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-: HAND WRITTEN NOTES:-

OF

CIVIL ENGINEERING

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-: SUBJECT:-

ENVIRONMENTAL ENGINEERING

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Environment :- The environment consists of atmosphere, hydrosphere, Lithosphere in which the living sustaining resources of the earth are contained. Atmosphere contains gaseous, composition, hydrosphere contains water composition and lithosphere contains solid composition.

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) Assement of future population during design period and assement 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

(i) Domestic water demand - According to manual of water supply of Govt of India it should be b/w 135 Ltr/p/day 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.

(ii) 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.

(4)

Type of industry	Water demand
Sugar "	1 to 2 KL per tonne of crushed sugarcane.
Fertilizer "	80 to 200 KL/Ton of "
Pulp and paper (more" req)	200 to 1000 KL/Ton of "
Automobile	40 to 50 KL/vehicle.
Leather	40 to 50 KL/T of leather
Petroleum refining	1 to 2 KL/Tonne of crude oil.

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

Commercial unit	Water demand
Office	45 lpcd
School	45 to 135 lpcd
Hotel	180 lpcd
Hospitals	350 to 450 lpcd
Cinema Halls	15 lpcd

iv) Demand for public uses :- It includes maintainces of parks, gardens, roads 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 l/pcd 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/cm^2 and must be maintained for 4 to 5 hrs.

(ii) 3 jets should be thrown simultaneously. one on burning body and 2 on adjacent bodies.

(iii) Discharge at each stream should be about 1100 ltr/per minute.

(iv) No. of fire jets required depend on the size of population and is given by $F = 2.8\sqrt{P}$

P → 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 = 1ltr/per minute

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

Q = 1ltr/min P = 1 thousand

National board formula

(American insurance Association formula)

(a) For high valued commercial cities population $\leq$ 2 lakh.

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

(b) For high valued commercial cities population > 2 lakh

$Q = 54600$ l/min and extra provision second and third fire.

For residential cities (6)

Small buildings $Q = 2200$ ltr/min

High buildings $Q = 4500$ ltr/min

High valued appartments $Q = 7650$ 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 permites 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 ≈ 335 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 avaiable in distribution system
(vii) Developement of sewage facilities
(viii) Cost of water

• Variation in water demand :→

Smaller towns have more variation

(i) Max^m monthly consumption → 1.28 times average monthly consumption

(ii) Max^m weekly consumption → 1.48 times average weekly.

(iii) Max^m daily comsumption → 1.8 time average daily comp.

(iv) Max^m hourly consumption peck demand → 2.7 time of average hourly comsption

It is also equal to 1.5 times max^m daily hourly comption.

Goodrich Formula to compute max^m / peck demand

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

$$P = \frac{\text{max}^m \text{ demand}}{\text{Avg demand}}$$ (8)

t = time in days

t = 1 for max^m daily

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

" GOI 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

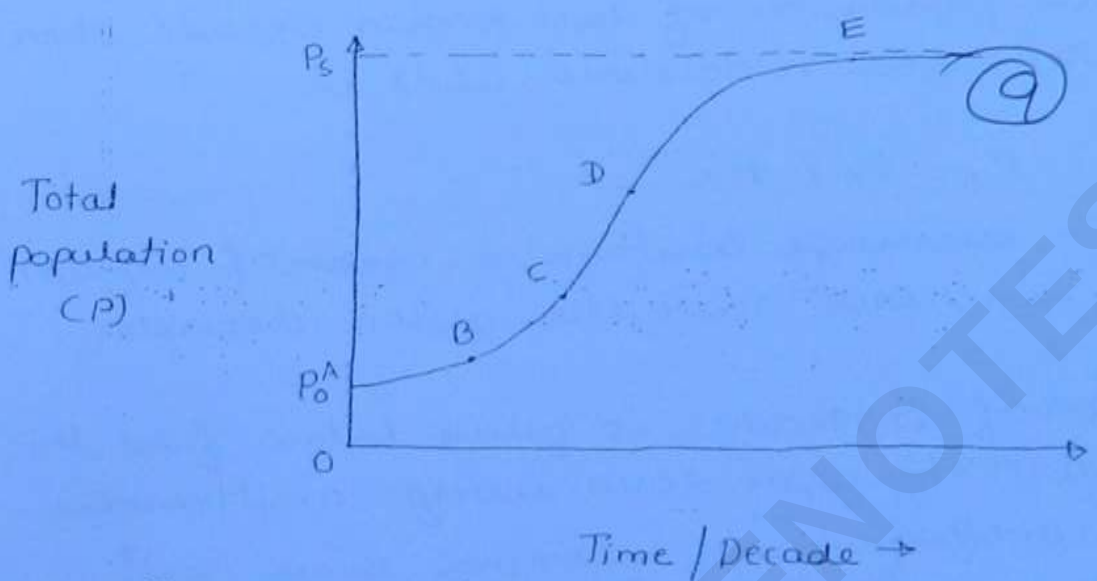
② Max^m hourly demand.

Design periods of water supply unit :→

Water treatment unit	Design Discharge	Design period
Dams and reservoir	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 take care of hourly fluctuation, Fire demand, Breakdown storage	

Distribution networks — Peak demand / Max^m hourly demand — 30 yrs.

Population Forecasting methods :→



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

in BCD → $\frac{dP}{dt}$ = 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 comparision method
(vii) Zoning or master plan method
(viii) Ratio or co-relation method
(ix) Logistic curve method or Verhulst method

(1) Arithmetic increase method :- This method assumes that population increases at a constant rate

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

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
1970	25,000	
1980	28,000	3000
1990	34,000	6,000
2000	42,000	8,000
2010	47,000	5,000
		22,000

$$\bar{x} = \frac{22,000}{4} = 5,500$$

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

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

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

(2) Geometric Increase method / Uniform increase method / Compounding rate method

Geometric Increase method

But since geometric average is always less than arithmatic 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	Popⁿ	% Growth rate
1970	25,000	
		12%
1980	28,000	
		21.43%
1990	34,000	
		23.53%
2000	42,000	
		11.90%
2010	47,000	

$$r = (r_1, r_2, r_3, r_4)^{\frac{1}{4}}$$

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

$$16.38\%$$

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

$$P_{2010} = 47{,}000\left[1 + \frac{16.38}{100}\right]^3 \quad (D)$$

$$P_{2040} = 74{,}087$$

③ Incremental increase method :-

It is also called method of varying increment. This method combines both arithmatic 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 where as new cities where as arithmatic 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.

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

Year	Pop^n	Increase	Incremental Increase
1970	25,000		
1980	28,000	3000	3000
1990	34,000	6000	3000
2000	42,000	8000	2000
2010	47,000	5000	-3000

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$$\bar{Y} = \frac{22,000}{4} \qquad \bar{Y} \frac{2000}{3}$$

$$= 5,500$$

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

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

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

(4) 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 years

(i) Find % increase in population for each decade

(ii) and workout decrease in % increase in each decade and fend average % decrease say x'.

(iii) The population of next decade from the last known decade is given as

$$P_1 = P_0 + \left(\frac{r_0 - x'}{100}\right) P_0$$

(14)

where P_0 = Population of last known decade.
R_0 = Growth rate of last decade
x' = Average decrease in growth rate.

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

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

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	% Growth rate (R)	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%
x' = Avg decrease in G.R. = $\frac{2.84 + 0.43}{2}$ = 1.635%

$$P_{2020} = P_{2010} + \left(\frac{R_0 - 3x'}{100}\right) P_{2010}$$

$$P_{2020} = 79,500 + \left(\frac{11.5 - 1.635}{100}\right) \times 79500$$

$$P_{2000} = 87,343$$

$$P_{2010} = 87,343 + \left(\frac{11.5 - 2 \times 1.635}{100}\right) \times 79500$$

$$P_{2010} = 94531$$

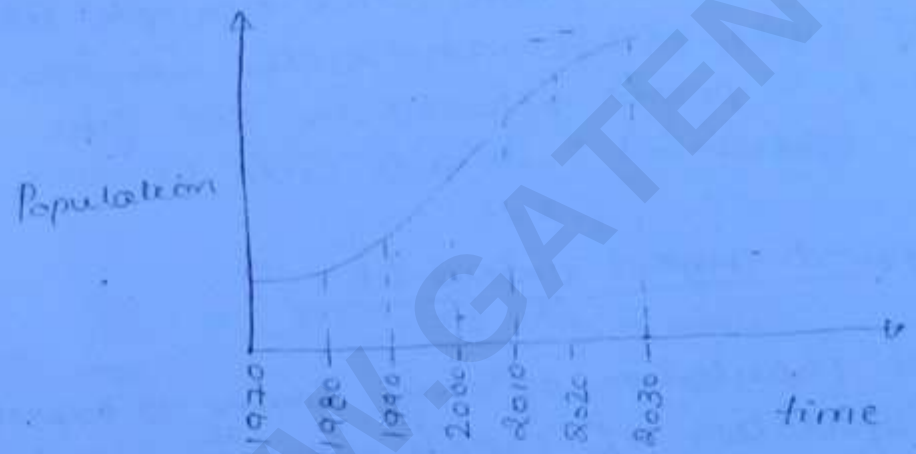
$$P_{2030} = 94531 + \left(\frac{11.5 - 3 \times 1.635}{100}\right) \times 94531$$

(15)

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

(5) Graphical extension method or simple graphical method :-

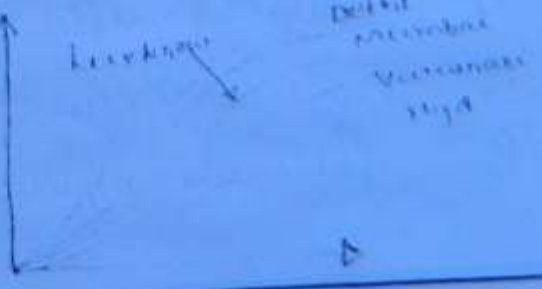
A graph is plotted b/w population and time for available data and the curve is smoothly extended for the desired year. For example let population is desired in the year 2030 and let population data are known for the last 50 years 1970 - 2010.



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

(6) Comparative 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 as from 2010 to 2040 will be similar to i.e which is avg. of growth of

(16)

① Delhi - 1940 to 1970
Mumbai - 1930 to 1960
Varanasi 1980 to 2010
Hyd. 1970 to 2000

④ Master plan or Zoning method :-

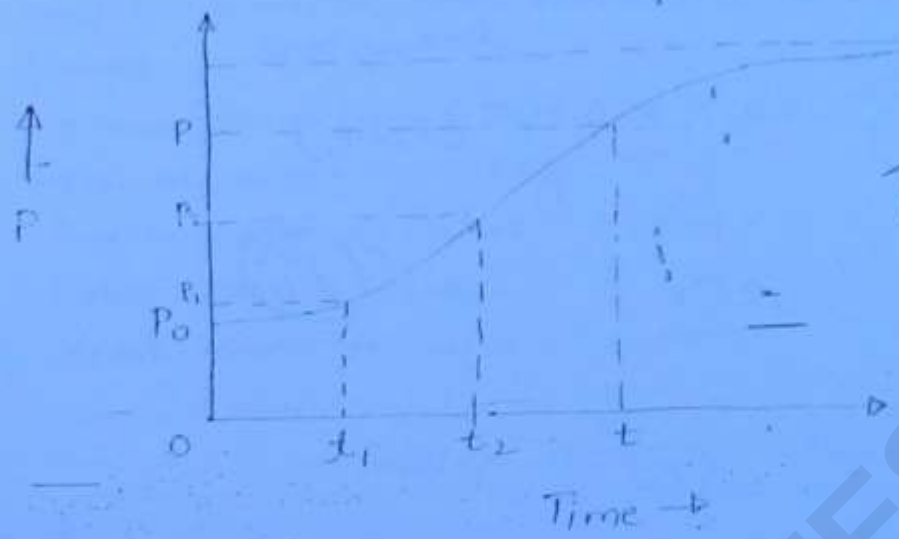
Generally in metropolitan cities growth is controlled by developement authorities in a planned manner only those extension are allowed which are proposed in master plan: For example let n= number of flats will be constructed in next = decade and 4 people allowed in one flat then population added in 2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

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.

⑨ Logistic Curve method or Vochults method :-

Let P_0 Population at the beginning of census record.
P_1 Population after time t_1 years.
P_2 Population after time t_2 years
P_s Saturation population



Then population after any time from the start is given as

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

$$P_S = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0 * P_2 - P_1^2}$$

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

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

Example :- 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

$P_0 = 30,000$ $P_2 = 3,00,000$

$P_1 = 1,70,000$ $t_1 = 30$ years

$t_2 = 40$ year

$t = 60$ year

(1) $$P_S = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0P_2 - P_1^2}$$

(18)

$P_S = 3,26,000$

(2) $$m = \frac{P_S - P_0}{P_0}$$

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

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

$= -0.119$

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

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

$P = 3,23,000$

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 - 0.009%
(v) Salinewater in lakes - 0.008%
(vi) Fresh water in river - 0.0001%

Water Quality Parameters

- Physical
  - Suspended solids
  - Turbidity
  - Colour
  - Taste and odour
  - Tempreture
- Chemical parameter
  - Dissolved solids
  - pH
  - Alkalinity
  - Hardness
  - Fluorides
  - Chlorides
  - Nitrates
  - BOD, COD (organics)
  - Metals
- Biological Parameter
  - pathogenic bacteria, Micro organism
    - Bacteria
    - Virus
    - Protozoa
    - Helminths
  - Non pathogenic / Coliforms

(I) Physical parameters

Suspended solids — Total solids may be present in the form of

(i) Suspended solids - 10^{-01} to 10^{-03} mm size
(ii) Colloidal solids - 10^{-03} to 10^{-06} mm size
(iii) Dissolved solids - $< 10^{-06}$ mm size

Suspended, Colloidal } — Dispersed solids

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

Measurment is done by gravimetric test unvolving mass of residues measurment.

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.

$$\text{Organic matter} \xrightarrow{\text{Heat}} CO_2\uparrow + H_2O\uparrow + \text{other gases}$$

Vapour

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 ppm (mg/L) for drinking water and in no case it should be greater 7 2000 ppm.

(2) Permissible limit of suspended solid is 30 mg/Ltr. 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 material like clay, silts, rock fragments, metal oxides, vegetation fibres and microorganisms. (21)

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 seat silt sealed the organis from disinfection.

Measurment of turbidity

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

Measuring Devices (i) Turbidity Rod
(ii) Jackson turbidity Rheter } from principal
(iii) Baylis turbidemeter
(iv) Modern Nephlometer } scattering principal.

(i) Turbidity rod :- Turbidity rod with platinium 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 JTU. (Jackson turbidity unit) which is based absorption principal.
* One JTU is equivalent to turbidity produced by 1 mg of fine silica (SiO_2) dissolved in one ltr of distilled water.

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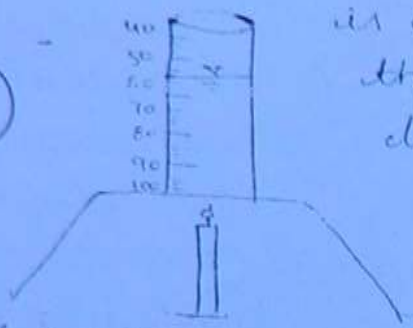
(22) Jackson Turbidometer - A burning candle is placed below a Jackson turbidometer and turbidity is determined by measuring the depth of water when decreasing candle is just invisible from the top. Longer the visibility lesser is the turbidity.



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

(222) 10.8 cm path is equivalent to 200 JTU and 25 20.5 cm path is equivalent to 100 JTU.

Baylis Turbidometer and Nephlometer :- These are based on colour matching technique i.e. on scattering principal 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 principal 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 1mg of formazine polymer dissolved in one ltr of distilled water.

Note :- For drinking water permissible limit of turbidity is 5 to 10 JTU but it should be as less as 1 JTU.

TON is computed for cold water because chang. in temprature may change od

3) Temprature :- Temprature affected chemical and biological activities if temprature increases by 10° biological activities are doubled decreases. 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 dies such as fishes, crabs, lobesters.

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

CHEMICAL WATER Quality Parameters

(Total Dissolved solids)

5) 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 clionic 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. Where as colour caused by dissolved solid is called true colour which is due to dissolved mineral, metals and gases

Measurment of Colour :→ It is done by colour matching techniques. True colour is measured on Burgress scale by Nesseler'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 platinate ions mixed in one litre of distilled water. (It gives yellowish brown colour).

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

The permissible limit of colour for drinking water is 5ppm 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.

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

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 conductens which is known as ionic strength of water which can be used by measure stone bridge method

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

Minor sources are → Fe^{2+}, Sr^{2+}, K^+, NO_3^-, F^-

(23)

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

Major compound causing alkalinity are CO_3^{2-} (Carbonate), HCO_3^- (bicarbonate), OH^- (Caustic alkalinity)

Minor compounds are → $HSiO_3^-$, $H_2BO_3^-$, 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

(1) $CO_2 + H_2O \rightleftharpoons H_2CO_3$ [Dissolved CO_2 & Carbonic acid]

(2) $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ {Bicarbonate}

(3) $HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$ {Carbonate}

(4) $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$ {Hydroxide}

The fourth reaction is a weak reaction but 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 then usualy OH^- may not present.

The cation (Ca_2^{+1}) may combened alkalenity of water and may forem solid precipitate of $CaCO_3$ which may get deposited on pipe surface and may cause incrustation in pipe.

(Tuberculation)

Note:- If water is acidic then there will be corossive action. NA.

Measurement of Alkalinity

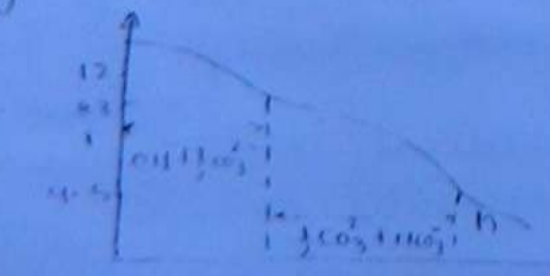
Measurment is done by titration of water with an acid. The alkalenity is expressed in mg/lit as $CaCO_3$. If 0.02 N H_2SO_4 is used as titrant then 1 ml of acid will neutralise 1 mg of alkalinity expressed as $CaCO_3$.

$$OH^- + H^+ \rightleftharpoons H_2O$$

$$CO_3^{2-} + H^+ \rightleftharpoons HCO_3^-$$

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3$$

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 at the last HCO_3^-.

If pH falls from original level to 8.3 then all the hydroxyl ion and $\frac{1}{2}$ CO_3^{2-} ions are neutralised when pH falls from 8.3 to 4.5 then remaining half of carbonate ions and bicarbonate ion are neutralised.

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

M = Amount of acid req. to fall pH from original level to 4.5

Conclusion ⇒

If P = M ⇒

alkalinity is due to OH ions.

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

If P = 0 and M ≠ 0 ⇒ Hence there is bicarbonate alkalinity

If P = 0 and M = 0 No alkalinity

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

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

Note : Mol wt of a compound = Sum of atomic wt (gms)

$CaCO_3 = 40 + 12 + 3 \times 16 = 100$ gm

$H_2SO_4 = 1 \times 2 + 32 + 16 \times 4 = 98$ gm

$NaCl = 23 + 35$

$NaOH = 23 + 16 + 1 = 40$ gm

(28)

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

Eqv. wt. of $CaCO_3 = \frac{100}{2} = 50$ gm

$H_2SO_4 = \frac{98}{2} = 49$ gm

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

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

1 Mole of $CaCO_3$ = 100 gms $CaCO_3$

1 Mole of H_2SO_4 = 98 gms H_2SO_4

1 Mole of NaOH = 40 gms NaOH

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

If 1 mole of $CaCO_3$ is present in 1 ltr of water then con^n is 1 M/L of $CaCO_3$.

It means 100 gms of $CaCO_3$ is present in 1 ltr of dist. water = 1 M/L

If 1 gm of $CaCO_3$ is present in 1 ltr then con^n

$= \left(\frac{1}{100}\right)$ M/L

$= 0.01$ 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 conc is : $\frac{490}{98}$ M/L

$= 5$ M/L

If 490 mg of H_2SO_4 is present conc is

$= \frac{0.005}{} 0.005$ M/L

$= 0.005$ M H_2SO_4

1 gm eqv wt = Eqv wt of compound in gms

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 Ltr of water

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

If 490 mg of H_2SO_4 is present in 1 Ltr of water

then Con^n is : 0.01 N H_2SO_4

If 980 mg of H_2SO_4 is present in 1 Ltr of water then Conc is : 0.02 N H_2SO_4

1M = 1N of Valancy is 1

1 Mole/lit : 1 gm eq/L of NaOH

1M : 1N of NaOH

If valancy is 2 { 1M = 2N, 0.01M = 0.02N } 1M = 3N } If valancy is 3

1 gm eqv. of OH is equal to 1 gm eq of carbonate ions ($CaCO_3$)

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 gm eqv. of OH^- ions = 1 gm of $CaCO_3$

1 gm eqv of CO_3^{--} = 1 gm of $CaCO_3$

1 gm eqv. of HCO_3^- = 1 gm of $CaCO_3$

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^{--}, 122 gms of HCO_3^- and 68 gms of OH^-. Find total alkalinity in the same water expressed as $CaCO_3$.

$$\text{gm eqv. of } CO_3^{--} = \frac{\text{wt. of } CO_3^{--}}{\text{Eqv. wt. of } CO_3^{--}}$$

$$= \frac{210}{30} = 7 \text{ gm eqv. (x)}$$

$$\text{gm eqv. of } HCO_3^- = \frac{\text{wt. of } HCO_3^- \text{ in gms}}{\text{Eqv. wt. of } HCO_3^-} = \frac{122}{61}$$

$$= 2 \text{ gm eqv (y)}$$

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

Total alkalinity = 7+2+4 = 13 gm eqv. of $CaCO_3$

wt. of $CaCO_3$ = 13 × 50 = 650 gms

Que: A 200 ml 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^- con^n is 5 mg/ltr as $CaCO_3$ and 11 ml of .02N H_2SO_4 is consumed to reach pH from original to 8.3. Then find

(i) Caustic Alkalinity (ii) Bicarbonate Alkalinity

(iii) Carbonate "

Expressed as $CaCO_3$.

(31)

Ans:

200 ml of sample of water

1 ml of 0.02 N H_2SO_4 neutralises 1 mg of alkalinity as $CaCO_3$.

30 ml 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 200 ml of water

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

= 150 mg/ltr.

as $CaCO_3$

OH^- alkalinity as $CaCO_3$ = 5 mg/ltr

CO_3^{2-} alkalinity as $CaCO_3$ + HCO_3^- alk as $CaCO_3$

= 150 - 5

= 145 mg/ltr

200 ml of sample of water

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

" " " 200 ml of water = $\frac{5}{1000} \times 200$

= 1 mg per 200 ml of water.

It means 1 ml of 0.02 N H_2SO_4 will be used to neutralise 1 mg of OH^- as $CaCO_3$.

Hence 0.02 N H_2SO_4 used to neutralise CO_3^{2-} + HCO_3^- as $CaCO_3$ = 30 - 1 = 29 ml.

11 ml of 0.02 N H_2SO_4 is used for $OH^- + \frac{1}{2} CO_3^{2-}$ = 11 ml

$\Rightarrow \frac{1}{2} CO_3^{2-} = 11 - 1 = 10$

$CO_3^{2-} = 20$ ml

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

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

= 100 mg/L as $CaCO_3$

$HCO_3^- = 150 - 100 - 5 = 45$ mg/Ltr as $CaCO_3$

Gate-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 as

(i) Methyle orange (Acidic indicator)
(ii) phenophthene 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 bivalent cations present in water solution. Hardness cation will react with anions in the water to form solid precipitate.

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

Hardness may be classified in 2 parts.

(i) Carbonate hardness (C.H.) or Temparary Hardness ↓ Carbonate and HCO_3^- or Ca^{2+} and Mg^{2+} (otherwise)

(ii) Bicarbonate Noncarbonate hardness (N.C.H.) Permanent Hardness ↓ Cl^-, SO_4^{2-} & NO_3^- of Ca^{2+} & Mg^{2+} (If other multivalent replace)

Hard water prevents formation of foam of soap leather increase laundry expensences.

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 barkish. (34)

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 multivalent

There are 3 methods to determine hardness

(i) Versanate mtd (EDTA mtd)
(ii) Clark's Mtd
(iii) Hehner's mtd

In versanate method hardness in water is determined by titration with versanate solution

EDTA is used with erechrome 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 = gm eqv of Ca^{2+} + gm eqv. of Mg^{2+}

T.H. = [gm eqv. of Ca^{2+} + gm eqv. of Mg^{2+} + gm eqv. of other multi valent ions] × Eqv. wt of $CaCO_3$

$\therefore$ (35)

$\therefore$ T.H as $CaCO_3$ in gms

T.H. in mg/ltr as $CaCO_3$ = [$\frac{\text{conc}^n \text{ of } Ca^{2+} \text{ in mg} \times L}{20}$ + $\frac{\text{con}^n \text{ of } Mg^{2+} \text{ mg/L}}{12}$ + $\frac{\text{Conc of other compound in mg/L}}{\text{Eqv wt of that compd}}$] × 50 mg/Ltr

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

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

$\therefore$ 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	$CaCO_3$, $MgCO_3$ } C.H
$Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $NaHCO_3$	$Ca(HCO_3)_2$, $Mg(HCO_3)_2$
$Ca(OH)_2$, $Mg(OH)_2$, $NaOH$	$CaCl_2$, $MgCl_2$ }
↓ Negligible	$CaSO_4$, $MgSO_4$ } N.C.H.
↓ Effective only on very high pH).	$Ca(NO_3)_2$, $Mg(NO_3)_2$ }

Caustic alkalinity

$$Na_2CO_3 + CaCl_2 \rightarrow CaCO_3 \downarrow + 2NaCl$$

$$2NaHCO_3 + CaCl_2 \rightarrow 2NaCl + Ca(HCO_3)_2$$

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 T.H > C.H and C.H. = Alkalinity.

Case-II If permanent hardness is absent T.H. = C.H. alkalinity > C.H.

From Case-I Permanent Hardness = T.H. − Alkalinity
N.C.H.

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

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

1 French " " " = 10 mg/lit 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.

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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) 179 (d) 358

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

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

$$T.H. = \left[\frac{55}{20} + \frac{10}{12.2}\right] \times 50 = 179 \text{ mg/ltr of } CaCO_3$$

Gate 2006 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+}	50	24
Al^{3+}	3	27
HCO_3^-	190	61
Cl^-	165	35.5

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pH of water is 7.

Qno① The total hardness of sample in mg/L as $CaCO_3$ is

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

Qno② N.C.H. of the sample is in meq/L of $CaCO_3$

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

① Total hardness $= \left[\frac{Ca^{2+} \text{ con}^n \text{ in mg/L}}{20} + \frac{Mg^{2+} \text{ in mg/L}}{12} + \frac{Al^{3+} \text{ conc}^n}{9}\right]$

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

$= 242$

② Alkalinity is caused by CO_3^{2-} (Not given), HCO_3^- & OH^-

OH^- 10^{-7} Negligible.

hence alkalinity is caused by bicarbonates.

$$\text{Alkalinity as } CaCO_3 = \frac{[HCO_3^-] \text{ in mg/L}}{\text{Eqv. wt of } HCO_3^-} \times \text{Eq wt of } CaCO_3$$

(39) $= \frac{190}{61} \times 50$

$= 156 \text{ mg/L}$

NCH = TH − Alk

= 242 − 156

NCH = 86

Gate 2007 Alk. and hardness of water sample are 250 mg/lit and 350 mg/lit as $CaCO_3$ respectively. The water has

(a) 350 mg/lit carbonate hardness & 0 N.C.H.

(b) 250 mg/lit C.H. & 0 N.C.H.

(c) 250 " " & 350 N.C.H.

(d) 250 " C.H & 100 mg/lit N.C.H.

Gate 2009 Common Data Question

Following chemical compounds reported from a source.

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

pH : 8.5

Qno:① T.H: in mg/lit is $CaCO_3$ is (a) 15,000
(b) 2000 (c) 3000 (d) 5,000

Qno:② Alkalinity present in water (40)
(a) 250 (b) 1500 (c) 1750 (d) 5,000

Total alk. = CO_3^{--} Alk + HCO_3^- + OH^-

= gm eqv of CO_3^{--} + gm eqv of HCO_3^- + gm eqv of OH^-

= gm Eqv of $CaCO_3$

= $(m\,Eq/L + m\,Eq/L + m\,Eq/L)$ = meqv of $CaCO_3$
(negligible)

= $(35 + 30 + 0) \times 50 = 35 \times 50 = 1750$ mg/lit

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

$= 10^{-5.5}$ gm Eq./L

$= 10^{-5.5} \times 10^{3}$ mg E/L — (Negligible)

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

ion	Conc^n (mg/Lit)	At wt.
Ca^{2+}	100	40
Mg^{2+}	6	24
Na^+	15	23
HCO_3^-	250	61

SO_4^{2-}	45	96
Cl^-	34	35.5

(41)

Que: Total hardness in mg/lit as $CaCO_3$ present in above water is

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

Ques: C.H. in mg/lit as $CaCO_3$ is

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

Ans

$$Alk \left[\frac{[CO_3^{-2}]}{Equt.} + \frac{(HCO_3^-)\ mg/Ltr}{Eqv.\ wt.} \right] \times 50$$

$$= \frac{250}{61} \times 50 = 205\ mg/lit.$$

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

$$= 275$$

$$N.C.H. = T.H. - Alk.$$

$$= 275 - 205$$

$$= 70$$

$$CH. = Alk\ 205$$

(7) Fluorides :-

Fluorides are essential for healthy teeth. Permissible limit is (1 to 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 flourosis or discolouration of teeth.

When fluorides is more than 5 mg/ltr then it may cause deformation of bones which is called bone flourosis.

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(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 alage which may pollute water in natural streams. Phosphorous also interfers with chemica coagulation.

(9) Iron and Magenes (Fe & Mn). Excess iron causes hard- bad taste, discolouration of clothes and incrustati of pipe due to formation crenothrix. 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 undergeround 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, Berium, Cadmium, Chromium, lead, Mercury and silver are toxic and hazardous these enter in human body through food chain. Cynaid is poisnous 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 activites. It imparts bad taste and makes water more corrosive

(iv) O_2 + O_2 is required for respiration of water species and it no case it should less 4 mg/Ltr

Nutrients :- Helps in growth of plant ex carbon, Nitrogen, phosphorous

Presence of organics :- There are two types of organics

(i) Biodegradable + These are utilised as food by micro organisms ex.- starch, fats, protein, Alcohal, Acids, Aldihides 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 amout of O_2 consumed during microbial utilization called BOD. BOD in drinking water should be nil.

Non Bidegradable organics are: lignic acid, cellulose, tanic acid, phenols, detergent compound and industrial waste.

COD is measure of biodegradable and non-biodegradeable organics hence non biodegradable organics are represents by

⇒ COD - BODu

or

⇒ COD - TOC. (45)

Type of aquatic plants

(i) Spemophyta → Water weeds
(ii) Bryophyta → Mosses
(iii) Peteridophyta → Ferns & horstails.
(iv) Thallo phyta → Algae → Photo synthesis plants

Aquatic Animals.

(i) Vertebrata → fish and Amphibian
(ii) Mollusca → Snails, slugs and lymplets.
(iii) Arthopoda → Insects, spiders, Slugs
(iv) Worms → Rotifera & thread worms.
(v) Metozoa → Polyzoa and hydra
(vi) Protzoa → E. Histolytica
↳ Entamoeba

Biological Characterstics

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

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

(ii) 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 synthesis protoplazm from surrounding environment.

(45)

Rod shaped bacteria are called - bacilli
Spherical shaped are called - Cocci
Spiral shaped - Spirilea.

Deseases caused by bacteria

Diseases	Bacteria
Typhoid Fear	Salmonella typhi
Cholera	Vibrio - Comma / Vibrio - Cholera
Baci Dysentry	Shiga bacillus
Lepto spirosis	Lepto spiral - Weallh's Desease

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

Deseases	Virus
Polio	Polio
Jaundices / Hepatitis	Hepefitis
Diarrhea	Cito Pathogen.

(iii) Protozoa :- These are unicellular organisms which have complex functional activity as compared to bacteria and viruse. Protozoal infection is usually characterized by gastro intestinal disorder.

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

Desease	Protozoa
Amboic Dysentry	Entamobia Entamobia Histolitica
Giardsis	Giardia-Lamblia

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(iv) Helminth :- These are also called paracetic worm These involve two or more animal host one of which may human or animal which will contain helmin.

Drafontiasis → Dracunculus-medinesis

Measurment of Pathogens

Indirectly pathogens are determined by measurment of coliforms. Since coliform survive longer than survival of pathogen hence if in drinking wate there is no presence of coliform, then there will be no presence of pathogens. Coliforms are harmless aerobic microorganisms which are found in intstine of all warm blooded animals. Common coliforms are
- B-Colli & E-Colli.

Methods to measure coliform

(i) Membrane filter technje
(ii) Test tube method (Most probable number method)
(iii) 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 membranon the pores of which do not exceed 0.45μ micrometer. Coliform bacteria are retained on the filter and then bacteria are placed on a selective media called M- Endows 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 (48) number method

It is generally prefered by microbiologist. 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 coliforms bacteria and results are refered with Standard statistical table given by Mecardi which can be used to find most probable no of BCoIM 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 mecardi Table MPN is 26 per 100 mL Vol of water.

WATER PURIFICATION SYSTEM

Water treatment units :-

(50)

Purpose of water treatment

(i) To remove colour, turbidity, dissolved solids, suspended solids.

(ii) To remove deaseses 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 [illegible] provided at intake points.

(ii) Aeration — Removal of Dissolved gases, iron and Mn upto to some extent.

(iii) Sedimentation or clarification → Removal of suspended impurities, silts, sands and other fine suspended particles and some of bacteria

(iv) filteration → Most important operation of water purification. It removes suspended impurities, colloidals impurities, micro organisms etc.

(v) Disinfection — Removal of pathogenic microganisms.

(vi) Softening → Removal of hardness

(vii) Deferrization → Removal of Fe and Mn chemically

(viii) Desalination → Removal of excess salts.

(IX) Flouridation & deflouridation → Addition of flouride in deficient condition & deflouridation is removal of excess flourine.

(X) Adsorbition units :→ Treatment with activated carbon. It is to remove suspended impurities.

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 gen...

Raw water → Aeration → Softening → Flocculation & Sedimentation → Filteration → Disinfection → Supply

Case-III Treatment of Turbid Surface water with organics

Raw water → Screening → Prechlorination & Aeration → Flocculation & Sedimentation → Filteration → Adsorption (Treatment with Activated carbon) → Disinfection → Misc. treatment (If required) → Supply

Screening :-

Screens

Coarse screen or Rack Screen

Fine screen or (Mesh) Wire Screen

(52)

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 racking 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 these 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 nozzels :- Efficient in removal of (98) 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 (S3)

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 [illegible] 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 stoke's law

① Plain sedimentation (Type I Sedimentation)
It is called discrete settling.
where no coagulants are added.

Coagulation sedimentation (Type-2 Settling).

Clarification

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

Types of sedimentation tank

(54)

Quescient type (Hazen & Dorow type)

Continuous type

① Quescient type :- Tank is filled with incoming water and is allowed to rest for detention period. Generaly 24 hrs. detentation 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 max^m daily demand - 1.8 times average daily demand.

These are obsdute 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

(1) Horizontal Flow tanks - These are rectangular
(2) Spiral or Radial flow - " " Circular
(3) Vertical flow " " Hopper bottom tank

Horizontal Flow rectangular sedimentation tank

Assumptions (1) Settling of particle is same as in case

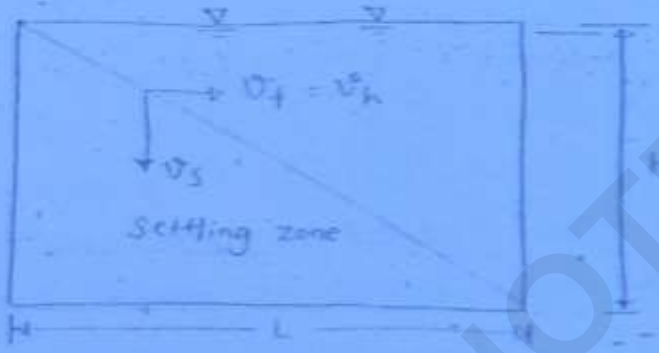
of quescient type of equal depth

(ii) The flow is horizontal and steady and settling velocity is uniform.

(iii) The conc^n of suspended particles is same at all vertical c/s.

(iv) Particles are removed when they reach at the bottom of settling zone.

(5)



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

for rectangular

$t = \frac{H}{V_s}$ — 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

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

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

It means these particles which will settle with velocity $V_s' > V_s$ will be 100% removed. Part of 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

$$\boxed{\% \text{ removal} = \frac{v_s'}{v_s} \times 100}$$

Let

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

Then

$$\boxed{\frac{v_s'}{v_s} = \frac{h}{H}}$$

Note:- ① v_s is also called overflow rate or surface overflow rate which is given by $\frac{Q}{BL} = v_s$

Surface overflow rate is a design property of sedimentation tank.

$$v_s' = \boxed{v_f = \frac{Q}{BH}}$$

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

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

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

Design Parameters

(i) Detention time — 4 to 8 hrs for plain sedimentation, 2 to 4 hrs for coagulation & sedimentation

It is theoritical 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.

$$t = \frac{L}{v_s} = \frac{H}{v_s} = \frac{V}{Q} \leftarrow \text{Volume}$$

(52)

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

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

(ii) Over flow rate $\left(v_s = \frac{Q}{BL}\right)$

v_s = 500 to 750 l/hr/m² or 12,000 to 18,000 l/day/m² } Plain sedimentation

v_s = 1000 to 1250 l/hr/m² or 24,000 to 30,000 ltr/day/m² } sedimentation with coagulation

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

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 (T)

It is the average time required for a batch of water to pass through the settling tank. Since the central portion of water has short detention period (t) always

(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. (≯ 1.8m to ≯ 6m)

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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 flow. Influent comes at the centre and moves radially outward. At the circumference weir 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.

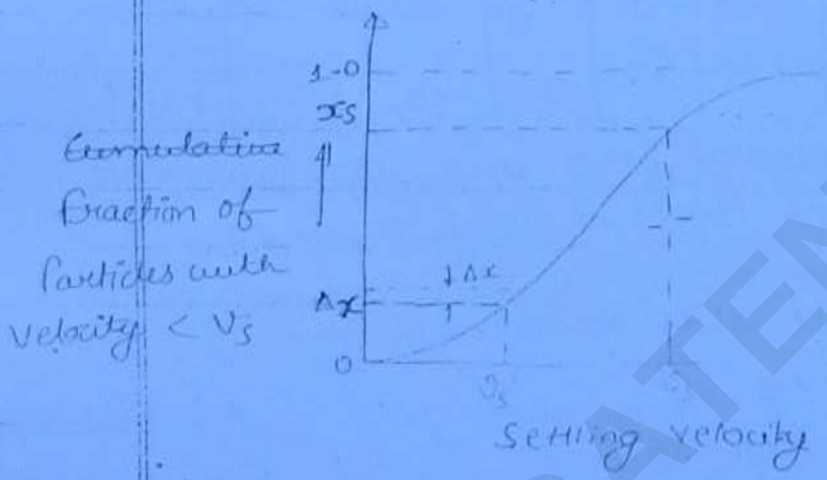
Hoffer bottom tank with vertical flow :- Water enters through centrally placed inlet pipe and is deflected downwards by the deflector box. Water travels vertically downward. The sludge settles at the bottom of hoffer from where it is removed with the help of sludge pipe connected to pump.

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 $v_s' \leq v_s$ 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

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

x_s = Fraction of particles which have velocity $< v_s$

It means $(1 - x_s)$ is fraction of those particles which have settling velocity $\geq v_s$.

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

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

Setting efficiency may be reduced by

1. Eddy currents
2. Surface currents
3. Vertical convection currents.
4. Density current (cold water sinks & flows hot water)

(60)

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

Size (mm)	0.1	0.2	0.3	0.4	.5	0.60	
% particles present	10%	20%	15%	5%	30%	20%	x_s
v_s' (mm/sec)	0.2	0.25	.30	.35	.40	.50	v_s'

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

Then find

1. Weight of suspended solids removed in gm
2. Setting 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 $v_s' < v_s$

$$= 0.1 + 0.20 + 0.15$$

$$= 0.45 < v_s$$

$$(1 - x_s) \quad 0.55 > v_s$$

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

$$+ \frac{0.30}{0.55} \times 0.15 = 0.328$$

% removal $= \left((1-x_s) + \varepsilon \frac{v_s'}{v_s} \times A_x\right) \times 100$

(61) $= (0.551 + 0.328) \times 100$

$= 87.8\%$

Weight of suspended solids removed $= 1000 \times 0.878$

$= 878 \text{ gm}$

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^n of suspended solids in influent water is 60 mg/lit and tank efficiency is 70%.

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

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

$t = \frac{6 \times 15 \times 3 \times 24 \times 60 \times 60}{2 \times 10^6 \times 10^{-3}}$

$t = 11664 \text{ sec}$

$t = 3.24 \text{ hrs}$

Horizontal flow velocity

$V_f = \frac{Q}{BH} = \frac{83.33}{6 \times 3} \text{ cum/m}$

$= 4.72 \text{ cm/min}$

Surface velocity or Overflow rate $v_s = \frac{Q}{BL} = \frac{2 \times 10^6}{24 \times 6 \times 15}$

$= 926 \text{ l/hr/m}^2$

Total weight of S.S entering tank per day

$= \frac{60\ mg \times 2 \times 10^{06}}{10^6}$ $\quad 1\ mg = 10^{-6}\ kg$

$= 120\ Kg/day$

(62)

% removal = 70%

wt of suspended solids removed $= 120 \times 0.7$

$= 84\ Kg/day$

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

Solution

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

Quantity of water to be treated in detention time $= 10^{03} \times \frac{3.5 \times 10^{06}}{24} \times 5 = 729.16\ m^3$

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

$D = 16.84m$

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

For effective removal $V_s' \geq V_c$

$V_c = V_s' = \frac{g(G_s - 1)d^2}{18\nu}$

$V_c' = \frac{981(2.65 - 1)(.025 \times 10^{-3})^2}{18 \times 0.01 \times 10^{-4}}$

$v_s' = 5.62 \times 10^{-04}$ m/sec.

$$\frac{v_f}{v_s} = \frac{L}{H}$$

$$v_f = \frac{60}{2.5} \times 5.62 \times 10^{-04} = 0.0135 \text{ m/sec}$$

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

Type :- 2 Sedimentation

It is also called clarification 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

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

① Alum ② Ferrous sulphate (Copperas) $FeSO_4$
③ Cholerinated copperas
④ Sodium aluminate Al_2O_3 $NaAlO_4$
⑤ Magnesium carbonate
⑥ Polyelectrolytes

Alum :→ It is also called aluminium sulphate

$Al_2(SO_4)_3 \cdot 18H_2O$

Alum reacts with $Ca(HCO_3)_2$ to form $Al(OH)_3$ which is a precipitate

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

Addition of Alum produces CO_2 which form carbonic acid which decreases pH and hence corrosiveness is increased. Addition of lime (Alum) 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 lime $Ca(OH)_2$ or Soda Na_2CO_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.

$$CaO + CO_2 \longrightarrow CaCO_3$$

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$

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

From above reaction it is clear that 1 mole of alum require 3 moles of CaO for alkalinity

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

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(OH)_2 \longrightarrow 2Al(OH)_3\downarrow + 3CaSO_4 + 18H_2O$$

It means 1 mole of alum produce 2 moles of $Al_2(OH)_3$ precipitate

If soda is added then following reaction will take place.

$$(SO_4)_3 \cdot 13H_2O + 3Na_2CO_3 \longrightarrow 2Al(OH)_3\downarrow + 3Na_2SO_4 + 3CO_2\uparrow + 115H_2O$$

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

$= 0.234$ gm of $Al(OH)_3$

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

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

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

$FeSO_4 \cdot 7H_2O$

when copperas is added in water with lime, then precipitate of $Fe(OH)_3$ is formed.

$$FeSO_4 \cdot 7H_2O + Ca(OH)_2 \longrightarrow CaSO_4 + Fe(OH)_2 + 7H_2O$$

$$4Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3 \downarrow$$

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

Iron salts are active only in pH range of more than 8.5. Therefore addition of lime is essential. The use of Iron 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.

$$Na_2Al_2O_4 + Ca(HCO_3)_2 \longrightarrow CaAl_2O_4 \downarrow + Na_2CO_3 + CO_2 \uparrow + H_2O$$

(61)

$$Na_2Al_2O_4 + CaCl_2 \longrightarrow CaAl_2O_4 \downarrow + 2NaCl$$

$$Na_2Al_2O_4 + CaSO_4 \longrightarrow CaAl_2O_4 \downarrow + Na_2SO_4$$

Note:- It is costlier than Alum.

Magnesium Carbonate with lime.

Other magnesium carbonate is used with lime.

$$MgCO_3 + Ca(OH)_2 \longrightarrow \underbrace{Mg(OH)_2 \downarrow}_{\text{Soluble in water}} + CaCO_3 \downarrow$$

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

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

limited because it maintains high pH beyond the permissible limit of drinking water. Moreover incrustation 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 ($Fe_2(SO_4)_3$) is active in pH range 4 to 7 and at pH more than 9. while as ferric chloride ($FeCl_3$) is active in the pH range 3.5 to 6.5 and at pH over 8.5. Hence resulting combination is effective in wide range of pH.

$Fe(SO_4)_3 + 3Ca(OH)_2 \longrightarrow CaSO_4 + 2Fe(OH)_3 \downarrow$

$2FeCl_3 + 3Ca(OH)_2 \longrightarrow 3CaCl_2 + 2Fe(OH)_3 \downarrow$

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

(2) Iron salts produce $Fe(OH)_3$ which cause discoloration in pipes hence produces bad taste and odour. Therefore not prefered for treating drinking water.

(3) Iron salt produce heavy floc and also time required for floc formation is less.

Sodium Aluminate ($Na_2Al_2O_4$)

It reacts with permanent hardness present in

$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + CaCO_3 \downarrow$

Hence it is not commonly used.

Poly electrolytes :—

These are high molecular wt water soluble polymers These work on wild 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 correctly 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 setting tank & coagulants may also be added in suction line of water which will get mixed with water

6. Compressed air agitation
8. Mixing basin with baffle walls
9. Mixing basin with mechanical devices :- It is use in most of the modern water treatment plant The mech. device is called Flash Mixer which contail pedals 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}

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

where P = Power input required in watt/m^3/hr of flow (1 - 3)

V = Vol to which power is applied for mixing

= Q × t

μ = dynamic viscosity coeffi. (N-s/m^2) / absolute viscosity.

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

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

$$C.O. = G_1 \times t \qquad \sec \uparrow \times \sec \downarrow = 1$$

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

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

Power induction flow = water flow also called displacement flow

Flow $\boxed{\text{Power Induction flow} = \sqrt{\frac{PV}{\mu}}}$

If G 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 G is small & t is long then lighter flocs are created.

Note 3 G is recommended $\geq 300\ sec^{-1}$ and
t is recommended ≤ 60 sec.

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

a) 32.4 W b) 36 W c) 324 W d) 32400 W

$G = 900\ sec^{-1}$

$t = 2\ min = 120\ sec$

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

$V = Q \times t$

$V = 0.333 \times 120$

$V = 40\ m^3$

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

$P = G^2 V \mu$

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

$= 32400$ Watts.

Filteration

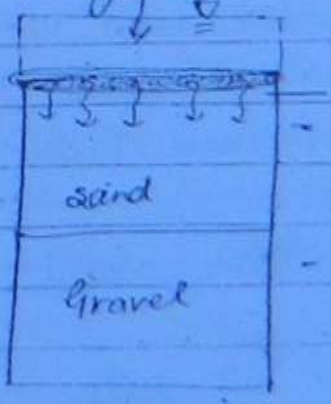
In Filteration the turbidity, colloidal metals, non settable metal, some dissolve metals, organic comp^d, micro organisms are removed

Following are the 4 operations during filteration

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 sands.

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



3 Biological action :- A layer of sticky partic of organic matter, silica clay, Fe, Mn & Bacterial content is formed at top surface of filter medium which is called slimy skin or SCHMUTZDECHE which may contain bacteria, protozoa and Helminths also.

The organic matter become food & m.o. beco consumer hence biological activities takes place Some times bacteria destroy each other to maintain bacterial balance.

4 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 these are designed rectangular basin L/B ratio 1.5 to 3. The pretreatment req^d 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/w 3 to 5 & total depth of slow sand filter 90-1100m (75)

→ Below the sand a gravel base is provided having particle size 3-65 mm of thickness of gravel base of 30-75 cm

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

→ The filteration rate is small of the order of 100 to 200 lit/hr/m^2 is the

→ The design period of filter is 10-15 yrs & design discharg is taken as max^m 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 efficent in removal of bacteria & removal upto 98-9% bacterial content & suspended solid.

The water is prechlorinated then eff. may be upto 99.9%. These may remove turbidity upto 50 ppm.

(76)

→ The cleaning of filter is done once in 2 to 3 month in which 1.5 to 3 cm layer is scrapped & washed manually. Amount of water is req^d for cleaning is 0.2 - 0.6 filtered water of a day.

→ Since these are very efficient hence suitable for smaller (discharge req^d less) treatment plant where low colour, low turbidity & low bacterial turbidity is req^d but hence these req^s large area hence uneconomical for large public supply & large public supply rapid sand filter is used.

→ The no of filters bed req^d depends on total filter area but usually one filter bed is provided at standby.

→ Guidelines to adopt no of filter beds :-

area	no of filter beds (running + standby)
$\leq 20 m^2$	2 (1 + 1)
20 - 250	3 (2 + 1)
250 - 650	4 (3 + 1)
650 - 1200	5 (4 + 1)
> 1200	6 (5 + 1)

Design a slow sand filter for following data

(77)

Popl^n → 50000

per capita water demand - 150 lpcd

max^m daily demand - 1.8 avg. daily demand

rate of filtration - 180 lt/hr/m^2.

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

avg. daily demand = 150 × 50000

= 7500000

max^m daily demand = 1.8 × 7500000

= 13.5 × 10^6 l/day.

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

= 562500 lt/hr.

Total filter area req^d = $\frac{562500}{180}$ = 3125 m^2

no of op^n filter bed = 5

∴ area of each op^n filter bed = $\frac{3125}{5}$

= 625

L : B = 2

area = 2B × B = 2B^2 = 625

B = 17.67 m

L = ~~35~~ 35 m

Rapid sand filter :-

→ The water to be treated must be coagulated & sedimented. The filter media is sand having size b/w 0.35 to 0.60 mm & uniformity coeff ranges 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 3mm 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 filter bed will be 10 to 80 m^2 & size of each filter unit may be 5m to 8m.

→ Rate of filtration - 3000 lt/hr/m^2 - 6000 lt/h (30 times of slow sand filter).

→ They are washed mechanically through backwashing either using water & compressed air. Backwashing is done at every 1 to 3 days & amount of water req^d for back washing 1 to 5 % of filtered water of a day & usually 30 min time is req^d 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 - 70 ppm turbidity.

Design steps :-

1. Estimate total vol. of water to be filtered per day which is equal to max^{m} probt daily demand for popl^{n}.
2. Assume suitable filteration rate (If not given in range of 3000 - 6000 lt/hr/m^2)
3. Find total area of filter^{n} req^{d}

$$= \frac{\text{Vol of water to be filtered per hr}}{\text{filteration rate (lt/hr/m}^2\text{)}}$$

4. Find the total no. of filter req^{d} for opn having area of each filter b/w 10 to 80 m^2.

If no of filters unit is 4-5 then provide 1 standby unit but no of filters unit may also be worked out by Monrel & Wallace formula

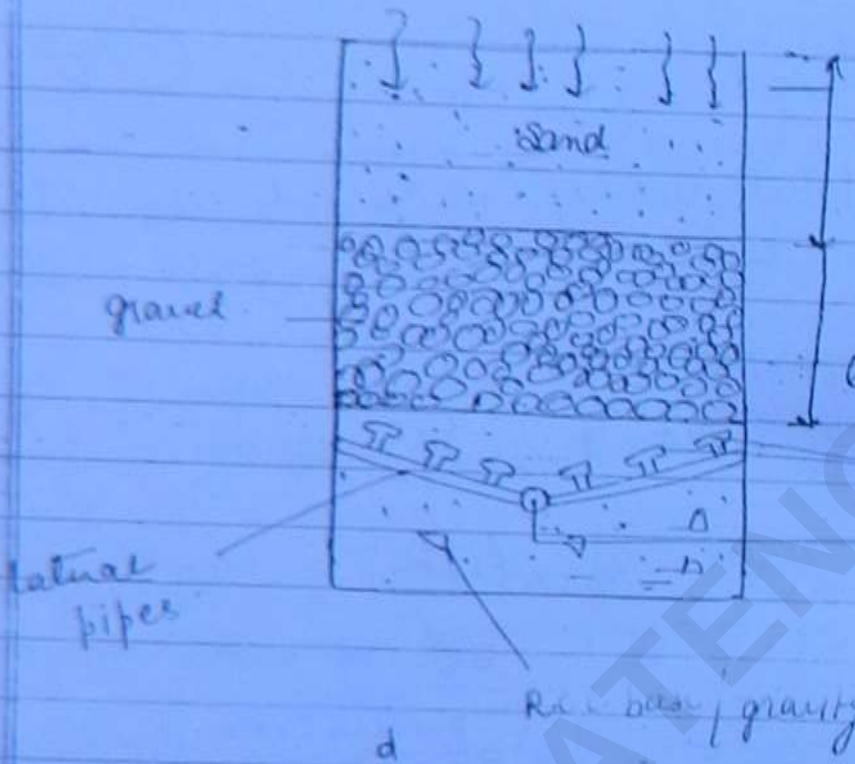
$$\text{no of filter units} = 1.22\sqrt{Q}$$

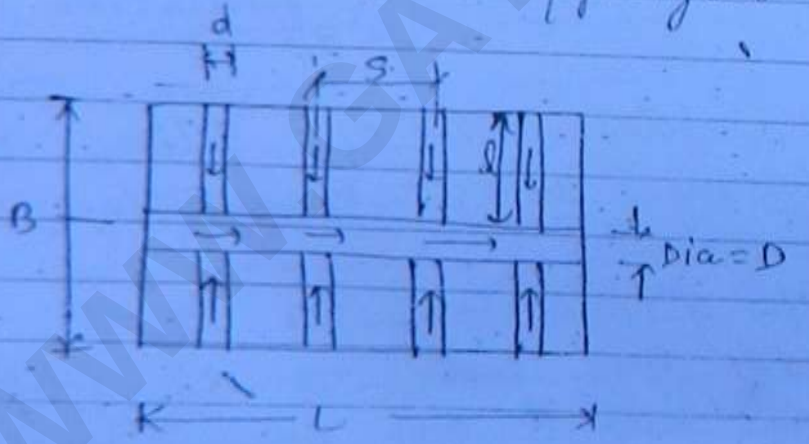
Q → MLD/day.

5. 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





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

S = 10 cm to 30 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 = 2L

(81)

Steps:-

The laterals are of two types

a) Pipes having perforations of whole size (6 - 30 mm
b) Pipes having strainers. Generally perforated type sugd high velocity for cleaning screen strainer type is perforated 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 2 - 4 times c/s area of perforations. Area of lateral may be taken 2 time of the perforation area when dia of perforation is 13mm & it should be taken 4 time when dia is 6m.

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

$$\frac{l}{d} \not> 60$$

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

The max^m permissible velocity in manifold to provide adequate backwashing but to

present U/p flow of sand is 1.8 to 2.9 m

Note:- The rate of application of wash water ≠ settling velocity of smallest particles to retained in filter to avoid boiling of sand.

Note-2 If V_b is back wash velocity or U/p flow ve & 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

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

where C_D = drag coeff.
G_s = sp. gr of solids
g = gravity
d = dia of settling particles or dia of particle

Note-3 when backwashing is done to expand porous bed / sand hydrolically then head loss occu -loss of head is given as -

$$\therefore \left[h_L = (G_s - 1)(1 - n)L\right]$$

Where l = length/ thickness of expanded porous media / sand

η = porosity.

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

ES 2000

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

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

Total water reqd to be filtered per day = $\frac{1.05 \times 1.8 \times 50000 \times 180}{}$

(1.05 ↓ account for backwash water)

$= 17.01 \times 10^6$ l/day.

(1 hr in backwashing, 23.5 hrs in filteration)

Total water to be filtered per hr = $\frac{17.01 \times 10^6}{23.5}$ l/hr

$= 723829.7$ lt/hr

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

There are two filter beds.

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

assume L : B = 1.5

$A = 1.5B^2 = 72.38$

$B = 6.94$ m

$L = 10.42$ m.

Ques Design R.G. filter for 4 MLd of water supply. Assume filtration rate 5000 lt/hr/m², amount of back washing 4% of filtered water & time lost in back washing 30 min. Find (1) no. of filter bed & size of each filter (2) Manifold lateral drainage system.

Assume S = 15 cm

Sol^n

Total water req^d to be filtered per day = Including backwash water

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

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

$= 0.177 \times 10^6$ l/hr.

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

$= 1.22\sqrt{4.16}$

$= 2.488$ [2 no of filter

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

$= 35.4$ m².

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

= 17.7 m^2.

(83)

assume L/B = 1.5

$1.5B^2 = 17.7$

B = 3.43 m

L = 5.15 m

under drainage system

area of perforations = 0.2% of filter area

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

= 0.0354 m^2.

Let us adopt 13mm dia of perforation

area of laterals = 2x area of perforat

= 2 x 0.0354

= 0.0708 m^2

area of main pipe (manifold) = 2 x 0.0708

= 0.1416 m^2.

dia of main pipe →

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

D = 0.424 m = 42 cm

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

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

$l = 1.505\ m$

no of lateral each side) $n = \frac{L}{s} = \frac{5.15 \times 100\ cm}{15\ cm}$

(86)

$= 34.33 \simeq 35$

Total no of laterals $= 2 \times 35 = 70$

area of all laterals $= 0.0708 m^2$

area of each lateral $= 0.001 m^2$

$= 2 \times 0.035 = 0.070$

area of manifold = 2x area of lateral

$= 2 \times 0.070$

$0.14 m^2$

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

$d = 0.035\ m$

$= 3.5\ cm$

$\frac{l}{d} = \frac{1.505}{3.5} = 0.43 = 43\ cm > 60$ OK

It means no of filter units = 2

size of each filter = 3.43×5.15 (B x L)

no of lateral pipe = $35 + 35 = 70$

dia of lateral = 3.5 cm

s = 15 cm c/c

size of perforation = 13 mm

$l = 1.505$ m

$D = 42$ cm

$L = 5.15$ m

Es-04

Ques. 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 filtⁿ is 15 m³/hr/m². Allow 5% of filtered water for back washing & 20 min period for back washing determine the no. of filter bed requires including 1 filter as stand by.

(87)

Assume area of each filter 10m × 4m.

also compute the upflow velocity & head loss to expand the porous bed to length of 0.66 m

assume $n = 0.5$ (porosity)

$G_s = 2.5$

$d = 0.6\ mm$

$C_D = 25.02$

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

Total water req^d to be filtered per day including back washing $= \frac{1.8 \times 275000 \times 200 \times 1.05}{23.5}$

$= 4.42 \times 10^6\ lt/hr$

$= 4.42 \times 10^3\ m^3/hr.$

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

$= 294.89\ m^2$

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

$= 7.36 \approx 8$

So Total no of filter $= 8 + 1 \rightarrow$ standby

$= 9$

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

(88)

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

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

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

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

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

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

$$h_L = (G_s - 1)(1 - n) L$$

$$= (2.5 - 1)(1 - 0.5) 0.66$$

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

89) **Filter Troubles :—** The problems in filter ——— arise due to either in proper design or poor ope^n. Following are the troubles

1. cracking & clogging of filter 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 gelatinous grains which may cracks. The cracks are more prominent near wall junction Due to cracks dirty matters may pass with the water hence efficiency may reduced To minimise cracking proper back washing is suggd.

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

Air binding :- When water percolates then it loosed its head which further increases with time when it is high the pr in water becomes -ve & when it falls below vapour pr then air gets seperated from the water when produces bubbles - which trapped on the pore hence air locks are cracked and filtn rate is reduced

The problem of air binding is more

When → 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 avoi head loss or excessive -ve head by providing extra over filter bed.
control of algae growth by adding Cl avoiding heating of water
avoiding supersaturation with air

Sand incrustation :— When sticky gelatino materials combines with sand due to crystalisation of $CaCO_3$ 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 $CaCO_3$ in dissolved state.

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

ppt ← dissolve form

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

coarse garnet layer or ilminite layer b/w sand & gravel. (91)

Sand leakage :- The d/w movement of sand and escape of finer particle may occur due to improper grading or when gravels are 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 pr. The pr 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 - 2-2.5 m
Length / height - 2.5 - 8 m
Filtration rate - 6000 - 15000 lt/hr/m² which 2-2.5 times of rapid sand filter
Filter material - Sand followed by gravel

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

Double filteration OR Roughning filter :-

(92) To increase the filteration rate through a slow sand filter without compromising the quality we use rapid sand filter before the slow sand filter this prouss is called double filteration and rapid sand filter is used called roughning filter or scrubber.

Disinfection

Disinfection means killing of pathogenic bacteria always
Sterlisation means killing of pathogenic & non pathogenic bacteria both.

(Q)

Disinfectants either destroy or inactivate micro organisms by following four mechanism.

1. Damage of cell wall of micro organisms
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 methods which removes 100% bacteria and other micro organisms. This is adopted by individuals bt not suetable 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 also reduces hardness
The necessary dose of lime (CaO) is to do mg/lt
The excess lime can be remove by carbonation of the water

3. Treatment with silver ion / electrocatalytic pro

(94)

Metallic silver ion have strong killing action. They require a 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 U-V 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 Å to 3000 Å). 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 bad taste producing organic matter. If pink colour disappear quickly then it indicate oxidation & presence of organic matter. It's small dose 1 & 2 mg/lt may be sufficient.

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

$$O_2 \xrightarrow{\text{high voltage}} O + O$$

$$O + O_2 \rightleftharpoons O_3$$

95

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

ote This mtd is adopted in Europe and was 1st in chandigarh in India. Since it is costly hence it has limited use in India.

8. 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 also it is also unstable hence it should be produced at site ~~sight~~.

Major Method :-

1 Chlorination :- when cl is added in H_2O it forms hypochlorous acid (HOCl)

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

(96)

$$HOCl \underset{pH-5\text{to}7}{\overset{pH>8}{\rightleftharpoons}} H^+ + OCl^-$$

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 m.o.
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 perchloron)
b) chloroamines ($cl + NH_3$)

c) free cl (either liquid or gaseous)
d) chlorine di oxide (ClO_2)
e) chlorine Tablets

(97)

a) Bleeching Powder :- It contains 30 - 33% cl contents whereas perchloron also contents 60 - 70 % of available cl

$Ca(OCl)_2 \rightleftharpoons Ca^{2+} + \underbrace{2OCl^-}_{\text{mol wt} = 2 \times 51 = 102 \text{ gms}}$

Mol wt = 142 gms

$OCl^- + H^+ \underset{pH > 8}{\overset{pH < 7}{\rightleftharpoons}} HOCl$

This process is also called hypochlorination.

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

= 0.718 gm of Hypo-chlorite ions.

i) Since bleeching 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

$H_2O + Cl_2 \rightleftharpoons HOCl + HCl$

$NH_3 + HOCl \underset{}{\overset{pH > 7.5}{\rightleftharpoons}} H_2O + NH_2Cl$ (monochloroamine)

$NH_2Cl + HOCl \xrightarrow{pH = 5 \text{ to } 6.5} H_2O + NHCl_2$ (dichloro-amine)

$NHCl_2 + HOCl \xrightleftharpoons{pH < 4.4} H_2O + NCl_3$ (Trichloramine)

(98)

Type of chloramine depends on pH of wa
if pH < 4.4 then trichloramine is form
which has no disinfection property.
Most commonly formed compound is
$NHCl_2$.

$NH_3 + HOCl$ together is called combin
cl.

c) Free chlorine :- either it may be applied in gaseous or liquid form
cl is 2.48 times more heavier than air.
one vol. of liquid cl gives 462 vol. of gaseous cl.
When cl gas is subjected to pr. of 7 kg, then it gets converted into liquid.
The dose of cl depends upon
→ Organic matters
→ pH value
→ Amount of CO_2 % present in water
→ temp.
→ contact period.
The free available cl after 10 min of contact time should be of the order of 0.2 mg/l

d) chlorine dioxide (ClO_2) :- It is unstable is produced from sodium chlorite ($NaClO_2$)

$2NaClO_2 + Cl_2 \rightleftharpoons 2NaCl + 2ClO_2$

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 :- 1 single cl tablets of 0.5 gm is sufficient for 200 lt of water. It is used by individuals.

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

chlorine demand = applied chlorine − residual chlorine

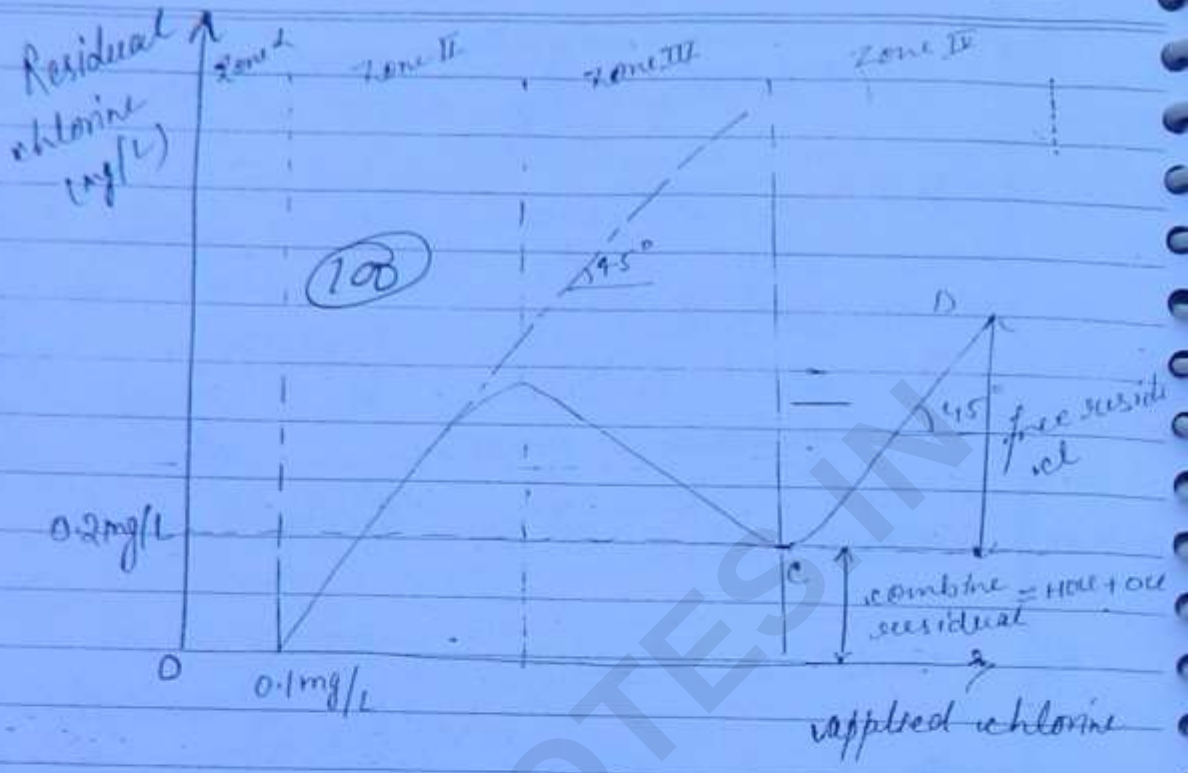
Water is satisfactorily disinfected if residual cl is of the order of 0.2 mg/l

Disinfecting action of cl :-

$$HOCl \underset{K_b}{\overset{K_f}{\rightleftharpoons}} H^+ + OCl^- \quad (pH > 8,\ pH = 5 \text{ to } 7)$$

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

concentration is in mole/lt



C → break point

Zone I :- The consumption of cl in zone I due to oxidation of Fe, Mn, H_2S & NO_2 (Nitrite)

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

Zone III at 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 consumption of Cl in Zone IV. If cl is added in Zone IV then it is called superchlorination stage & entire cl remains as free residual cl.

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

Types of Chlorination :- (101)

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

1. Plain chlorination :- cl 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 mg/l.

2. Prechlorination :- cl 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 E. histolytica are present then higher dose with higher retention is req^d

Post chlorination :- It's std process to apply cl
(102) after sedimen filteration.

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

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

cl 1st kills bacteria then oxidises organic compound.

Brake pt is= that pt at which all the added cl appears as free residual cl. It represents completion stag 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 breakpt then it is called super chlorination. It is reqd for removal of high conc^n of organic matters, cysts of E histolytica & for prevention of future contamination

Dechlorination :- It is the process of removal of excess of Dechlorination is done either by aeration or by using chemicals such as Sodium Thiosulphate ($Na_2S_2O_3$), Sodium meta bisulphate ($Na_2S_2O_5$), Sodium sulphite (Na_2SO_3) Potassium Permanganate ($KMnO_4$), Sodium bisulphite ($NaHSO_3$), activated carbon, sulphur dioxide.

Testing of residual of Methods :- (103)

Ortho Tolidene Test
Starch Iodide Test
Chlorotex Test
DPD Test

Q.

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

$$HOCl \underset{}{\overset{K=2.7\times10^{-8}}{\rightleftharpoons}} H^+ + OCl^-$$

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

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

(90% → HOCl), 10% - OCl^-

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

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

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

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

$$pH = -\log_{10} H^+$$

$$= -\log_{10}[2.43 \times 10^{-7}]$$

$$= 7 - \log_{10} 2.7$$

$$= 6.6$$

Ques Cl gas 8 mg/l as Cl_2 was added to drinking water if free cl residual was measured as = 2 mg/l as Cl_2 & pH was measured as 7.5. What is the conc^n of Cl^- ions in the water.

Assuming Cl_2 gas is completely converted into HOCl & OCl^-

At wt of Cl → 35.5

$$OCl^- + H^+ \underset{\longleftarrow}{\overset{K = 10^{7.5}}{\longrightarrow}} HOCl$$

free residual cl = 2 mg/l of Cl_2

2×10^{-3} gm/l of Cl_2

$$= \frac{2 \times 10^{-3}}{2 \times 35.5} = 2.816 \times 10^{-5} \text{ mole/lt}$$

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

pH = 7.5

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

$K = \frac{[HOCl]}{[H^+][OCl^-]}$ (105)

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

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

$[HOCl] = [OCl^-]$

$[OCl^-]$ of $[HOCl] = 50\%$

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

Water Softening :-

Removal of Temporary hardness :-

Methods -

(106)

(1) Boiling :- Usually $CaCO_3$ gets dissolved in water if CO_2 is present

$$CaCO_3 + CO_2 + H_2O \longrightarrow \underset{\text{soluble}}{Ca(HCO_3)_2}$$

When water is boiled then

$$Ca(HCO_3)_2 \xrightarrow{\text{heat}} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

$CaCO_3$ can be sedimented out in settling tank.

ii:- Magnesium carbonate & bicarbonate cannot be removed by boiling b/c these are soluble in H_2O hence lime addition is req^d.

(2) Addition of lime :-

$$MgCO_3 + Ca(OH)_2 \longrightarrow CaCO_3 \downarrow + Mg(OH)_2 \downarrow$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2 \downarrow$$

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + 2H_2O$$

i:- 1 mole of $MgCO_3$ requires 1 mole of lime but 1 mole of $Mg(HCO_3)_2$ requires 2 mole of lime.

Removal of permanent hardness :-

Methods :-

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

(1) Lime Soda Method :-

$Ca(OH)_2 + Na_2CO_3$

$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$

$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow$

$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2\downarrow$

Hence lime removes temp hardness

$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2$

$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaSO_4$

$Mg(NO_3)_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + Ca(NO_3)_2$

It means lime converts Mg hardness into Ca hardness hence Soda is required to remove Ca hardness (permanent)

Sodium is singularly

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$$

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + Na_2SO_4$$

$$Ca(NO_3)_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaNO_3$$

(108)

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

Note 2 Lime helps in removal of CO_2

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O$$

which prevents corrosive action (CO_2 eliminate

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

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O$$

Note- If lime & soda is added with alum i.e softening + coagulation is combined then demand of coagulent 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 with contain following compound. The dry sludge will have wt of following compound — (109)

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

wt of $CaCO_3$, $Mg(OH)_2$ } Product of lime soda process

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 resins are synthetic material. Zeolites are made of salts, clays silicates of sodium & aluminium having general formula as $Na_2O \cdot Al_2O_3 \cdot x SiO_2 \cdot yH_2O$ $(x \geq 2, y \geq 2)$

Sodium Zeolite = Z = $Na_2O \cdot Al_2O_3 \cdot x SiO_2 \cdot y H_2O$

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

$Na_2Z + Ca/Mg$ (with CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-) $\longrightarrow$ CaZ or MgZ + Na Salts (Na_2CO_3, $2NaHCO_3$, $2NaHCO_3$, Na_2SO_4, $2NaCl$)

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

$$CaZ \text{ or } MgZ + 2NaCl \longrightarrow Na_2Z + CaCl_2/MgCl_2$$
(5 to 10%)

(1/0)

Note:- Zeolyte OR resins have excellent property of exchanging their cations. These resemble with sand filter in which filtration medium is zeolyte rather than sand.
Zeolyte are green hence often called green sand whereas synthetic resins are white which is called permutit which is manufactured using clay, falspar, kaolin, soda

Advantages of Zeolyte Method:—

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

Disadvantages

1) If Fe & Mn are present then ~~Fe~~ 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 deionised water.

Treatment With ACTIVATED CARBON.

Activated carbon is porous 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 DARCO & NUCHAR.

It can also remove phenolic substances.
It is added either before or after the coagulation but before filteration & best way is to add partly before sedimentation & partly after sedimentation, this

Advantage of activated Carbon in coagulation

If it is added before, then it helps in coagulation

(112)

It reduces Cl demand.

It removes taste, odour, 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 and check growth of algae. It often applied in deep reservoirs and lakes.

Desalanation (Removal of Suspended Solids)

1. Reverse Osmosis
   Distillisation
   Electrodilysis
   Freezing process
   Solar distilation

Flouridation - If flourine presence in H_2O is less than 1mg/l then flourine may be added by adding following compound.

1. Sodium flourides
2. Sodium Silicoflouride
3. Hydrosilicoflouride

(113)

Deflondation

If flourines presence more than 1.5 mg/lt then excess flourine may be removed by following mtd

1. Adding activated alumina
2. Nalgonda technique
3. Reverse Osmosis
4. Adding flourex
5. Adding Bone charcoal
6. activated carbon
7. ion exchange mtd
8. Tricalciumphasphate
9. Adding lime

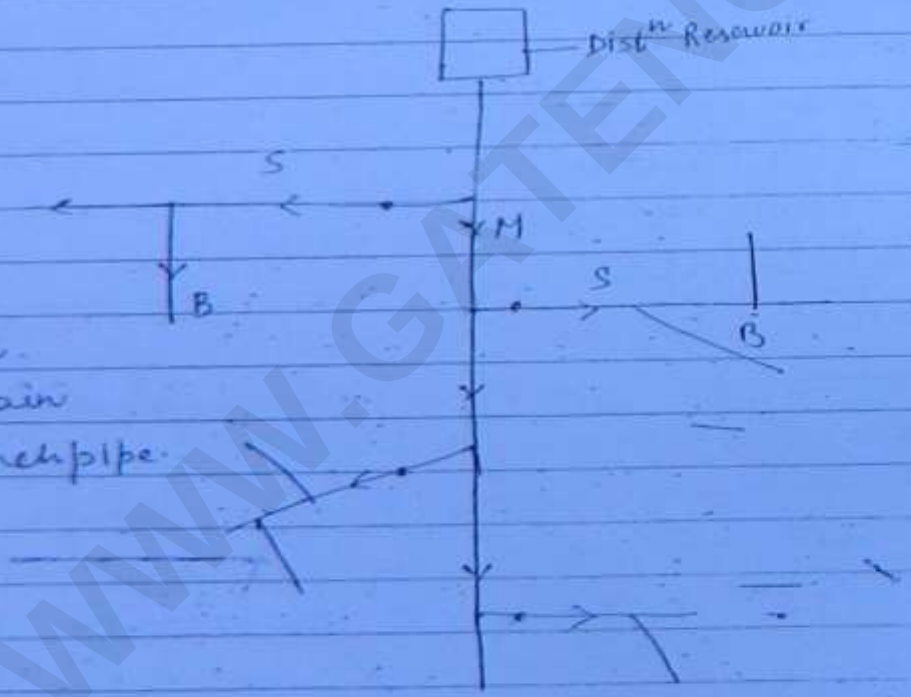
DISTRIBUTION SYSTEM

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

(114)

1. Dead end system
2. Grid iron system
3. Ring system
4. Radial System

1. Dead end system :-



(Tree System)

It follows network of roads and it is suitable for those localities & town which has developed irregularity (haphazard).

Advantages

Easy computation

Less no. of cut of valves

shorter pipe length

cheap & simple

(115)

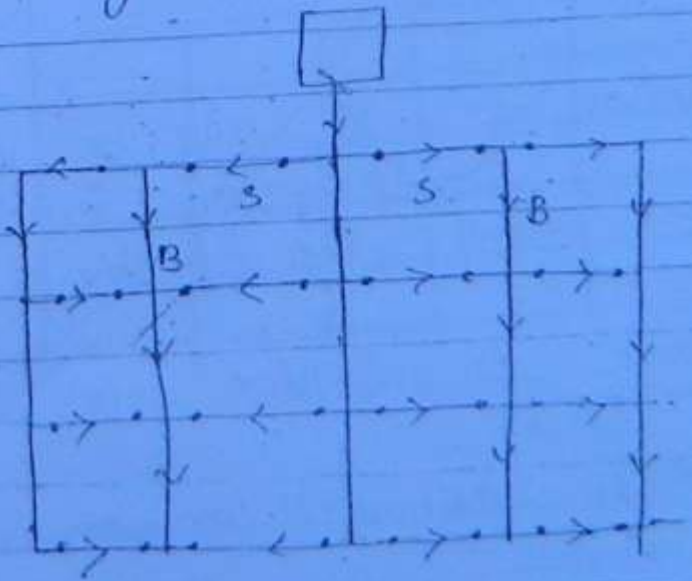
Disadvantages :- (1) There is only one route of supply hence if it is damaged then entire d/s supply is affected.

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

(3) Difficult to get additional water during fire brake down

(4) Pr keeps on decreasing towards dead end

2. Grid iron System :-



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

Advantages :- (116)

(1) There are more than 1 paths of flow hence friction losses 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 stagination & pole

(4) During fire more water can be drawn from alternative routes

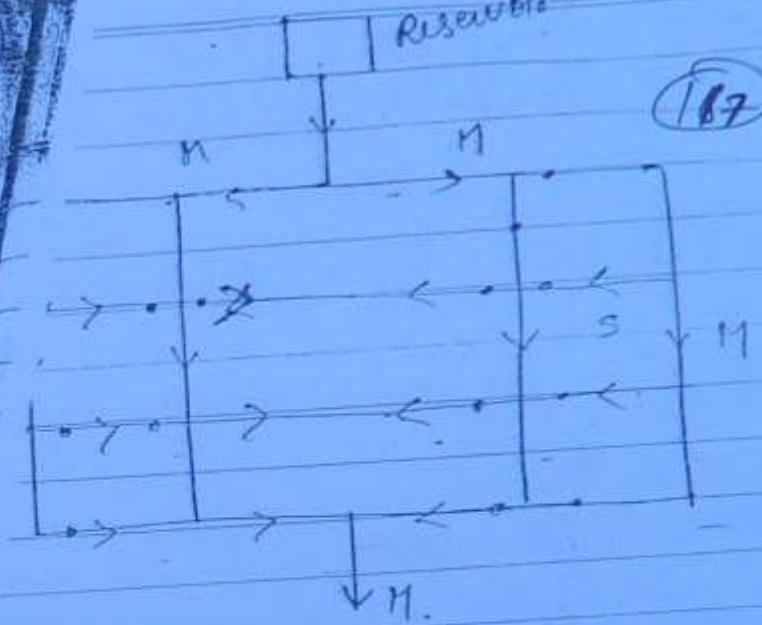
Disadvantages :-

(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

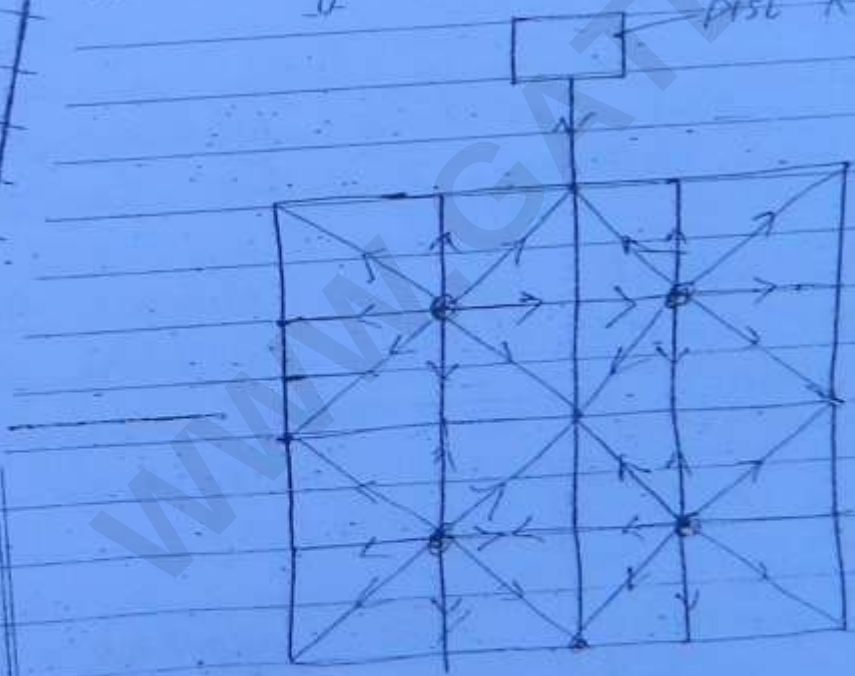
Entire area is divided into circular or radial blocks.

It is suitable for well planned cities



& Disad's are similar to grid iron tem

Radial System :-



If roads are radial then water is 1st stored in the distⁿ reservoir / tanks from which it is supplied through radially laid pipes.

This mtd maintains high pr & efficient water distribution

(118)

Analysis of pr 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 & is based on following 2 rules.

a) In each seperate pipe or element there will be a relation b/w head loss & discharge given as

$$h_f = K \cdot Q^n \quad \text{eq 1.25}$$

b) At each junction the algebric sum of the quantity of water entering and leaving the junction is zero

$$\Sigma Q = 0$$

iv) In any closed loop or path the algebric sum of headloss in the individual element is zero.

$$\boxed{\Sigma h_i = 0} \quad (119)$$

Type of water supply System :-

(1) Continuous System → water supplied 24 hrs.

(2) Intermittent System → water is supplied during fixed hrs.

for eg. - 6 am to 8 am
4 pm to 8 pm.

The intermittent system has drawbacks as

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

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 } ≈ 25% of total capacity

V = Bal cap + emergency cap
= Bal cap + 0.25V

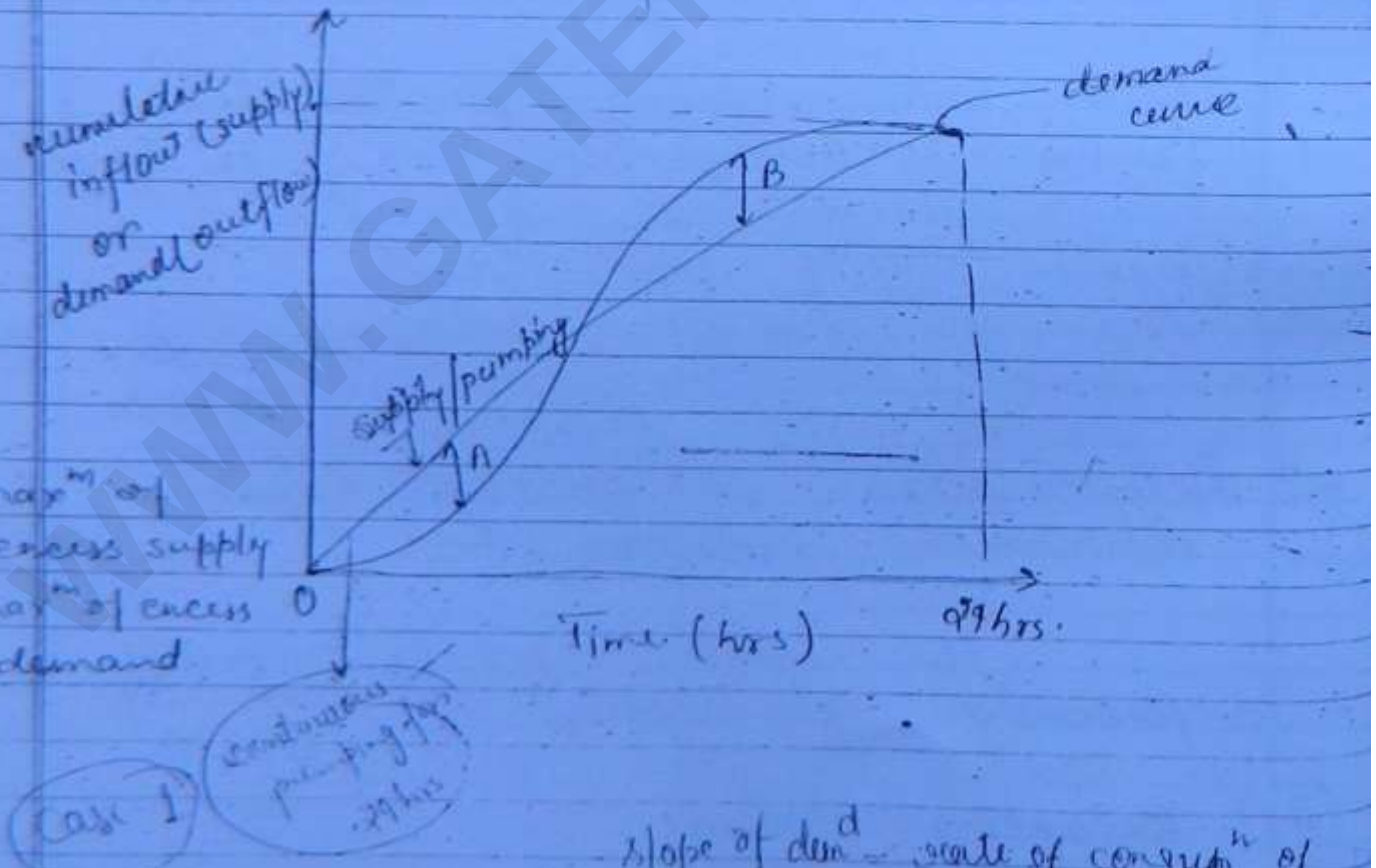
Determination of balancing storage :—

Methods —

(120)

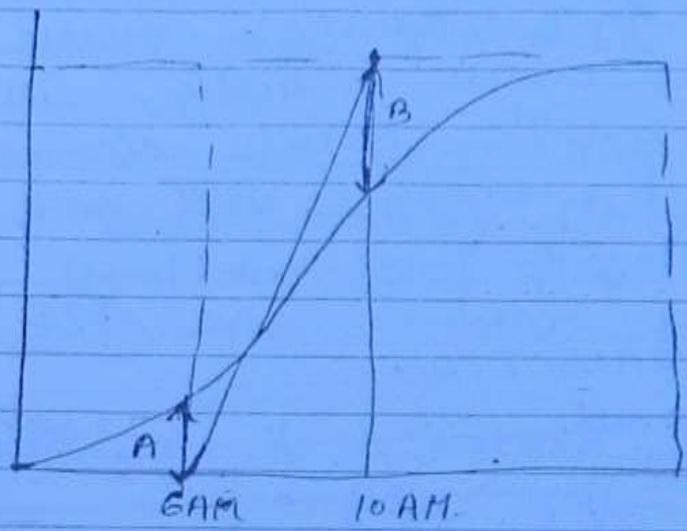
(1) Mass curve Mtd.
(2) Analytical Mtd

(1) Mass curve Mtd :- Mass curve is a plot of ~~accumulated~~ cumulated inflow :- V/s time or cumulated outflow V/s time



Slope of dem^d curve - rate of consump^n of water

Balancing storage = A + B

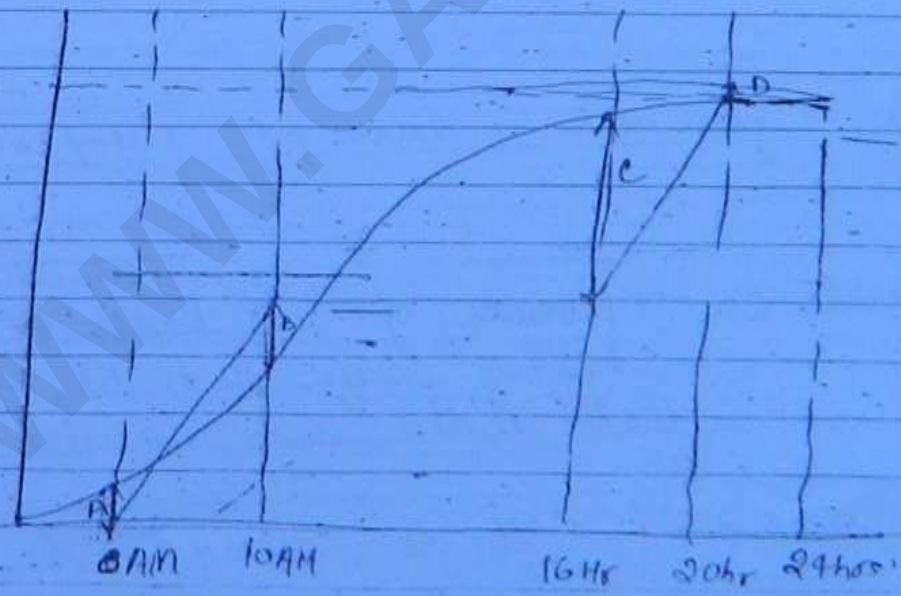


Case (2) pumping has one morning 6 AM to 10 AM

A → excess demand (max)

B → max. excess supply

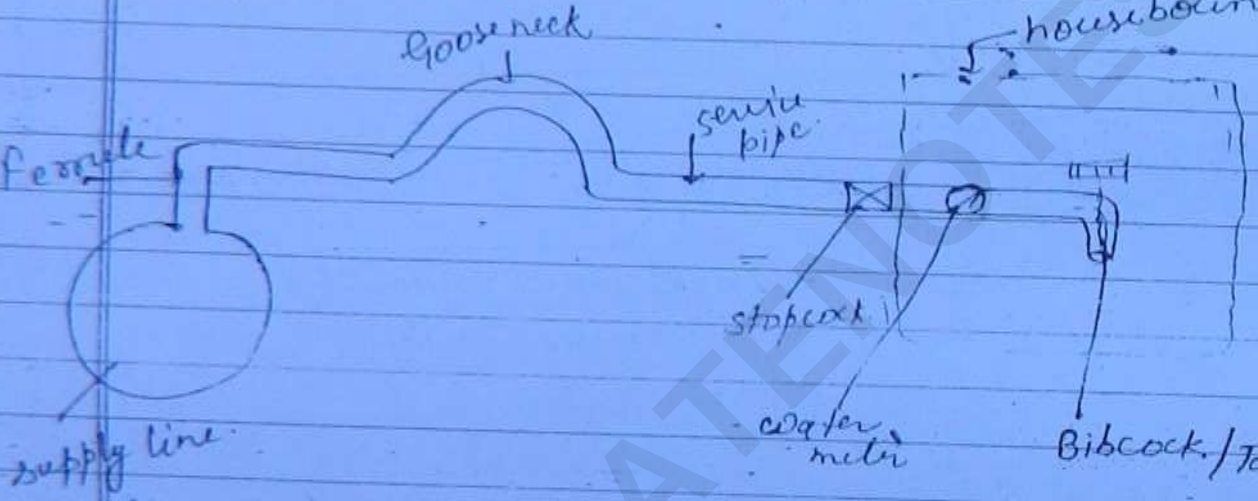
Bal. cap. = A + B



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 & cumulated 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.

HOUSE CONNECTION :- (122)



Ferrule → goose neck → service pipe → stop cock → water meter → bibcock

1. Ferrul :- → made of brass or gun metal having size 10 to 50 mm connects main & service pipe.

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

to absorbe shocks & disturbances.

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

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

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

Bib cocks : To control the flow.

(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. (125)

(7) Disposal of sewage.

(8) Air pollution

(9) Solid waste management

(10) Ecological system

acidic

Basic term in Sanitary Engg. (126)

(1) Refuge :- 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, putricified.

(2) Rubbish :- Dry form of waste i.e. waste paper, pieces of card board, office waste, restaurants (Inorganic in nature). (Combustible).

(3) Sewage :- All the waste generated from the domestic and industrial process in the form of liquidged state. (99.9% Liquid form, remaining in Solids)
Dark in colour, foul smell, water

(5) Sullage :- 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 run off 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

(1) 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 separat 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. metropolition cities.

(3) In this system the pipe lines are designed for the entire sewage and a part of the Storm wate

(X) 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.

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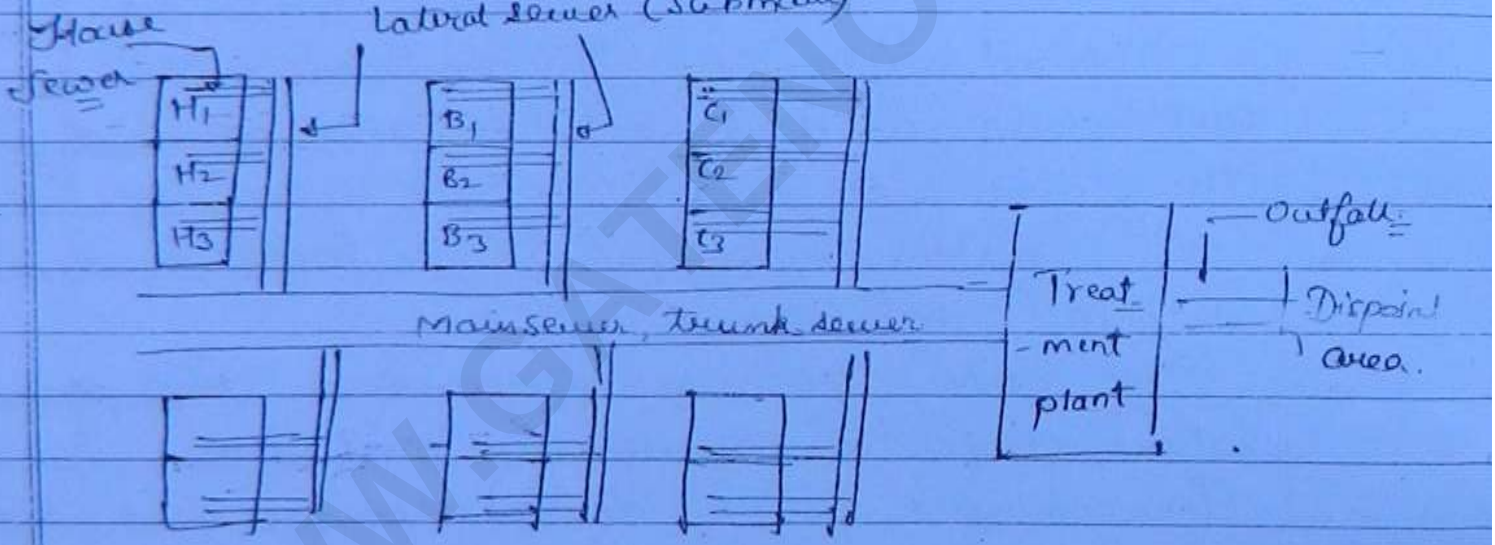
Type of Sewers



(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 household 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 bring it to the main sewer.

(3) The main sewer carries 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 captia consumption of water = x lpcd.
Total drinking water supply = px lit/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.

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

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) (T30)

= 3q

The sewer pipeline should be checked for min^m flow ~~rate~~ 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.

$= \frac{1}{2} \times \frac{2}{3} q$

$= \frac{1}{3} q$ (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 :-

(i) Treatment plant = 30 years

(ii) Trunk sewer = 15 - 20 year

(iii) Pumping system = 5 - 10 year

average value of K is taken as

$$K = \frac{K_1 A_1 + K_2 A_2 + \cdots K_n A_n}{A_1 + A_2 + \cdots A_n}$$

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

$$Q_p = \frac{K P_c A}{36} = m^3/sec.$$

where K = Runoff Coefficient.
0.9 to 1.0 (for the impervious areas pavement).

For Garden / Grass = 0.15

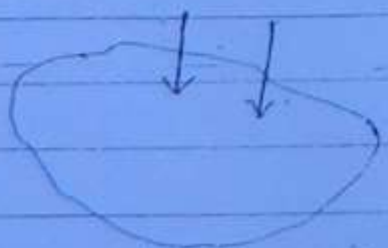
P_c = Critical rainfall intensity. (cm/hr).

A = Catchment area in "Hectare" (1Ha = 100 × 100 m.)

Critical rainfall intensity

Q_p = Storm water discharge in m^3/sec.

↓ is defined as the maximum runoff obtain in the catchment area during time of concentration (t_c).



Time of concentration is defined as the period during which max^m runoff is contribute to catchment area. which is equal to

$$t_c = t_e + t_f$$

$$t_i = \left(0.885 \frac{L^3}{H}\right)^{0.385}$$

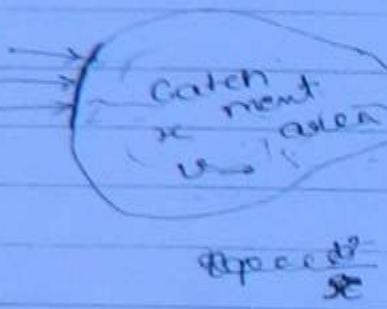
H = height (full height)

(133)

where t_e = time of entry (critical rainfall duration)

t_f = time of flow

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.

Note :→ 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 → 20 - 100 minute

$$P_c = \frac{100}{t_c + 20} \text{ cm/hr}$$

Empirical formula

> 400ha Southern India

1) Dickan's formula (North India)

$$Q_p = C_d A^{3/4}$$

Englis formula - Old Bombay State of India

$$Q_p = 123\sqrt{A}$$

Nawab Jung Bahadur formula - derived from hyderabad deccan Catchments

Dredge or Burge's formula -

$$Q_p = 19.6 \frac{A}{L^{1/3}}$$

Catchment A = Area - in km^2

C_d : Coefficient depends upon Geological terrain and other factor like runoff coefficient.

Avg value of $C_d = 11.5$

(b) Ryve's formula (South India)

$C_d = 6.8$

$$Q_p = C_d A^{2/3}$$

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Note:- Sewerage 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 m^3/sec is

P = Population = 1,00,000

x = 200 lpcd

Total drinking water supply = $10^5 \times 200$ L/day

$$q = \frac{75 \times 200 \times 1000 \times}{24 \times 3600} = \frac{125.00 \times 10^{-03}}{72}$$

$$q = 0.17 \, m^3/sec.$$

Ex A residential area has 50 Hectare of land. Assume critical rainfall intensity as 1 cm/hr

runoff coefficient as 0.80, Calculate storm discharge in cumecs

Soln

$$Q_p = \frac{K \cdot P_c A}{36}$$

$$Q_p = \frac{0.8 \times 1 \times 50}{36} = 1.11 \text{ m}^3/\text{sec}.$$

Question: A city with a population of 5 lakhs has an area of 100 ha. Rate of water supply is 200 lpcd and average runoff coefficient for the entire area is 0.5. Time of concentration is 50 m. Assume 80% of water supply reaches sewer. Find 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.

Soln:

P = Population = 500,000

per capita consumption x = 200 lpcd.

Total drinking water supply = Px =

$5,00,000 \times 200$ Lit/day

80% of water of sewage

$$= \frac{80}{100} \times 5 \times 10^5 \text{ lit/day}$$

DWF = q = 0.926 m³/sec. Average daily flow

Storm water 'Qp'

$$Q_p = \frac{K P_c A}{36}$$

t_c = 50 min

K = 0.5 , A = 150 ha , $P_c = \frac{100}{t_c + 20}$

$= \frac{100}{50+20} = 1.43$ cm/h

(138)

$Q_p = \frac{0.5 \times 1.43 \times 100}{36} = 1.98 \ m^3/sec.$

(ii) System is designed for = Sewage + Storm water

$= 3q + Q_p$

$= 3 \times 0.926 + 1.98$

Design Discharge = $4.77 \ m^3/sec$

CS

Question Design the section of a combined circular sewar for full flow from the data given belo

Area to be served = 150 ha.

Population of locality = 50,000

Max^m permissible velocity = 3.2 m/sec

Time of entry = 5 min.

" of flow = 20 min.

Rate of water supply = $\frac{270}{200}$ lpcd.

Runoff coefficient = 0.45

Assuming 75% of water supply converts into sewage.

Ans

Pop

Total drinking water supply = $P.x$ = 50,000 × 27

=

75% of drinking water as sewage = $\frac{75}{100} \times \frac{50,000 \times 2}{1000 \times 24 \times 36}$

$q = 0.117 \ m^3/sec.$

(iii) Storm water $Q_p = \frac{kP_cA}{36}$

$= \frac{0.45 \times P_c \times 150}{36}$

$= \frac{0.45 \times 2.22 \times 150}{36}$

$= 4.16 m^3/sec.$

$P_c = \frac{100}{(t_c + 20)}$

$P_c = \frac{100}{25+20}$

$P_c = 2.22 cm/hr$

(iv) Total design discharge $= 3q + Q_p$

$= 3 \times 0.117 + 4.16$

$= 4.51 m^3/sec.$

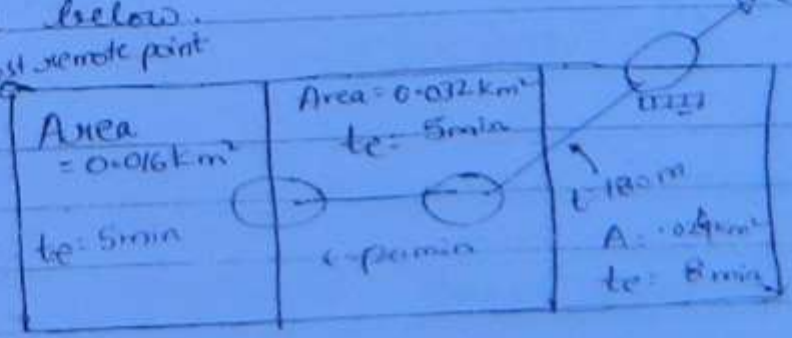
Assuming "d" = dia of circular sec.

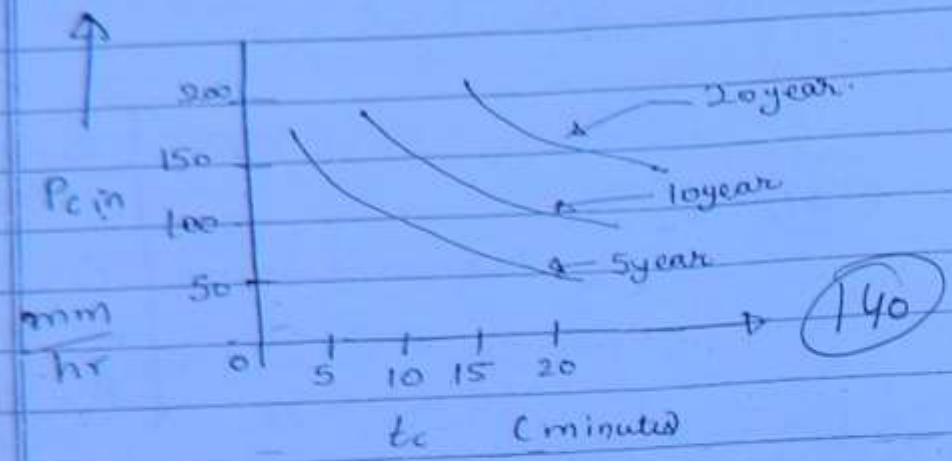
$Q = AV$

$4.51 = \frac{\pi}{4} \times d^2 \times 3.2 \quad [\because V = 3.2 m/sec]$

$\boxed{d = 1.34 m}$

IES Que. 1 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_{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.





K = 0.3

V = 0.75 m/sec.

Time of concentration of area A_1 = $t_{c_1} + t_{f_1}$

$t_{c_1} = 5 + \left(\frac{120 + 180}{0.75}\right)$

$t_{c_1} = 11.67$ min

$t_{c_2} = 5 + \frac{180}{.75} = 9$ min

$t_{c_3} = 8$ min

max^m t_c will be taken = 11.67 min

$P_c = 100$ mm/hr (From above graph).

$$Q_p = \frac{K P_c A}{36}$$

$$= \frac{0.3 \times 100 \times 7.2}{36 \times 10}$$

$Q_p = 0.6 \ m^3/sec.$

$$A_1 = \frac{0.016 \times (1000)^2 h}{10,000}$$

A = 1.6 ha

Total area A = $A_1 + A_2 + A_3$

= 0.016 + 0.032 + 0.024

= 0.072 km^2

A = 7.2 ha

Sewage Characteristic

↓ Sewage Contains 99.9% water remaining solids

(141)

Aerobic process (In the process of oxygen) → Gases released (CO_2, Sulphates, Nitrates)

Anaerobic process (In the absence of oxygen) → CH_4 (CO_2, methan, H_2S, NH_3 + Ammonia).

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 less

↓

Septic - black in Colour / Dark → Foul smell

(3) Temperature :- If temperature increases in Sewage D.O gets reduced hence effect following

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(3) Biological activity (4) Dissolved gases.

Total Solids (500 - 1000 mg/l) — on their Nature:
- Suspended Solids → > 1 μ
- Colloidal Solids → 1 to 10^{-3} μ
- Dissolved Solids → < 10^{-3} μ

Organic 45% (undergo decomposition) | Inorganic 55% (do not undergo decomposition process.)

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* 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°-105°C)

* Suspended Solids :- can be found by subjecting the sewage sample to the process of filteration of 1 μ size filter. The particles which are residing 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

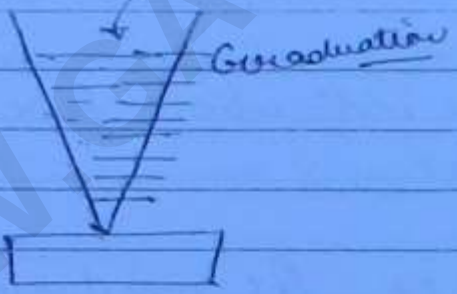
* Suspended Solid can be classified as volatile solid (evaporable) and fixed solid.

Volatile solid can be found by keeping suspended sample of sewage sample in a muffle furnace at 550°C for 20 minute.

The organic matter which was burnt in muffle furnace = Volatile solids and remaing solids are known as fixed solids.

Fixed Solids = Suspended Solids - Volatile

* Settleable solids :- can be found in the laboratory by the imhoff 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 settleable solid.



* Ph of the sewage sample :- Fresh sewage appears to be light grey colour and possess 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 'O_2' :- 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 effect on activity and Dissolved gases. (144)

Biological Oxygen Demand (Biochemical)

(BOD) It is the amount of O_2 or demand of oxygen that is required for Biological decomposition of biological degradible matter at a specificed 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 absolete, this phenomena is known as eutrophication.

→ BOD is reported at 20°C for a period of 5 days ($BOD_{5,20°C}$)
→ BOD takes care of only biologically active ~~oxy~~ organic matter

organic Matter → Biologically active
organic Matter → Biologically Inactive

→ ∴ COD > BOD

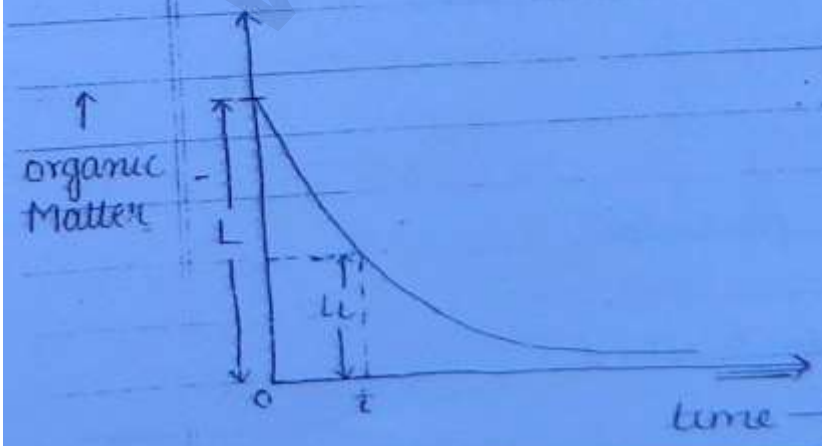
COD (Chemical Oxygen demand)
The amt of Oxygen or demand of ~~Oxygen~~ i.e required for the Chemical decomposition of organic matter is called COD. COD can be tested by Chemical ~~Rx~~ n ⁻ pottassium di Chromate ($K_2Cr_2O_7$) & pottassium permagnate ($KmnO_4$). COD takes care of both biologically active organic matter. For the COD 2 to 3 hour duration of time is enough but BOD takes several days.

Theoritically Oxygen demand (TOD)
It is the [illegible] of organic matter calculated from the Chemical ~~Rx~~ n theoritically

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

TOD > COD > BOD

BOD calculation :- time ↑ $\xrightarrow[\text{oxidation}]{\text{bio}}$ organic ↓ → BOD ↓



∴ Consumed Oxygen : $L - L_t$

The rate of decomposition of organic matter w.r.t time is directly proportional to amt of organic matter at any time t

$$\frac{dL_t}{dt} \propto -L_t$$

(146)

$$\frac{dL_t}{dt} = -KL_t$$

$$\frac{dL_t}{dt} + KL_t = 0 \quad \text{---(i)}$$

Sol^n of above eq^n $\log_e(L_t) = -Kt + C$ ---(ii)

at $t = 0 \Rightarrow L_t = L$

$\log_e L = C$

putting the value of C in eq^n (ii) we get

$\log_e(L_t) = -Kt + \log_e L$

$\log_e\left(\frac{L_t}{L}\right) = -Kt$

$\frac{L_t}{L}$

$$\boxed{L_t = Le^{-Kt}}$$

BOD at any time $t = L - L_t = BOD_t$

$\Rightarrow L - Le^{-Kt}$

$\Rightarrow L(1 - e^{-Kt})$

∴ 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)

$$BOD_{t,T^\circ C} = L(1 - e^{K_T t}) = L(1 - 10^{-K_D T t})$$

Where K_T = Rate constant at a particular temp T°C

$K_{20^\circ C} = 0.23$ per day

K_D = Deoxygenation rate constant

$K_{D_T} = \frac{K_T}{2.3}$ per day

$K_{D_{20°C}} = \frac{0.23}{2.3} = 0.1$ per day

$K_{T°C} = K_{20°C} (1.047)^{T-20°C}$

T → temp at ⊆ rate constant is required

Similarly $K_{DT°C} = K_{D20°C} (1.047)^{T-20°C}$

base 10 = K_D

base e = K

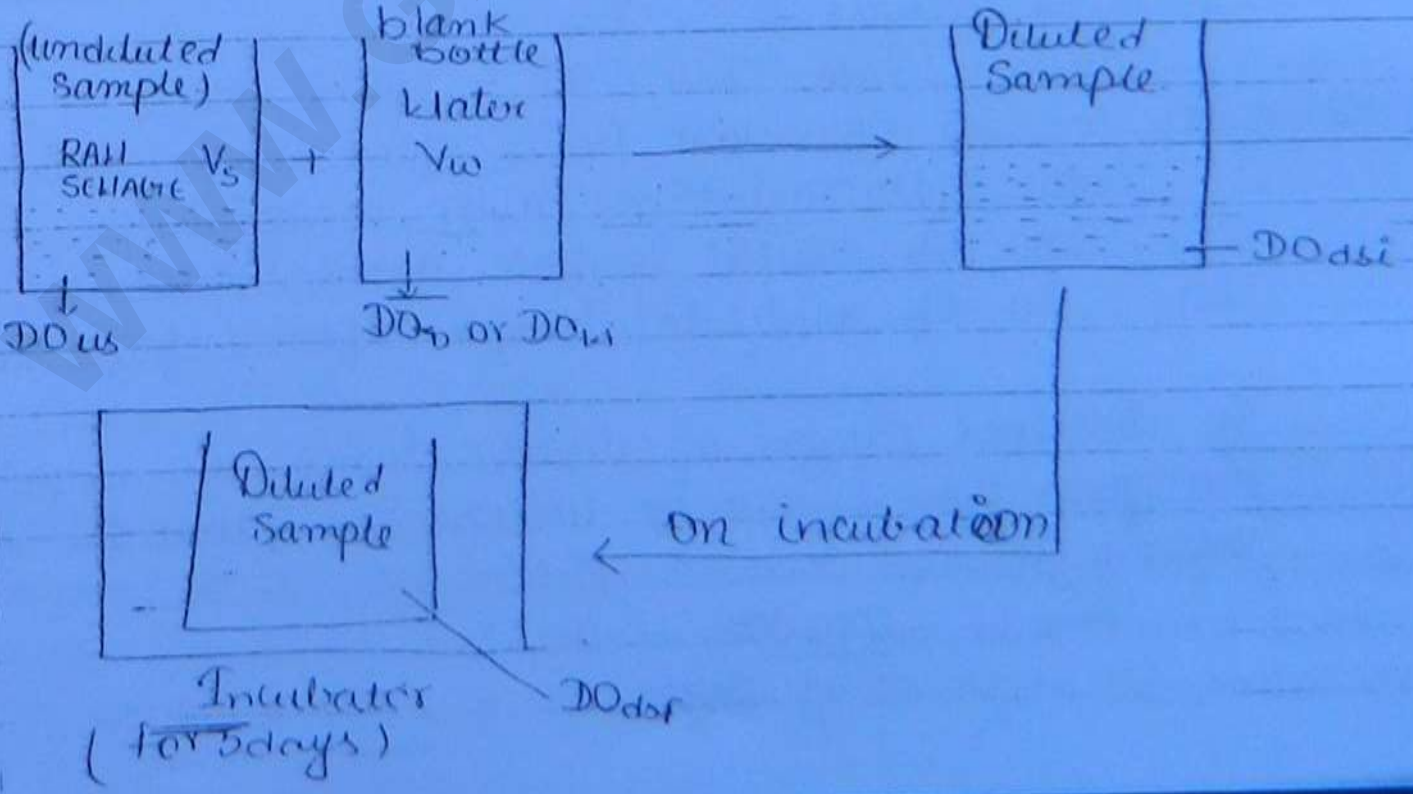
L → represents initial or ultimate BOD (BOD_u)

$BOD_{5,20°C}$ = 68% of organic matter decompose

& at 20 days = 95 - 99% decomposition occurs.

BOD : 5 day = 3 hr

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 use for the dilution process having a volume of V_w & its DO is DO_b or DO_{ti}
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 ie DO_{dsf}

$$BOD_{5\ 20^\circ C} = (DO_{dsi} - DO_{dsf})\ DF \quad (148)$$
$$= (\text{Intial DO} - \text{final DO})\ \text{Dilution factor}$$

Where
dilution factor $= \frac{100}{x}$ (If x.l. of Soln is added then)

$$D.F = \frac{V_s + V_w}{V_s} \qquad V_s = \text{Vol. of Sewage}$$
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 ie initial DO is not given then it will be worked out from the known volume of V_s & V_w & from DO_s & DO_w

$$DO_i = \frac{DO_s V_s + DO_w V_w}{V_s + V_w}$$

A waste water sample having 5 days 30°C BOD is 110 mg/litre. Calculate the 5 day BOD at 20°C Assuming $K_{D20°C}$ = 0.1 per day

Soln $BOD_{5,30°C}$ = 110 mg/litre

$L(1-e^{-kt})$

$L(1-10^{-K_{D30°C}})$ = 110

$K_{DT} = K_{D20°C}(1.047)^{T-20°C}$

$K_{D30°C} = 0.1(1.047)^{30-20}$

= .15 per day

⇒ $L(1-10^{-.15\times5})$

L = 131.29 mg/l

$BOD_{20°C\ 5} = L(1-10^{-K_{D20°C}\cdot t})$

$= 131.29(1-10^{-0.1\times5})$

= 89.71 mg/litre for 5 days

149

006 ATE Ques To determine the BOD of a waste water sample 5, 10 & 15 ml of waste water were dilute to 300 ml 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	138
2	10 ml	9.1	4.4	30	141
3	50 ml	8.4	0	6	50.4

Soln $V_S + V_W$ = 300 ml

Avg BOD at 5 days = 109.8 mg/l

ate-2011 Ques 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 with 294 ml water containing 8.6 mg/l of DO. After Incubation at

20°c for 5 days The DO of Mix was 5.4 mg/l litre The BOD rate Constant to the base e $K_{20°c}$ = 0.25 per day.

Sol V_s = 6 ml DO = 0

V_w = 294 ml DO = 8.6 mg/l

Dilution factor $\frac{6+294}{6}$ = 50

After Incubation DO = 5.4 mg/l litre

$DO_i = \frac{6\times 0 + 294 \times 8.6}{6+294}$

= 8.428 (150)

BOD = (8.428 − 5.4) 50

= 151.4 mg/l

$151.4 = L(1-e^{-K_{20°c}t})$

Initial BOD L = 212.19° mg/l

Ques The 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 inculation 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

Dilution factor = $\frac{100}{5}$ = 20

$BOD_t = (DO_b - DO_f)DF - (DO_b - DO_s)$

(8.8 − 3.8) 20 − (8.8 − .80)

= 92 mg/litre

Ques The 5 day BOD of a waste water sample is obtained as 190 mg/l/dr & K = 0.01/hr. The ultimate BOD of the sample in mg/l will be

Sol:- BOD $L(1-e^{-Kt})$

$190 = L(1-e^{0.24\times 5})$

$L = 271.89$ mg/l

Late-2010

Ques If the BOD of a waste water sample after 3 days is 75 mg/l & the n^{th} rate constant K (base e) is 0.345/day. The amt. of BOD remaining in the given sample after 10 days is

$BOD_{3\,days} = L(1 - e^{-K_T \cdot t})$

$75 = L \times .644$

$L = 116.32$ mg/l

$BOD_{10\,days} = L(1 - e^{-K_T t})$

$= 112.63$ mg/l

Remaining BOD = 3.7 mg/l litre

2nd-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/l litre. The n^{th} rate constant (base e) = at 20°c is 0.18 per day. The n^{th} rate constant at other temp. may be estimated by $K_{T°C} = K_{20°C}(1.047)^{T-20}$. The temp at a portion of the sample should be tested to exert the same BOD in 2.5 days is

$BOD_{5,20C} = 180$ mg/l

$K = 0.18$ per day

$L = 303.32$ mg/l

$BOD_{2.5\,T°C} = L(1 - e^{-K_{T°C} \times 2.5})$

$180 = L(1 - e^{-K_{T°C} \times 2.5})$

$1 - e^{-K_{T°C} \times 2.5} = .593 \Rightarrow K_{T°C} = 0.36$

$K_{T°C} = K_{20C}(1.047)^{T-20}$

$0.36 = 0.18(1.047)^{T-20}$

$T = 35.09°C$

Ques:- If BOD por the 3 days of a waste water is 75 mg/l & K = 0.015 per day, what is the ultimate bod

Sol^n $75 = L(1 - e^{-K \cdot t})$

$L = 1104.45$ mg/litre

(152)

The foowing observation were made on a 4% dilution of waste water DO of aerated 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. Calulate the BOD of sample after 5 days & ultimate BOD of the ~~two~~ sample $K_D = 0.1$ /day

Sol:- $D.F = \frac{100}{4} = 25 = \frac{96+4}{4} = \frac{V_s + V_w}{V_w}$ $V_s = 4$, $V_w = 96$

$BOD = (3 - 0.8) \times 25 - (3 - 0.6)$

$BOD = 52.6$

$BOD = L(1 - 10^{-K_D \cdot t})$

$52.6 = L(1 - 10^{-0.1 \times 5})$

$L = 76.92$ mg/l

OR $DO_f = \frac{DO_s V_s + DO_w \times V_w}{V_s + V_w} = \frac{0.6 \times 4 + 3 \times 96}{100} = 2.9$

$BOD = (DO_i - DO_f) DF$

$= (2.9 - 0.8) 25$

$= 52.6$ mg/l

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. $K = 0.1$ per day. Calculate BOD & intial BOD.

$BOD = (7.8 - 4.3) 60$

$BOD = 210$ mg/litre

$\left[D.F = \frac{300}{5} = 60 \right]$

Sol^n $210 = L(1 - e^{-0.1 \times 5})$

Ultimate $L = 533.71$ mg/l

IES-2005

Ques. The 5 days BOD at 20°C of a given sample is 450 mg/litre. Calculate the ultimate BOD at 35°C. Given that K_D at 20°C 0.1 per day

$K_{D\,35°C} = K_{D\,20°C}(1.047)^{35-20}$

$= 0.199$

$BOD_{20°C} = L(1 - 10^{-0.1\times5})$

$450 = L \times 0.684$

$L = 658.11$ mg/l.

$BOD_{5\,35°C} = L(1 - 10^{-0.199\times5})$

$= 658.11(1 - 10^{-0.199\times5})$

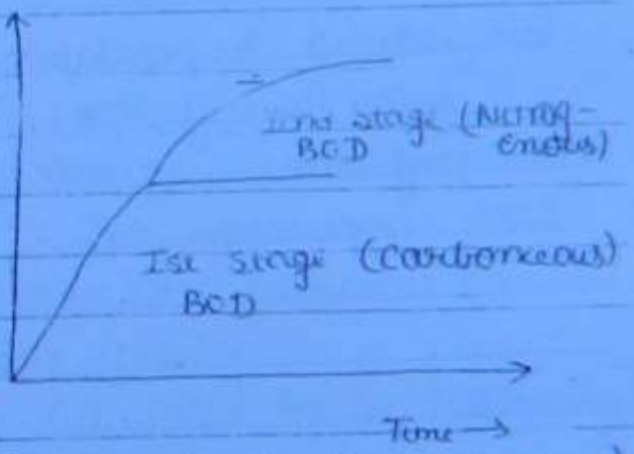
$BOD_{5\,35°C}$ 591.54 mg/litre (initial BOD)

BOD - Types

→ BOD is of two type

(i) Ist Stage BOD

(ii) IInd Stage BOD



→ 98% of BOD is of Carbonaceous matter only

$\frac{BOD_u}{COD}$ Ratio = 0.92 to 1.0 (Sewage in Biodegradble type)

$\frac{BOD_5}{COD}$ = 0.63 to 0.68 (Sewage is said to have containing biodegradable waste)

population equivalent = $\frac{\text{Total BOD produces by the Industry per day of a city}}{\text{BOD produced by an individual per day}}$

Standard BOD produced by an individual per day = 0.08 kg

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) $100\ (1-0.794^{t_{20°C}})$

(ii) $100\ (1-0.604^{t_{37°C}})$

Where $t_{20°C}$ = No. of days req for the decomposition of Carbonaceous matter at 20°C

$t_{37°C}$ - No. of days req for the decomposition of Carbonaceous matter at 37°C

Ques Calculate the population eqv 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

Soln population eqv = $\frac{\text{Total BOD Contributed to city per day}}{\text{Individual BOD per day}}$

$$= \frac{95 \times 10^6 \frac{\text{lit}}{\text{day}} \times 300 \times 10^{-3} \times 10^{-3} \frac{\text{kg}}{\text{litre}}}{0.08 \text{ kg}}$$

$$= 356250$$

The period of Incubation is 10 days at 20°C, then the % of Relative Stability of the sewage sample is

Sol $100\ (1-0.794^{t_{20°C}})$

$100\ (1-0.794^{10})$

$= 90.04\ \%$

Ques Find out the BOD of a waste water containing 300 mg/l of ketone of chemical formula $CH_3COC_2H_5$. The oxidation eqn is given by

$$CH_3COC_2H_5 + \frac{11}{2}O_2 \longrightarrow 4CO_2 + 4H_2O$$ (155)

$$12+3\times1+12+16+24+5 \quad + \quad \frac{11}{2}\times2\times16$$

$$72 \quad + \quad 176$$

72 mg ⟶ 176 mg of oxygen

300 mg ⟶ ?

$$= \frac{176}{72} \times 300 = 733.3 \text{ mg/l}$$

Design of Sewer

↓

Designed for the $\frac{1}{2}$ or $\frac{3}{4}$ full

→ Should have the self cleansing 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

(i) Chezy equation

$$V = C\sqrt{RS}$$

C → Chezy's Constant

R → Hydraulic Mean depth = $\frac{A}{P}$ = $\frac{\text{Wetted area}}{\text{Wetted perimeter}}$

S → Gradient or slope at c sewer is place

V → Velocity of flow for sewage

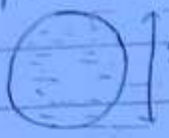
(ii) Manning's equation

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

n = Manning's coefficient

There are 3 condition in Sewage pipe line to be maintained -

(i) Full flow condition

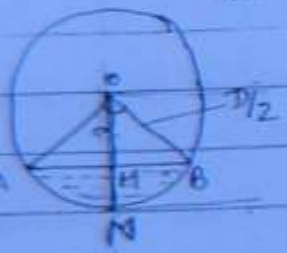


$$R = \frac{\pi/4 D^2}{\pi D} = \frac{D}{4}$$

(ii) Half full 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 OH - OH

$$\frac{D}{2} - \frac{D\cos\alpha}{2} \cdot \frac{2}{2}$$

$$MN = \frac{D}{2}\left(1 - \cos\frac{\alpha}{2}\right)$$

$$A \Rightarrow 360^\circ \longrightarrow A \left(\frac{\pi}{4}D^2\right)$$

$$\alpha^\circ \longrightarrow ?$$

$$= \frac{\pi D^2}{4} \times \frac{\alpha}{360^\circ}$$

Wetted area $a = \Delta \frac{A \times \alpha}{360^\circ} - \frac{1}{2}\frac{D}{2}\cos\frac{\alpha}{2}\left(\frac{D}{2}\sin\frac{\alpha}{2} + \frac{D}{2}\sin\frac{\alpha}{2}\right)$

$$= \frac{\pi \times \alpha}{360^\circ} - \frac{D^2}{4}\cos\frac{\alpha}{2}\sin\frac{\alpha}{2}$$

$P = \pi D$ $\quad 360^\circ \longrightarrow P$

$\alpha^\circ \longrightarrow ?$

$= P \times \frac{\alpha}{360^\circ}$

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.

Sol. It is condition of Half flow

$$R = \frac{D}{4} = \frac{20}{4} = 5\,cm$$

$$V = \frac{1}{0.014} R^{2/3} S^{1/2}$$

$$V = 13.209\ cm/sec$$

$$Q = AV = \frac{\pi}{4} D^2 \times 13.209$$

$$Q = 4149.84\ cm^3/sec$$

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

Sol

$$\frac{V_1}{V_2} = \frac{R_1^{2/3} S_1^{1/2}}{R_2^{2/3} S_2^{1/2}}$$

$$\frac{1}{V_2} = \frac{(1/4)^{2/3} \left(\frac{1}{1000}\right)^{1/2}}{\left(\frac{1}{4}\right)^{2/3} \left(\frac{1}{1000}\right)^{1/2}} \qquad V_2 \quad 1\ m/sec$$

Ques A 20cm dia Sewer @ a Slope of 1 in 500 is running full calculate of rate of flow in Sewer. Given n = 0.012.

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$= \frac{1}{0.012} \left(\frac{20}{4}\right)^{2/3} \left(\frac{1}{500}\right)^{1/2}$$

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$$V = 0.50 \text{ m/sec}$$

$$Q = AV$$

$$Q = 0.015 \text{ m}^3/\text{sec}$$

DTE- BOD$_{5, 20^\circ C}$ of Municipal waster water - 100 to 500 mg/L

→ COD > BOD$_u$

COD - BOD$_u$ - Non biodegradable organics

BOD. $\frac{COD}{TOC}$ → is considered to be an imp factor in waster water treatment = 2.66

Sewage treatment

1. Preliminary treatment → 2 Primary treatment → Secondary treatment → final treatment

1. Preliminary treatment

- Screening
  - in order to remove floating matter & debris)
- Grit Chambers
  - (Remove sand silt grit particle (Inorganic in nature))
  - (Remove particle size >2mm)
  - Detention time - 1 Hr
  - flowing velocity = 0.3 m/sec
- Skimming tank
  - (Remove oil, grease etc)
  - ↓
  - Detention time - 2-5 min

2. Primary treatment

- Primary Sedimentation tank (PST)
  - (Removal of Suspended Particles)
  - ↓
  - Detention time - 2-3 hr
  - flowing velocity = 0.3 m/min

Secondary treatment

(Removal of pathogens & BOD remaining using fine dissolved organisms)

- Aerobic biological unit
  - filter
  - Aeration tank
  - oxidation Pond &
  - Aerated lagoon

final treatment

- Anaerobic biological unit
  - Anaerobic lagoons
  - Septic tank
  - Imhoff tank

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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 in full, the velocity of flow of the sewer when it is flowing half full will

full flow

$$V_1 = \frac{1}{n} (R_1)^{2/3} (S_1)^{1/2} \quad \text{(1)}$$

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 20cm dia sewer with a slope of 1 in 500 is running full. calculate the rate of flow in sewer given that $n = 0.012$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$V = \frac{1}{0.012} \left(\frac{0.20}{4}\right)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

$$V = 0.50$$

$$Q = \frac{\pi}{4} (0.20)^2 \times 0.508$$

$$Q = 0.015 \text{ m}^3/\text{sec}$$

Sewage Treatment :-

a) Preliminary treatment
(2) Primary treatment
(3) secondary treatment
(4) Final treatment
(5) Disposal

(162)

Preliminary Treatment -

1) Screening → floating matter & Debris
2) Grit chamber → remove sand, silt, grit particles (inorganic in nature)
3) skimming tank → Oil, grease etc

↓ Detention time 2-5 min

↓ remove particle size > 2mm
Detention time = 1 minute
Flowing velocity = 0.3 m/sec

Primary Treatment → Primary sedimentation tank
↓
removal of suspended particles
↓
2-3 hours detention time
flowing velocity = 0.3m/min.

Secondary Treatment → Sewage ~~treatment~~ effluent coming from the primary sedimentation tank is treated aerobically or anaerobically to get the clearer effluents

the [illegible] sludge [illegible] the primary sedimentation tank, this process of mixing is called seeding.

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Secondary treatment

(163)

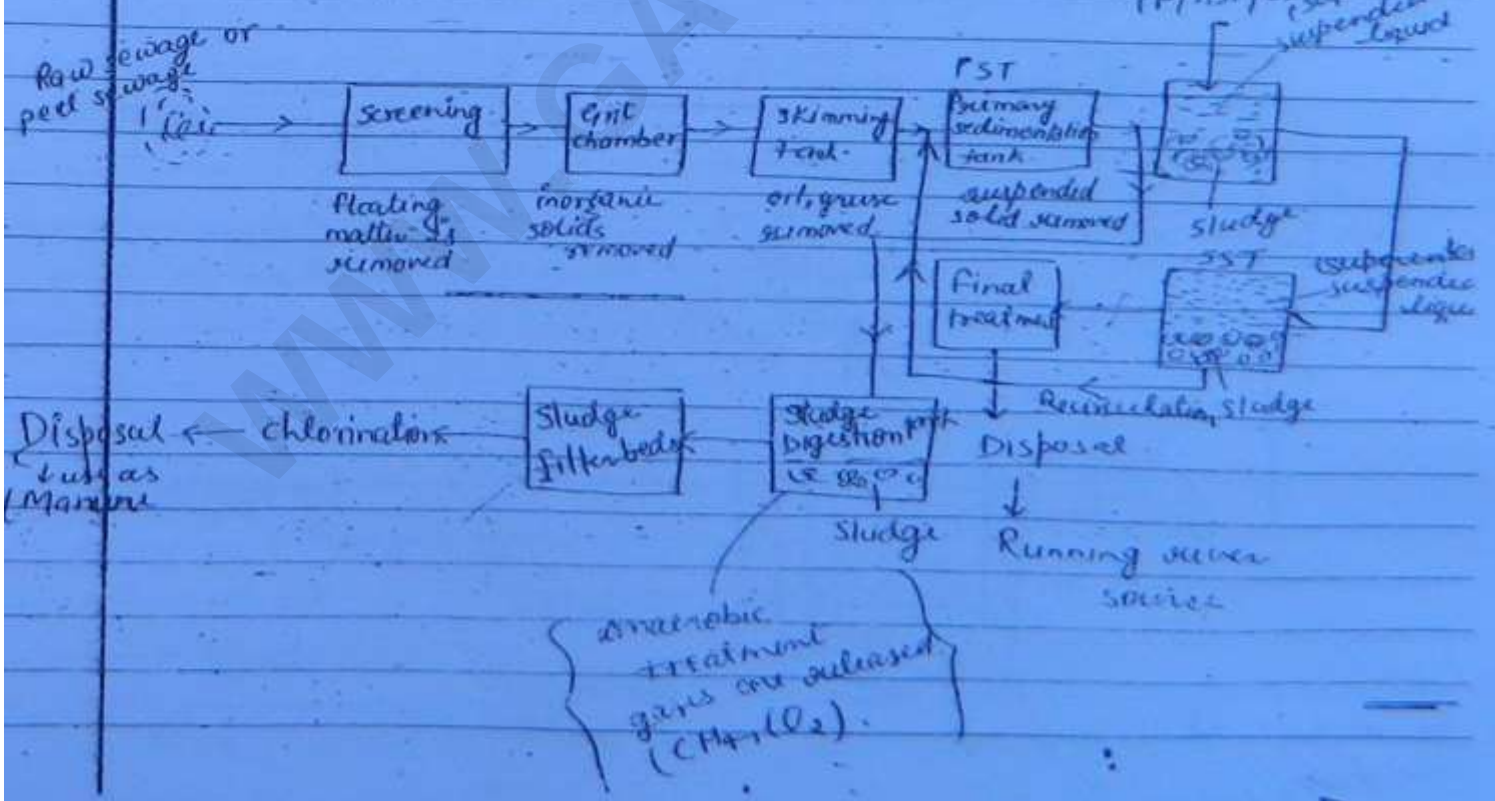
Aerobic treatment (Presence of O_2)	Anaerobic treatment (absence of O_2)
(1) Trickling filter (TF)	(1) Sludge Digestion tank.
(2) Activated sludge process (ASP)	(2) Septic tanks.
(3) Oxidation ponds	(3) Imhoff tanks.
4 Aeration tanks	(4) Anaerobic lagoon.
5. Aerated lagoon	

Final Treatment :- Effluent coming out from the secondary treatment is treated with Cl_2 (chlorination is done).

↓

Disposal

Flowchart for treatment :-

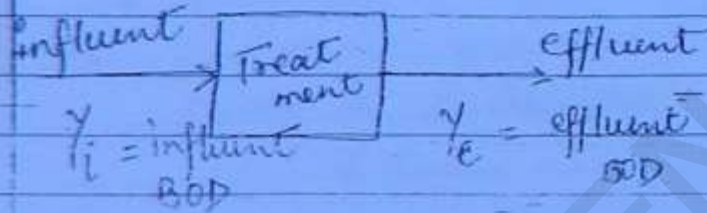


Addition of active sludge to the raw sewage is known as seeding.

(*) → Rate of decomposition depends (164)

→ pH
→ temperature
→ Stearing
→ seeding
→ growth of bectria.

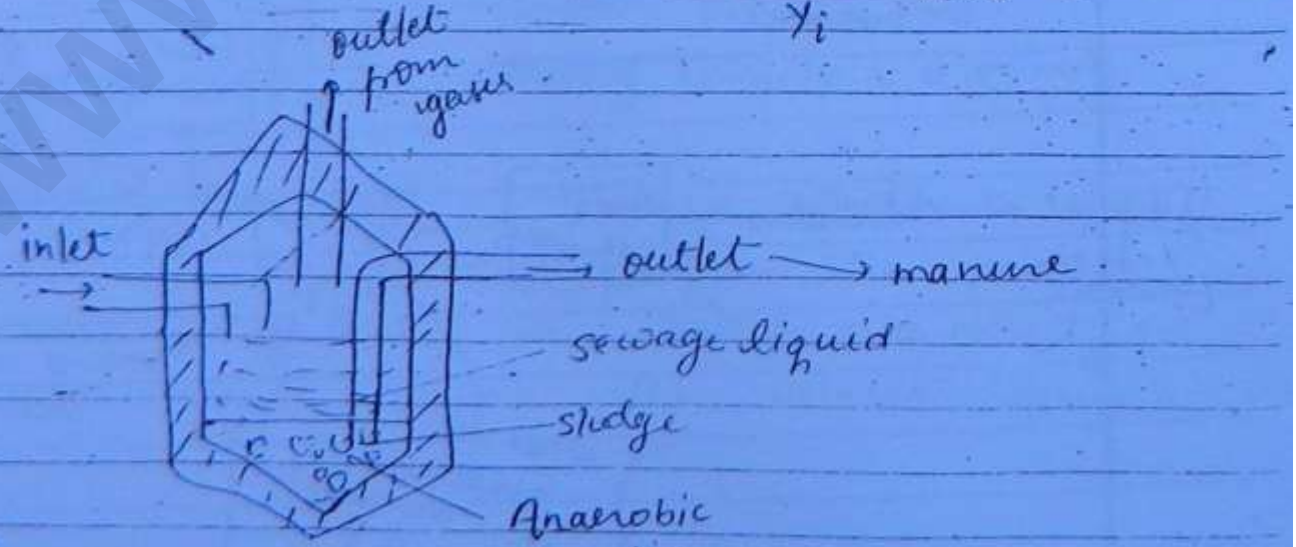
Septic Tank :-



BOD removal = $Y_i - Y_e$

(*) efficiency of the tank = $\frac{\text{BOD removal}}{\text{BOD applied}} \times 100$

$= \frac{(Y_i - Y_e)}{Y_i} \times 100$



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(*) (Q_t) Detention time = 12 to 36 hrs

↓

Process involved → sedimentation

sludge digestion through anaerob action

(165)

(*) cleaning time period t_c = 6 month - 3 year

(*) Sludge accumulation rate -

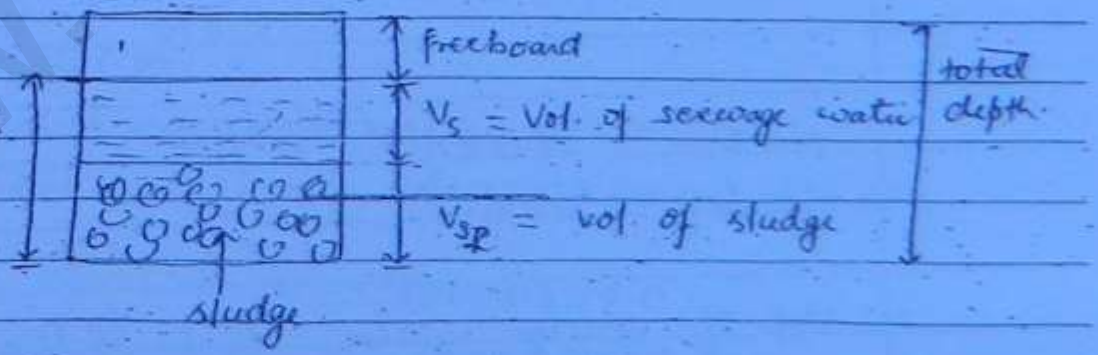
q_a = 30 lt / capita / year

Q = Sewage flow rate

(*) $\frac{\text{Length}}{\text{Breadth}} = \frac{L}{B}$ = 4 to 5

(*) Removal of BOD = 100 - 200 ppm

(*) Freeboard = 0.3 to 0.45 m



Total Vol of the tank $V = V_{sl} + V_s$

$= q_a \cdot t_c + Q \cdot D_t$

Total Vol of tank $V = L \cdot B \cdot H$

where → 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 deposition of sludge is 40 lt/person/year. The depth of the tank is to be kept as 2 m. Provide a freeboard of 0.3 m. assume $\frac{L}{B}$ ratio as 3.

166.

Population of colony = 200

supplied water = 135 lped.

Total drinking water = $\frac{135 \times 200}{1000 \times 24 \times 60 \times 60}$ $\left\{ 1000 \text{ lt} = 1 \text{ m}^3 \right.$

$= 3.125 \times 10^{-4} \text{ m}^3/\text{sec}$

sewage rate = $\frac{75}{100} \times 3.125 \times 10^{-4}$

$= 2.34 \times 10^{-4} \text{ m}^3/\text{sec}$

$Q = 2.34 \times 10^{-4} \text{ m}^3/\text{sec}$

$D_t = 24 \text{ hrs}$

Vol of sewage water $V_s = Q \cdot D_t$

$= 2.34 \times 10^{-4} \times 24 \times 60 \times 60$

$= 20.22 \text{ m}^3$

Vol of sludge $V_{sl} = q \cdot t_c$

$= \frac{40}{10^3} \times 200 \times 1 = 8 \text{ m}^3$

DATE :

Total Volume $V = V_{se} + V_s$

$= 8 + 20.22\ m^3$

(167) $= 28.22\ m^3$

Vol of tank $= L \cdot B \cdot H$

$= 3B \cdot B \cdot (2 - 0.3)$

$= 5.1B^2$

$5.1B^2 = 28.22$

$B = 2.35\ m$
$L = 7.05\ m$
$H = 2.0\ m$ } Ans

Q1 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 2.7 times the avg. sewage discharge demand.

population = 40,000

per capita consumption = 140 lpcd

total $= 40000 \times 140$ lt/day.

$= \frac{40000 \times 140}{1000 \times 24 \times 60 \times 60}$

$= 0.0648$

sewage discharge $Q_s = \frac{70}{100} \times 0.0648 = 0.0454\ m^3/sec$

DATE :

max design discharge

$$Q = 27 \times 0.0454$$
$$= 0.1225 \ m^3/sec$$

Assume — D_t = 2hrs (168)

Vol of sedimentation tank = $Q \times D_t$

$$= 0.1225 \times 2 \times 60 \times 60$$
$$= 882 \ m^3$$

assume effective depth of the tank = 3m (without free board)

Surface area of tank = $\frac{\text{Vol.}}{\text{depth}}$

$$= \frac{882}{3}$$
$$= 294 \ m^2$$

Since the tank is circular

$$\frac{\pi}{4} d^2 = 294$$

$$d = 19.34 \ m$$

By calculation of the surface loading for the sedimentation tank per day it becomes

Surface loading of tank = $\frac{\text{capacity of tank or Volume of tank}}{\text{Surface area}}$

$$= \frac{882}{294} = 3 \ m^3/m^2/day$$

$$\text{OR} \quad \frac{0.1225 \times 24 \times 60 \times 60}{294} = 36 \ m^3/m^2/day$$

DATE :

The permissible surface loading for sedimentation tank is $50\ m^3/m^2/day$.

surface loading = $36\ m^3/m^2/day < 50\ m^3/m^2/day$

so design is safe.

(169)

8. Estimate the size of septic tank ($L/B = 2.25$) liquid depth 2m with 500mm 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 if 80% of water consumption, the sludge produced of $0.04\ m^3$/capita/yr and the retention time of 3 days. Desludging is done when the tank is 1/3 full of the sludge. A percolation test indicated an allowable hydraulic loading of $100\ lt/m^2/day$.

Population = 300

per capita consumption = 100 lpcd

total = 300×100 l/day.

$$\text{Sewage rate} = \frac{80}{100} \times \frac{300 \times 100}{1000 \times 24 \times 60 \times 60}$$

$$= 2.77 \times 10^{-4}\ m^3/sec$$

(V_s) Vol of tank = $Q \cdot D_t = 2.77 \times 10^{-4} \times 3 \times 24 \times 60 \times 60$

$= 71.7984\ m^3$ — (1)

total depth = 2.3m

freeboard = 0.3

liquid depth = 2.0 m

$V_{sl} = \frac{V}{3}$

170

$V = V_s + V_{sl}$

$V = V_s + \frac{V}{3}$

$V_s = V - \frac{V}{3} = \frac{2}{3}V$ —— (2)

$V = L B H$

$= 2.25 B^2 \cdot 2$

$V = 4.5 B^2$ —— (3)

$V = V_s + V_{sl}$

$4.5B^2 = 71.7984 + \left\{V - \frac{V}{3}\right\}$

$4.5B^2 = 71.7984 + \frac{2}{3}(4.5B^2)$

from (1) & (2)

$\frac{2}{3}V = 71.7984$

$V = 107.69\ m^3$ —— (4)

from (3) & (4)

$107.69 = 4.9B^2$

$B = 4.6\ m$, $L = 10.5\ m$

$H = 2/0.3 = 2.3\ m$.

Hydraulic loading is defined as the rate of flow / surface loading area.

$$\text{loading} = \frac{\text{rate of flow}}{\text{surface area}}$$

(171)

$$\frac{100}{1000 \times 24 \times 60 \times 60} = \frac{2.77 \times 10^{-4}}{A}$$

$$A = 239.33 \text{ m}^2$$

$$V_{sl} = q_a \times t_c$$

$$\frac{V}{3} = q_a \times t_c$$

$$35.89 = 0.04 \times 300 \times t_c$$

$$t_c = 2.99$$

$$t_c = 3 \text{ years}$$

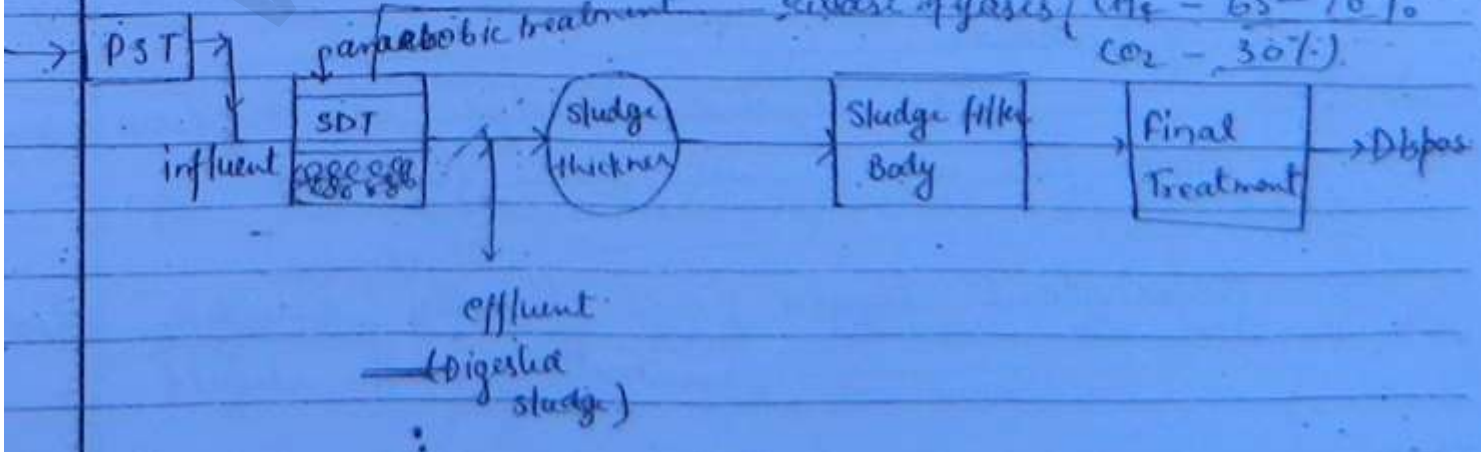
Sludge Digestion Tank (SDT) :-

↓

It is an anaerobic process

↓

carries in the absence of O_2



→ 40-60% of organic solids are get digested.

CH_4 gas released is around $0.9 m^3$ per kg of volatile solids of the digested sludge. volatile
$CH_4 \rightarrow 0.6 m^3$ for raw sewage.

Three stages of 'SOT' :-

1. Acid fermentation
2. Acid Regression
3. Alkaline fermentation

(172)

The parameter which influence sludge digestion are -

(1) temp.
(2) pH
(3) mixing phenomenon
(4) mixing of seeded sludge
(5) Nature of bectria — Mesophellic Bectria - 29°c
Thermophilic Bectria - 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 bectria containing cysts of bectria.

The digested sludge is dried up and can be used as a fertilizer.

2. Supernatant liquid :- Finely ~~Finely~~ divided solid matter and liquid

containing 3000 ppm quantity of BOD.
It is recirculated in the treatment plant and sent back to the raw sewage (173)

3. Gases of Decomposition :- CH_4 around 65 to 70%, CO_2 - 30%, other gases like N_2, H_2S 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 seperated. The sludge becomes alkaline in nature, At this stage BOD falls rapidly and large volume of the CH_4 gas with small amount of other gases is evolved

The parameters which influence sludge Digestion are -

1. Temperature :- At temp increases the rate of the digestion will be more

In the case of sludge digestion at 29°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 ($Ca(OH)_2$)

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.

Mixing a seeding sludge can be done by means of stirring rods & bacterial enzymes present in digested sludge should be mixed throughly 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.

DATE :

2) The sludge from the sedimentation tank contai 95% moisture content. (75)

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 ~~seeding~~ into sending it into sludge thickner tank. The m.c of sludge can be calculated by —

$$m.c = \frac{w_w}{w_w + w_s} = \frac{95}{95+5}$$

w_s = wt. of solids.

w_w = wt. of water.

If sludge having a m.c of P_1 & volume V_1 in initial & it 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

(76) $$\boxed{V_1(100 - P_1) = V_2(100 - P_2)}$$

In this case this eqn holds good

iii 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 —

$$V_1(100 - P_1) = V_2(100 - P_2)$$

$$x(100 - 98) = V_2(100 - 96)$$

$$x \times 2 = V_2 \times 4$$

$$V_2 = x/2$$

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

a) Wt of sludge produced per day assuming the m.c of sludge as 96%

b) If the sp. gr of sludge is 1.02, calculate the sludge quantity in bulk (volume).

Soln

$Q = 4.5$ MLD

Sewage contains = 275 mg/l of suspended solid

Total discharge = 4.5×10^6 lit/day.

total suspended solids in sewage = $4.5 \times 10^6 \times 275 \times 10^{-3} \times 10^{-3}$

= 1237.5 kg/day.

Total removal suspended solids = $\frac{55}{100} \times 1237.5$

= 680.62 kg/day.

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

680.62 " " $\frac{100}{4} \times 680.62$

= 17015.5 kg.

= 17.015 tonnes

Density = $\frac{\text{wt of sludge}}{\text{Vol of sludge}}$

Vol. of sludge = $\frac{\text{Wt of sludge}}{\text{sp. gravity density}} = \frac{17.05 \text{ tonnes}}{1.02 \text{ t/m}^3}$

(177)

$= 16.68 \text{ m}^3$.

Torsion sp. gravity = $\frac{\gamma_{sub}}{\gamma_w}$

$1.02 = \frac{\gamma_{sub}}{1 \text{ t/m}^3}$

$\gamma_{sludge} = 1.02 \text{ t/m}^3$ Ans

Sludge Digestion Tank :-

$V_1 (100 - P_1) = V_2 (100 - P_2)$

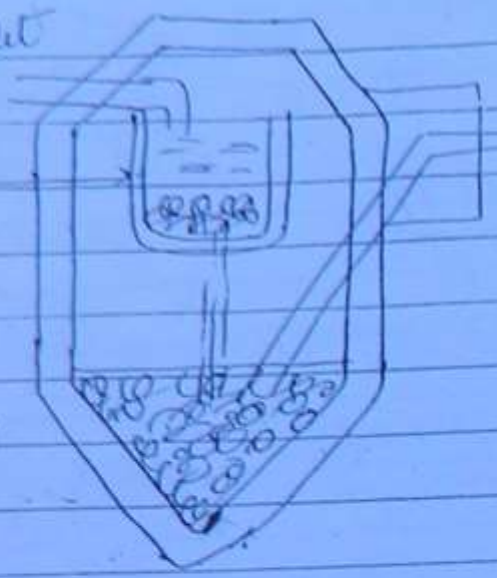
Vol of the sludge digested = $\frac{1}{3} \times$ (volume intake)

The vol of sludge = $V_1 - \frac{2}{3}(V_1 - V_2)$

IMHOFF TANK :- Where congested area is not possible to have sedimentation tank & anaerobic tank (septic tank) seperate there we use in the better lesser space by combining the action 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 inhoff 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

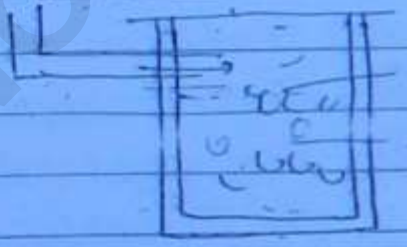
Disposal Methods of sludge :-

1. Absorption Trenches
2. Soap pits
3. Cess pools

1. In absorption trenches the digested sludge can be carried out through the open jointed pipes into the trenches digged 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

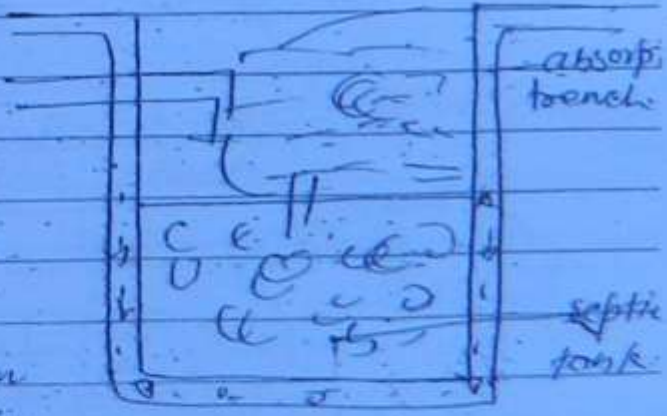
are can grow the vegetation plants silently. This phenomenon known as organic farming. (179)

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.c. 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. & 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.



biomass.

unit process → involving biological and/or chemical reaction

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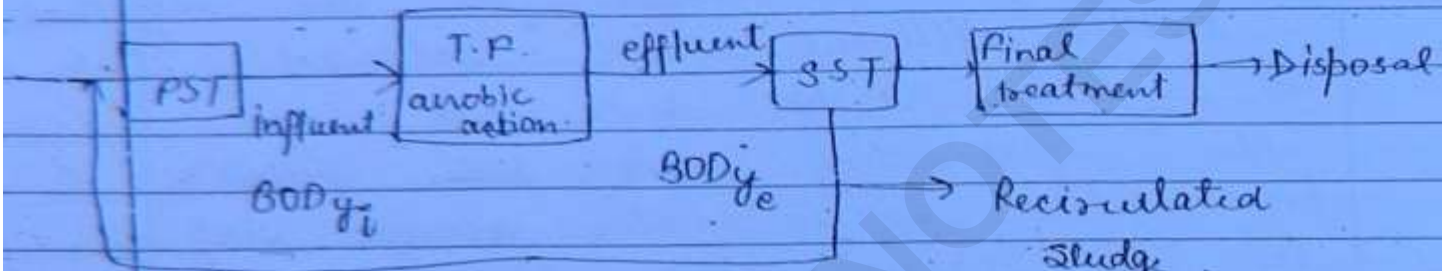
Aerobic Treatment — 1) Trickling filter
2) ASP
3) Oxidation Pond.

Trickling Filter :-

80



① Trickling filter is an aerobic Treatment ✓
② Growth 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.
⑤ 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 within is "upflow anaerobic sludge blanket"

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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

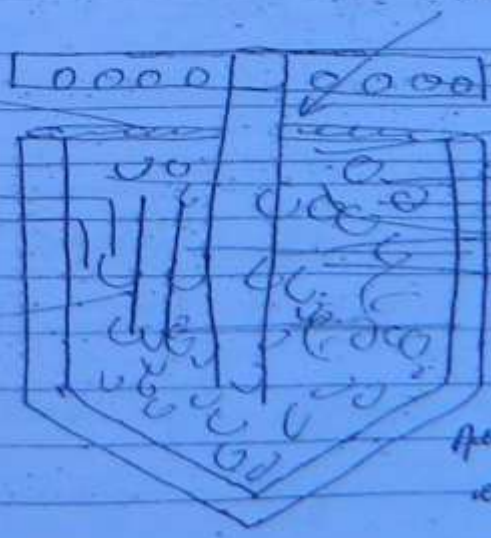
3 (A) Low Rate (Standard Rate) Filters — Stone aggregated → 70-80% BOD removed, Recirculation ratio = 0

2 High Rate Filters — Stone aggregate, but sludge is recirculated — BOD removed 80-90%

(B) Problems of filters:-

① Flies (spreading of flies) → Psychoda.
② odour → prevent by chlorination.
③ Ponding — Clogging of pores of filterbeds of algae & other plants

Rakers.



Parameters useful for design of TF :-

Organic loading $u = \frac{Qy_i}{V}$ (182)

where Q = discharge rate of sewage
V = Volume should be kept in tank

Recirculation Ratio $R = \frac{R}{I}$

R = rate of recirculation
I = rate of influent

In case of high rate filters the recirculation 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.

Recirculation factor :- $F = \frac{1 + R/I}{(1 + 0.1 R/I)^2}$

Efficiency of T.F

(for low rate) - $\eta = \frac{100}{1 + 0.0044\sqrt{u}}$

u = organic loading

For high rate filter $\eta = \frac{100}{1 + 0.004 \left| \frac{u}{P} \right|}$

where $u = \frac{Qy_i}{V}$, P = recirculation factor depends on recirculation ratio

In case of design of T.F., the required vol. of the filter can be formed by making use of organic loading to vol of filter

$$V = \frac{Qy_i}{u}$$

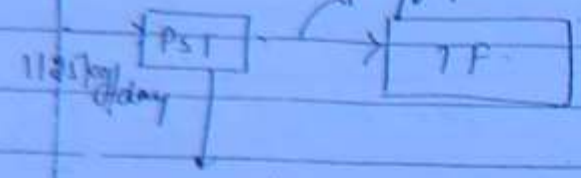
→ The depth of the tank is 2.3 m

Q. Estimate the efficiency of a 30 m dia & 1 m 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 = 4.5×10^6 lit/day
$Q = 4.5 \times 10^6$ lt/day

BOD of raw sewage = $y = 250 \times 10^{-6}$ kg/lt
Total BOD of sewage = $Q \times y = 250 \times 10^{-6} \times 4.5 \times 10^6$
= 1125 kg/day



BOD supply as influent to T.F = 75% of 1125

$= \frac{75}{100} \times 1125$

$Q_{y_i} = 843.75$

Recirculation factor = 1.4

$$F = \frac{1 + R/I}{(1 + 0.1\sqrt{R/I})^2}$$

$$F = \frac{1 + 1.4}{(1 + 0.1 \times 6.9)^2}$$

$F = 2.846$

Dia of T.F = D = 30m

depth = 1m

Volume of T.F = $\frac{\pi}{4} d^2 h = \frac{\pi}{4} \times (30)^2 \times 1$

$= 706.85\ m^3 = 706.85\ kl$

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{u}{F}}} = \frac{100}{1 + 0.0044\sqrt{\frac{Q \cdot y_i}{VF}}}$$

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{843.75}{706.8}}}$$

$$\eta = 73.86\ \%$$

2001 CS

Q. A trickling filter plant treats 1500 ~~cum~~ m^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 kgs/kg of the applied BOD

Trickling filter treats = 1500 m^3/day of sewage

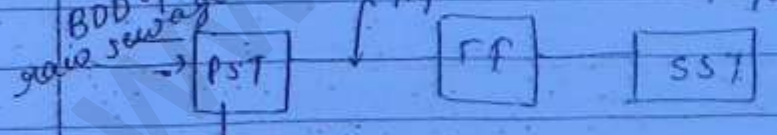
BOD of sewage of sewag = 220 ppm

Suspended solids BOD = 250 mg/l.

Primary clarifier removed = 30% of BOD.

& 60% of Influent solids.

Solids production rate = 0.5 kgs/kg.



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 rate of sewage flow given in the problem

as 1500 m^3/day

Total rate of BOD sent to the TF = $1.54 \times 10^{-4} \times 15000$
= 231 kg/day.

88

1 Kg → 0.5 kg

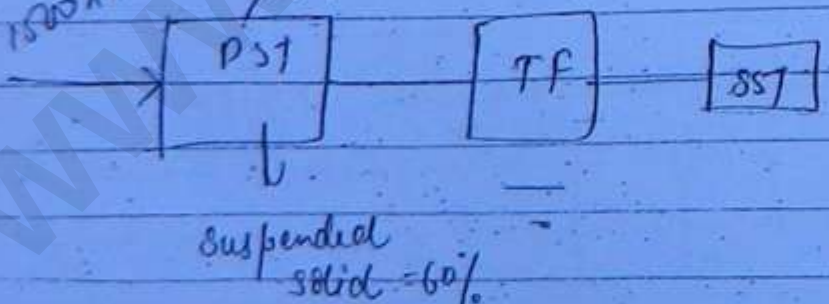
231 kg → $\frac{0.5}{1} \times 231 = 115.5$ kg

The suspended solids removal is 60% of influent, consisting of 250 ppm BOD in the PST

Total sewage flow rate = 1500 m^3/day

total wt of solids in influent = $1500 \frac{m^3}{day} \times 250 \times 10^{-6}$ kg/l
=
= 0.375

60% of influent is classified by PST
= $0.6 \times 1500 \times 10^3 \times 250 \times 10^{-6}$ kg/da
= 225 kg/day.



Total wt of suspended solids = 225 kg/day
Total wt of solid reducing the TF = 115 kg/day
Total solids produced = 225 + 115
= 340.5 kg/day

Q. Determine the dimensions of a high rate T.F given that

(187)

a) Sewage flow = 3 MLD
b) Recirculation ratio = 1.5
c) BOD of raw sewage = 250 mg/lt
d) BOD removed in Primary tank = 25%
e) Final effluent BOD desired = 30 mg/lt

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

Sol^{n}

$Q = 3 \times 10^{+6}$ lt/day.

BOD of raw sewage = 250 mg/lt

Total BOD of sewage = $3 \times 10^{-6} \times 250 \times 10^{6}$ = 750 kg/day

influent of T.F = 75% = $\frac{75}{100} \times 750 = 562.5$ kg/d

$\Downarrow$

y_i

after treatment in TF

effluent BOD = 30 mg/lt = $30 \times 10^{+6} \times 3 \times 10^{-6}$

= 90 kg/day

$\eta = \frac{y_i - y_e}{y_i} \times 100 = \frac{562.5 - 90}{562.5} \times 100$

= 84%.

Recirculation factor

$$P = \frac{1 + R/I}{(1 + 0.1\,R/I)^2}$$

188

$$P = \frac{1 + 1.5}{(1 + 0.1 \times 1.5)^2}$$

$$= 1.89$$

$$\eta = \frac{100}{1 + 0.0044\sqrt{w/f}}$$

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{qyi}{VF}}}$$

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{562.5}{V \times 1.89}}}$$

By assuming the depth = 2m

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

$$\frac{100}{1 + 0.0044\sqrt{\frac{562.5}{\frac{\pi}{2} d^2 \times 1.89}}} = 0.84$$

$$d = 31.7\ m$$

(ii) For standard rate filter.

$\frac{R}{I} = 0$

(189)

$F = 1$

$$\eta = \frac{100}{1 + 0.0044\sqrt{u}} = \frac{100}{1 + 0.0044\sqrt{\frac{562.5}{V}}}$$

$$84 = \frac{100}{1 + 0.0044\sqrt{\frac{562.5}{V}}}$$

$V = 3001.5\ m^3$

Assuming the depth of T.P = 2m.

$$\text{Area} = \frac{3001.5}{2} = 1500.75\ m$$

$$\frac{\pi}{4} d^2 = 1500.75$$

$d = 43.71\ m$

% of modification with respect to high rate filter $= \frac{43.71 - 31.7}{31.71} \times 100$

$= 37.5\ \%$

Q: Design a sludge digestion tank for the primary sludge ie 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
c) 60% of suspended solids is removed in the primary sedimentation tank
d) m.c of the digested sludge is around 85
e) Sp gs of sludge = 1.02
f) Digestion period in the sludge digestion tank = 30 days

avg flow of sewage = 20 MLD
total flow rate = 20×10^6 lit/day.

Total wt of suspended solids = 300 mg/l
Total wt of suspended solids removed = 60%.

$$= \frac{60}{100} \times 20 \times 10^6 \times 300 \times 10^{-6}$$

$$= 3600 \text{ kg/day}$$

Digested volume of sludge = $\frac{1}{3}$ of initial volume.
on assuming $V_2 = \frac{1}{3} V_1$

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

$$V_2 = V_1/3$$

using $V_1 (100 - P_1) = V_2 (100 - P_2)$

$$V_1(100 - P_1) = \frac{V_1}{3}(100 - 85)$$

$$P_1 = 95\% \quad (19)$$

5 kg of solid in sludge — 95 kg of water in sludge

3600 — $\frac{95}{5} \times 3600$

$= 68400$ kg of water

Total wt of sludge $= \omega_s + \omega_w$

$= 3600 + 68400$

$= 72000$ kg

Given that sp gr of sludge = 1.02

$$\text{Volume} = \frac{\text{weight of sludge}}{\text{sp gr}}$$

$V_1 = 70.58\ m^3$

$V_2 = \frac{V_1}{3}$

$V_2 = \frac{70.58}{3} = 23.5\ m^3$

Total volume $V = \left[V_1 - \frac{2}{3}(V_1 - V_2)\right] D_t$

$V = \left[70.58 - \frac{2}{3}(70.58 - 23.5)\right] \times 30$

$V = 1175.8\ m^3$

depth = 4 m (assume)

of SDT

$\frac{\pi}{4} d^2 = \frac{1175.8}{4}$

$d = 19.34$ m

2009 GATE

Q. An anaerobic reactor receives waste water at a flow rate of 500 m^3/day & COD of 2000 mg/lt. The effluent COD is 400 mg/lt. 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 unit loading of 0.175 kg/m^3/day. If the influent BOD of sewage is 150 mg/l then effluent BOD is —

Q. The BOD of sewage entering into the T.F is 200 ppm. If the effluent of sewage is 60 ppm then the η of T.F = ?

$$\text{Sludge age } \theta_c = \frac{V \cdot X_i}{Q_w \cdot X_R + (Q_i - Q_w) X_e}$$

Q_i = Inflow

V = Vol. of aerator

$$Q_R = \frac{R}{100} Q$$

DATE :

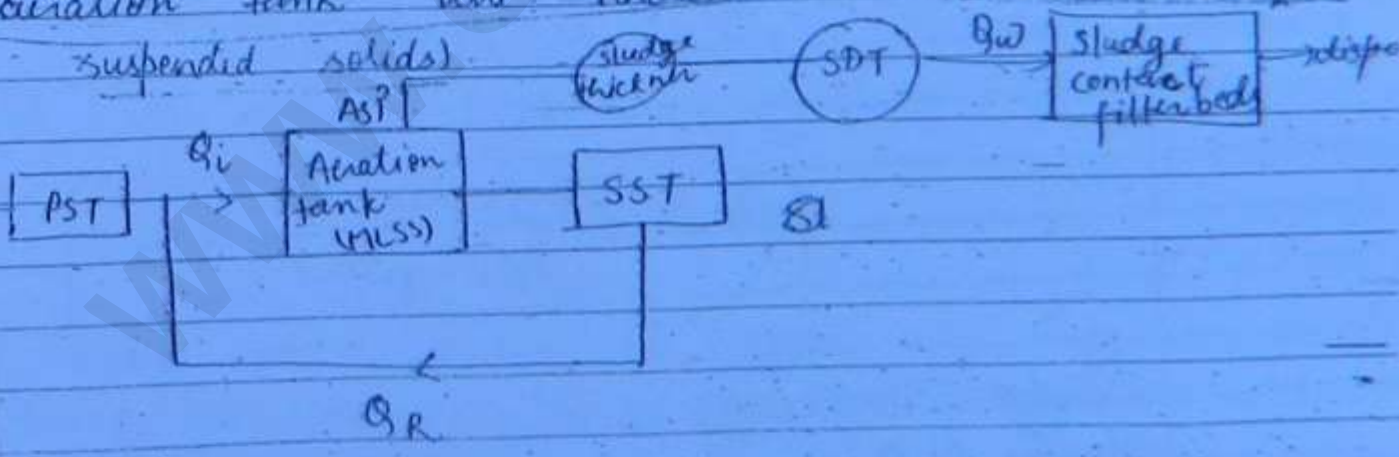
Activated Sludge Process (ASP) :—

(193)

It is an aerobic process.
decomposition of sludge takes place under aerobic bacteria.
Making use of activated sludge

Activated Sludge ⇨ Sludge having high concentration of active microorganisms → (from secondary sedimentation plant SST)
The activated sludge is mixed with raw sewage in aeration tank (ASP) with high supply of aeration or oxygen & kept for 4-8 hours.
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 flowrate X_R = concentration of recirculated solids

DATE :

Design consideration –

(194)

Hydraulic Retention time :– It is defined as volume of tank to the rate of flow of the sewage into the tank.

$$HRT = \frac{V}{Q} = \frac{q_{yi}}{q}$$ V = Vol of loading

Volumetric Organic loading :– The volumetric organic loading is defined as BOD load applied per unit Volume of the aeration tank.

$$u = \frac{q_{yi}}{V}$$

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 thinkner & 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 - thus resulting swelling of the sludge volume Due to the sludge bulking, it remains in the suspension & carried in the effluent of secondary clarifiers.

To avoid the bulking of sludge following are the remedial measurements

~~Eliminate~~

a) Eleminates the industrial waste
b) chlorinate the sewage
c) Supply excess amount of oxygen are 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 30min

$$SVI = \frac{\text{Vol. of sludge settled in ml}}{\text{MLSS in gm.}}$$

SVI = 50 – 150 should be adopted.

(196)

F/M Ratio :- Food to Micro organisms 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.

$$F/M = \frac{Q y_i}{V x_t}$$

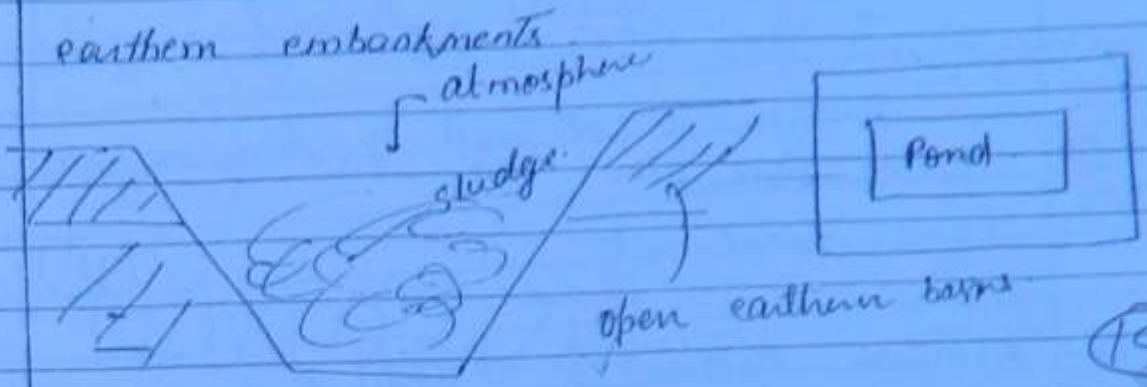
Where V = Vol. of the sludge
x_t = concentration of mixed liquor solids.

Note :- Higher the F/M ratio lower is the removal of the BOD and vice versa.

② for a activated sludge process F/M ratio should be 0.3 to 0.4.
The efficiency of aeration tank, depends upon the quantity of BOD removal.

lagoon Oxidation Pond :- Water Stabilization pond
↓
cheapest treatment → area requirement is more
↓
nuisance is more

Oxidation ponds of the earthern basins open channel constructed below the G.L surrounded by the



In case of oxidation Ponds the principale involved is establisation 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 present of sunlight & the O_2 is utilised the

m.o. & The end products in the oxidation pond of CO_2, NH_4 & phasphates. The discharge in the form of waste 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 ½ hectare to 2 hectare and Detention time is 20-30 days.

BOD removal = 90%.

Cleaning period of settled sludge = 6 years.

To estimulate 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

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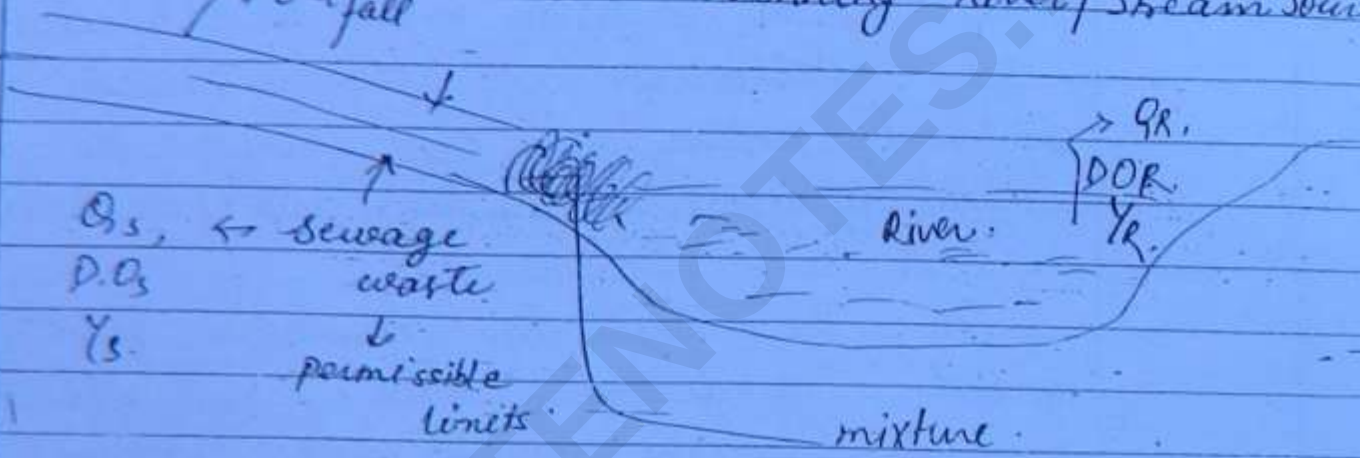
1. Dilution Method :- Effluent is discharged into a running River / stream sou



$$DO_{min} = \frac{Q_R (DO)_R + Q_s (DO)_s}{Q_R + Q_s}$$

BOD of mixture -

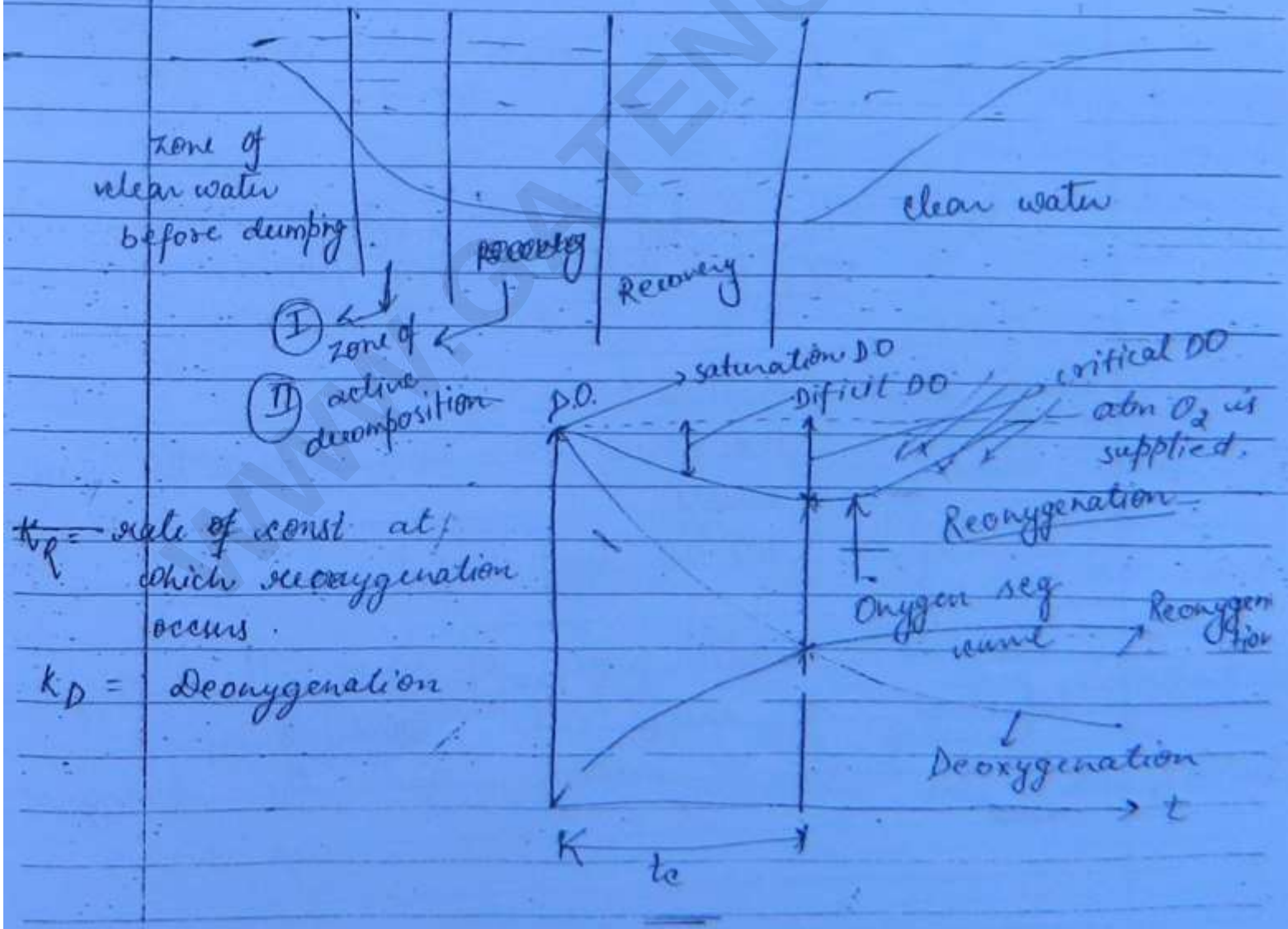
$$Y_{min} = \frac{Q_R Y_R + Q_s Y_s}{Q_R + Q_s}$$

Stages of River in the self Purification

Stages of River in are 4.

1) Zone of clean water
~~Zone of active decay~~

(I) Zone of clear water
a) Zone of degradation
b) Zone of active decomposition
c) Zone of recovery
d) Zone of clear water.



k_R = rate of const at which reoxygenation occurs.

k_D = Deoxygenation

DATE :

DO Dificit = Saturation DO − present DO

initial DO Dificit = saturation DO − DO min

Self purification coefficient

(200)

Self purification constant of a river $\boxed{f = \frac{K_R}{K_D}}$

$$D_f = \frac{K_D \cdot L}{K_R - K_D}\left[10^{-K_D t} - 10^{-K_R t}\right] + \left[D_0 10^{-K_R t}\right]$$

$$D_c = \frac{K_D \cdot L}{K_R}\left[10\right]^{-K_D t_c}$$

$$t_c = \frac{1}{K_D(f-1)} \log\left[\left[1 - (f-1)\frac{D_0}{L}\right] f\right]$$

where D_c = critical DO

t_c = time period at which critical DO dificit occurs.

D_f = DO at any time t

For the dilution proess of river, it is very important to check the qualities of running river or stream and the geological area

DATE :

Land Treatment :- Directly dumping the effluent sewage effluent onto the land
After sometime, the pores of the soil will be clogged and filteration & donot take place properly nuisance of effluent (sewage sickness)
↓
land pollution & leading of sewage or leachate forms GWT get polluted.
↓ coloured leachate

(291)

Factors Affecting the self Purification of system of sive :-

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 causes formation of the sludge banks and causes foul odours. And in the slow current sedimentation takes place causing the growth of algae resulting in the product of oxygen.

Temperature :- As the activities of organisms depends upon the temp, the self purification will also depend upon the temp.

(202)

At lower temp the organisms activities are slow due to the slow rate of decomposition.

As in the ~~submerged~~ ~~sea~~ 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 ~~f~~ organisms present in water. The process prevails till the

completer onidation of organic matter.
The onygen idemand in satisfied & steam becomes purified idue to this phenomenon.

(203)

Reduction - It occurs in steams due to hydralysis of organic matter biologically & chemically, anaerobic organisms start the splittings of complen organic substances present in the sewage.
This action produces odours & gases and thus estabilization comes into the picture.

us. A site adjacent to a river is consider for the location of a municipal waste water treatment plant having an avg. inflow of 2500 m^3/da
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 desk paramelh if required.

DATE :

max^m hydraulic loading = 2 ∧ avg sewage flow

= 2 × 2500

= 5000 m³/day

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By assuming the flow velocity as 0.3 and retention time period D_t = 2 minutes then the length of the grit channel L = velocity × D_t

= 0.3 × 2 × 60

= 36 m

The surface area of channel can be calculated as -

area = $\frac{\text{design flow rate}}{\text{velocity}}$

= $\frac{5000}{0.3}$ = $\frac{5000}{24 \times 60 \times 60}$ / 0.3

= 0.192 m²

by assuming the depth of channel as 1m

B = $\frac{\text{area}}{\text{Depth}}$ = $\frac{0.192\ m^2}{1\ m}$ = 19 cm

Hence we provide the dimension of grit channel as

L × B × H = 36m × 0.19m × (1 + 0.3)

↳ freeboard

L × B × H = 36 × 0.19 × 1.3

Date-03

Q: 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

$$SVI = \frac{\text{vol settled}}{\text{MLSS}}$$

$$= \frac{200 \times 10^3}{2800}$$

$$= 71.4$$

Ques: 1 lt of sewage when allowed to settle for 30 min gives a sludge vol of 27 cm^3. If the dry wt of the sludge is 3gms the the SVI = ?

$$SVI = \frac{27}{3} = 9$$

Date-05

Ques: In certain situation, the waste water discharge into a river mixes with the river water instantaneously & completely. Following is the data available.

Waste water DO = 2.00 mg/l

discharge rate = 1.10 m^3/sec

River water DO = 8.3 mg/lt

Initial amount of DO in the mixture of river & waste shall be —

$DO_s = 2.00$ mg/l

$Q_s = 1.10$ m³/sec

$DO_R = 8.3$ mg/l (206)

$Q_R = 8.7$ m³/sec

temp = 20°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 m³/d, temp = 25°C) is discharged to surface stream (flow rate 12 m³/s, temp 15°C). What is the temp of stream after mixing -

$Q_S = 0640\ m^3/d$, $T_S = 25\ ^\circ C$

$Q_R = 1.2\ m^3/s$ $T_R = 15\ ^\circ C$

$$t_{min} = \frac{Q_S \times T_S + Q_R \times T_R}{Q_S + Q_R} \quad (207)$$

$$= \frac{\frac{0640 \times 25}{24 \times 60 \times 60} + 1.2 \times 15}{\frac{0640}{24 \times 60 \times 60} + 1.2}$$

$$15.769\ ^\circ C$$

Ques - A $125\ m^3/s$ sewage of a city is discharged in a perennial river (continuous) which is fully saturated with O_2 and flows at a rate of $1600\ m^3/s$ with a velocity of $0.12\ m/s$. If BOD of sewage is 300mg/lt. 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 9.2mg/l

$$f = K_R/K_D = \frac{0.44}{0.11} = 4$$

$$t_c = \frac{1}{K_D(f-1)} \log\left[1 - (f-1)\frac{D_0}{L}\right] f$$

$$t_c = \frac{1}{0.11(4-1)} \log\left[\left(1 - 3 \times \frac{DO}{L}\right)\right] 4 = \text{Ans}$$

$$DO_{min} = \frac{Q_R (DO)_R + Q_s (DO)_s}{Q_R + Q_s}$$

$$= \frac{1600 \times 9.2 + 125 \times 0}{1600 + 125}$$

$$= 8.5333 \quad (2.8)$$

Initial DO deficit

D_0 = Saturation DO − DO min

$= 9.2 - 8.53$

$= 0.66$

$L = 125\%$ of BOD min

$L = \frac{125}{100} \times y_{min}$

$$y_{min} = \frac{Q_R \times y_R + Q_s \times y_s}{Q_R + Q_s}$$

$$y_{min} = \frac{1600 \times 0 + 125 \times 300}{1600 + 125}$$

$y_{min} = 21.74$

$L = 27.1739$ mg/lit.

from eq^n (1)

$$t_c = \frac{1}{0.11 \times 3} \log \left[1 - 3 \times \frac{0.66}{27.1739} \right] \times -1$$

$t_c = 1.725$ days

$$D_t = \frac{k_0 L}{k_R} [10]^{-k_0 \times t_c}$$

$$= \frac{0.11}{0.44} \times 27.1739 \, [10]^{-0.11 \times 1.725}$$

$D_c = 4.38876$

Length of flow into river = velocity of flow $\times t_c$

$= 0.12 \times 1.72 \times 24 \times 60 \times 60$

$= 17832.96$ m

$= 17.83$ km.

DATE :

ES-07.

Que. A River before its entry into the town had a discharge of 100 lt/sec & 20 mg/lt was the concentration of a conservative parameter (BOD). The towns waste water outfall having 200 mg/lt concentration of 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.

(2009)

PAGE NO.
DATE :

Ecology

exosphere
thermosphere
mesosphere
stratosphere

(ozone layer)
(stratosphere
(Ozone)

(loud formation

Troposphere

11 km Atmosphere

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Seas, ocean
lakes Rivers, ponds

Mantle

Subsurface water bodies

Aquifer
Aquifuge
Aquitard

Core

Subsurface water bodies
+
Surface water bodies
} Hydrosphere

Eco System

Dissolve oxygen
C, H, N, Sunlight,
Temp., salts,
humidity
moisture content

non living things (abiotic factors)

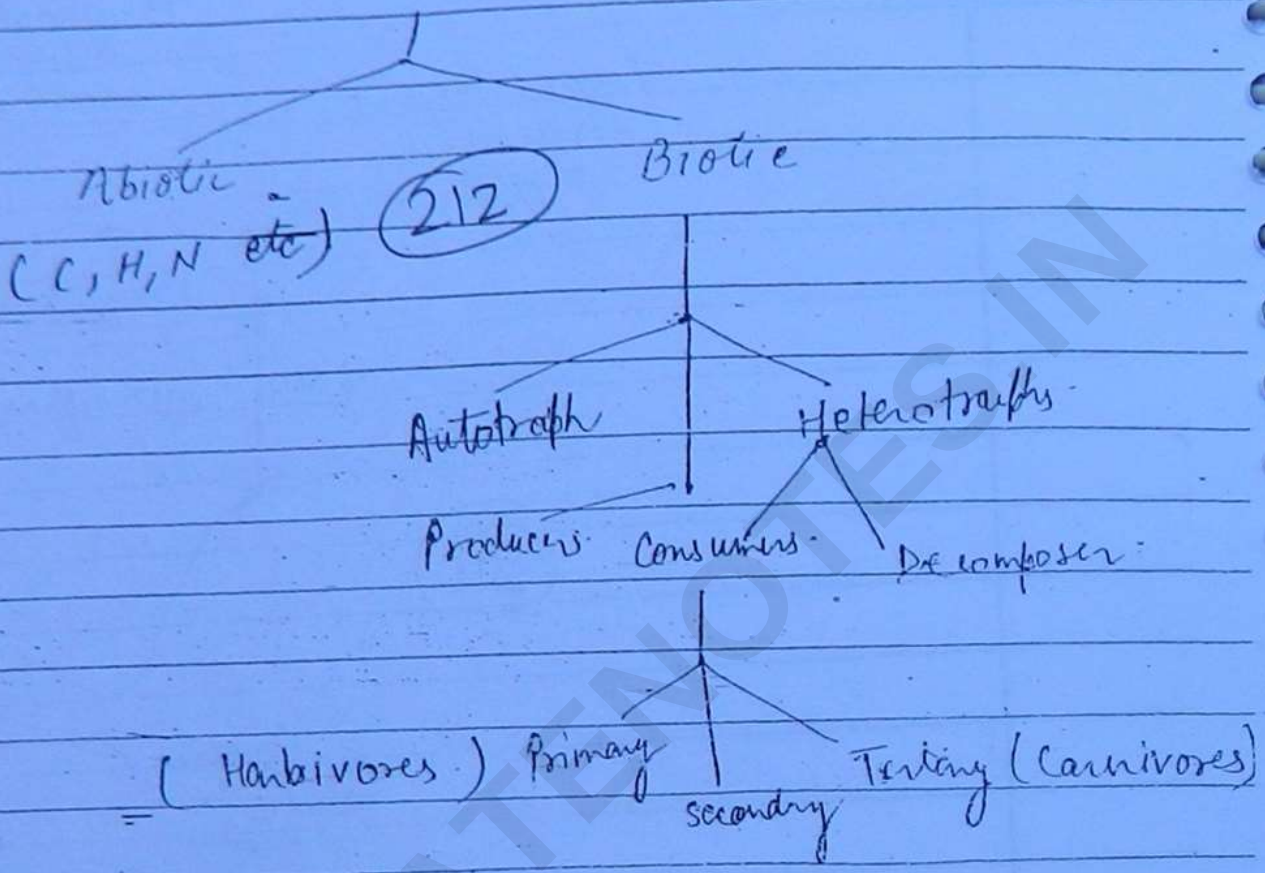
living things (Biotic factors)

→ Producer plants
Consumers Animals
Decomposer Bacteria viruses fungi, protozoa

ECOSYSTEM

↓

Structure



Food chain In an ecosystem transfer the energy from one level to another level.

Food chain
- Grazing food chain → Normal food chain
- Detritus food chain
  - ↳ starts from the decomposition process
  - Bacteria

Food chain – Eaters eaten by the another eater
producer → consumer → Decomposer

Transfer of energy from one level to another level is known as Trouphic level – Trouphic energy. longer the food chain, least in the energy transfer to the last consumers.
Rules of thermodynamics ; law of conservation of energy.

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Eco System
- Natural ecosystem
  - Forest ecosystem
  - Oceans/seas ecosystem
  - Desert ecosystem
- Artificial ecosystem
  - Limnic ecosystem (Fresh water bodies)
    - lentic (stagnated water eg:- Lake)
    - lotic (Running water, River)

Industrial (Terrestrial)
Marine Ecosystem
Aquarium Ecosystem
Agriculture Ecosystem
Anthropogenic Ecosystem

In ecosystem

↓

① ecological succession

② Sustainable development (2/4)

↓

environmental impact - assesment 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 eg:- forest, deserts & oceans

2) Artificial ecosystem eg- industrial agricultural limnic Aquarium.

Every ecosystem consists of abiotic factors (Non living things) and biotic factors (living things) and mutual interrelationship b/w them.

Each ecosystem consists of its own str. by maintaining systematic balance.

Air Pollution : It is defined as releases of excessive foreign matter into the air beyond its permissible level, which becomes toxic in nature and causes damage to the humanbeings, animals & property

Pollution
↓
Pollutants
↓
toxic element beyond its permissible level

In the ecosystem
↓
Sources for the pollutants - which cause pollution

Natural pollution	Man made sources
① pollengrains - Anther flowers	① Thermal Powerplants
② forest forces	② Nuclear Reactors
③ Volcanic eruption	③ Agriculture source
	④ Automobiles

Sources :-

Primary Air Pollutants :- (i) SO_x gases, NO_x gases, carbon related (CO_2, CO), Hydrocarbons, hydrogen sulphide, Hydrogen fluoride, particular matter, Aerosols, lead, Mercaptans (e.g. ...)

Secondary Pollutants :-

Because of the reaction b/w the two primary pollutants

(216)

"Air Pollution is defined as the excessive concentration of foreign matter in the air which adversely affects the well beings of an individual or causes damaged the 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 :-

(1) Products from the atm reactions (chemical reactn like oxidation, Photochemical reactn, polymerization

2) Aerosols :- Aerosols are finely divided solids and liquid particles of microscopic sizes held suspended or dispersed in atm
eg:- 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 elergic reaction.

5) Radioactive minerals :- The radiation eminated from the reaction power plants causes damaging effects.

6) Volcanic ash and gases :- 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.

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 radio active 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, CO_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 atm as a result of interaction b/w two or more primary air pollutants or by the reaⁿ b/w primary pollutant & atm constituents by photochemical reaction phenomenon

1) H_2SO_4
2) O_3
3) PAN
4) Formaldehydes
5) Smog
6) Photochemical smog.

H_2SO_4 is formed by the simple chemical reaction b/w SO_2 & water vapour. It causes acid rain.

Ozone, PAN, Formaldehyde are formed by the photochemical reactions caused by the sunlight b/w the two primary air pollutant. (219)

SO_2 industries related to the Gases —

1) SO_2 from the thermal Power plant.
2) CO_2 from automobiles → Carboxy hemoglobin is formed and acts as asphyxiant & leads to the cardio Vascular diseases.
3) HC from the automobiles exhausts
4) Lead → It is released into the atm by the automobiles running on petrol.
5) NO_x gases → they are released from the wise oxidation, electrical discharges, Solar radiation, welding operations in the industries.

Effects of Air Pollution :—

1) Air pollution causes Bronchiolis (Asthma)
2) The high concentration of SO_2, NO_2, photochemical smog, pollengrains cause asthma
3) lead discharge from the automobiles cause lungs infaction

4) Hydrogen Floride released from the Fluoride industries cause the melting of teeth (discolouration of colour) teeth.

DATE :

5) CO cause death due to asphyxiation.
6) Radioactive components cause cancer due to the carcinogenic agents, lessening age & genetical effects
7) The NO_x gases cause eye irritation nasal irritation & respiratory syndromes (Breathing problems).
8) Silicosis & Asbestosis are the diseases caus to the person who work in cement industry, coal mines & thermal power plants.

Effects on Plants :- (220)

The air pollutants can cause —

1 chlorosis (discolouration of plants i.e yellow colour

2 Necrosis (air pollutant excessive levels can lead to the tissue killing of plan

3 Abscision :- (unnecessary falling of leaves du to the excessive air pollutant concentratio is called as Abscision.

4 Epinasty :- D/w 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 mixing of the secondary pollutants in atm level ie H_2SO_4 causes acid rain.

(221)

(i) 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.

(ii) The pH of the acid rain in b/w 5 to 5.5. Acid rain causes damaged to the forest, crops, buildings & monuments (by the leaching action) increased levels of Acid rain causes dissolved oxygen ↓ to the flora & 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 eminations & trap the sunlight in the lower levels & prevent the reflected sunlight to go up into the higher zone.

The trapping of sunlight leads to the increased the temp at the global

level to this phenomenon is known as Global Warming.

Global Warming is due to the increased industrialisation & emination of chloro floro carbon (CFC_s), CCl_4, CH_4, chloroform ($CHCl_3$), Isoprene, Refrigerants, CO_2.

(*) 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 age.

Ozone layer Depletion

Ozone is present in stratosphere & it it called as stratospheric ozone.

(*) The unit of the ozone measurements are 'DABSON'. due to the rate 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 emination in the excessive concentration levels, some of them break the ozone layer &

concentration of ozone layer is gets reduced in the atm

effects of Ozone layer diplation :-

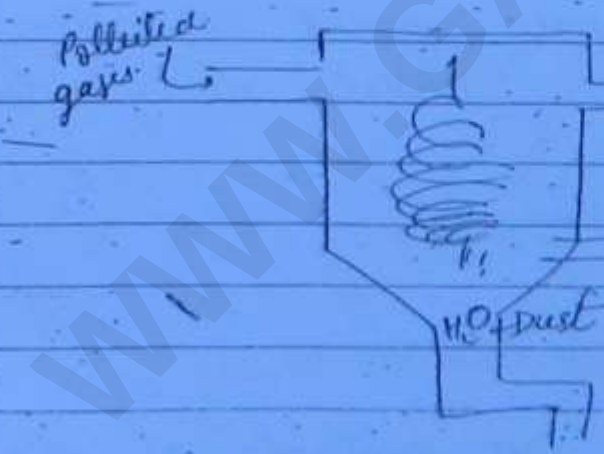
1) Damage to the immune system
2) Disturbance in ecosystem
3) increased skin cancer
4) shortening of life of plants & lower yield of crop.

(223)

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.

DATE :

Conversion of Suspended particulate matter (SPM) :-

From ppm to $\mu g/m^3$

$$\mu g/m^3 \text{ (of SPM)} = \frac{(\text{PPM of SPM}) \times \text{gram mole mass of gas} \times 10^3}{\text{Vol. of gas (lt/mole)}}$$

↓ substitution of molecular wt of a gas

(224)

Any gas, at 1 atm pressure or 760 mm & 0°C i.e 273°K → occupies 22.4 lt/mole of vol.

Avagadro'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 value as 1 mole of any other gas at the same temp and pressure.

At 273°K and 1 atm pr. the vol of gases is 22.4 lt/mole.

To convert the vol. given at other temp. & pressure the above avagadro's law is used.

Qw 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.

Sol^n

$CO = 12 + 16 = 28$

mg/m^3 of $CO = \frac{9 \times 28 \times 10^3}{22.4} = 11250$

(225)

Ques The mean indoor airborne chloroform ($CHCl_3$) concentration in a room was determine to be 0.4 $\mu g/m^3$ use the following data

$T = 29.3°K$, $P = 1$ atm, Gas const. $R = 82.05 \times 10^{-3}$ atm-m^3/mol-K

Atomic wt of $C = 12$, $H = 1$, $Cl = 35.5$.

This concentration is expressive in parts/billion (Vol^m basis) is equal to

$CHCl_3 = 12 + 1 + 3 \times 35.5 = 119.5$

mg/m^3 of $CHCl_3 = \frac{ppm \times 119.5 \times 10^3}{V}$

$0.4 = \frac{PPb \times 119.5 \times 10^3}{V_1}$

$0.4 = \frac{PPb \times 119.5 \times 10^3}{24.04}$

$P = 0.08$ ppb Ans

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\frac{22.4}{273} = \frac{V_2}{298}$

$V_2 = 24.04$ lit/

Ques Particulate matter (fly ash) carried effluent gases from the furnaces burning fossil fuels are better removed by

a) Bag house filter
b) Wet scrubber
c) ESP
d) Mixing with air is zero

Q. Two primary air pollutants are
a) SO_2 & O_3
b) NO_2 & PAN (Paryle acetyle Nitrate).
c) SO_2 & HC
d) O_3 & PAN

Meterological conditions — (226)

Air pollution changes
① Wind velocity (Anemometer)
② Wind direction (wind rose diagram)
③ Lapse Rate
④ Plume behaviour
⑤ Stack height

lapse Rate -
a) Decrease of temp. with increase of altitude. (ELR).
b) Adiabatic lapse rate (ALR) - The temp. of a particular air parcel or air packet decrease with the increase of altitude.

ELR < ALR = Sub adiabatic - lapse rate
ELR > ALR = Super adiabatic
ELR = ALR = Neutral state

Inversion :- increase of temp with increase of altitude i.e negative lapse rate.

Dry air cools at rate of 9.8°C/km → dry ALR
Br saturated (wet air) rate is calculated to be 6°C/km → Wet ALR

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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 Metrological 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 internal decrease of Temp with height which occurs in the rising parcel of air mass without exchange of heat from the surrounding is known as ALR.

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Sub adiabatic lapse rate :-

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When ELR < DALR ; 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 :- (ELR > ALR) ;

The rising air parcel will always remain warmer and lighter than the surrounding environment. The air parcel will continue to accelerate & 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 :- ELR = 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

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Solid Waste Management

Solid waste in dry form of refuse

density = 300 - 600 kg/m³

Municipal solid waste (MSW) ← [fused card board pieces, papers, biodegradable waste, Rubbish, Garbage

Solid Waste (229)

↓

causes:- 1) Domestic 2) Industrial sources

Disposal of Solid waste -

1) Sanitary land filling
2) Incineration or pyralysis
3) Pulvarization
4) Barging (dumping) into the sea
5) Composting → Indore Process → Aerobic treatment
→ Bangalore process → Anaerobic treatment

(1) Energy produce KJ/kg (dry basis) = Energy in kJ/kg (of described) × 100 / (100 - %m.c.)

(2) Energy Produced in KJ/kg (dry basis) with ash free =

energy in kJ/kg (as described) × 100 / (100 - %ash - %mc)

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If the chemical formula of solid waste is given

(3) energy in KJ/kg.

$$= \text{modified Dulong formula}$$

$$= 337(C) + 1428\left(H - \frac{O}{8}\right) + 95(S)$$

where C = % of carbon
O = % of oxygen
H = % of hydrogen
S = % of sulphur

(230)

Solid Waste can be disposed by the following method

1. By Sanitary land filling Method :- Refuse is carried 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 bectria. The refuse is kept for a period of 2-4 month.

Lechate :- During the rainy season when excess water seeping through the area, may come out of the solid waste as a coloured liquid called as lechate.

The lechate is highly toxic in nature & it pollutes the GWT

Production of Gases :- In the most cases the decomposition of solid waste release CH_4, CO_2

The gases can be collected by the gas collector & they can be used as fuel.

(231)

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

4. 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 anobically or anaerobically.

5. Barging into the sea :- The solid waste is directly dumped into the sea & disposed of, but care should be taken to prevent the formation of sludge banks.

6. 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 field.

In Indian condⁿ there are two methods available for the disposal of refuse & night soil.

(232)

1. Indore Process:- It uses the mixture of refuse & night soil for the decomposition under aerobic condition.

Bangalore.

2. Banglore Process:- It is primarily anaero in natur & 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 earthern trench.

This mass is covered by 15cm of layer of earth & it is kept for the decomposition. After 4-5 month the refuse gets stabilized and changes into the brown colour, odourless manure called as Humus.

Ans 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	(233)	700

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 2%.

c) Determine the energy content on an ash free basis assuming the ash content as 5%.

a) Total energy in KJ/kg. = $4600 \times 0.15 + 16750 \times 0.45 + 16300 \times 0.10 + 32600 \times 0.10 + 6500 \times 0.10 + 18600 \times 0.05 + 700 \times 0.05$

$0.15 + 0.45 + 0.10 + 0.10 + 0.10 + 0.05 + 0.05$

$= 14732.5$ KJ/kg

b) energy content on dry basis $= 14732.5 \times \frac{100}{100 - 2}$

$= 18648.73$ KJ/kg.

c) energy content on an ash free $= 14732.5 \times \frac{100}{100 - 21.5}$

$= 18908.7$ KJ/kg.

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2nd Late

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

Wt = 100 kg

	Component	% by weight	Vol (m^3)	sp. weight (kg/m³)
①	Food waste (234)	50	0.166	300
②	Dirt & Ash	30	0.06	500
③	Plastics	10	0.1538	65
④	Wood & Yard waste	10	0.08	125
			0.4598 ≈ 0.46	

Total sp. wt of MSW = $\frac{\text{total wt}}{\text{total vol.}} = \frac{100}{0.46} = 217.14 \text{ kg/m}^3$

3rd Late

Ques: Two biodegradable components of municipal solid waste are

a) Plastic & wood
b) Cardboard & Glass
c) Leather & tin cans
d) Food waste & Garden trimming.

2 Aggregate

Ques: 50 gms of CO_2 & 25 gms of CH_4 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 prod 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 (233)

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 ——— $\frac{50}{120} \times 500 \times 10^3 = 208.3 \times 10^3$ kg

$\frac{208.3 \times 10^3}{10^6}$ per million

$= 208.3$ gm of CO_2 per capita

$\frac{208.3 \times 10^3 \times 10^3}{10^6}$

=

120 gm MSW $\xrightarrow{\text{release}}$ 25 gm of CH_4

500 tonnes ——— $\frac{25 \times 500 \times 10^3}{120} = 104.167 \times 10^3$ kg

$= \frac{104.167 \times 10^3 \times 10^3}{10^6}$

$= 104.167$ of CH_4

Total green house gases = 208.3 + 104.167

= 312.5 gm/capita/day

Q. Estimate the theoritical vol. of CH_4 gas that would be expected from anaerobic digestion of a tonne of waste having composition $C_{50}H_{100}O_{40}N$. The chemical expression :

involved is as follows :-

$$C_aH_bO_cN_d + \frac{(4a-b-2c+3d)}{4} H_2O \longrightarrow \frac{(4a+b-2c-3d)}{8} CH_4 + \frac{(4a-b+2c+3d)}{8} CO_2 + d.x$$

= 236

Assume the density value of CH_4 as 0.7167 kg/m³.

50 m

$C_{50}H_{100}O_{40}N$ → a = 50, b = 100, c = 40, d = 1

$$\therefore \frac{(4a+b-2c-3d)}{8} = \frac{4\times50+100-2\times40+3\times1}{8}$$

$$= 27.825$$

Molecular wt = $C_{50}H_{100}O_{40}N$

$50\times12+100\times1+40\times16+1\times14$

= 1354

CH_4 → 12+4 = 16

1354 gm ⟶ 27.825×16

1 gm ⟶ $\frac{27.825\times16}{1354}$ = 0.32053 gm

1 tonne ⟶ $\frac{27.875\times16\times10^3}{1354}$ = 320 kg

Vol = $\frac{320.5}{0.7167}$ = 447.23 m³

Q The ultimate analysis of municipal solid waste is given below

component	Mass (kg)	% by mass
Carbon	34.57	36.3
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

(237)

Estimate the error the content of waste by using modified dulong formula.

Dulong formula $= 337(C) + 1428\left(H - \frac{O}{8}\right) + 95(S)$

$= 337 \times 36.3 + 1428\left(7.3 - \frac{51.10}{8}\right) + 95 \times 0.10$

$= 13545.65$ KJ/kg.

Ques. Estimate the mc of solid waste sample with the following composition.

component	% by mass	m.c %	wt of component	m.c
Food waste	20	70	0.20 W	$0.20 \times \frac{70}{100} = 0.1$
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 trimings	5	60	0.05 W	0.03 W

Wood	5	20	0.05 W	0.01 W
Tin cans	5	3	0.05 W	0.0015 W
		90%		0.2115 W

Let total wt of MSW = W kg.

moisture content = $\frac{\text{total wt of the moisture}}{\text{total weight}}$

0.2 → secondary of 0.9% of pw by mass

$= \frac{0.2115\,W + 0.11W}{W}$

$= 0.3115$

(238) $= 31.15\%$

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Noise Pollution

↓

defined as unwanted sound

The sound changes due to the change in the pressure levels due to the environmental changes.

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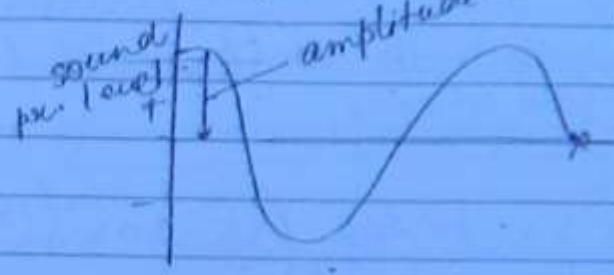

Sound is periodic, regular & long duration of time, pleasant sound

Sound is aperiodic, irregular, short duration, noise

Any sound that just audible is having a pressure level called at 'Threshold level" = 20 μpa = 0.00002 N/m²

Sound in the form of noise is measured in Decibal.

The range of sound = 0.00002 N/m² to 200 N/m²

The range of sound = 80 db
= 45 db
= 120 db } Turbines
140 db } & jet

Measurement of sound w.r. to P_{ref}

$$SPL = 20 \log_{10}\left(\frac{P}{P_{ref}}\right) \quad (240)$$

where P = measured sound w.r to the threshold level ($20\ \mu Pa$).

If two sources are there :-

$$L_{eq} = 10 \log_{10}\left(\sum_{i=1}^{n} 10^{L_i/10} \times t_i\right)$$

where L_{eq} = the equivalent sound pressure level in decibal

n = total no. of sound pressure level recorded

L_i = values of the sound pressure level recorded in db with $i = 1, 2, 3, \ldots$

t_i = time duration of the diff^n sound pressure levels recorded, expressed as the fraction of total recording time

80 db — 5 min
90 db — 15 min

$L_1 = 80$ db, $t_1 = 5/100$
$L_2 = 90$ db, $t_2 = 15/100$

$$L_{eq} = 10 \log_{10}\left(10^{80/10} \times \frac{5}{100} + 10^{90/10} \times \frac{15}{100}\right)$$

$= 81.90$ db

Causes of Sound Pollution

(1) Domestic Sources
(2) Vehicular Sources (24)
(3) Construction Activities
(4) Machineries
(5) Election Campaign & Loud speakers / Public fun^{n}.

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

(11) Sound can be classified as three types

(1) Continuous noise :- It is an unintrupted sound level that varies less than 5db.
eg :- Running fan

2. Intermittent Noise :- It is a noise which is continuous for more than 1 sec & it is interrupted intermittently.
eg a drilling machine (242)

3. Impact Noise :- It is characterised by change of sound pr of atleast 40 db within the duration of less than 1 sec.
eg :- Turbines & hammers.

Ques The reference Pr used in the determination of sound pr is -

a) 20 μpa b) 20 db c) 10 μpa d) 10 db

Ques According to the Noise pollution regulation & control rules of 2000 of the ministry of environmental & forest of India, the day time & night time noise limits in ambient air for residential area expressed in db.

Ans night - 45 db day - 55 db

Q A 60 db of noise is measure with the 20 μpa noise and another 60 db is measured with the 20 μpa 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

$$P_{rms} = \sqrt{P_1^2 + P_2^2} \quad (24)$$

$$SPL = 20 \log_{10}\left(\frac{P_1}{P_{ref}}\right)$$

$$\overset{3}{\cancel{6}}p = 2p \log_{10}\left(\frac{P_1}{20}\right)$$

$$P_1 = 20 \times 10^3 \mu Pa = P_2$$

$$P_{rms} = \sqrt{P_1^2 + P_2^2}$$

$$= \sqrt{2 \times (20 \times 10^3)^2}$$

$$= 28284.2 \mu Pa$$

$$SPL = 20 \log_{10} \frac{P_{rms}}{P_{ref}}$$

$$= 20 \log_{10}\left(\frac{2.82 \times 10^4}{20 \mu Pa}\right)$$

$$SPL = 63.01 \text{ dB}.$$

Qe. A noise level of 80 db is lasting for 10 min 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?

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$$SPL = 10 \log_{10} \left[\sum_{i=1}^{n} 10^{Li/10} \times t_i \right]$$

$$= 10 \log_{10} \left[10^{80/10} \times \frac{10}{95} + 10^{60/10} \times \frac{80}{95} + 10^{100/10} \times \frac{5}{95} \right]$$

$$= 87.3 \text{ db}$$

Thumb Rule:- If the two pr. intensities of the noises are x & y decibals, and if the difference in pressure level is more than or 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.

Q. While recording the weighted sound level 4 reading have been taken at a sight site at diff^{n} types of the day these readings are 20, 56, 66, 42 dB. With reference to the 20 μpa, then the avg sound level expressed in the dB each.

$$SPL = 20 \log_{10}\left(\frac{P}{P_{ref}}\right)$$ (2M)

$$20 = 20 \log_{10}\left(\frac{P_1}{20}\right)$$

$$P_1 = 20 \times 10^{1} \mu pa$$

$$56 = 20 \log_{10}\left(\frac{P_2}{20}\right)$$

$$P_2 = 12619.14 \mu$$

$$66 = 20 \log_{10}\left(\frac{P_3}{20}\right)$$

$$P_3 = 39905.24$$

$$42 = 20 \log_{10}\left(\frac{P_4}{20}\right)$$

$$P_4 = 2517.8$$

$$P_{avg} = \frac{P_1 + P_2 + P_3 + P_4}{4}$$

$$= 13310.45$$

$$SPL = 20 \log_{10}\left(\frac{13310.45}{20}\right)$$

$$SPL = 56.78 dh.$$

Q.65.

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.c. 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 1.04, density of water is 1000 kg/m³, The digestion period is 15 days.

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Quality of sewage water = 5 MLD

$= 5 \times 10^6$ lit/day.

suspended solids in sewage water $= 250 \times 10^{-6}$ kg/l $\times 5 \times 10^6$ l/d

$= 1250$ kg/day.

60% of suspended solids removed by PST

$= 0.6 \times 1250$

$= 750$ kg/day

m.c of influent sewage sludge = 96%

4 kg of solid makes ——— 100 kg of sludge

750 ——— $\frac{100}{4} \times 750$

$= 18750$ kg/day.

sp. gr. of sludge = $\frac{\rho_{sludge}}{\gamma_w}$ (247)

density of sludge ρ_{sludge} = 1.03×10^3 kg/m^3

= 1030 kg/m^3.

Vol. of sludge = $\frac{\text{wt. of sluge}}{\text{density of sludge}}$

$V_1 = \frac{18750}{1030} = 18.20 \text{ m}^3$

for calculation of V_2 –

Total solids = volatile solids + non-volatile solid.

= $\frac{70}{100} \times 750 \times 0.35 + \frac{30}{100} \times 750$

= 408.75 kg/day.

digested sludge having 8% of sludge.

8 kg of solids makes — 100 kg of sludge.

408.75 kg — = $\frac{100}{8} \times 408.75$

= 5109.375 kg/day.

density of the digested sludge = sp gr $\times \gamma_w$

= 1.04×10^3

= 1040 kg/m^3

Vol. of digested sludge = $\frac{5109.375}{1040} = 4.9 \text{ m}^3$

$V_2 = 4.91 m^3$

$V = \left(V_1 - \frac{2}{3}(V_1 - V_2)\right) t_1$ (248)

$= \left(18.20 - \frac{2}{3}(18.20 - 4.91)\right) \times 15$

$V = 140.1 m^3$

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.

Total vol. of the sewage = 10000 m^3

Total suspended solids = 200 mg/l

Total suspended solids = $10000 \times 10^3 \times 200 \times 10^{-6}$

= 2000 kg.

a) By assuming 60% of the suspended solids are removed in the PST = $\frac{60}{100} \times 2000 = 1200$ kg

b) By assuming out of the removed suspended solids (1200 kg) → volatile solids as 65%.

$= \frac{65}{100} \times 1200 = 780$ kg (volatile)

0.9 m^3/kg of CH_4 released :

1 kg — 0.9

780 kg — $0.9 \times 780 = 702 m^3$ } remaining

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SDT → CH_4 → 65-70%
CO_2 → 30%.

4. A population of town is 30,000, domestic sewage produced is 120 lit/capita/day having BOD of 200 mg/lt. Industrial sewage produced is 3×10^5 lit/day having BOD of 800 mg/lt. 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.

Ans:-

79.5, BOD = 40.8