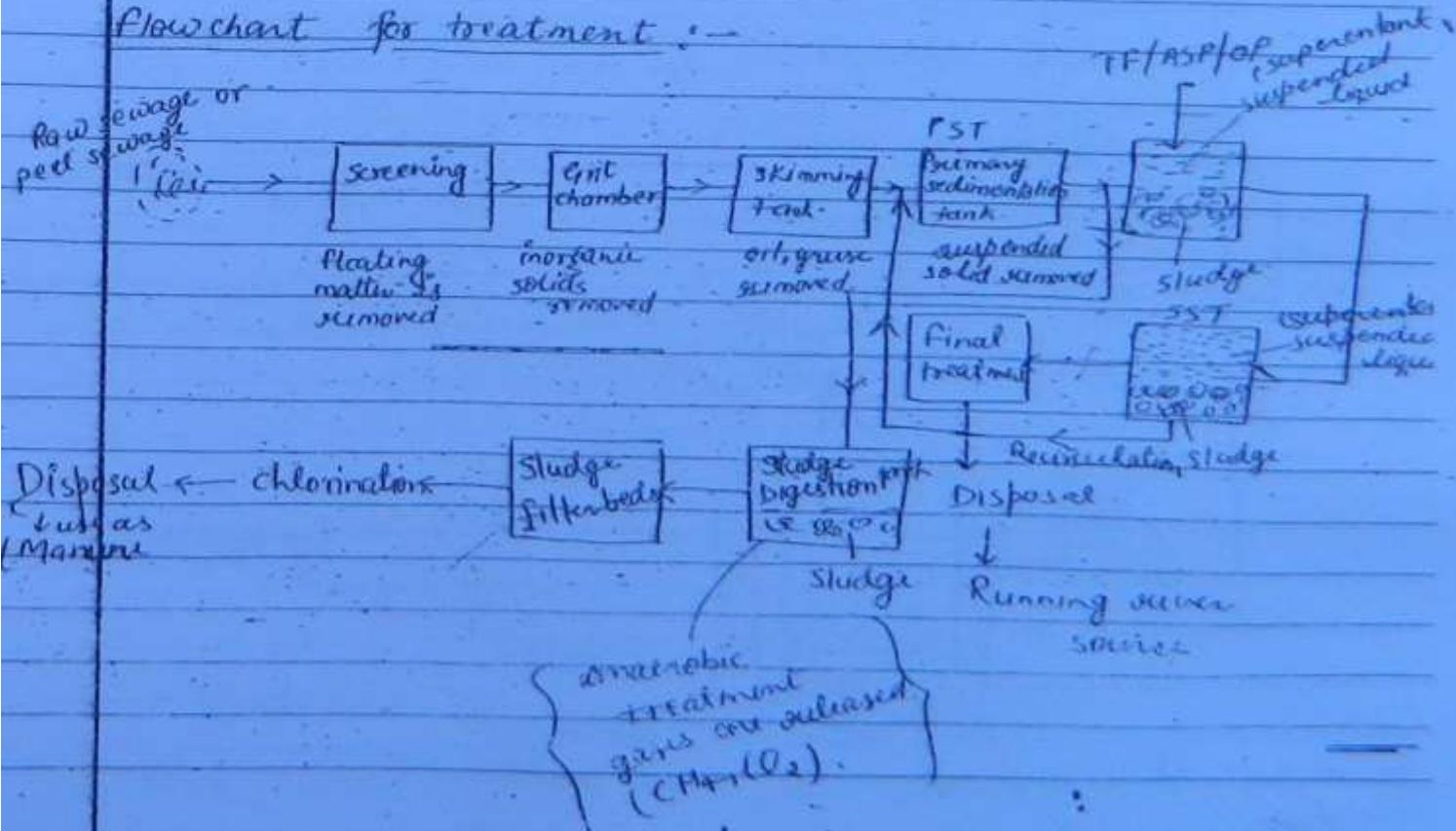
Final Treatment :-

Effluent coming out from the secondary treatment is treated

with Cl_2 (chlorination is done).

Disposal

Flowchart for treatment :-



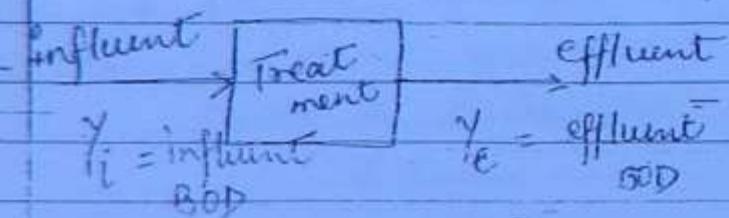
Addition of active sludge to the raw sewage is known as seeding.

④ → Rule of decomposition depends

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- pH
- temperature
- stirring
- seeding
- growth of bacteria

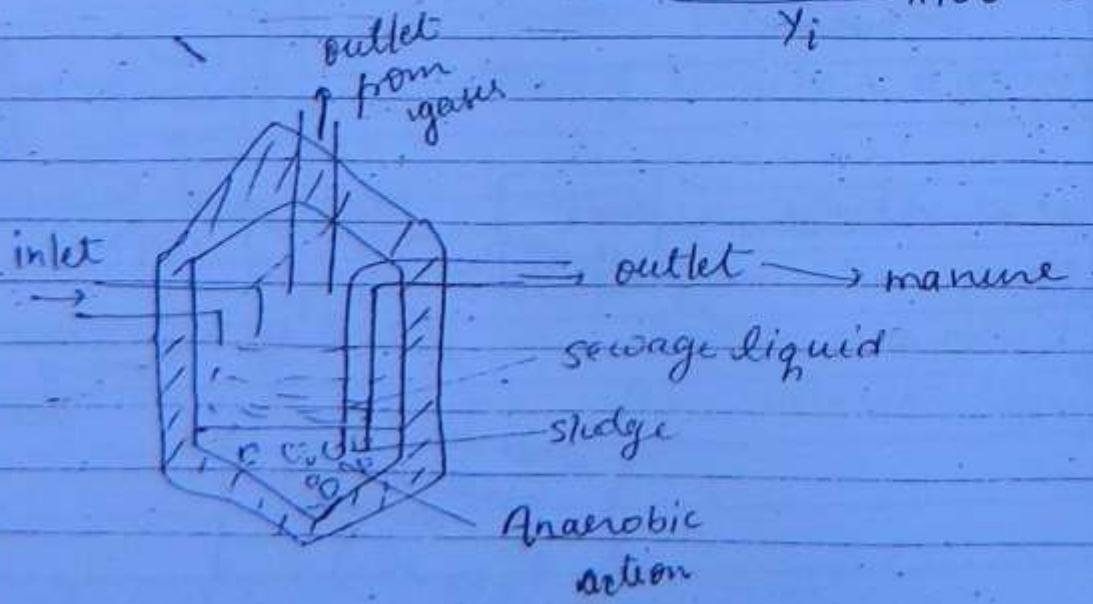
Septic Tank :-



$$\text{BOD removal} = y_i - y_e$$

⑤ efficiency of the tank = $\frac{\text{BOD removal}}{\text{BOD applied}} \times 100$

$$= \frac{(y_i - y_e)}{y_i} \times 100$$



④ (Q) Detention time = 12 to 36 hrs

↓

process involved → sedimentation

(165)

sludge digestion through anaerobic action

④ cleaning time period t_c = 6 month - 3 years

④ Sludge accumulation rate -

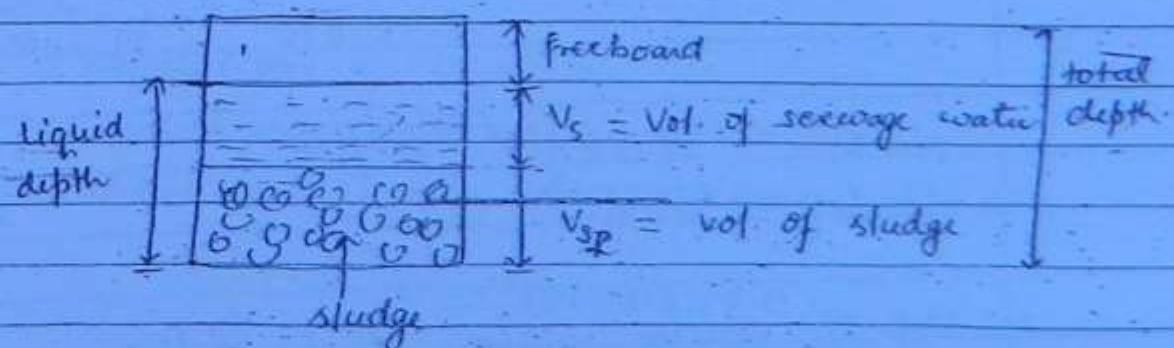
$$q_a = 30 \text{ lit/capita/year}$$

Q = sewage flow rate

$$\frac{\text{Length}}{\text{Breadth}} = \frac{L}{B} = 4 \text{ to } 5$$

④ Removal of BOD = 100 - 200 ppm

④ Freeboard = 0.3 to 0.45 m



$$\text{Total Vol. of the tank } V = V_s + V_s$$

$$= q_a \cdot t_c + Q D_2$$

$$\text{Total Vol. of tank } V = L \cdot B \cdot H$$

where $\rightarrow L$ = length of tank, B = width of tank, H = depth of tank.

Ques. Design a septic tank for a colony of 200 people, the colony is supplied water at a rate of 135 lped. Assume retention period of 24 hrs and 75% of water becomes the waste water. The tank is cleaned once in a year. The rate of volatilization of sludge is 70 lt/person/year. The depth of the tank is to be kept as 3 m. Provide a freeboard of 0.3 m. assume L ratio as 3

(166)

$$\text{Population of colony} = 200$$

$$\text{supplied water} = 135 \text{ lped}$$

$$\begin{aligned}\text{Total drinking water} &= \frac{135 \times 200}{1000 \times 24 \times 60 \times 60} \\ &= 3.125 \times 10^{-4} \text{ m}^3/\text{sec}\end{aligned}\quad \left\{ 1000 \text{ lt} = 1 \text{ m}^3 \right.$$

$$\begin{aligned}\text{sewage water} &= \frac{75 \times 3.125 \times 10^{-4}}{100} \\ &= 2.34 \times 10^{-4} \text{ m}^3/\text{sec}\end{aligned}$$

$$Q_s = 2.34 \times 10^{-4} \text{ m}^3/\text{sec}$$

$$D_t = 24 \text{ hrs}$$

$$\begin{aligned}\text{Vol. of sewage water } V_s &= Q_s D_t \\ &= 2.34 \times 10^{-4} \times 24 \times 60 \times 60 \\ &= 20.22 \text{ m}^3\end{aligned}$$

$$\text{Vol. of sludge } V_{sl} = q \cdot t_c$$

$$= \frac{40}{10^3} \times 200 \times 1 = 8 \text{ m}^3$$

$$\begin{aligned}\text{Total Volume } V &= V_{sp} + V_s \\ &= 8 + 20.22 \text{ m}^3 \\ &= 28.22 \text{ m}^3\end{aligned}$$

(167)

$$\begin{aligned}\text{Vol of tank} &= L \cdot B \cdot H \\ &= 3B \cdot B \cdot (2 - 0.3) \\ &= 5.1 B^2\end{aligned}$$

$$5.1 B^2 = 28.22$$

$$\left. \begin{array}{l} B = 2.35 \text{ m} \\ L = 7.05 \text{ m} \\ H = 2.0 \text{ m} \end{array} \right\} \text{Ans.}$$

d. Estimate the design a circular sewage tank for a town population of 40000. The avg. water demand is 140 lpcd. Assume that 70% of water reaches at the treatment unit & the max. design discharge of sewage is taken as 27 times the avg. sewage discharge demand.

$$\begin{aligned}\text{population} &= 40,000 \\ \text{per capita consumption} &= 140 \text{ lpcd} \\ \text{total} &= 40000 \times 140 \text{ lt/day} \\ &= 40000 \times 140 \\ &= 1000 \times 24 \times 60 \times 60\end{aligned}$$

$$= 0.0648$$

$$\text{sewage rate} = \frac{70}{100} \times 0.0648 = 0.0454 \text{ m}^3/\text{sec}$$

max. design discharge

$$Q = 27 \times 0.0454 \\ = 1.225 \text{ m}^3/\text{sec}$$

assume - $\Delta t = 2 \text{ hrs}$

(168)

$$\text{Vol of sedimentation tank} = Q \times \Delta t / \\ = 0.1225 \times 2 \times 60 \times 60 \\ 882 \text{ m}^3$$

assume effective depth of the tank = 3m (without free board)

surface area of tank = $\frac{\text{Vol.}}{\text{depth}}$
 $= \frac{882}{3}$
 $= 294 \text{ m}^2$

since the tank is circular

$$\frac{\pi d^2}{4} = 294$$

$$d = 19.34 \text{ m}$$

By calculation of the surface loading for the sedimentation tank per day it becomes

Surface loading of tank ~~area~~ =

capacity of tank or volume of tank

Surface area

$$= \frac{882}{294} = 3 \text{ m}^2/\text{m}^2 \text{ day}$$

$$F: \frac{0.1225 \times 24 \times 60 \times 60}{294} = 36 \text{ m}^3/\text{m}^2 \text{ day}$$

The permissible surface loading for sedimentation tank is $50 \text{ m}^3/\text{m}^2/\text{day}$.

surface loading = $36 \text{ m}^3/\text{m}^2/\text{day} < 50 \text{ m}^3/\text{m}^2/\text{day}$
~~so design is safe.~~

(169)

Estimate the size of septic tank ($L/B = 2.25$) liquid depth 2m with 300mm freeboard), desludging (removal of sludge) intervals in years and the total trench area of percolation field for a small colony of 300 people. Assume a water supply of 100 lts/capita/day, the waste water flow is 80% of water consumption, the sludge product of $0.04 \text{ m}^3/\text{capita}/\text{yr}$ and the retention time of 3 days. Desludging is done when the tank is $\frac{4}{3}$ full of the sludge. A percolation test indicated an allowable hydraulic loading of $100 \text{ lt/m}^2/\text{day}$.

$$\text{Population} = 300$$

$$\text{per capita consumption} = 100 \text{ lpcd}$$

$$\text{Total} = 300 \times 100 \text{ l/day}$$

$$\text{sewage rate} = \frac{80}{100} \times \frac{300 \times 100}{1000 \times 24 \times 60 \times 60}$$

$$= 2.77 \times 10^{-4} \text{ m}^3/\text{sec}$$

$$(V_s) \text{ Vol. of tank} = Q \cdot D_t = 2.77 \times 10^{-4} \times 3 \times 24 \times 60 \times 60 \\ = 71.7984 \text{ m}^3 - (1)$$

$$\text{total depth} = 9.3 \text{ m}$$

$$\text{freeboard} = 0.3 \text{ m}$$

$$\text{liquid depth} = 9.0 \text{ m}$$

$$V_{se} = \frac{V}{3}$$

(170)

$$V = V_s + V_{se}$$

$$V = V_s + \frac{V}{3}$$

$$V_s = V - \frac{V}{3} = \frac{2}{3}V \quad \text{--- (3)}$$

$$W_g = \rho g V \quad V = L B \cdot H \\ = 225 B^2 \cdot 2$$

$$V = 4.5 B^2 \quad \text{--- (3)}$$

~~$$W_g = V_s + V_{se}$$~~

~~$$4.5 B^2 = 71.7984 + \left\{ V - \frac{V}{3} \right\}$$~~

~~$$4.5 B^2 = 71.7984 - \frac{2}{3}(4.5 B^2)$$~~

$$B =$$

~~$$\text{from (1) & (3)}$$~~

$$\frac{2}{3}V = 71.7984$$

$$V = 107.69 \text{ m}^3 \quad \text{--- (4)}$$

~~$$\text{from (3) & (4)}$$~~

$$107.69 = 4.5 B^2$$

$$B = 4.6 \text{ m}, L = 10.5 \text{ m}$$

$$H = 9 + 0.3 = 9.3 \text{ m}$$

Hydraulic loading is defined as the rate of flow / surface loading area.

$$\text{loading} = \frac{\text{rate of flow}}{\text{surface area}}$$

(171)

$$\frac{100}{100 \times 24 \times 60 \times 60} = \frac{2.77 \times 10^{-4}}{A}$$

$$A = 239.33 \text{ m}^2$$

$$V_{se} = q_a \times t_c$$

$$\frac{V}{3} = q_a \times t_c$$

$$35.89 = 0.04 \times 300 \times t_c$$

$$t_c = 2.99$$

$$t_c = 3 \text{ years}$$

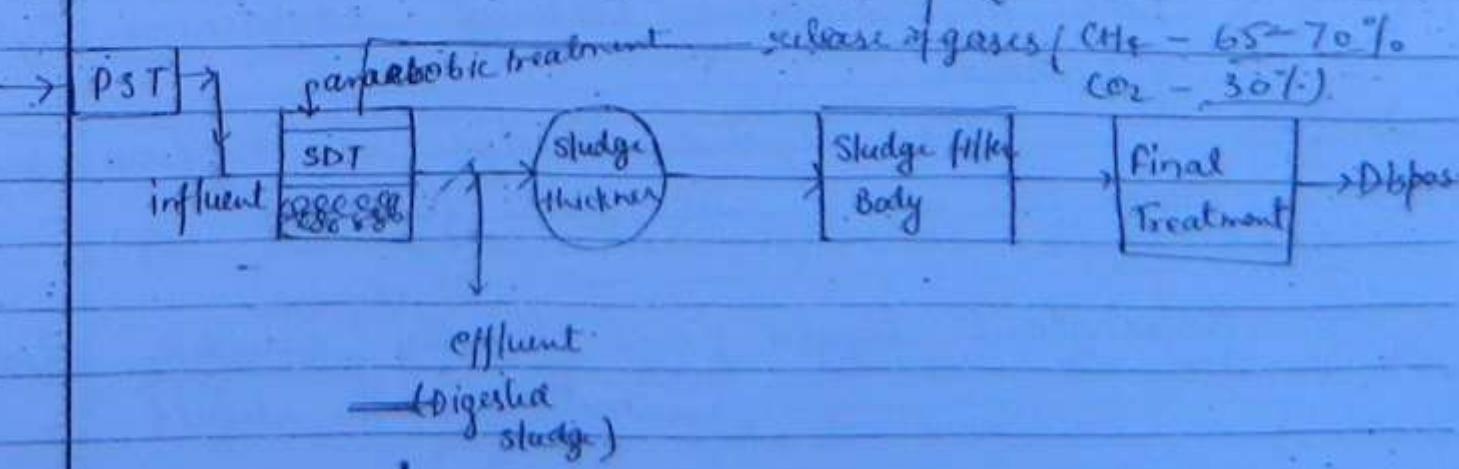
Sludge Digestion Tank (SDT) :-



It is an anaerobic process



works in the absence of O₂



→ 40-60% of organic solids are digested.

CH₄ gas released is around 0.9 m³ per kg of volatile solids of the digested sludge. volatile CH₄ → 0.6 m³ for sewage.

Three stages of 'SDT' :-

1. Acid Fermentation
2. Acid Regression
3. Alkaline fermentation

(172)

The parameters which influence sludge digestion are -

- (1) temp.
- (2) pH
- (3) seeding phenomenon
- (4) mixing of seeded sludge
- (5) nature of bacteria

Mesophilic Bacteria - 29°C

Thermophilic Bacteria - 35-50°C

Acid Fermentation :- Sludge digestion process contains the following 3 forms.

1. Digested sludge :- stable solid matter like humus with black in colour free of pathogenic bacteria containing cysts of bacteria.

The digested sludge is dried up and can be used as a fertilizer.

2. Supernatant liquid :- finely dispersed solid matter and liquid

containing 3000 ppm quantity of BOD.

It is retreated in the treatment plant and sent back to the raw sewage

(173)

3. Gases of Decomposition :- CH₄ around 65 to 70%, CO₂ - 30%.

other gases like N₂, H₂S are evolved.

The various stages involved in the process of digestion of sludge are

1. Acid Fermentation :- The sewage will be acidic in nature and it indicates the beginning of the digestion process.

2. Acid Regression :- At this stage of sludge digestion, BOD remains high & sludge becomes foamy, scum is formed at the top due to which gases are trapped.

3. Alkaline Fermentation :- During this stage the liquid and the digested solids and gases get separated. The sludge becomes alkaline in nature, at this stage BOD falls rapidly and large volume of the CH₄ gas with small amount of other gases is evolved.

The parameters which influence sludge digestion are -

1. Temperature :- If temp increases the rate of the digestion will be more.

In the case of sludge digestion at 27°C , it takes 30 days for the decomposition process.

The mesophilic bacteria is acting in this process. As the temp. increases there will be the action of thermophilic bacteria.

(134)

2. pH :- The sewage in the form of sludge in the sludge digestion tank should have a pH of around 7.2 to 7.4.

For the proper growth of bacteria to encourage bacterial action lime should be added in the form of calcium hydroxide ($\text{Ca}(\text{OH})_2$)

3. Seeding Phenomenon :- Proper seeding can be done by the addition of activated sludge (which is rich in concentration of active micro organism) to the raw sewage in order to reduce the time period of decomposition.

Mining a seeding sludge can be done by means of steering rods & bacterial enzymes present in digested sludge should be mined thoroughly for the better decomposition.

Bacteria has two types -

Mesophilic bacteria works out at lower temp. & helps in the anaerobic action whereas the thermophilic bacteria acts at high temp. and it decomposes the sludge at a faster rate.

- 8) The sludge from the sedimentation tank contains 95% moisture content. (175)

After treatment in the sludge digestion tank if the moisture content of the sludge is going to become more, then it can be reduced by sending it into sludge thickener tank. The m.c. of sludge can be calculated by -

$$\text{m.c.} = \frac{w_w}{w_w + w_s} = \frac{95}{95 + 5}$$

w_s = wt. of solids.

w_w = wt. of water

If sludge having a m.c. of P_1 & volume V_1 , in initial form is dried up, $V_1(100 - P_1) = V_2(100 - P_2)$ after drying the m.c becomes P_2 & volume V_2 . Then

$$(175) \quad [V_1(100 - P_1) = V_2(100 - P_2)]$$

In this case this eqn holds good

For the solid content if the quantity of sludge with a m.c of 98%, is x , then the quantity of sludge with a m.c. of 96% will be -

$$V_1(100 - P_1) = V_2(100 - P_2)$$

$$n(100 - 98) = V_2(100 - 96)$$

$$n \times 2 = V_2 \times 4$$

$$V_2 = \frac{n}{2}$$

Ques A sedimentation tank is treating 4.5 MLD of sewage containing 275 ppm of suspended solids - The tank removes 55% of suspended solids calculate -

(176)

- wt of sludge produced per day assuming the mc of sludge as 96%.
- If the sp.gr of sludge is 1.02, calculate the sludge quantity in bulk (volume).

Soln:

$$Q = 4.5 \text{ MLD}$$

sewage contains = 275 mg/l of suspended solid

$$\text{Total discharge} = 4.5 \times 10^6 \text{ lit/day}$$

$$\begin{aligned}\text{total suspended solids in sewage} &= 4.5 \times 10^6 \times 275 \times 10^{-3} \\ &= 1237.5 \text{ kg/day}\end{aligned}$$

$$\text{Total removal suspended solids} = \frac{55}{100} \times 1237.5$$

$$= 680.62 \text{ kg/day}$$

$$\text{moisture content of sludge} = 96\% = \frac{96}{100} = \frac{96}{96+4}$$

$$\frac{W_w}{W_w + W_s}$$

4 kg of solids - producing 100 kg. of sludge

$$\frac{100}{4} \times 680.62$$

$$= 17015.5 \text{ kg.}$$

$$= 17.015 \text{ tonnes}$$

$$\text{Density} = \frac{\text{wt of sludge}}{\text{Vol of sludge}}$$

$$\text{Vol. of sludge} = \frac{\text{wt. of sludge}}{\text{sp. gravity density}} = \frac{17.05 \text{ tonnes}}{1.02 \text{ t/m}^3} = 16.68 \text{ m}^3$$

(77)

$$\text{Triton sp. gravity} = \frac{\gamma_{\text{sub}}}{\gamma_w}$$

$$1.02 = \frac{\gamma_{\text{sub}}}{1.0 \text{ t/m}^3}$$

$$\gamma_{\text{sludge}} = 1.02 \text{ t/m}^3 \quad \text{Ans}$$

Sludge Digestion Tank :-

$$V_1 (100 - P_1) = V_2 (100 - P_2)$$

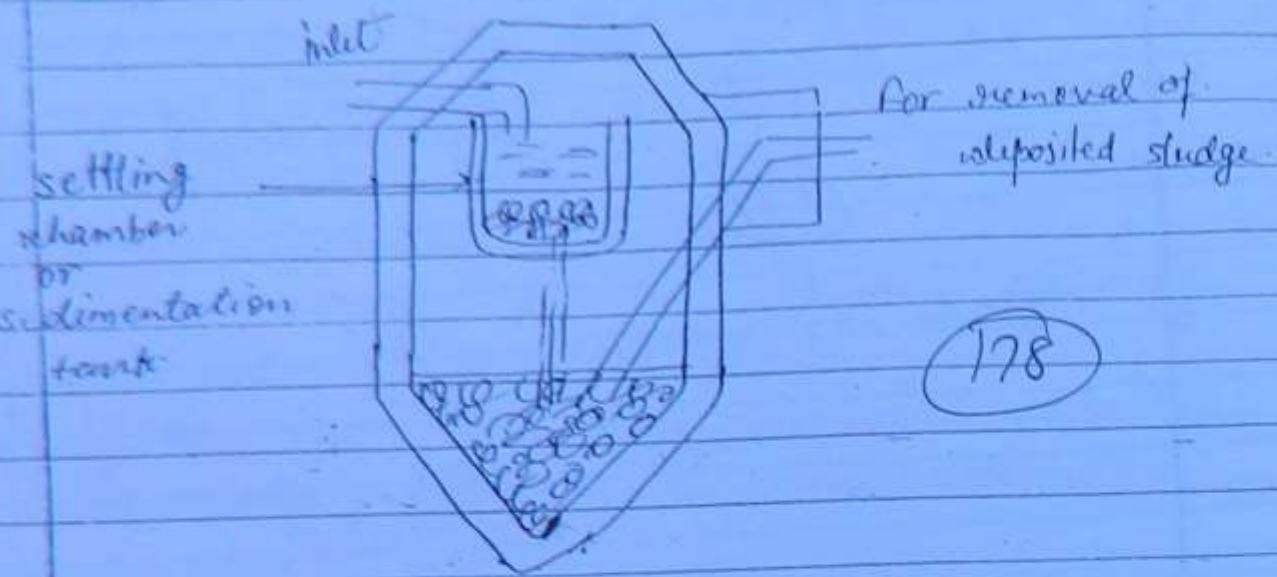
$$\text{Vol. of the sludge digested} = \frac{1}{3} \times (\text{volume intake})$$

$$\text{The vol. of sludge} = V_1 - \frac{2}{3} (V_1 - V_2)$$

IMHOFF TANK :- Where concreted area is not possible to have sedimentation tank & anaerobic tank (septic tank) separately then we use in the better lesser space by combining the reaction together in imhoff tank.

Physical forces are acting i.e. the sedimentation of the sludge is taking place by gravitational forces.

The unit operation of imhoff cone, basically



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converts the form of the sludge from one form into the another form i.e. the impurities are converted chemically into the other form by the anaerobic action.

Detention time can be kept upto 30 days

'Disposal Methods of sludge':-

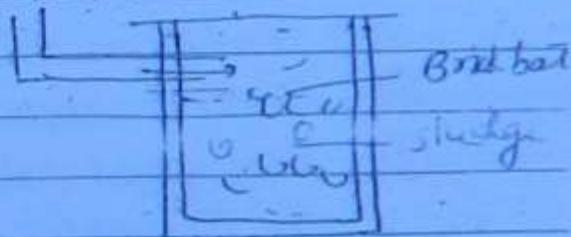
1. Absorption Trenches
2. Soap pits
3. Cess pools.

E In absorption trenches the digested sludge can be carried out through the open jointed pipes into the trenches digging below the G.L. After 2-3 months of periods, the entire sludge discharge into the trench will become earthy material and it acts as a good manure. In the absorption trenches

are used to grow the vegetation plants successfully. This phenomenon known as organic farming.

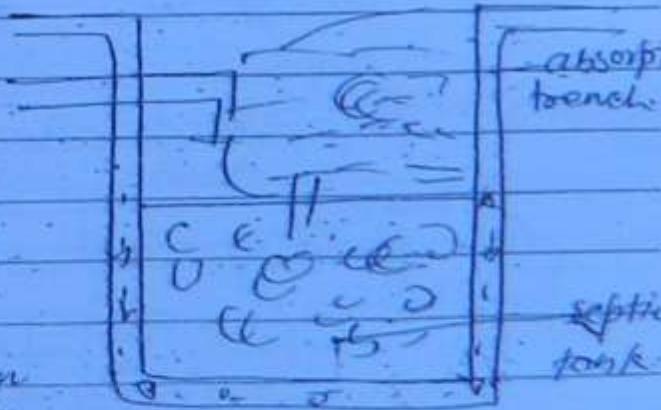
(179)

2. Soak Pits :- Soak pit is a mechanism in which in a pit is excavated upto a certain depth & the digested sludge effluent is allowed into the pit, the sludge m.e. is get reduced by the surrounding brick bats filled up in the pit. After sometime the sludge is converted into the manure in dry form and it can be utilise as a manure.



3. Cess Pools :-

Cess pools, top portion acts as a absorption tank and bottom portion acts as septic tank. If when the soil is porous there is a danger of the percolation of sludge to the nearby wells. In the areas of cess pools, care should be taken that no open well should exist in the surrounding area.

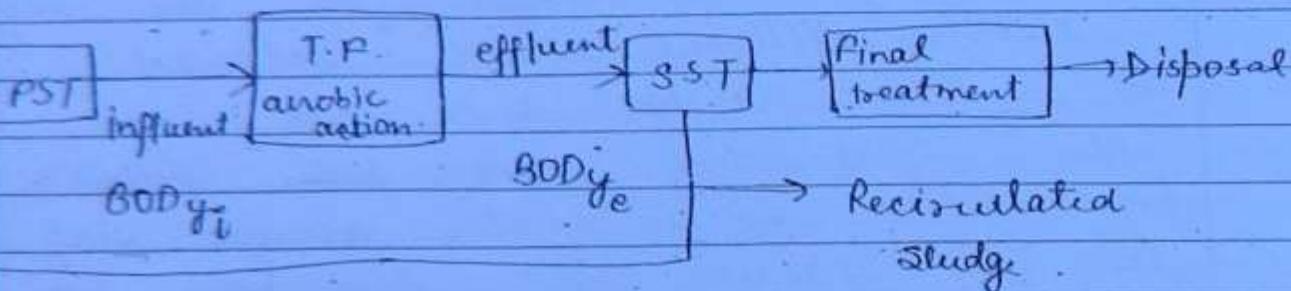


unit process → involving biological and/or ~~chemical~~ chemical reaction

- Aerobic Treatment -
- 1) Trickling filter
 - 2) ASP
 - 3) Oxidation Pond.

Trickling Filter :-

(180)



- ① Trickling filter is an aerobic Treatment ✓
- ② smooth aerobic bacteria is dominant
- ③ Biological decomposition takes place through the aerobic action ✓
- ④ The presence of attached growth bacteria in the filter beds makes easy for the aerobic decomposition.

$$\text{Efficiency } \eta = \frac{\text{BOD removed}}{\text{Applied BOD}} = \frac{Y_i - Y_e}{Y_i} \times 100$$

- Types of T.F :-
- 1) Intermittent T.F.
 - 2) contact bed filters
 - 3) low rate (standard rate) filter
 - 4) High rate filter

→ unit process not based on suspended growth culture
is "upflow anaerobic sludge blanket"

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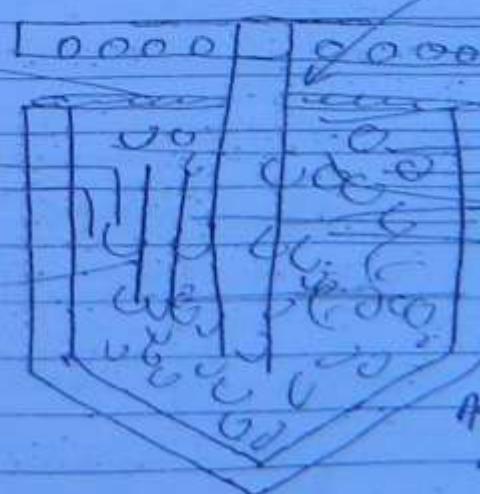
DATE :

- 1 Intermittent TF → Filter beds contains coarse sand, BOD removal is 90-95%
(181)
- 2 Contact Bed Filters → Filter bed contains gravel 60-70% - BOD removed.
- 3 (d) Low Rate (Standard Rate) Filters - stone aggregated → 70-80% BOD removed. Recirculation ratio = 0.
- 3 High Rate Filters - Stone aggregate; but sludge is recirculated - BOD removed - 80-90%.

⑧ Problems of filters:-

- ① flies (spreading of flies) → Psychoda.
- ② odour → prevent by chlorination.
- ③ Ponding - Clogging of pores of filterbeds of Rakers.
↓ aeration

Wastewater
Biological
film formation
film enriched
with biomass
Rakers
or swarms



Rotating drum
nozzles
seam
outlet filterbeds
growth of bacteria
anaerobic decomposition

Parameters useful for design of TF :-

$$\text{Organic loading } u = \frac{Q \gamma_i}{V} \quad (182)$$

where Q = discharge rate of sewage

V = Volume should be kept in ha-m.

$$\text{Recirculation Ratio } R = \frac{R}{I}$$

R = rate of recirculation

I = rate of influent

In case of high rate filters the circulation of sludge is done whereas in case of low rate filter there is no need of recirculation.

Organic loading - It is defined as the amount of BOD i.e. supply to the trickling filter at the given flow rate per unit volume.

$$\text{Recirculation factor : } p = \frac{1 + R/I}{(1 + 0.1 R/I)^2}$$

Efficiency of TF

$$(\text{for low rate}) \quad \eta = \left[\frac{100}{1 + 0.0074 \sqrt{u}} \right]$$

u = organic loading

$$\text{for high rate filter} \quad m = \frac{100}{140.004 / u/\rho}$$

where $m = \frac{Qy_i}{v}$, ρ = recirculation factor depends on recirculation ratio.

(183)

In case of design of T.F., the required vol. of the filter can be formed by making use of organic loading so vol of filter

$$V = \frac{Qy_i}{u}$$

→ The width of the tank is 2-3 m

Q. Estimate the efficiency of a 30m dia & 1m deep single stage high rate trickling filter for the following data -

Sewage flow = 4.5 MLD

Recirculation ratio = 1.4

BOD of raw sewage = 250 ppm

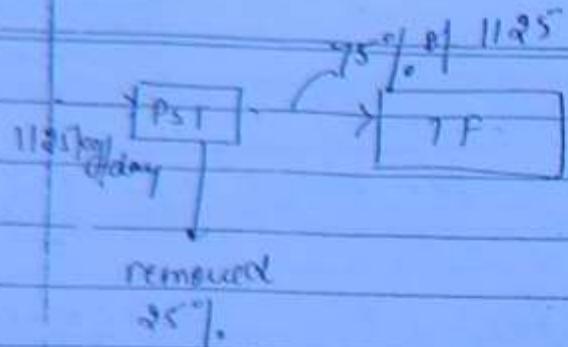
BOD removed in the primary clarifier (PST) = 25 %

Sewage flow = $4.5 \times 10^6 \text{ ml/l/day}$

$$Q = 4.5 \times 10^6 \text{ l/l/day}$$

BOD of raw sewage - $y = 250 \times 10^{-6} \text{ kg/l}$

$$\begin{aligned} \text{Total BOD of sewage} - Q \times y &= 250 \times 10^{-6} \times 4.5 \times 10^6 \\ &= 11.25 \text{ kg/day} \end{aligned}$$



$$\begin{aligned}
 \text{BOD supply as influent to T.F.} &= 75\% \text{ of } 1185 \\
 &= \frac{75}{100} \times 1185 \\
 Q_i &= 843.75
 \end{aligned}$$

Recirculation factor = 1.4

$$F = \frac{1 + R/t}{(1 + 0.1R/t)^2}$$

$$F = \frac{1 + 1.4}{(1 + 0.1 \times 1.4)^2}$$

$$F = 2.846$$

Dia of T.F. = D = 30m

depth = 1m

$$\begin{aligned}
 \text{Volume of T.F.} &= \frac{\pi}{4} d^2 h \approx \frac{\pi}{4} \times (30)^2 \times 1 \\
 &= 706.85 \text{ m}^3 = 706.85 \text{ ha}
 \end{aligned}$$

$$\eta = \frac{1}{1 + 0.0044 \sqrt{\frac{H}{F}}} = \frac{1}{1 + 0.0044 \sqrt{\frac{8.75}{VF}}}$$

$$\eta = \frac{100}{1 + 0.0044 \sqrt{\frac{843.75}{706.88}} - 1.846}$$

(18)

$$\eta = 73.86\%$$

Ques:

A trickling filter plant treats 1500 dm^3/day of sewage with a BOD of 220 ppm and a suspended solid concentration of 250 ppm. Estimate the total solids production assuming that the primary clarification removes 30% of BOD & 60% of influent solids. Take the solid production in trickling filter as 0.5 kg/s/kg of the applied BOD.

Trickling filter treats = 500 m^3/day of sewage

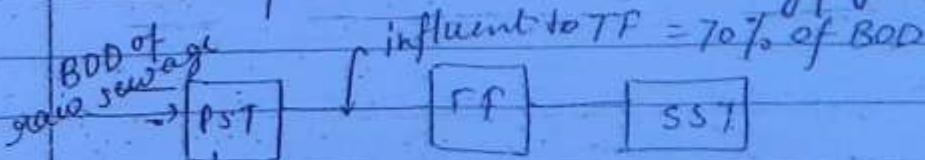
BOD of sewage = 220 ppm

Suspended solids BOD = 250 mg/l

Primary clarifier removed = 30% of BOD

& 60% of influent solids

Solids production rate = 0.5 kg/s/kg



BOD removed - BOD of sewage given as = 220 mg/l

$$= \frac{70}{100} \times 220 \times 10^{-6}$$

$$= 1.54 \times 10^{-4} \text{ kg/l}$$

The scale of sewage flow given in the problem

as $1500 \text{ m}^3/\text{day}$

$$\begin{aligned}\text{Total wt. of BOD sent to the TF} &= 1.54 \times 10^{-4} \times 1500 \\ &= 231 \text{ kg/day.}\end{aligned}$$

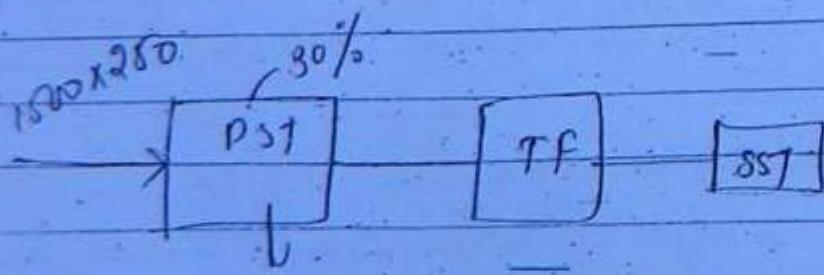
$$\begin{array}{l} 1 \text{ Kg} \longrightarrow 0.5 \text{ kg} \\ 231 \text{ kg} \longrightarrow \frac{0.5 \times 231}{1} = 115.5 \text{ kg} \end{array}$$

The suspended solids removal is 60% of influent, consisting of 250 ppm BOD in the PST.

Total sewage flow rate = $1500 \text{ m}^3/\text{day}$.

$$\begin{aligned}\text{total wt. of solids in influent} &= 1500 \text{ m}^3 \times 250 \times 10^{-6} \text{ day} \\ &= 0.375\end{aligned}$$

$$\begin{aligned}60\% \text{ of influent is classified by} \\ \text{PST} &= 0.6 \times 1500 \times 10^3 \times \\ &250 \times 10^{-6} \text{ kg/day.} \\ &= 225 \text{ kg/day.}\end{aligned}$$



Suspended solid = 60%.

Total wt. of suspended solids = 225 kg/day

$$\begin{aligned}\text{Total wt. of solid reducing the TF} &= 115 \text{ kg/day.} \\ - \text{ Total solids produced} &= 225 + 115.5 \\ &= 340.5 \text{ kg/day.}\end{aligned}$$

Q. Determine the dimensions of a high rate T.F given that

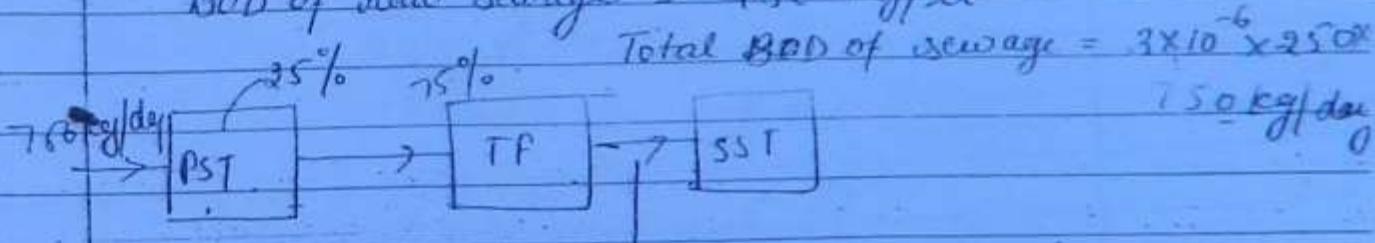
- a) sewage flow = 3 MLD
- b) Recirculation ratio = 1.5
- c) BOD of raw sewage = 250 mg/lit
- d) BOD removed in Primary tank = 25%
- e) Final effluent BOD desired = 30 mg/lit

(187)

By what % of the dia. of the filter will have to be modified if it is to be designed as standard rate T.F. for the above requirement.

$$Q = 3 \times 10^6 \text{ lit/day}$$

$$\text{BOD of raw sewage} = 250 \text{ mg/lit}$$



$$\text{influent of T.F.} = 75\% = \frac{75}{100} \times 750 = 562.5 \text{ kg/day}$$

y_i

after treatment in T.F

$$\text{effluent BOD} = 30 \text{ mg/lit} = 30 \times 10^6 \times 3 \times 10^{-6} = 90 \text{ kg/day}$$

$$\eta = \frac{y_i - y_e \times 100}{y_i} = \frac{562.5 - 90}{562.5} \times 100 = 84\%$$

Recirculation Factor

$$F = \frac{1 + R/F}{(1 + 0.1 R/F)^2}$$

(188)

$$F = \frac{1 + 1.5}{(1 + 0.1 \times 1.5)^2} \\ = 1.89$$

$$\eta = \frac{100}{1 + 0.0044 \sqrt{q/F}}$$

$$\eta = \frac{100}{1 + 0.0044 \sqrt{\frac{q}{V_F}}}$$

$$\eta = \frac{100}{1 + 0.0044 \sqrt{\frac{562.5}{V \times 1.89}}}$$

By assuming the width = 2m

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

$$\frac{100}{1 + 0.0044 \sqrt{\frac{562.5}{\frac{\pi d^2 \times 1.89}{2}}}} = 0.84$$

$$d = 31.7 \text{ m}$$

iii) For standard scale filter

$$R = 0 \\ I$$

(189)

$$F = 1$$

$$\eta = \frac{100}{1 + 0.0044 \sqrt{u}} = \frac{100}{1 + 0.0044 \sqrt{\frac{562.5}{V}}}$$

$$\phi_{0.84} = \frac{100}{1 + 0.0044 \sqrt{\frac{562.5}{V}}}$$

$$V = 3001.5 \text{ m}^3$$

assuming the width of T.P. = 2m.

$$\text{area} = \frac{\phi_{0.84} \cdot 3001.5}{2} = 1500.75 \text{ m}^2$$

$$\frac{\pi}{4} d^2 = 1500.75$$

$$d = 43.71 \text{ m}$$

$$\begin{aligned} \% \text{ of modification} &= \frac{43.71 - 31.7}{31.7} \times 100 \\ &\text{with respect to high} \\ &\text{rate filter} \\ &\equiv 37.5\% \end{aligned}$$

Q: Design a sludge digestion tank for the primary sludge i.e. raw sludge from the primary sedimentation tank with following data.

(190)

- a) Avg. flow of sewage = 20 MLD
- b) Total suspended solids of raw sewage = 300 mg/l
- c) 60% of suspended solids is removed in the primary sedimentation tank
- d) m.c. of the digested sludge is around 85%
- e) Sp. gr. of sludge = 1.02
- f) Digestion period in the sludge digestion tank = 30 days

$$\text{avg. flow of sewage} = 20 \text{ MLD}$$
$$\text{total flow rate} = 20 \times 10^6 \text{ lit/day}$$

$$\text{Total wt. of suspended solids} = 300 \text{ mg/l}$$

$$\text{Total wt. of suspended solids removed} = 60\%.$$

$$= \frac{60}{100} \times 20 \times 10^6 \times 300 \times 10^{-3}$$

$$= 3600 \text{ kg/day}$$

Digested volume of sludge = $\frac{1}{3}$ of initial volume -

$$\text{on assuming } N_2 = \frac{1}{3} V_1$$

given that m.c. of digested sludge = 85%.

Let P_1 be the m.c. of undigested sludge

P_2 be the m.c. of digested sludge

$$V_2 = V_1 / 3$$

$$\text{using } V_1 (100 - P_1) = V_2 (100 - P_2)$$

$$V_1(100 - P_1) = V_1(100 - 85)$$

$$P_1 = 95\% \quad (191)$$

5 kg. of solid in sludge — 95 kg of water in
sludge

$$3600 \text{ kg} \times \frac{95}{5} = 68400 \text{ kg}$$

$$= 68400 \text{ kg of water.}$$

$$\begin{aligned}\text{Total wt. of sludge} &= w_s + w_w \\ &= 3600 + 68400 \\ &= 72000 \text{ kg}\end{aligned}$$

Given that sp. gr. of sludge = 1.02

$$\text{Volume} = \frac{\text{weight of sludge}}{\text{sp. gr}}$$

$$V_1 = 70.58 \text{ m}^3$$

$$V_2 = \frac{V_1}{3}$$

$$V_2 = \frac{70.58}{3} = 23.5 \text{ m}^3$$

$$\text{Total Volume} \cdot V = \left[V_1 - \frac{2}{3}(V_1 - V_2) \right] D_t$$

$$V = \left[70.58 - \frac{2}{3}(70.58 - 23.5) \right] \times 30$$

$$V = 1175.8 \text{ m}^3$$

depth = 4 m (assume)

$$\text{of S.D.T} \quad \frac{\pi d^2}{4} = \frac{1175.8}{4}$$

$$d = 19.34 \text{ m}$$

~~Ques~~ Ques 9 GATE
 An anoxic reactor receives waste water at a flow rate of $500 \text{ m}^3/\text{day}$ of COD of 2000 mg/l . The effluent COD is 900 mg/l . Assuming the waste water contains 80% of biodegradable waste, the daily vol of CH_4 produced by the reactor is -

(192)

Q. A T.F. is designed with an organic loading of $0.175 \text{ kg/m}^3/\text{day}$. If the effluent ^{BOD} of sewage is 150 mg/l then effluent BOD is

Q. The BOD of sewage entering into the TF is 200 ppm . If the effluent of sewage is 60 ppm then the η of TF = ??

$$\text{Sludge-age } \theta_c = \frac{V \cdot X_i}{Q_w \cdot X_R + (Q_i - Q_w) \cdot X_0}$$

Q_i = Inflow

V = Vol. of reactor

$$\theta_R = \frac{R}{100} Q$$

Activated Sludge Process (ASP) :-

(193)

It is an aerobic process.

Decomposition of sludge takes place under aerobic bacteria.

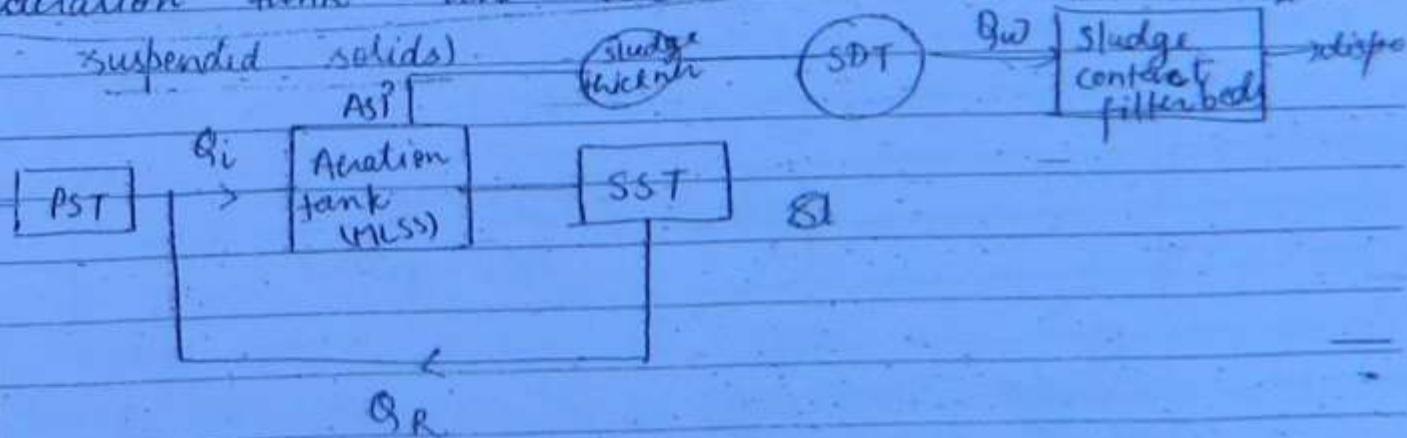
Making use of activated sludge

Activated sludge \rightarrow sludge having high concentration of active microorganisms \rightarrow (from secondary sedimentation plant SST).

The activated sludge is mixed with raw sewage in aeration tank (ASP) with high supply of air or oxygen & kept for 4-8 hours.

~~existing~~ The active sludge mixed in aeration tank as mixed liquor.

(*) The solids that are formed in the aeration tank are known as 'MLSS' (Mixed liquor suspended solids).



Q_w = flow rate of waste, X_w = concentration of solids in the waste

Q_i = flow rate of influent X_i = concentration of influent solids.

Q_E = flow rate of effluent X_E = concentration of effluent

Q_R = Recirculation flow rate X_R = concentration of recirculated solids.

Design consideration :-

(194)

Hydraulic Retention time : - It is defined as volume of tank to the rate of flow of the sewage into the tank.

$$HRT = \frac{V}{Q_i}$$

V = Vol. of tank

loading :

Volumetric Organic : The volumetric organic loading is defined as BOD load applied per unit volume of the reaction tank.

$$\mu = \frac{Q_i y_i}{V}$$

Efficiency of Aeration tank : - It is defined as

$$\eta = \frac{y_i - y_e}{y_i} \times 100$$

$$\boxed{\eta = \frac{\text{BOD removed}}{\text{BOD applied}} \times 100}$$

Sludge Thickening :-

Sludge Bulking

Sludge volume index (SVI)

F/M ratio → food to microorganisms

Sludge Thickening :- Sludge from secondary settling tank contain too much of m.c. that is 98 - 99 %. The m.c. is 1st reduced by sending into the sludge thickener & m.c. will be reduced from 98 - 93 %.

It helps in reducing the capacity of digestion tanks.

It is similar to the circular settling tank with retention time of 12 - 24 hrs.

(195)

Bulking of sludge :- Under sick condition, the settled sludge may contain more moisture and there resulting swelling of the sludge volume. Due to the sludge bulking, it remains in the suspension & remained in the effluent of secondary clarifiers.

To avoid the bulking of sludge following are the remedial measures

- a) Eliminates the industrial waste.
- b) Chlorinate the sewage.
- c) Supply excess amount of oxygen and increased aeration.
- d) Raising the pH of the sewage to 8 by the addition of lime.

Sludge Volume Index :- It is defined as it is the volume occupied in ml by 1 gm of solids in the mixed liquor after settling for a period of 30 min.

$$SVI = \frac{\text{Vol. of sludge settled in ml}}{\text{MLSS in gm}}$$

SVI = 50 - 150 should be adopted.

(196)

P/M Ratio :- Food to Microorganisms Ratio

It is called as organic loading

It is defined as the ratio of BOD applied per kg day to the MLSS in the aeration tank.

$$P/M = \frac{Q_{BOD}}{V \cdot x_f}$$

Where V = Vol. of the sludge

x_f = concentration of mixed liquor solids.

Notes :- Higher the P/M ratio lower is the removal of the BOD and vice versa.

for a activated sludge process P/M ratio should be 0.3 to 0.4

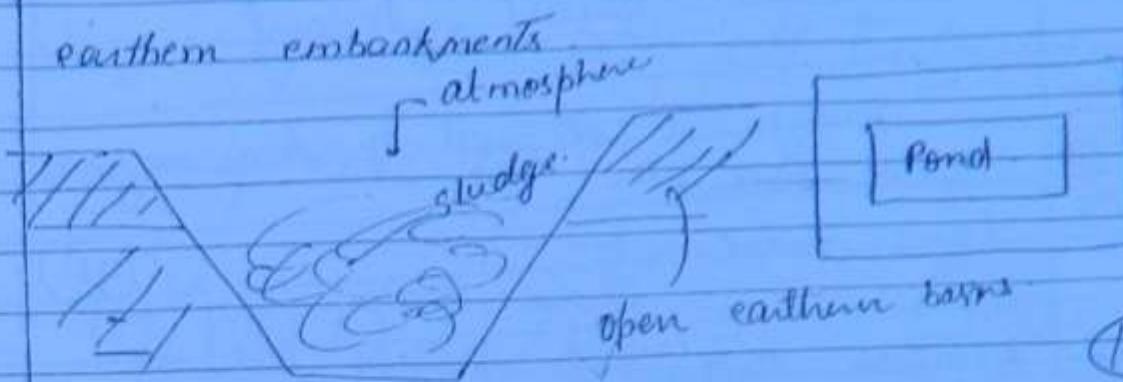
The efficiency of aeration tank depends upon the quantity of BOD removal.

Oxidation Pond :- Water Stabilization pond

cheapest treatment \rightarrow area requirement is more

\downarrow
nuisance is more

Oxidation ponds of the eastern basins open channel constructed below the GL surrounded by the



(197)

In case of oxidation ponds the principle involved is stabilisation of organic matter by the combined action of algae and the other micro organisms by the symbiotic relationship.

In the case of oxidation pond the symbiotic relationship exist b/w algae & micro organism in the sense algae produced O_2 while growing in the presence of sunlight & the O_2 is utilised by m.o. & The end products in the oxidation pond of CO_2 , NH_4 & phosphates. The discharge in the form of water i.e. coming from the oxidation pond after decomposition can be used it in land irrigation system.

In the case of oxidation pond the area required is around $\frac{1}{2}$ hectare to 1 hectare and Retention time is 20-30 days.

BOD removal = 90%.

Cleaning period of settled sludge = 6 years. To stimulate the process of decomposition, to reduce the time of decomposition Sodium Nitrate is added.

Sewage Effluent Disposal

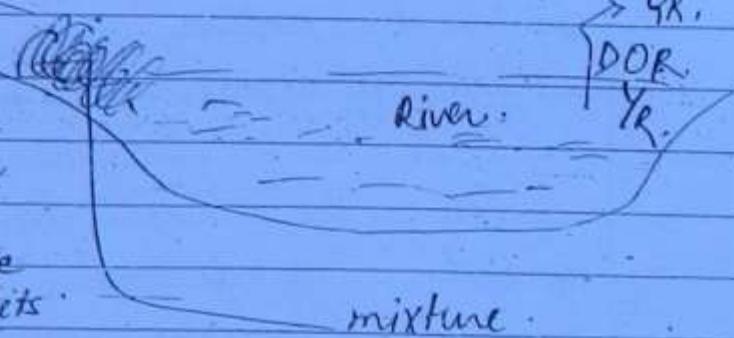
Sewage is disposed by two methods

- (1) Dilution method.
- (2) Land treatment

(198)

(1) Dilution Method :- Effluent is discharged into a running River/stream soon after outfall

Q_s , sewage waste
 $D.O_s$
 y_s . permissible limits



$$Q_m = Q_R + Q_s$$

$$D.O_{min}$$

$$BOD_{min}$$

$$D.O_{min} = \frac{Q_R (D.O)_R + Q_s (D.O)_s}{Q_R + Q_s}$$

BOD of mixture -

$$y_{min} = \frac{Q_R y_R + Q_s y_s}{Q_R + Q_s}$$

Stages of River in the self Purification

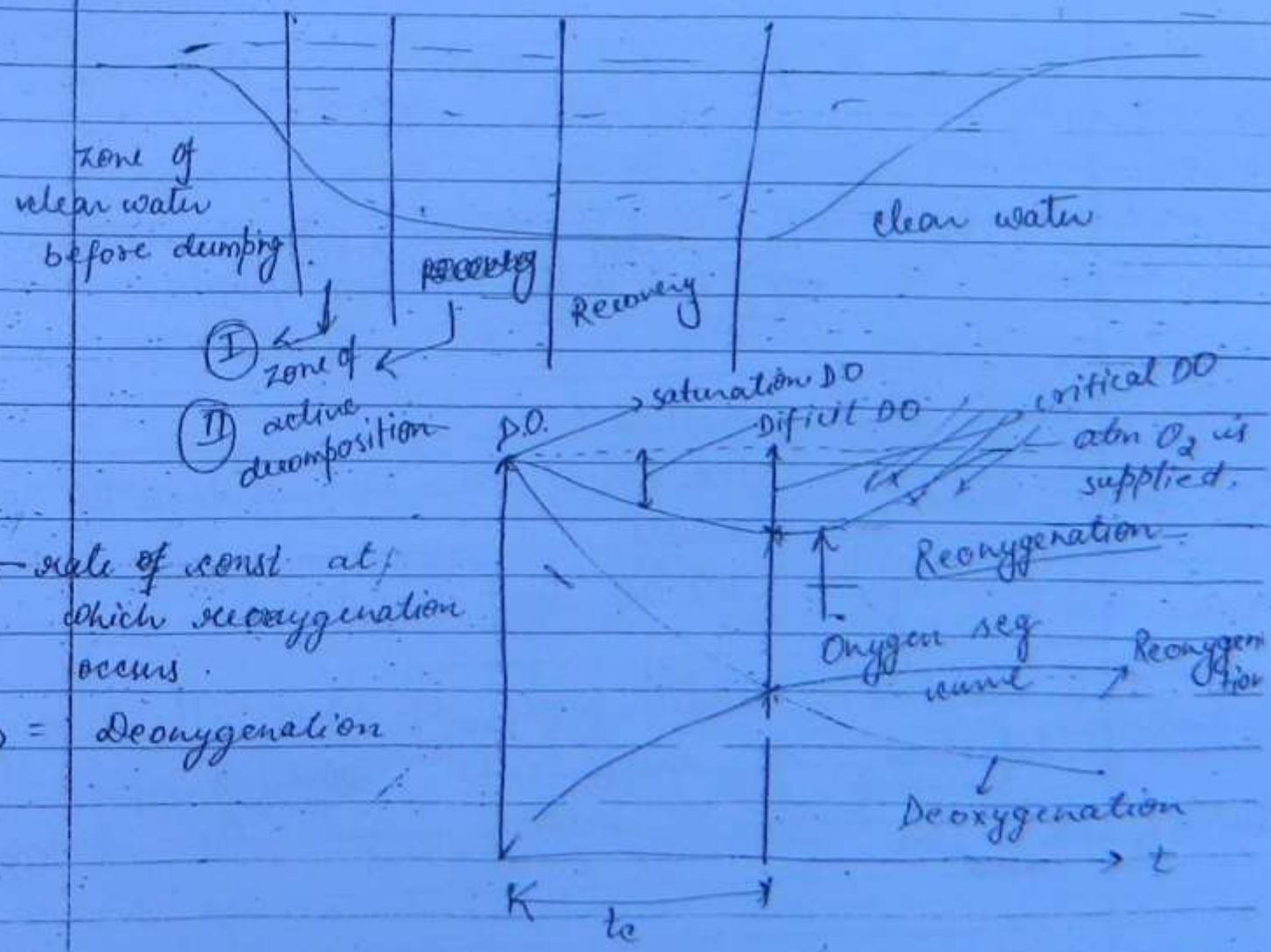
Stages of River are 4

(i) Zone of clear water
Zone of active decomposition

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① Zone of clear water

- Zone of degradation
- Zone of active decomposition
- Zone of recovery
- Zone of clear water



initial DO deficit = saturation DO - present DO

initial DO deficit = saturation DO - DO_{min.}

Self coefficient

(200)

Self Purification constant
of a river | $f = \frac{k_R}{k_D}$

$$D_f = \frac{k_D \cdot L}{k_R - k_D} \left[10^{-k_D t} - 10^{-k_R t} \right] + [D_0 10^{-k_R t}]$$

$$D_c = \frac{k_D \cdot L}{k_R} \left[10 \right]^{-k_D t_c}$$

$$t_c = \frac{1}{k_D(f-1)} \log \left[\left[1 - (f-1) \frac{D_0}{L} \right]^{f-1} \right]$$

where D_c = critical DO

t_c = time period at which critical DO deficit occurs.

D_t = DO at any time t

For the dilution process of rivers, it is very important to check the qualities of running river or stream and the geological area

Land Treatment :- Directly dumping the effluent sewage effluent onto the land After sometime, the pores of the soil will be clogged and filtration & donot take place properly nuisance of effluent (sewage sickness)

↓
land pollution & leading of sewage or leachate forms GWT get polluted.
coloured water

(201)

Factors Affecting the self Purification of system of river :-

Dilution :- If the sewage is mixed with large vol. of water or it is much diluted, sewage always remains in the aerobic condition & anaerobic condition never comes b/c always DO remains present in the water.

Current :- The self purification of stream is directly depends upon the currents. When there is no current, sewage matter deposit near the outfall cause formation of the sludge banks and causes foul odours. And in the slow current sedimentation takes place causing the overgrowth of algae resulting in the reduction of oxygen.

Temperature :- As the activities of organisms depends upon the temp, the self purification will also depend upon the temp.

(262)

At lower temp the organisms activities are slow due to the slow rate of decomposition. As in the summer season the temp increases, the stream will get self purification is less. In the winter season

Sedimentation :- With the slow current the heavier solids settle in the stream bed & start anaerobic decomposition. The products of decomposition are again mixed with the water by current. If dilution is sufficient, anaerobic condition will not develop.

Sunlight :- The pathogens are killed if they are expose to the sunlight; therefore sunlight helps in the self purification process. Algae also grow in sun light causing the production of oxygen.

Oxidation :- The organic matter immediately mixed with the stream starts getting oxidised due to the development of oxidising organisms present in water. The process prevails till the

complete oxidation of organic matter
The oxygen demand is satisfied
in stream becomes purified due to
this phenomenon.

(203)

Reduction :- It occurs in streams due to hydrolysis of organic matter biologically & chemically, anaerobic organisms start the splittings of complex organic substances present in the sewage.

This action produces odours & gases and thus stabilization comes into the picture.

A site adjacent to a river is considered for the location of a municipal waste water treatment plant having an avg. inflow of $2500 \text{ m}^3/\text{day}$.
The selected treatment sequence is as follows

1. grit channel -

2. Primary sedimentation process

3. Activated sludge process

4. Secondary sedimentation process

Design the grit channel assuming max. hydraulic loading as the twice the avg. inflow rate. Assume appropriate design parameters if required.

maxⁿ hydraulic loading - 21 aug sewage flow

204

$$= 2 \times 2500$$

$$= 5000 \text{ m}^3/\text{day}$$

By assuming the flow velocity as 0.3
and retention time period $D_t = 2$ minutes
then the length of the
grit channel $L = \frac{\text{velocity} \times D_t}{0.3 \times 2 \times 60}$
 $= \frac{0.3 \times 2 \times 60}{26 \text{ m}}$

The surface area of channel can be calculated as -

$$\text{area} = \frac{\text{design flow rate}}{\text{velocity}}$$

$$= \frac{5000}{0.3} = \frac{5000}{24 \times 60 \times 1000} \\ = 0.192 \text{ m}^2$$

by assuming the depth of channel as 1m

$$B = \frac{\text{area}}{\text{depth}} = \frac{0.192 \text{ m}^2}{1 \text{ m}} = 19 \text{ cm}$$

Hence we provide the dimension of grit channel as

$$L \times B \times H = 36 \text{ m} \times 0.19 \text{ m} \times (1 + 0.3)$$

$$[L \times B \times H = 36 \times 0.19 \times 1.3] \quad \text{freeboard}$$

Ques-03:

A settling test on a sample drawn from the aeration tank liquor of ASP / MLSS = 2800 mg/l was carried out with 1 lt. sample.

The test yielded, the settled vol. of 200 ml. The vol. of sludge vol index shall be

$$SVI = \frac{\text{vol settled}}{\text{MLSS}}$$

$$\text{SVI} = \frac{200 \times 10^3}{2800}$$

71.4 ml/gm

Ques- 1 lt. of sewage when allowed to settle for 30 min. gives a sludge vol. of 27 cm³. If the dry wt. of the sludge is 3gms then the SVI = ?

$$SVI = \frac{27}{3} = 9$$

Ques-05

In certain situation, the waste water discharging into a river mixes with the river water instantaneously & completely. Following is the data available.

$$\text{Waste water DO} = 2.00 \text{ mg/l}$$

$$\text{Discharge rate} = 1.10 \text{ m}^3/\text{sec}$$

$$\text{River water DO} = 8.3 \text{ mg/l}$$

Initial amount of DO in the mixture of river & waste shall be -

$$D.O_s = 2.00 \text{ mg/l}$$

$$Q_s = 1.10 \text{ m}^3/\text{sec}$$

$$D.O_R = 8.3 \text{ mg/l} \quad (206)$$

$$Q_R = 8.7 \text{ m}^3/\text{sec}$$

$$\text{temp.} = 20^\circ\text{C}$$

$$D.O_{min} = \frac{Q_R(DO)_R + Q_s(DO)_s}{Q_R + Q_s}$$

$$= \frac{8.7 \times 8.3 + 1.10 \times 2}{8.7 + 1.10}$$

$$= 7.59 \text{ mg/l}$$

Ques. If mc of sludge is reduced from 98 to 96%.
then the vol of sludge decreases by

$$V_1(100 - P_1) = V_2(100 - P_2)$$

$$V_1(100 - 98) = V_2(100 - 96)$$

$$V_1 \times 2 = V_2 \times 4$$

$$\frac{V_1}{V_2} = 2$$

$$V_1 = 2V_2 \quad (50\% \text{ of } V_1)$$

Ques. Effluent from waste water treatment plant (flow rate $864.0 \text{ m}^3/\text{d}$, temp. $= 25^\circ\text{C}$) is discharged to surface stream (flow rate $12 \text{ m}^3/\text{s}$, temp 15°C). What is the temp of stream after mixing?

$$Q_S = 8640 \text{ m}^3/\text{d}, T_S = 25^\circ\text{C}$$

$$Q_R = 1.2 \text{ m}^3/\text{s}, T_R = 15^\circ\text{C}$$

$$t_{min} = \frac{Q_S \times T_S + Q_R \times T_R}{Q_S + Q_R} \quad (207)$$

$$= \frac{8640 \times 25}{24 \times 60 \times 60} + 1.2 \times 15$$

$$= \frac{8640 \times 25}{24 \times 60 \times 60} + 1.2$$

$$15.769^\circ\text{C}$$

Ques- A 125 m³/s sewage of a city is discharged in a perennial river (continuous) which is fully saturated with O₂ and flows at the rate of 1600 m³/s with a velocity of 0.12 m/s. If BOD of sewage is 300 mg/l. Find out where critical DO will occur in the river. Assume K_R = 0.44/day.

K_D = 0.11/day & ultimate BOD is 125% of BOD mixture of waste & River water.
Take saturation DO level of river is 9.2 mg/l

$$f = K_R/K_D = \frac{0.44}{0.11} = 4$$

$$t_c = \frac{1}{K_D(f-1)} \log \left[1 - (f-1) \cdot \frac{D_0}{L} \right] f$$

$$t_c = \frac{1}{0.11(4-1)} \log \left[\left(1 - 3 \times \frac{D_0}{L} \right) \right] f = 4.08264$$

$$\text{DO}_{\min} = \frac{Q_R(00)R + Q_S(00)s}{Q_R + Q_S}$$

$$= \frac{1600 \times 9.2 + 125 \times 0}{1600 + 125}$$

$$= 85333$$

(28)

initial DO deficit

$$\begin{aligned} D_0 &= \text{saturation DO} - \\ &\quad \text{DO}_{\min} \\ &= 9.2 - 0.53 \\ &= 0.66 \end{aligned}$$

from eqn (1)

$$= t_c = \frac{1}{0.11 \times 3} \log \left[\frac{1 - 3 \times 0.66}{27.1739} \right] \times 4$$

$$t_c = 1.725 \text{ days}$$

$$\begin{aligned} D_c &= \frac{k_D L}{k_R} [10]^{-k_D \times t_c} \\ &= \frac{0.11 \times 27.1739}{0.44} [10]^{-0.11 \times 1.725} \end{aligned}$$

$$D_c = 438876$$

length of flow into river = velocity of flow $\times t_c$

$$\begin{aligned} &= 0.12 \times 1.72 \times 24 \times 60 \times 60 \\ &= 17832.96 \text{ m} \\ &= 17.83 \text{ km} \end{aligned}$$

$$\begin{aligned} L &= 125 \% \text{ of BOD min} \\ \text{Polar } L &= \frac{12.5}{100} \times y_{\min} \end{aligned}$$

$$y_{\min} = \frac{Q_R \times y_R + Q_S \times y_S}{Q_R + Q_S}$$

$$y_{\min} = \frac{1600 \times 0 + 125 \times 300}{1600 + 125}$$

$$y_{\min} = 21.74$$

$$L = 27.1739 \text{ mg/l}$$

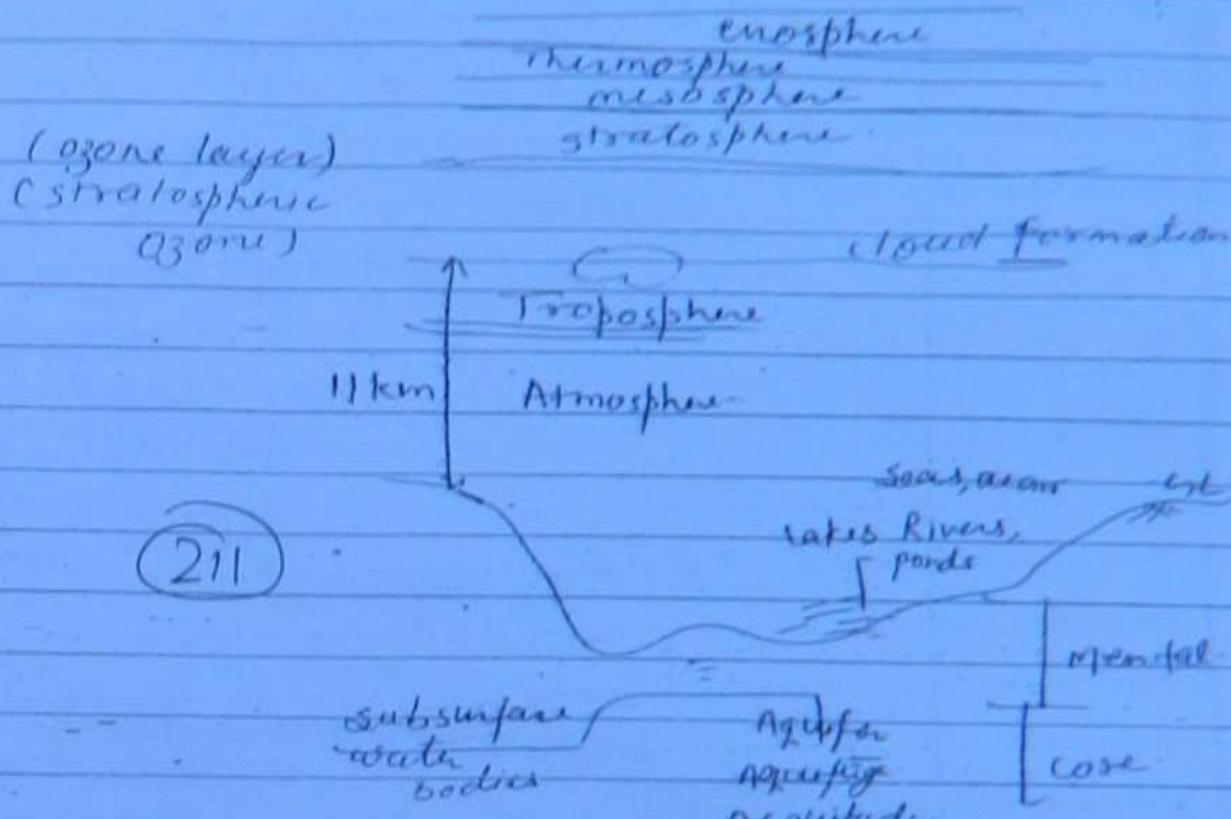
Ques. 07:

A River before its entry into the town had a discharge of 100 l/sec & 20 mg/lt as the concentration of a conservative parameter (BOD). The towns waste water outfall having 200 mg/lt concentration up the same conservative parameter raised the concentration of river to 50 mg/lt after a complete mix with the river water. Determine the dilution ratio resulting from the discharge of waste water outfall.

(209)

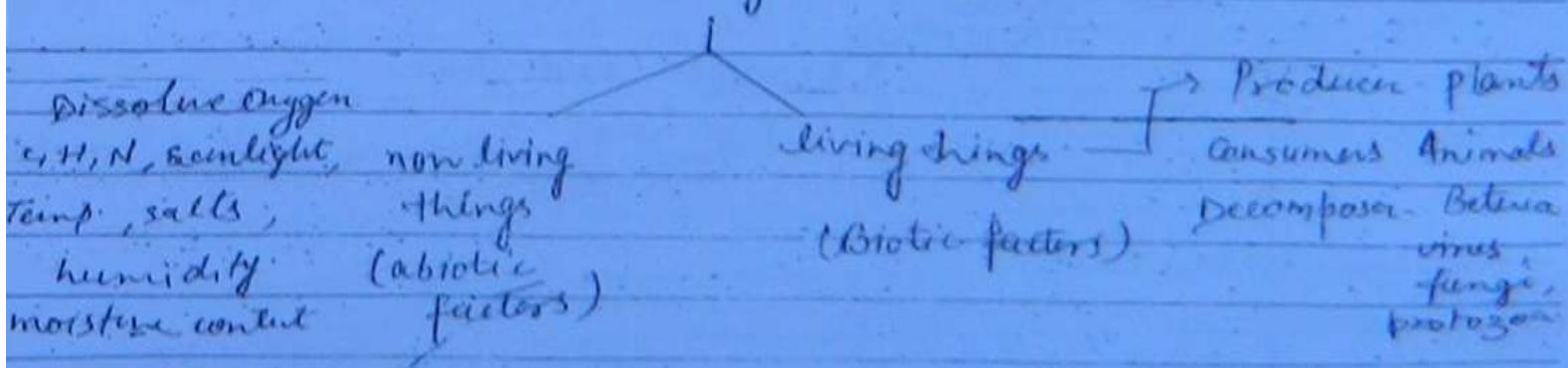
20

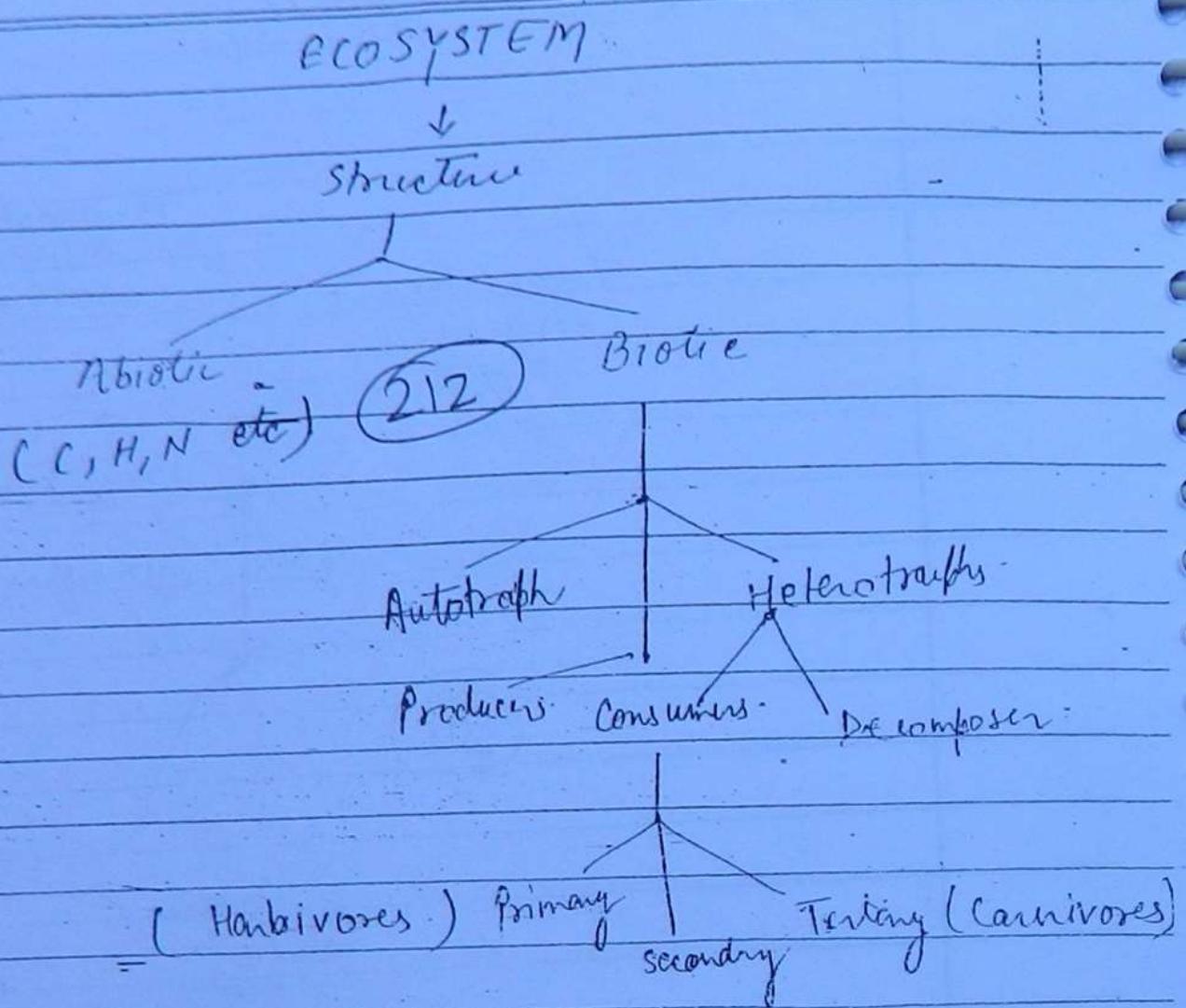
ECOLOGY



Subsurface water bodies + Surface water bodies } Hydrosphere

BIO System





Food chain In an ecosystem transfer the energy from one level to another level.

Food chain → Grazing food chain → Normal food chain

Food chain → Detritus food chain

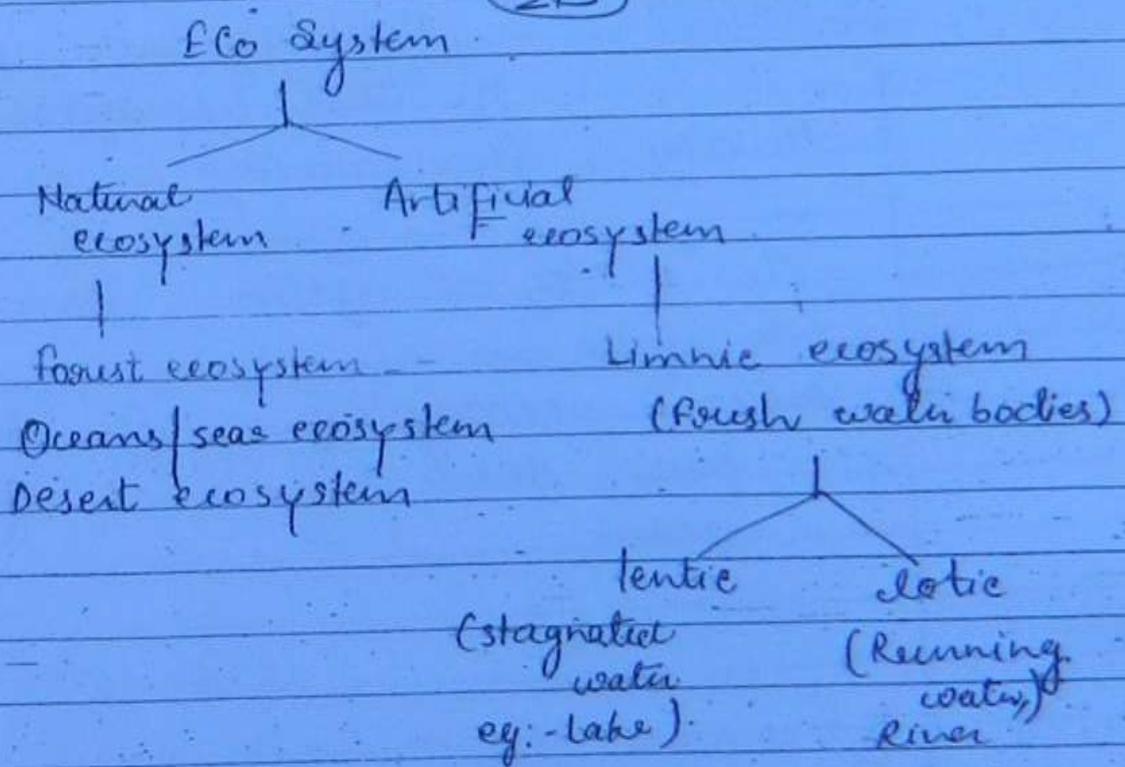
Detritus food chain → starts from the decomposition process
Bacteria

Food chain - Eaters eaten by the another eaters
producer → consumer → Decomposer

Transfer of energy from one level to another level is known as Trophic level - Trophic energy. Longer the food chain, least in the energy transfer to the last consumers.

Rules of thermodynamics; law of conservation of energy.

213



Industrial (Terrestrial)

Marine Ecosystem

Aquarium Ecosystem

Agriculture Ecosystem

Anthropogenic Ecosystem

In ecosystem

- ① ecological succession
- ② sustainable development

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environmental impact → assessment of environmental impact
↓
ecological imbalance

ECOLOGY:- Ecology is defined as the study of the ecosystem in relation to the surrounding environment.

The ecological system can be classified as two types -

- 1) Natural ecosystem 2) Artificial ecosystem
- eg:- forest, deserts & oceans
- eg- industrial agricultural
Limnic
Aquarium

Every ecosystem consists of abiotic factors (Non living things) and biotic factors (living things) and mutual interrelationships b/w them.

Each ecosystem consists of its own str. by maintaining systematic balance.

Air Pollution : It is defined as presence of excessive foreign matter into the air beyond its permissible level, which becomes toxic in nature and causes damage to the human beings, animals & property.

Pollution
↓
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Pollutants

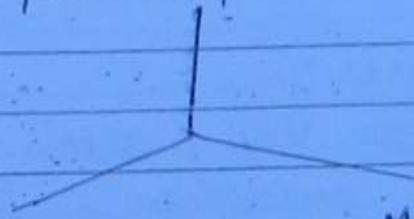
↓

Toxic element beyond its
permissible level.

In the ecosystem

↓

Sources for the pollutants - which cause
pollution.



Natural pollution

Man made
sources

- ① pollen grains - Anther flowers
- ② forest fires
- ③ Volcanic eruption

- ① Thermal power plants
- ② Nuclear Reactors
- ③ Agriculture source
- ④ Automobiles.

Sources :-

Primary Air Pollutants : - (i) Six gases, Non gases,
carbon related (CO_2 , CO),
Hydrocarbons, hydrogen sulphide, Hydrogen fluoride
Methane (CH₄), particular matter, aerosols, lead

Secondary Pollutants :-

Because of the reaction b/w the two primary pollutants.

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"Air Pollution is defined as the excessive concentration of foreign matter in the air which adversely affects the well-being of an individual or causes damage to property and affects plants, animals, buildings."

Sources of Air Pollution :-

Air pollution sources can be classified as

- ① Natural sources ② Manmade sources

① Natural Sources :-

- (i) Products from the atm. reactions (chemical reactions like oxidation, Photochemical reaction, polymerization)

(ii) Aerosols :- Aerosols are finely divided solids and liquid particles of microscopic size held suspended or dispersed in atm.

e.g:- dust, smoke, fog, mist, fume (generated from steel plant)

3) Microorganisms which infect plants & animals

4) Pollen grains :- These are the small grains from the anther flowers which cause allergic reaction.

5) Radioactive minerals :- The radiation emanated from the nuclear power plants causes damaging effects.

and gases :-

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6) Volcanic ash, gases & odours from the marshy lands.

7) Man-made Sources -

1) Combustion of fuel - (CO_2 , SO_2 , NO_2 ..)

2) Industrial emission such as SO_2 , CO_2 , NO_2 & CO , NH_3

3) Thermal Power Plants :- These mainly emit SO_2 gases.

exhaust

4) Automobiles :- The exhaust from the automobiles contains CO , CH_4 unburnt carbon.

5) Agricultural Activities :- activity related to agriculture using field burning crops Spraying

6) The nuclear power plants emit the radioactive substance

Primary pollutants

- 1) Pollens
- 2) Sulphur compounds (SO_2 , SO_3 , H_2S)
- 3) Nitrogen compounds (NO , N_2O , NO_2 , NH_3)
- 4) Carbon compounds (CO , C_2H_2)
- 5) Lead
- 6) Radio-active substances
- 7) Halogen compound
- 8) Hydrocarbons

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Secondary Pollutants

These are the pollutants which are formed in the atmosphere as a result of interaction between two or more primary air pollutants or by the reaction of primary pollutant & other constituents by photo reaction phenomenon.

- 1) H_2SO_4
- 2) O_3
- 3) PAN
- 4) Formaldehyde
- 5) Smog
- 6) Photochemical smog

H_2SO_4 is formed by the simple chemical reaction of SO_2 & water vapour. It causes acid rain.

Ozone, CO, PAN, Formaldehyde are formed by the photochemical reactions caused by the sunlight b/w the two primary air pollutant.

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SO₂ industries related to the Gases —

- 1) SO₂ from the thermal Power plant.
- 2) CO₂ from automobiles → Carboxy hemoglobin is formed and acts as anaphyrant & leads to the cardio vascular diseases.
- 3) HC from the automobiles exhausts
- 4) Lead → It is released into the water by the automobiles running on petrol.
- 5) NO_x gases → They are released from the car oxidation, electrical discharges, solar radiation, welding operations in the industries.

Effects of Air Pollution :-

- ① Air pollution causes Bronchiitis (Asthma)
- ② The high concentration of SO₂, NO₂, Photochemical smog, pollen grains cause asthma.
- ③ Red lead discharge from the automobiles cause lungs infection.
- ④ Hydrogen Fluoride released from the Fluorocarbon industries cause the mottling of teeth (discolouration of teeth).

- 5) CO cause death due to asphyxiation.
- 6) Radioactive components cause cancer due to the carcinogenic agents, lessening the age of genetical effects.
- 7) The NO_x gases cause eye irritation, nasal irritation & respiratory syndromes (Breathing problems).
- 8) Silicosis & Asbestosis are the diseases caused to the person who work in cement industry, coal miners & thermal power plants.

Effects on Plants :-

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1. Chlorosis (discolourisation of plants i.e yellow color)
2. Necrosis (air pollutant excessive levels can lead to the tissue killing of plant)
3. Abscission - (unnecessary falling of leaves due to the excessive air pollutant concentration) is called as Abscission.
4. Epinasty - (bow curvature of leaf due to air pollution) is known as Epinasty.

Global effects of Air pollution

- 1) Acid rain
- 2) Global warming
- 3) Ozone layer depletion
- 4) Green house effect

1 Acid Rain :- The rain water is slightly acidic, the acidity level increases with the SO_2 & NO_2 . Mining of the secondary pollutants in atm. level i.e. H_2SO_4 causes acid rain.

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⑧ Major part of the acid rain is due to the SO_2 which is produced mainly by the burning of the coal & oil in the industry.

⑨ The pH of the acid rain is b/w 5 to 5.5. Acid rain causes damaged to the forest, crops, buildings & monuments (by the leaching action) in lower levels of. Acid rain causes dissolved oxygen to the forest & fauna and skin cancer & change in ecological system.

2 Global Warming :- It is the outcome of the air pollution caused by the man made activities.

Global warming may lead to the forest fires and burning of the crops.

The increased level of temp. in the atm zone due to the release of various air pollutants & vehicular emmisions & trap the sunlight in the lower levels to prevent the reflected sunlight to go up into the higher zone.

The trapping of sunlight leads to the increased the temp. at the global

due to this phenomenon is known as Global Warming.

Global warming is due to the increased industrialization & emission of chlorofluorocarbon (CFCs), CCl₄, CH₂Cl₂, chloroform (CHCl₃), Isoprene, Refrigerants, CO₂.

④ Global warming effecting —

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- ① changes in sea-levels.
- ② increased levels of seas are causing imbalance in the ecological system.
- ③ global warming effecting the growth rate of algae.

Ozone layer depletion

Ozone is present in stratosphere & it is called as stratospheric ozone.

- The unit of the ozone measurements are 'DABSON'. Due to the effect of global warming, ozone layer depletion is taking place & harmful ultraviolet rays are reaching the earth surface and causing the damage to the ecosystem.

When chemical pollutants such as CFCs & refrigerants, other industrial emission in the excessive concentration levels, some of them break the ozone layer &

concentration of ozone layer is gets reduced
in the winter
effects of Ozone layer depletion:-

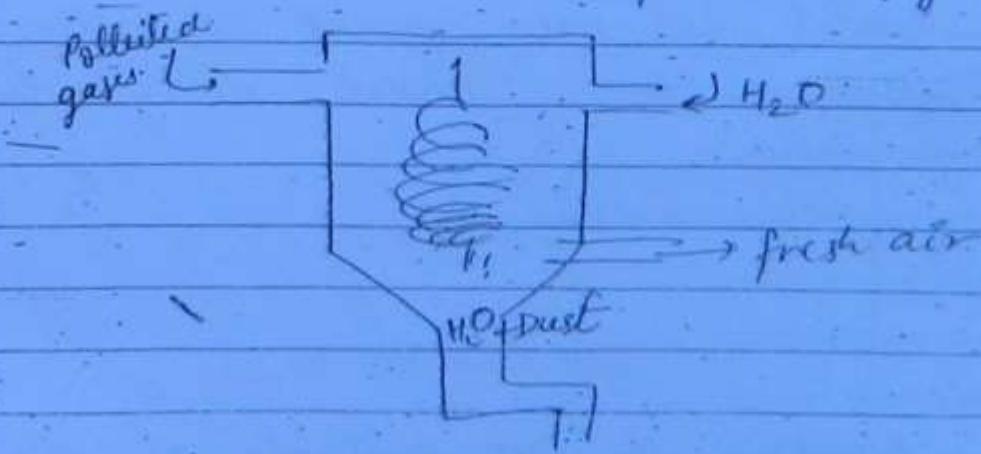
- 1) Damage to the immune system
- 2) Disturbance in ecosystem
- 3) increased skin cancer
- 4) shortening of life of plants & lower yield of crop.

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Control Methods :-

- ① Electrostatic Precipitators (ESP)
- ② wet scrubber
- ③ Bag houses filters

ESP :- Thermal Power Plants (flyash).



The treatment of air pollution depends upon the concentration of air pollution.

Conversion of Suspended particulate matter (SPM) -

From ppm to $\mu\text{g}/\text{m}^3$

$$\mu\text{g}/\text{m}^3 (\text{of SPM}) = \frac{(\text{PPM of SPM}) \times \text{gram} \times \text{mole mass of gas} \times 10^3}{\text{vol. of gas (lit/mole)}}$$

↓ substitution of
molecular wt of a gas

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Any gas, at 1 atm pressure or 760 mm

at 0°C i.e. 273°K , \rightarrow occupies 22.4 lit/mole of vol.

Avogadro's law :-

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

The 1 mole of any 1 gas occupied the same volume as 1 mole of any other gas at the same temp and pressure.

at 273°K and 1 atm pr., the vol. of gas is 22.4 lit/mole.

To convert the vol. given at other temp. to pressure the above avagadro's law is used.

Ques A sample of air analysed at 0°C & 1 atm pr. is reported to contain 9 ppm of CO. Determine the equivalent CO concentration in micrograms/ m^3 .

Solⁿ

$$CO = 12 + 16 = 28$$

$$\text{mg/m}^3 \text{ of CO} = \frac{9 \times 28 \times 10^3}{22.4} = 11250$$

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(CHCl₃)

Ques

The mean indoor airborne chloroform concentration in a room was determined to be 0.4 $\mu\text{g}/\text{m}^3$. Use the following data.

$$T = 293^\circ\text{K}, P = 1 \text{ atm}, \text{Gasconst. } R = 8.3105 \times 10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}\cdot\text{K}$$

$$\text{Atomic wt. of C} = 12, \text{H} = 1, \text{Cl} = 35.5$$

If this concentration is expressed in parts/billion (Vol^m basis) is equal to

$$CHCl_3 = 12 + 1 + 3 \times 35.5 = 119.5$$

$$\text{mg/m}^3 \text{ of CHCl}_3 = \frac{\text{ppm} \times 119.5 \times 10^3}{V}$$

$$0.4 = \frac{\text{ppb} \times 119.5 \times 10^3}{V}$$

$$0.4 = \frac{\text{ppb} \times 119.5 \times 10^3}{24.04}$$

$$P = 0.08 \text{ ppb}$$

$$\begin{array}{c|c} \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} & \\ \frac{0.4}{22.4} = \frac{0.08}{29.3} & \\ V_2 = 24.04 \text{ lit} & \end{array}$$

Ques

Particulate matter (flyash) carried effluent gases from the furnaces burning fossil fuels are better removed by

- a) Bag house filter
- b) Wet scrubber
- c) B.S.P.
- d) Minimum depth of air is zero

(Q4)

- Two primary air pollutants are
- $\text{SO}_2 + \text{O}_3$
 - $\text{NO}_2 + \text{PAN}$ (Peroxy Acetyl Nitrate)
 - $\text{SO}_2 + \text{HC}$
 - $\text{O}_3 + \text{PAN}$

(Q) Meteorological conditions -

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Air pollution changes

- Wind velocity (Anemometers)
- Wind direction (wind rose diagram)
- Lapse Rate
- Plume behaviour
- Stack height

Lapse Rate -

- Decrease of temp. with increase of altitude (ELR).
- Adiabatic lapse rate (ALR) - The temp. of a particular air parcel or air pocket decrease with the increase of altitude.

 $\text{ELR} < \text{ALR}$ = sub adiabatic - Lapse rate $\text{ELR} > \text{ALR}$ = super adiabatic $\text{ELR} = \text{ALR}$ = Neutral state

Inversion:- Increase of temp. with increase of altitude i.e. negative lapse rate.

Dry air cools at rate of $9.8^\circ\text{C}/\text{km}$ \rightarrow dry ALR
For saturated (wet air) rate is calculated
to be $6^\circ\text{C}/\text{km}$ \rightarrow wet ALR.

Solid Waste Management

~~Solid waste is defined as the dry form of refuse.~~

~~Density of solid waste = 300 - 600 kg/m³~~

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Effect of meteorological condition on air pollution

Wind velocity & wind dirⁿ :- The higher the wind speed the more rapidly the pollutants would be carried away from the source and concentration of pollutants will get decrease.

Lapse Rate :- Rate of change of temp. of air with altitude is known as LAPSE RATE } Environmental lapse rate ELR }

In the lower atmosphere (known as troposphere upto a dist. of about 11 km above the earth surface), the temp. decreases linearly with increase in the height.

In the upper region of atmosphere which extends from about 11 km to 30 km const. temp. prevails.

Adiabatic Lapse Rate (ALR) :- The interval decrease of Temp. with height which occurs in the rising parcel of air mass without exchange of heat from the surroundings is known as ALR.

Sub adiabatic lapse rate :-

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When $\text{ELR} < \text{ALR}$; The rising air parcel will be cooling more quickly than its surroundings and it will not be able to rise up to the greater altitude.

Such an atm condition is said to be stable and however not favourable for effective dispersion of pollutants, it results more pollution.

Super adiabatic lapse Rate :- ($\text{ELR} > \text{ALR}$)

The rising air parcel will always remain warmer and lighter than the surrounding environment. The air parcel will continue to accelerate to go up. In such a case the atm condition is said to be unstable i.e. dispersion of pollutants is rapid and effective which leads to the less pollution.

Neutral State :- $\text{ELR} = \text{ALR}$; the atm condition is said to be neutral.

Negative lapse rate :- When the temp of air increase with increase in the altitude, then the lapse rate is known as negative lapse rate or inversion.

Solid Waste Management

solid waste in dry form of surface
density - 300 - 600 - kg/m³

Municipal solid waste \leftarrow fused sand bond pieces, papers, biodegradable waste, Rubbish, Garbage
(MSW)

Solid Waste

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causes:- 1) Domestic 2) Industrial sources

Disposal of Solid waste -

- 1) Sanitary land filling
- 2) Incineration or pyrolysis
- 3) Vulcanization
- 4) Barging ^{dumping} into the sea -
- 5) Composting
 - \rightarrow Indian Process \rightarrow Aerobic treatment
 - \rightarrow Bangaluru process \rightarrow Anaerobic treatment

$$\text{① Energy produced kJ/kg (dry basis)} = \frac{\text{Energy in kJ/kg}}{\text{(as described)}} \times 100$$

$$100 - \% \text{ mc}$$

$$\text{② Energy produced in kJ/kg (dry basis) with ash free} =$$

$$\frac{\text{energy in kg/kg}}{\text{(as described)}} \times \frac{100}{(100 - \% \text{ ash - } \% \text{ mc})}$$

If the chemical formula of solid waste is given

(3) energy in
kJ/kg

$$\begin{aligned}
 &= \text{modified Du Long formula} \\
 &= 337(C) + 14.28(H - \frac{O}{8}) + 95(S)
 \end{aligned}$$

where C = % of carbon

O = % of oxygen

H = % of hydrogen

S = % of Sulphur

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Solid Waste can be disposed by the following method

1. By Sanitary land filling Method :- Refuse is covered and dumped into the low-lying area & covered by earth material, so that refuse is not directly exposed.

The waste is stabilized by aerobic & anaerobic process by the bacteria. The refuse is kept for a period of 2-4 month.

2. Leachate :- During the rainy season when excess water seeping through the area may consist of the solid waste as a coloured liquid called as leachate.

The leachate is highly toxic in nature & it pollutes the GWT

Production of Gas :- In the most cases the decomposition of solid waste releases CH_4 , CO_2

The gases can be collected by the gas collector & they can be used as fuel.

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2. Incineration :- Burning of Refuse at high temp. in furnace (incinerator) is known as the incineration. Upon heating within the O_2 free atmosphere, most of the organic substances can be split into the gases and solid fractions. and this process of burning is known as pyrolysis.

3. Barging

3. Pulverization :- Refuse is pulverized in the grinding machine so that the reduce the vol. & change its physical character. After this it is disposed in the trenches aerobically or anaerobically.

4. Barging into the sea :- The solid waste is directly dumped into the sea to disposed of, but care should be taken to prevent the formation of sludge banks.

5. Composting :- This decomposition is effected either under aerobic condition or under anaerobic condition are both.

The final end product is known as manure (compost) and it can be used as fertilizer in agricultural fields. In Indian context there are two methods available for the disposal of refuse to night soil.

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1. Indore Process:- It uses the mixture of refuse & night soil for the decomposition under aerobic condition.

Bangalore

2. Bangalore Process:- It is primarily aerobic in nature & does not involve directly handling of mass (as it is in Indore method). This method is widely accepted by the municipal authority & in this method refuse & night soil are placed in the layer in an underground earthen trench.

This mass is covered by 15cm of layer of earth & it is kept for the decomposition. After 4-5 months the refuse gets stabilized & changes into the brown colour, odourless manure called as Humus.

Ques The following composition of solid waste is given below and the data given as -
Component :- % by mass energy kJ/kg

| | | |
|------------|----|-------|
| Food waste | 15 | 4600 |
| Paper | 45 | 16750 |

| | | |
|---------------|----|-------|
| Card board | 10 | 16300 |
| Plastics | 10 | 32600 |
| Garden things | 10 | 6500 |
| wood | 5 | 18600 |
| Tin cans | 5 | 700 |

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- a) Compute the energy content of solid waste given in the above table form.
- b) determine the energy content on dry basis if the m.c of waste is 20%.
- c) Determine the energy content on an ash free basis assuming the ash content as 5%.

$$\begin{aligned}
 \text{a) Total energy in kJ/kg.} &= 4600 \times 0.15 + 16750 \times 0.45 + \\
 &16300 \times 0.10 + 32600 \times 0.10 + \\
 &6500 \times 0.10 + 18600 \times 0.05 + \\
 &700 \times 0.05 \\
 &\frac{0.15 + 0.45 + 0.10 + 0.10 +}{0.10 + 0.05 + 0.05} \\
 &= 14732.5 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \text{b) energy content on dry basis} &= \frac{14732.5 \times 100}{100 - 20} \\
 &18648.73 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \text{c) energy content on an ash free} &= \frac{14732.5 \times 100}{100 - 21.5} \\
 &= 19908.71 \text{ kJ/kg}
 \end{aligned}$$

Ques. A composition of a certain municipal solid waste sample & sp. wt. of its various components are given below & calculate the sp. wt. of the municipal solid waste in kg/m³

$$M = 100 \text{ kg}$$

| Component | % by weight | Vol. (m ³) | sp. weight (kg/m ³) |
|---------------------|-------------|------------------------|---------------------------------|
| ① Food waste | (234) | 50 | 0.166 |
| ② Dirt & Ash | | 30 | 0.06 |
| ③ Plastics | | 10 | 0.1538 |
| ④ Wood & Yard waste | | 10 | 0.08 |
| | | | 0.4598 |
| | | | 0.046 |

$$\frac{\text{Total sp. wt. of MSW}}{\text{total vol.}} = \frac{\text{total wt.}}{\text{total vol.}} = \frac{100}{0.46} = 217.39 \text{ kg/m}^3$$

Ans:

Two biodegradable components of municipal solid waste are

- a) Plastic & wood
- b) Cardboard & Glass
- c) Leather & tins
- d) Food waste & Garden trimming

Ques:

50 gms of CO₂ & 25 gms of CH₄ are produced from the decomposition of municipal solid waste with a formula wt (molecular wt) of 120 gm.

What is the avg. per capita green house gas produced in a city of 1 million people with a municipal solid waste production rate of 500 tonnes/day.

city population = 1 million

solid substance (MSW) = 120 gm. (23)

120 gm $\xrightarrow{\text{burnt}}$ 50 gm of CO_2 + 25 gm of CH_4

120 gm MSW $\xrightarrow{\text{release}}$ 50 gm of CO_2

500 tonnes

$$\frac{50 \times 500 \times 10^3}{120} = 208.3 \times 10^3 \text{ kg}$$

208.3×10^3 per million

$$= 208.3 \text{ gm.}$$

10^6

$208.3 \times 10^3 \times 10^3$

of CO_2 per capita

120 gm MSW

$\xrightarrow{\text{release}}$ 25 gm of CH_4

500 tonnes

$$\frac{25 \times 500 \times 10^3}{120} = 104.167 \times 10^3 \text{ kg}$$

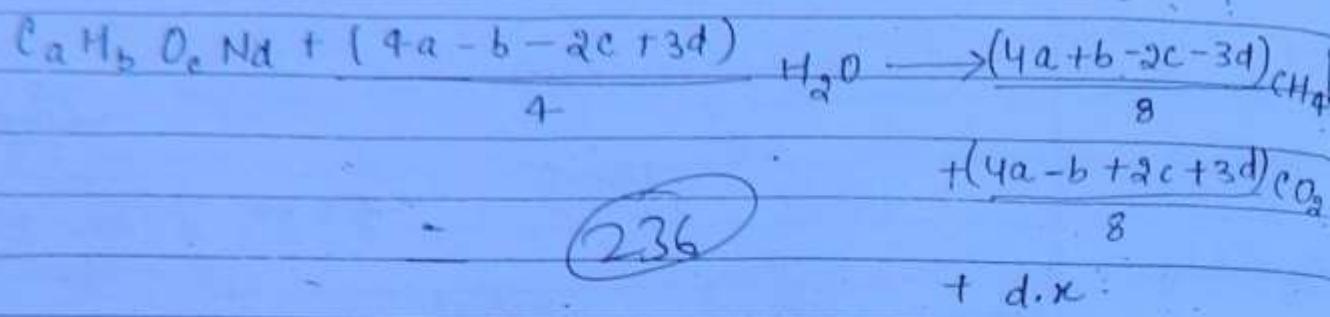
$$= \frac{104.167 \times 10^3 \times 10^3}{10^6}$$

$$= 104.167 \text{ of } \text{CH}_4$$

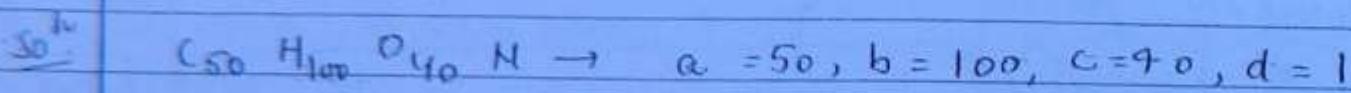
Total green house gases = $208.3 + 104.167$
 $= 312.5 \text{ gm/capita/day}$

- Q. Estimate the theoretical vol. of CH_4 gas that would be expected from anaerobic digestion of a tonne of waste having composition $\text{C}_{60}\text{H}_{100}\text{O}_{40}\text{N}$. The chemical equation:

involved is as follows :-



Assume the density value of CH_4 as 0.7167 kg/m³.



$$\therefore \frac{(4a + b - 2c - 3d)}{8} = \frac{4 \times 50 + 100 - 2 \times 40 + 3 \times 1}{8} \\ = 45.875 \quad 27.875$$

Molecular wt. = $C_{50} H_{100} O_{40} N$

$$50 \times 12 + 100 \times 1 + 40 \times 16 + 1 \times 14 \\ = 1354$$

$$CH_4 \rightarrow 12 + 4 = 16$$

$$1354 \text{ gm} \rightarrow 27.875 \times 16$$

$$1 \text{ gm} \rightarrow \frac{27.875 \times 16}{1354} = 0.32053 \text{ gm}$$

$$1 \text{ tonne} \rightarrow \frac{27.875 \times 16 \times 10^3}{1354 \times 1000} = 320 \text{ kg}$$

$$Vol = \frac{320}{0.7167} = 447.23 \text{ m}^3$$

Ans

Q

The ultimate analysis of municipal solid waste is given below

component

Mass (kg)

% by mass

carbon

34.57

36.3

(237)

Hydrogen

6.90

7.3

Oxygen

48.58

51.10

Nitrogen

0.43

0.50

Sulphur

0.13

0.10

Ash

4.47

4.7

Total

95.02

100

estimate the calorific content of waste by using modified dulong formula.

Dulong formula

$$= 337(C) + 1428(H - \frac{O}{8}) + 95(S)$$

$$= 337 \times 36.3 + 1428 \left(7.3 - \frac{51.10}{8} \right)$$

$$+ 95 \times 0.10$$

$$= 13545.65 \text{ kJ/kg}$$

Ques.
D)

Estimate the m.e. of solid waste sample with the following composition.

| component | % by mass | m.e. | wt. of component | m.e. |
|------------------|-----------|------|------------------|-------------------------|
| Foodwaste | 20 | 70 | 0.20 w | $0.20 \times 70 = 0.14$ |
| Paper | 40 | 6 | 0.40 w | $0.024 w$ |
| cardboard | 10 | 5 | 0.10 w | $0.005 w$ |
| Plastics | 5 | 2 | 0.05 w | $0.001 w$ |
| Garden trimmings | 5 | 60 | 0.05 w | $0.03 w$ |

| | | | | |
|---------|---|------------|-------|----------------|
| wood | 5 | 20 | 0.05W | 0.01 W |
| Tin can | 5 | 3. | 0.05W | 0.0015W |
| | | <u>90%</u> | | <u>0.2115W</u> |

Let total wt. of MSL = W kg.

moisture content = $\frac{\text{total wt. of the moisture}}{\text{total weight}}$

$$0.1 \rightarrow 0.9\% \text{ of } W \text{ by mass}$$

$$= \frac{0.2115 W + 0.11W}{W}$$

$$= 0.3115$$

$$= 31.15\%$$

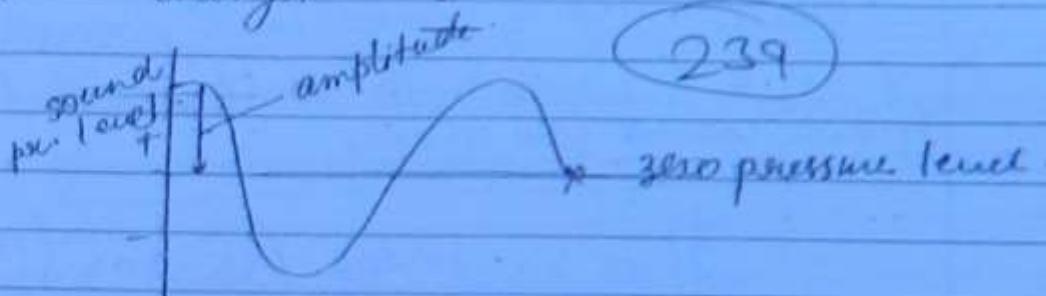
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Noise Pollution

DATE:

Defined as unwanted sound

The sound changes due to the change in the pressure levels due to the environmental changes.



Sound is periodic, regular & long duration of time, pleasant sound.

Sound is aperiodic, irregular, short duration, noise.

Any sound that just audible is having a pressure level called at 'Threshold level'
 $= 20 \text{ micPa} = 0.00002 \text{ N/m}^2$

Sound in the form of noise is measured in Decibel.

The range of sound = 0.00002 N/m^2 to 200 N/m^2 .

The range of sound = 80 db
= 45 db
= 120 db } Turbines
140 db } & jet

Measurement of sound w.r.t. to P_{ref}

$$SPL = 20 \log_{10} \left(\frac{P}{P_{ref}} \right) \quad | \quad 240$$

where P = measured sound w.r.t. the
threshold level (20 μ Pa)

If two sources are there :-

$$L_{eq} = 10 \log_{10} \left(\sum_{i=1}^n 10^{L_i/10} x t_i \right)$$

where L_{eq} = the equivalent sound pressure level
in decibel.

n = total no. of sound pressure level
recorded

L_i = values of the sound pressure level
recorded in db with $i = 1, 2, 3, \dots$

t_i = time duration of the diffⁿ sound
pressure levels recorded, expressed as
the fraction of total recording time

$$\begin{array}{c} 80 \text{ db} \\ 90 \text{ db} \end{array} \begin{array}{c} 5 \text{ min} \\ 15 \text{ min} \end{array} \left\{ \begin{array}{l} L_1 = 80 \text{ db}, t_1 = 5/100 \\ L_2 = 90 \text{ db}, t_2 = 15/100 \end{array} \right.$$

$$L_{eq} = 10 \log_{10} \left(10^{\frac{80}{10}} \times \frac{5}{100} + 10^{\frac{90}{10}} \times \frac{15}{100} \right)$$

$$= 84.776 \text{ db} \quad 81.90 \text{ db}$$

Causes of Sound Pollution

- ① Domestic Sources
- ② Vehicular sources
- ③ Construction Activities
- ④ Machinaries
- ⑤ election campaign f sound speakers / Public fun"

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Effects of Noise Pollution :-

Increased levels of blood pressure.

Decreased efficiency due to fatigue.

Nervous weakness leading to cardiac attack.

Acoustic trauma.

Temporary deafness.

Irritation & headache.

Remedial Measurements :-

- ① By Regularity acts & laws
- ② ear plugs
- ③ using methods of Isolation
- ④ using of insulating materials
- ⑤ minimising the traffic

(H) Sound can be classified as three types.

① Continuous noise :- It is an uninterrupted sound level that varies less than 5db.

e.g:- Running fan

2 Intermittent Noise :- It is a noise which is continuous for more than 1 sec & it is interrupted intermittently.

e.g. a drilling machine

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3 Impact Noise :- It is characterised by change of sound pr. of atleast 20db within the duration of less than 1 sec.
e.g. Turbines & hammers.

~~see qstn~~
Ques.

The reference pr. used in the determination of sound pr. is -

- (a) 20 kpa b) 20 db c) 10 kpa d) 10db

Ans. According to the Noise pollution regulation & control tools of 2000 of the ministry of environmental forest of India, the day time & night time ^{noise level} limits in ambient air for residential area expressed in db. -

Ans. night-45 db Day- 55 db

Q A 60 db of noise is measured with the 20kpa noise and another 60 db is measured with the 10kpa reference level, then the total noise level in the db will be equal to -

Note When two sources are given for a sound the equivalent pr. of the noise can be calculated by the sine wave curve by means of root mean square pressure

$$P_{\text{rms}} = \sqrt{P_1^2 + P_2^2}$$

(245)

$$SPL = 20 \log_{10} \left(\frac{P_1}{P_{\text{ref}}} \right)$$

$$\text{dB} = 20 \log_{10} \left(\frac{P_1}{20} \right)$$

$$P_1 = 20 \times 10^3 \mu\text{Pa} = P_2$$

$$P_{\text{rms}} = \sqrt{P_1^2 + P_2^2}$$

$$= \sqrt{2 \times (20 \times 10^3)^2}$$

$$= 2.8284 \cdot 2 \mu\text{Pa}$$

$$SPL = 20 \log_{10} \frac{P_{\text{rms}}}{P_{\text{ref}}}$$

$$= 20 \log_{10} \left(\frac{2.82 \times 10^4}{20 \mu\text{Pa}} \right)$$

$$SPL = 63.01 \text{ dB}$$

Qn. A noise level of 80 db is lasting for 10 min. is followed by 60 db for 80 min & 100 db for 5 min one after the other. What is the equivalent sound pr. level if the recording time is 95 min?

(244)

$$SPL = 10 \log_{10} \left[\sum_{i=1}^n 10^{L_i/10} \times t_i \right]$$

$$= 10 \log_{10} \left[10^{80/10} \times \frac{10}{95} + 10^{60/10} \times \frac{80}{95} + 10^{100/10} \times \frac{5}{95} \right]$$

- 27.3 db

Thumb Rule :- If the two pr. intensities of the noises are x & y decibals, and if the difference in pressure level is more than one equal to 16 db then the total noise level will be numerically equal to the magnitude of higher value.

If the two noise levels are of each x db then the total noise level will be equal to the $(x+3)$ db.

Ques While recording the weighted sound level, 4 reading have been taken at a site at diffⁿ types of the way these readings are 40, 56, 66, 42 dB. with reference to the 20 μ Pa, then the avg. sound level expressed in the dB each.

$$SPL = 20 \log_{10} \left(\frac{P}{P_{ref}} \right) \quad (245)$$

$$20 = 20 \log_{10} \left(\frac{P_1}{20} \right)$$

$$P_1 = 20 \times 10^1 \mu\text{Pa}$$

$$56 = 20 \log_{10} \left(\frac{P_2}{20} \right)$$

$$P_2 = 12619.14 \mu\text{Pa}$$

$$66 = 20 \log_{10} \left(\frac{P_3}{20} \right)$$

$$P_3 = 39905.24 \mu\text{Pa}$$

$$42 = 20 \log_{10} \left(\frac{P_4}{20} \right)$$

$$P_4 = 2517.8 \mu\text{Pa}$$

$$P_{avg} = \frac{P_1 + P_2 + P_3 + P_4}{4}$$

$$= 13810.45 \mu\text{Pa}$$

$$SPL = 20 \log_{10} \left(\frac{13810.45}{20} \right)$$

$$SPL = 56.78 \text{dB}$$

Ques: Find out the vol. of anaerobic digester for 5 MLD of domestic waste water treatment plant having 60% of suspended solids removed by the primary clarifier (PST) and 250 mg/l suspended solids were present in the waste water. The m.e. of the influent sewage sludge (from PST) is 96%. Initial volatile solid contents is 70%, volatile solids destroyed is 65%, digested sludge solid content is 8%, sp.gr of the primary sludge is 1.03 & sp.gr of the digested sludge 1.07. Density of water is 1000 kg/m³. The digestion period is 15 days.

~~population = 100000~~

(246)

Quality of ^{sewage} water = 5 MLD

$$= 5 \times 10^6 \text{ l/d}$$

$$\text{suspended solids in sewage water} = \frac{250 \text{ kg/l}}{10^6 \text{ l/d}} \times 5 \times 10^6 \text{ l/d}$$

$$= 1250 \text{ kg/day}$$

60% of suspended solids removed by PST

$$= 0.6 \times 1250$$

$$= 750 \text{ kg/dm}$$

m.e. of influent sewage sludge = 96%

4 kg of solid makes 100 kg of sludge

750

$$\frac{100}{4} \times 750$$

$$= 18750 \text{ kg/day}$$

sp. gr. of sludge = ρ_{sludge}

γ_w (247)

density of sludge $\rho_{\text{sludge}} = 1.03 \times 10^3 \text{ kg/m}^3$

$$= 1030 \text{ kg/m}^3$$

Vol. of sludge = $\frac{\text{wt. of sludge}}{\text{density of sludge}}$

$$V_1 = \frac{18750}{1030} = 18.20 \text{ m}^3$$

for calculation of V_2 -

$$\begin{aligned} \text{Total solids} &= \text{volatile solids} + \text{non-volatile solid} \\ &= \frac{70}{100} \times 750 \times 0.35 + \frac{30}{100} \times 750 \\ &= 408.75 \text{ kg/day.} \end{aligned}$$

digested sludge having 8% of sludge

$$\begin{aligned} 8 \text{ kg of solids makes} &= 100 \text{ kg of sludge} \\ 408.75 \text{ kg} &= \frac{100}{8} \times 408.75 \\ &= 5109.375 \text{ kg/day.} \end{aligned}$$

$$\begin{aligned} \text{Density of the digested sludge} &= \text{sp.gr.} \times \gamma_w \\ &= 1.04 \times 10^3 \\ &= 1040 \text{ kg/m}^3 \end{aligned}$$

$$\text{Vol. of digested sludge} = \frac{5109.375}{1040} = 4.9 \text{ m}^3$$

$$V_2 = 4.9 \text{ m}^3$$

$$V = \left(V_1 - \frac{2(V_1 - V_2)}{3} \right) t,$$

$$= \left(18.20 - \frac{2}{3} \times \frac{18.20}{4.91} \right) \times 15$$

$$V = 140.1 \text{ m}^3$$

(248)

A sewage containing 200 mg/l suspended solids is passed through primary sedimentation tank. The solids from the PST are digested to recover the gases. Find the vol. of the CH_4 & CO_2 produced in the digestion of sludge from 10000 m^3 of sewage. State clearly the assumptions made.

$$\text{Total vol. of the sewage} = 10000 \text{ m}^3$$

$$\text{Total suspended solids} = 200 \text{ mg/l}$$

$$\text{Total suspended solids} = 10000 \times 10^3 \times 200 \times 10^{-6}$$
$$= 2000 \text{ kg}$$

a) By assuming 60% of the suspended solids are removed in the PST = $\frac{60}{100} \times 2000 = 1200 \text{ kg}$

b) By assuming all of the removed suspended solids (1200 kg) → volatile solids as 65%.
 $= \frac{65}{100} \times 1200 = 780 \text{ kg (volatile)}$

0.9 m^3/kg of CH_4 released:

$$1 \text{ kg} = 0.9$$

$$780 \text{ kg} = 0.9 \times 780 = 702 \text{ m}^3$$

Formation
in 1 h

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SDT ACH_e - 65-70 %
 CO_2 - 30 %

(249)

A population of town is 30,000, domestic sewage produced is 120 l/capita/day having BOD of 200 mg/l. Industrial sewage produced is 3×10^5 l/day having BOD of 800 mg/l. Design a high rate single stage trickling filter with the following data:

- 1) PST removes 35% of BOD
- 2) Organic loading is 10000 kg per hectare m per day
recirculation ratio = 1
- 3) hydraulic loading is 170 ML/ha/day
- 4) find the efficiency of T.F. & the BOD of effluent

74.5, BOD = 40.8