**7. Disinfection

→ Disinfection is method of removing disease causing organisms (present in water (infectious matter).

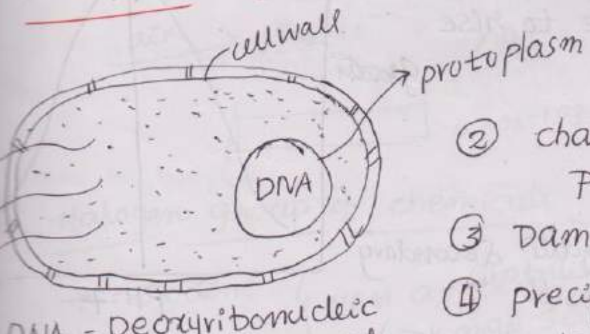
→ In addition to this to safe guard water against feature possible potential contamination while conveying the water to the consumers.

→ The substances used to disinfect water are known as "Disinfectants."

* Requirements of Disinfectants :-

1) Kill the organisms.
2) Instantenous killing of the organism.
3) Residual power is required for Long time.
4) Disinfectant only kill the pathogens it is not affect the human beings.
5) It is easily Detectable.

* Methods of destruction of organisms :-



① Damage of the cell wall

② changing the cell wall Permeability.

③ Damage of protoplasm.

④ precipitation of essential nutrients, enzymes etc

DNA - Deoxyribonucleic acid

* Methods of disinfection :-

① Physical Methods.

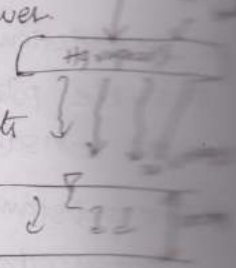
② Chemical Methods - widely used

① physical Methods :— (NO residual power

ⓐ using heat energy ex. – Boiling. (best method
(very expensive
(Instant kill)

ⓑ using light energy ex:– u.v. ray treatment

→ No residual power.
→ Instant kill
→ No side affects



$$\boxed{\ln \frac{N_t}{N_0} = -KIt}$$

→K = Inactivation rate constant.
I = Instensity of u.v radiation ($\mu w/cm^2$)
t = exposure time (min)@ "sec"
Nt, No = no of organisms final & Initial.

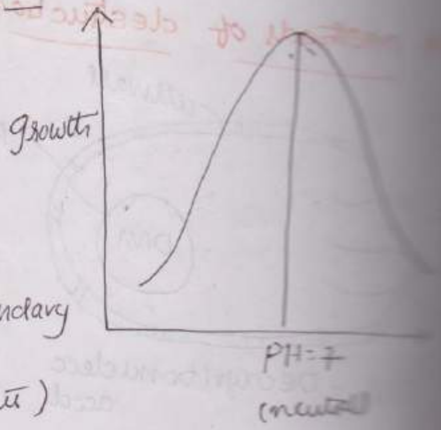
* wave length 250 – 260 nm

② chemical Methods :—

ⓐ using acids & Alkales :—

→ using excess lime to rise the pH of water

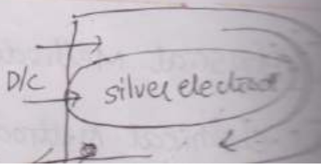
$p^H > 9.5$



→ lime added to water secondary effects. ~~are~~ is possible
(precipitation is, colous of water)
form with lime.

ⓑ Using Metal ions :—

→ Silver (20–40% PPb)
↓
→ **Electrokatadyn process



ⓒ using surface active chemicals.

eg:- soaps, detergents, phenols etc

ⓓ potassium permanganate.

eq (It is slow procen) (24 - 48 hrs) → pink colour

(rural wells are ~~d~~ used this procen)

ⓔ ozone. :—→ effective kill

→ little residual powes

→ No secondary problem

ⓕ $O_3 + H_2O \rightarrow \boxed{2H_2O_2}$] (~~hydratecat~~ produce radicals) (hydroxyl free

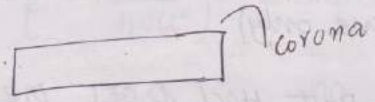
$O_3 + HO_2 \rightarrow 2O_2 + \boxed{HO}$] → oxidized power is more

=) HO_2 & HO — Hydroxyl free radicals.

=) It can't stove generate before the procen.

ozone ⇒ $\boxed{1\,kg\ O_3 \ \cancel{Kw} \rightarrow 0.82\ Kw\text{-}hr}$

→ ozone is produced by Ozonator



$air \rightarrow O_2 + 2e^- \rightarrow O_3$

$\rightarrow 2O$

$O + O_2 \rightarrow O_3$.

ⓕ Halogen group of chemicals.

→ Iodine } Non availability

Bromine } Large scale operation is not there

chlorine → long persistent residual powes

↓

* Tri halo methanes (THM) → carcinogenic (cancer)

* Chlorination - To treat water with the

* chlorination:-

→ chlorination is the method of adding chlorine or its compounds to water.

→ It is cheap (low cost) ÷

→ very high residual power.

→ Available plenty.

$$cl_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{\underbrace{Hocl}} + Hcl \quad {}_{\rightarrow pH<7.5}$$

$$Hocl \underset{pH>7.5}{\overset{pH}{\rightleftarrows}} H^+ + ocl^-$$

→ $\left.\begin{matrix} Hocl \\ ocl^- \end{matrix}\right\}$ freely available chlorine.

→ very high destructive power (Hocl >> ocl⁻)

→ Hocl → Neutral compound

*① pH : 0 – 5 → only Hocl present in water.
(But in reality in this pH range cl_2 remain as elemental chlorine only).

② pH : 5 – 7.5 → Both Hocl & ocl⁻ present in water
(But Hocl >>> ocl⁻) (Hocl predominently present in water)

③ pH : 7.5 – 10 → Both Hocl & ocl⁻ present in water
(But ocl⁻ >>> Hocl)

④ pH > 10 → only ocl⁻ ~~present~~ present in water.

⇒ $cl_2 + H_2O \rightarrow Hocl + Hcl$

⇒ Ionization constant

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

$$\Rightarrow \boxed{\frac{OCl^-}{HOCl} = \frac{K}{H^+}} \longrightarrow (I)$$

$$* \quad \boxed{\% \, HOCl = \frac{HOCl}{HOCl + OCl^-} * 100} \longrightarrow (II)$$

→ convert into Molar concentration

(P4) HOCl = 90%

$$90\% = \frac{HOCl}{HOCl + OCl^-} \times 100$$

$$90\% = \frac{1}{1 + \frac{OCl^-}{HOCl}} * 100$$

$$90\left[1 + \frac{OCl^-}{HOCl}\right] = 100$$

$$\frac{OCl^-}{HOCl} = \frac{100}{90} - 1$$

$$\frac{OCl^-}{HOCl} = 0.111$$

$$\Rightarrow \frac{K}{H^+} = 0.111$$

$$\frac{2.7 \times 10^{-8}}{0.111} = H^+$$

$$H^+ = 2.43 \times 10^{-7} \text{ mol/lit}$$

$$p^H = \log_{10}\left[\frac{1}{H^+}\right] = \log_{10}\left[\frac{1}{2.43 \times 10^{-7}}\right]$$

$$pH = 6.6$$

(14) $K = 2.5 \times 10^{-8}$ mol/L ; HOCl $pH = 7.0$

sol

$$\frac{OCl^-}{HOCl} = \frac{2.5 \times 10^{-8}}{10^{-7}}$$

$pH = 7.0$

$H^+ = 10^{-7}$ mol/lit

$$\Rightarrow \left[HOCl + OCl^- \rightleftharpoons HOCl \quad K = \frac{[HOCl]}{[HOCl + OCl^-]} \right]$$

$$\frac{OCl^-}{HOCl} = 0.25$$

$$\Rightarrow \% HOCl = \frac{1}{1 + \frac{OCl^-}{HOCl}}$$

$$= \frac{1}{1 + 0.25} = \frac{1}{1.25} = 0.8$$

$$\boxed{\% HOCl = 0.8}$$

① If 0.6 mg/L of chlorine is added to water whose pH is 6.8. Find out HOCl & OCl⁻ concentrations in water in (mg/l)? Take $K = 2.7 \times 10^{-8}$ mol/lit

sol:-

$$H^+ = 10^{-6.8} \text{ mol/lit}$$

$$\frac{OCl^-}{HOCl} = \frac{\cancel{25}\ 2.7 \times 10^{-8}}{10^{-6.8}} = 2.7 \times 10^{-1.2}$$

$$\frac{OCl^-}{HOCl} = 0.17$$

$OCl^- = 14.53\%$

$\% HOCl = 0.85 = 85.47\%$ ~~OCl = 0.15~~

$$* \underset{(mol/lit)}{Cl_2} = \frac{Cl_2 (mg/l)}{mol\ wt \times 1000} = \frac{0.6}{(2 \times 35.5) \times 1000}$$

$$* \ Cl_2 (mol/lit) = 8.45 \times 10^{-6} \text{ mol/lit}$$

$\Rightarrow$ HOCl (mol/lit) = $8.45 \times 10^{-6} \times \frac{85.47}{100} = 7.22 \times 10^{-6}$ mol/lit

$\Rightarrow$ OCl^- (mol/lit) = $8.45 \times 10^{-6} \times \frac{14.53}{100} = 1.22 \times 10^{-6}$ mol/lit

$\rightarrow$ HOCl (mg/l) = HOCl (mol/lit) * mol. wt HOCl × 1000

$= 7.22 \times 10^{-6} \times (1+16+35.5) \times 1000$

$= 0.379$ (mg/l).

$\rightarrow$ OCl^- (mg/l) = OCl^- (mol/lt) * mol. wt OCl^- × 1000

$= 1.22 \times 10^{-6} \times (16+35.5) \times 1000$

$= 0.063$ (mg/l)

* chlorine Demand of water :-

→ chlorine first reacts with Iron & Manganese,

→ Next reacts with the Ammonia → present in water

→ After reacting with ~~NH~~ ammonia if any excess chlorine present in water then it reacts with Microorganisms present water

* if any chlorine remains as in water it apperas as a chlorine residual. Therefore

chlorine demand of water = chlorine dose added − Residual Cl_2 in water

* $\boxed{\text{chlorine demand of water} = \text{Chlorine dose added} - \text{Residual } Cl_2 \text{ in water.}}$

② A chlorine dose of 1.2 mg/l is added to the water to have a chlorine residual of 0.2 mg/l. Find total chlorine demand of water in (kg/day) to treat 5 mLD of water sol:- chlorine demand = $1.2 - 0.2 = 1$ (mg/l)

Total chlorine demand = Q × chlorine demand (mg/l)

= 5×1

= 5 (kg/day)

(02) ~~Q = : Q = 20000 m³/day ⇒ 8kg~~

~~chlorine demand =~~

~~Total chlorine demand = 20,000~~

(02) $Q = 20{,}000\ m^3/day$; total chlorine demand = 8 kg/day.

Residual ~~cl~~ chlorine = 0.15 mg/l.

$Q = \frac{20{,}000 \times 1000}{10^6}$ $\quad Q \times Cl_2 = 8$ kg/day

$Cl_2 = \frac{8}{20}$ (mg/l)

Q = 20 MLD $\quad Cl_2 = 0.4$ mg/l

Chlorine demand = $0.4 - 0.15$

= 0.25 (mg/l)

(09) Total chlorine Demand = 0.7 mg/l.

$pH = 7$ ($pH = 8$, $k = 2.7 \times 10^{-8}$ @ 20°c)

sol: $H^+ = 10^{-7}$ mol/lit ; $H^+ = 10^{-8}$ mol/lit ; $k = 2.7 \times 10^{-8}$

$$\% HOCl = \frac{1}{1 + \frac{2.7 \times 10^{-8}}{10^{-7}}} \times 100 = 78.74$$

$$\% HOCl = \frac{1}{1 + \frac{2.7 \times 10^{-8}}{10^{-8}}} \times 100 = 27.03$$

$$\therefore \left[Cl_2 \text{ dose at any } pH = Cl_2 \text{ dose @ given } pH * \frac{\% HOCl \text{ @ given } pH}{\% HOCl \text{ @ any } pH} \right]$$

$\therefore$ Cl_2 dose at any pH = $0·7 \times \frac{78·74}{27·03} = 2·04\ mg/l$

* If pH reduces to 6·5 %. Cl_2 dose is less

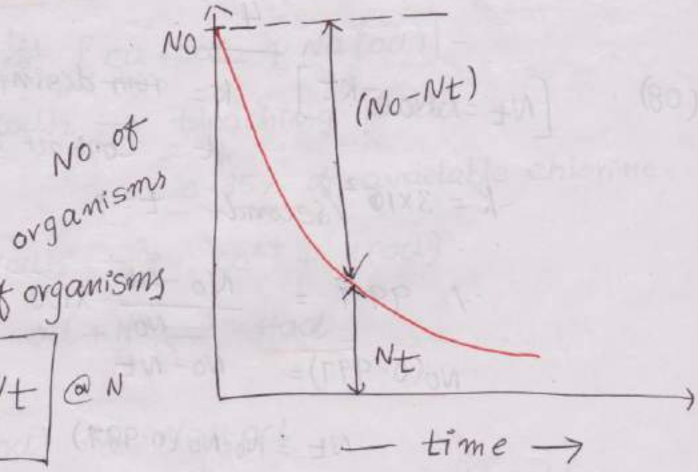
$$\therefore \%\ HOCl = \frac{1}{1 + \frac{2·7\times10^{-8}}{10^{-6·5}}} \times 100 = 92·13$$

$$\therefore \quad = 0·7 \times \frac{78·74}{92·133} = 0·598\ mg/l$$

$$= 0·6\ mg/l$$

* Chick's law for disinfection:-

$$\rightarrow \boxed{\text{percentage kill (or) destruction} = \frac{N_0 - N_t}{N_0} * 100}$$



→ Rate of change of organisms

$$\boxed{\frac{dN}{dt} \propto N_t} \ @\ N$$

$$\frac{dN}{dt} = -K N_t\ (N)$$

$$\int_{N_0}^{N_t} \frac{dN}{N_t\ (N)} = \int_0^t -K\,dt \Rightarrow \ln[N_t]_{N_0}^{N_t} = -K[t]_0^t$$

$$\Rightarrow \ln\left[\frac{N_t}{N_0}\right] = -Kt$$

$$\frac{N_t}{N_0} = e^{-Kt}$$

$$\boxed{N_t = N_0 e^{-Kt}}$$ → chick's law for

⑪ MPN of total coliform as $10^6/100$ ml.

MPN Declines to total coliform $10^2/100$ ml

% ge removal = % Kill

$$= \frac{N_0 - N_t}{N_0} \times 100$$

$$= \frac{10^6 - 10^2}{10^6} \times 100$$

$$= 10^6$$

$$= 99.99\%$$

$$\boxed{\begin{aligned}\log_{10}(R) &= \log_{10}(N_0) - (\log)_{10}(N_t)\\ &= \log_{10}(10^6) - \log_{10}(10^2)\end{aligned}}$$

$$= \underline{4.}$$

(08) $[N_t = N_0 e^{-kt}]$ k = ~~fem~~ disinfection constant

t = contact time

$k = 3\times10^{-2}$/second t = ?

$$\% \; 99.7 = \frac{N_0 - N_t}{N_0} \times 100$$

$$N_0(0.997) = N_0 - N_t$$

$$N_t = N_0 - N_0(0.997)$$

$$N_t = N_0(1 - 0.997)$$

$$N_t = N_0(10^{-3})$$

$$\cancel{N_0}(10^{-3}) = \cancel{N_0}\, e^{-3\times10^{(-2)}(t)}$$

$$10^{-3} = e^{-}$$

$$-6.90 = \ln(-3\times10^{-2})(t)$$

$$* \quad \% ge\ (kill) = \frac{N_0 - N_t}{N_0} \times 100 = \frac{N_0 - N_0 e^{-kt}}{N_0} \times 100$$

$$= (1 - e^{-kt}) \times 100$$

$$\Rightarrow 99.7 = (1 - e^{-kt}) \times 100$$

$$\left(1 - \frac{99.7}{100}\right) = e^{-kt}$$

$$\left(1 - \frac{99.7}{100}\right) = e^{-3 \times 10^{-2} \times t}$$

$$\Rightarrow \quad t = 192.6\ sec \quad (3\ min\ 23\ sec)$$

$$\therefore \quad t = 192.6\ sec\ (3\ min\ 23\ sec)$$

* Form's chlorine :-

I. Hypochlorites [$Ca(ocl)_2$ & $Na(ocl)$]

ⓐ $Ca(ocl)_2 \rightarrow$ bleaching powder

$\downarrow$ 30-35% of available chlorine.

$$Ca(ocl)_2 \longrightarrow Ca^{2+} + 2(ocl)$$

$$ocl + H \rightleftharpoons Hocl$$

ⓑ $Na(ocl) \rightarrow Na + ocl$

$\downarrow$ 5-15% of available chlorine

Adv.-

⇒ cheap

Dis.-

→ ① little amount of chlorine is available.

② It doesn't mix with water easily. great effort is required

③ It doesn't store long time (time — loose strength)
expose to light, air

④ It imparts, colour, taste, odour to water.

* chlorine (Cl_2) dose : x mg/l.

$$\text{Bleaching powder dose} = \frac{Cl_2 \text{ dose}}{\% \text{ chlorine in bleaching powder}}$$

Ex → (P₁) 10 kg of bleaching ~~poweder~~ per day is ~~water~~ added to water to Disinfectant ~~[illegible]~~ 1 MLD of water to have a residual chlorine of 0.1 mg/L. Assume bleaching powder content is 30% available Also find out chlorine demand of water ?

sol:- $$\text{Bleaching powder dose} = \frac{~~10\,kg~~\ Cl_2 \text{ dose.}}{\% \text{ chlorine in bleaching powder}}$$

$$(10\,mg/l)\ (~~10\,kg~~) = \frac{Cl_2 \text{ dose}}{(30)\%}$$

$$Q = 1\,MLD.$$

→ Total bleaching powder used = 10 kg/day.

→ Total bleaching powder = Q × dose of bleaching powder

$$10 = 1 \times \text{dose of bleaching powder}$$

$$\text{Bleaching powder dose} = \frac{10}{1}\ mg/l.$$

∴ chlorine dose = bleaching powder dose × %ge available of chlorine

$$= 10 \times \frac{30}{100} = 3\,mg/l$$

* Chlorine demand = Cl_2 dose − Residual Cl_2

$$= 3 - 0.1 = 2.9\,mg/l.$$

Q. A 2 MLD of water ~~disinfected~~ by chlorination using ~~is~~ bleaching powder. A chlorine dose of 0.8 mg/L ~~of~~ is ~~residual~~ ~~[illegible]~~ to have a residual 0.2 mg/L. find the monthly bleaching powder requirement if it contain 35% of available chlorine Also workout total chlorine demand in kg/day.

chlorine dose required = 0.8 mg/L

~~Bleaching powder dose =~~

Bleaching powder dose required = $\frac{0.8}{\frac{35}{100}}$

= 2.285 mg/l

⇒ 2.285 mg/L bleaching powder = 0.8 mg/L of chlorine dose

Q = 2MLD

* Total bleaching powder demand = Q × dose of bleaching powder

= 2 × 2.285

= 4.57 kg/day

* Monthly bleaching powder requirement : daily requirement × 30

= 4.57 × 30

= 137.1 kg/month

* chlorine demand = chlorine dose − Residual chlorine

= 0.8 − 0.2 = 0.6 mg/l

→ Total Cl_2 demand = Q × dose of Cl_2

= 2 × 0.6 = 1.2 kg/day

(P-29)

(P1)

chlorine dosage is = 0.2 ppm = 0.2 mg/l

bleaching powder contains = 30%

Bleaching powder dose required = $\frac{0.2}{\frac{30}{100}}$

= 0.667 mg/l

* Total bleaching powder demand = Q × dose of bleaching powder

(m^3 = 1000 L)

⇒ 150 lt/day

Q = 150 × 10^{-3} m^3/day

Q = population × per capita water dem

Q = 20,000 × 150 ~~×~~ m^3/day

= 3 MLD

= ~~0.450~~ 3 × 0.667

= 2 kg

② Chloramines :— It produce (Combined Residual)

Adv :— 1) To produce long persistent residualals.

2) Quickly dissolve in water.

3) No side effect (secondary problems are not there).

It doesn't produce any carcinogenic materials are produced

Dis :— 1) It is not so fast (Instantaneously not react).

$Cl_2 + H_2O \rightarrow HOCl + OCl$

$HOCl + NH_3 \rightarrow \underline{NH_2Cl} + H_2O$

** NH_2Cl — Mono chloramine ($pH > 8.5$) } (both are present)

$HOCl + NH_2Cl \rightarrow NHCl_2 + H_2O$

* $NHCl_2 \rightarrow$ Dichloramine (pH 5-8) }

$HOCl + NHCl_2 \rightarrow NCl_3 + H_2O$

~~NH~~ * $NCl_3 \rightarrow$ Trichloramine

***

$pH > 8.5 \rightarrow$ Mono chloramine

$pH : 5-8 \rightarrow$ Mono &, dichloramine.

$pH : 4.4-5 \rightarrow$ only dichloramine.

$pH < 4.4 \rightarrow$ Trichloramine

***

$NH_2Cl \rightarrow pH > 8.5$

NH_2Cl & $NHCl_2 \rightarrow pH : 5-8$

$NHCl_2 \rightarrow pH : 4.4-5$

$NCl_3 \rightarrow pH < 4.4$

③ chlorine gas (Cl_2) (elemental chlorine)

→ It produce free residual → (HOCl & OCl⁻)

Dis. – ① T.H.M (Trihalo methanes) are formed in water.

④ chlorine dioxide (ClO_2) :-

→ As powerful as chlorine ozone → NO T.H.M formation

→ It is independent of pH. Highly ~~destitive~~ destuctive power

Dis. – ① very expansive

② we cant store gas

* Types of chlorination :-

① ~~pre~~ plain chlorination → only chlorine is used to treat water e.g. (springs) (Infiltration galleries)

② pre " → Add chlorine before filtration.

③ post " → Add chlorine after filtration.

④ Double chlorination → before & after filtration Chlorine add

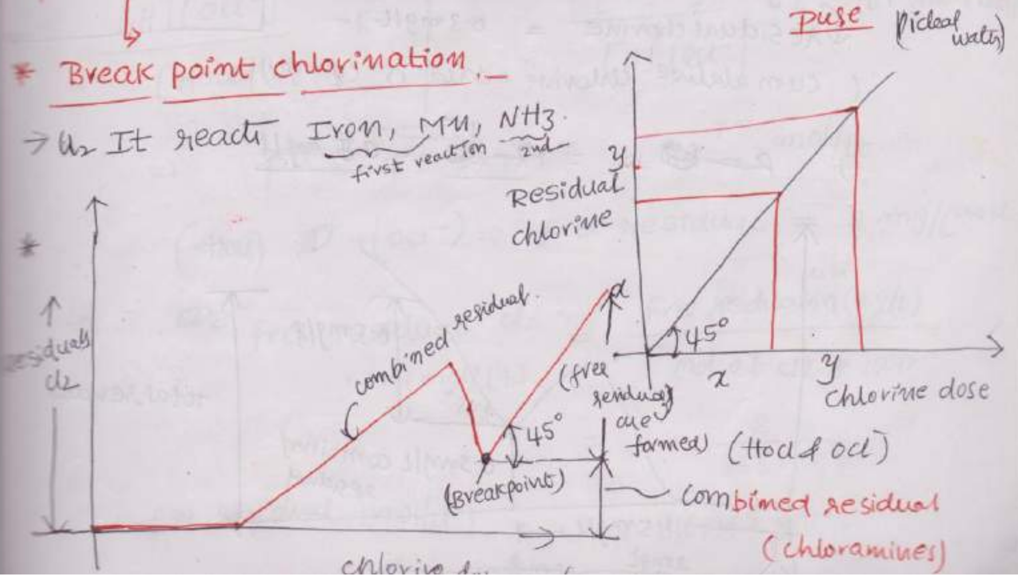
⑤ super chlorination → beyond the ~~do~~ normal dose chlorine is added.

⑥ Dechlorination → is carried out by treat water with the (Sodium Thiosulphate)

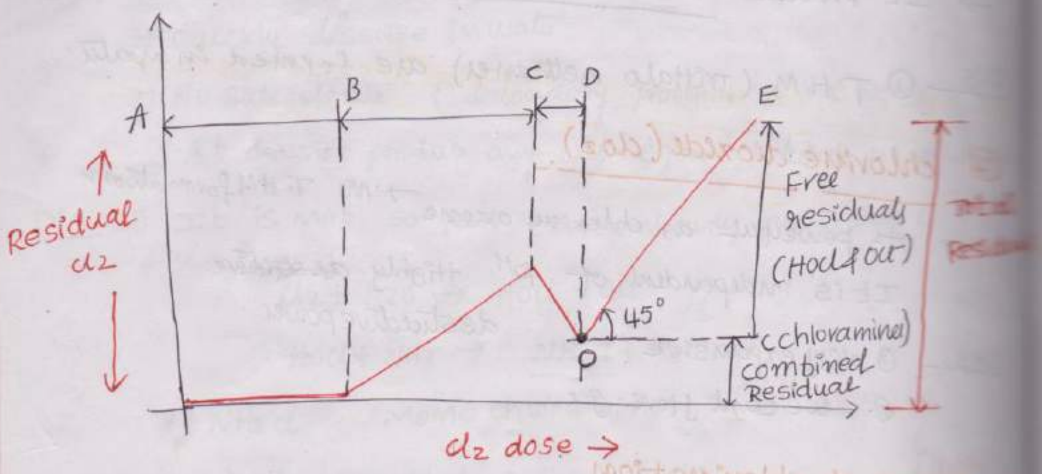
*** ⑦ Break point chlorination

* Break point chlorination :-

→ Cl_2 It reacts Iron, Mn, NH_3.
first reaction 2nd



* Free residual + combined Residual → Total Resid



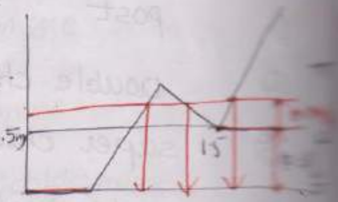
* AB :- Cl_2 oxidizing Fe^{2+} & Mn^{2+}

BC :- Cl_2 reacting with NH_3 & ~~for~~ forming chloramin

CD :- Destruction of micro organisms.

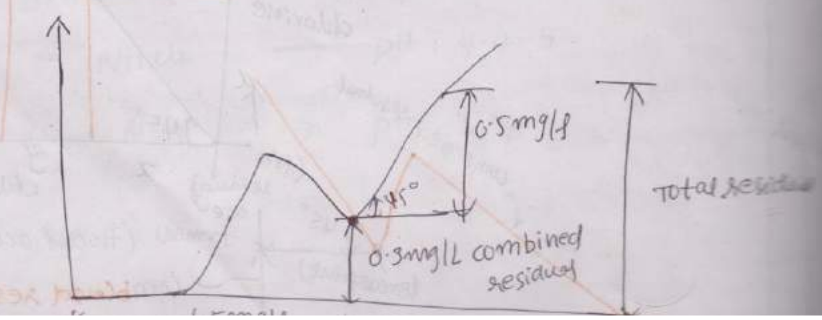
DE :- Formation of free residuals.

P → Break point



(P)
(03) (P) dosage at break point = 1.5 mg/l.
residual chlorine = 0.3 mg/l.
(cumulative chlorine added is 2~~8~~ mg/l)

=) ~~P – 1.3~~ = $\frac{15}{~~2 - 0.3~~}$ = ~~0.5 mg/l~~



* Total Residual = 0.8 mg/l.

free residual = 0.5 mg/l

Combined residual = 0.3 mg/l.

* Test to be performed to find out residual chlorine :-

ⓐ orthotolidine test (o - tolidine)

→ lime yellow colour is formed (chlorine is present)
(2 drops of o-tolidine is added to water).
(No colour change chlorine is absent)

ⓑ OTA (orthotolidine arsenete test).
↙ → Due to free chlorine
↓ (suppersed) Due to combined chlorine

ⓒ Starch - Iodide test

(P12) Cl_2 added to drinking water = 8 mg/L as Cl_2.

Free chlorine residual = 2 mg/L as Cl_2

pH = 7.5

concentration of OCl^-. ($Cl = 35.5$) (Atomic weight)

$HOCl \rightleftharpoons H^{+} + OCl$

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

$H^{+} + OCl^{-} \rightleftharpoons HOCl$

$$\frac{[HOCl]}{[H][OCl^-]} = K = 10^{7.5}\ \text{mol/lt}$$

$\Rightarrow$ pH $= 7.5 \Rightarrow H^{+} = 10^{-7.5}$ mol/lt.

$(HOCl) + (OCl^-) \Rightarrow$ free residual $= 2$ mg/L as Cl_2.

$$\Rightarrow \text{free residual } Cl_2 \text{ in (mol/Lt)} = \frac{\text{free residual } Cl_2 \text{ in (mg/L)}}{\text{mol wt } Cl_2 * 1000}$$

$$= \frac{2}{35.5 \times 1000}$$

free residual (mol/lt) $= 2.816 \times 10^{-5}$ mol/lt

$$\Rightarrow \frac{[HOCl]}{[OCl]} = K[H^+] = 10^{7.5} \times 10^{-7.5}$$

$$= 1$$

$$\Rightarrow [HOCl] = [OCl]$$

but $\overset{[HOCl]}{\cancel{[HCl]}} + [OCl^-] = 2.816 \times 10^{-5}$ mol/lit

$$\Rightarrow OCl^- + OCl^- = 2.816 \times 10^{-5}$$

$$OCl^- = \frac{2.816 \times 10^{-5}}{2}$$

$$OCl^- = 1.408 \times 10^{-5} \text{ mol/lit}$$

* concentration of residual $OCl^- = 1.408 \times 10^{-5}$ mol/lit.

(13) Amount of bleaching powder = 20%

(bleaching powder = 5 kg)

(chlorine = 1 kg)

(

neutral)

$10^{-7.5}$ mol/~~lit~~

mol/lit.

al. = 2 mg/L as Cl_2

$$\frac{Cl_2 \text{ residual in (mg/L)}}{\text{mol wt } Cl_2 * 1000}$$

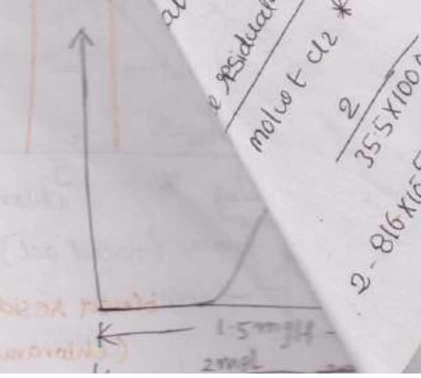
$$\frac{2}{35.5 \times 1000}$$

2.816×10^{-5} mol/lit

① (03) (P)

(Cl

=) A



* factors affecting chlorination

① pH of water   ↑ pH → efficaency ↓
↓ pH → efficieny ↑

② Dose of chlorine

③ form of chlorination

④ Types of organisms.

⑤ contact time

⑥ Temperature

* Factors affecting disinfection

(i) pH

② method of disinfection

③ dosage

④ Types of organisms

⑤ Exposure time

⑥ Temperature

* vanthoff Arhimeus equation

$$\boxed{\ln \frac{t_1}{t_2} = \frac{E(T_2-T_1)}{R T_1 T_2}}$$

$$\boxed{c^n t_p = k}$$

C- concentration of dose.

→ Ground water is free from dissolved solids & colloids.

* First treatment is given to Ground water is Aeration:-

① Aeration:- 1. To expel undesirable dissolved gases such as CO_2 & H_2S.

② Increase of O_2 Levels.

③ colour removal $[Fe^{2+}$ & $Mn^{2+}]$

④ Iron & Manganese removal

⑤ ~~Colour~~ odour & taste control.

* Henry's law $\boxed{\frac{dc}{dt} \propto (C_s - C_t)}$

$C_t > C_s \rightarrow$ desorption

$C_t < C_s \rightarrow$ absorption

C_t – Actual concentration of gas

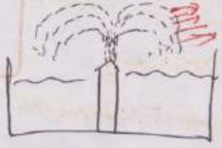
C_s → saturation concentration of gas.

→ Aeration is carried out by 2 methods:-

ⓐ dispersing water into air. [(desorption >> absorption)]

ⓑ Dispersing air into water [(Absorption >> desorption)]

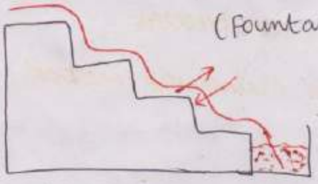
ⓐ Dispersing water into air:-



(Fountain Aerators)

1. Fountains aerators

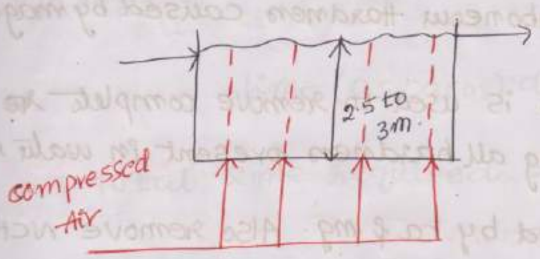
2. cascade aerators



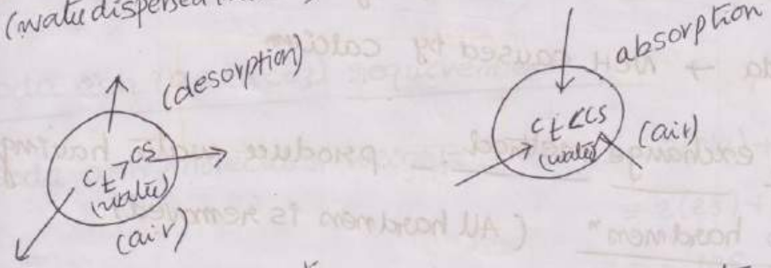
3. Tray Towers.

* $\left.\begin{matrix}Fe^{2+}\\Mn^{2+}\end{matrix}\right\}$ Solute $\left.\begin{matrix}Fe^{3+}\\Mn^{4+}\end{matrix}\right\}$ Insoluble.

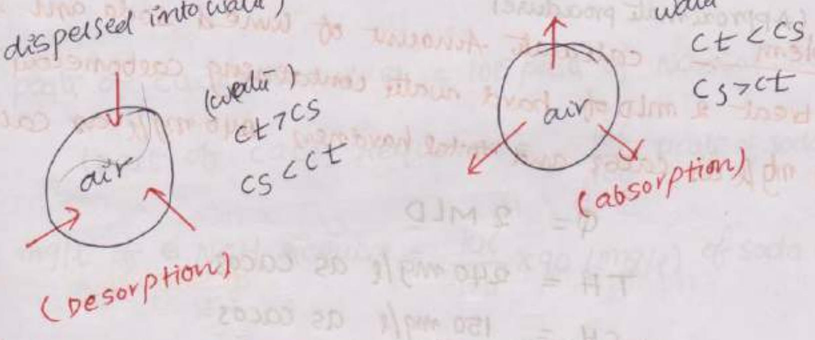
⑥ Dispersing air into water :-



⑦ (water dispersed into air)



(Air is dispersed into water)



* Removal of Hardness :- (water softening)

1) Boiling
2) Lime treatment
3) lime soda process
4) Ion exchange Method.

* Boiling :- only remove carboneous hardness caused by calcium (Ca^{2+}) alone. (remaining hardness present in water without being remo

→ It is inefficient to remove other hardness / Mg^{2+} etc

* lime treatment :- Removes all carboneous hardness but also remove non carboneous Hardness caused by magnesium

* lime soda process :- is used to remove complete ~~re~~ hardness. (remaining all hardness present in water).

lime → CH caused by ca & mg. Also remove NCH caused by mg.

Soda → NCH caused by calcium.

* Ion exchange method :- produce water having "zero hardness" (All hardness is removed).

(Approximate procedure)

Problem :- calculate Amount of lime & soda ash required to treat 2 mLD of hard water containing carboneous hardness 150 mg/l as $CaCO_3$ and total hardness 240 mg/l as $CaCO_3$.

sol :-

$Q = 2$ MLD

TH = 240 mg/l as $CaCO_3$

CH = 150 mg/l as $CaCO_3$.

NCH = 90 mg/l as $CaCO_3$.

$$\boxed{NCH = (TH - CH)}$$

* lime (CaO) calculation is requirement is calculated based on T.H.

* Soda ash (Na_2CO_3) requirement is calculated based on NCH.

* lime (as $CaCO_3$) requirement :-

→ 100 part of $CaCO_3$ require : 56 part of lime as ~~$CaCO_3$~~ CaO.

1 part of $CaCO_3$ required = $\frac{56}{100}$ part of lime as CaO.

→ 240 mg/l of $CaCO_3$ required = $\frac{56}{100} \times 240$ (mg/l) of CaO

lime (as $CaCO_3$) dose = 134.4 mg/l.

* Total lime required = Q × dose of lime
= 2 × 134.4
= 268.8 kg/day.

* Soda ash (as $CaCO_3$) requirement :-

→ soda ash molecular weight (Na_2CO_3) = 2(Na) + C + 3(O)
= 2(23) + 12 + 3×16
= 106.

→ 100 part of $CaCO_3$ requires = 106 part of Na_2CO_3. (soda)

1 part of $CaCO_3$ required = $\frac{106}{100}$ part of soda ash.

→ 90 mg/l of NCH require = $\frac{106}{100} \times 90$ (mg/l) of soda ash.

dose of soda ash = 95.4 mg/l.

* Total soda ash required = Q × dose of Na_2CO_3
= 2 × 95.4
= 190.8 kg/day

* Exact procedure :- [each of the
is given]

$Ca(OH)_2$: $\cdot CO_2 + HCO_3^- + Mg^{2+}$
[Hydrated lime]

Na_2CO_3 : $Ca^{2+} + Mg^{2+} - $(Alkalinity)
(Soda ash)

Ⓟ1 calculate the amount of lime & soda ash required for the water softening the concentration of hardness & alkalinity causing substances given below.

Substance	concentration	eq.wt	$m.eq/lit = \frac{x(mg/l)}{eq.wt}$
CO_2 :	10 mg/l.	22	0.45
Ca^{2+} :	70 mg/l.	20	3.5
Mg^{2+} :	40 mg/l	12	3.33
HCO_3^- :	250 mg/l	61	4.09
CO_3 :	2 mg/l.	30	0.067
OH^- :	0.02 mg/l	17	0.00117

Alkalinity

Sol:- Dose of $Ca(OH)_2$ [Hydrated lime] $= CO_2 + HCO_3^- + Mg^{2+}$

$$= 0.45 + 4.09 + 3.33$$

$$= 7.87 \text{ m.eq/lit}$$

$$Ca(OH)_2 \text{ mg/l} = Ca(OH_2)(\text{m.eq/lit}) \times \text{eq wt of } Ca(OH)_2$$

$$= 7.87 \times \frac{[40 + 2(16) + 2(1)]}{2}$$

$$Ca(OH)_2 \text{ mg/l} = 291.19 \text{ mg/l}$$

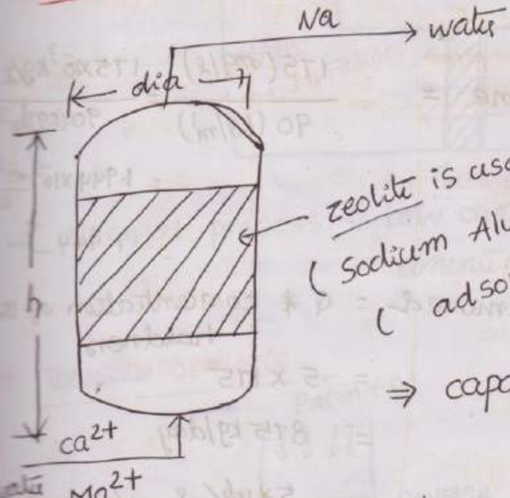
⇒ dose of Na_2CO_3 (soda ash) required : $(3.5)+(3.33)-[4.09+0.067+0.00117]$

: 2.67 m.eq/lit

$$Na_2CO_3 (mg/l) = 2.67 \times \frac{[106]}{2}$$

$$= 141.51\ mg/l.$$

④ Ion exchange process :-



zeolite is used as exchanger. (Sodium Aluminium silicate) (adsorber)

⇒ capacity of Exchanger

15 kg/m³ – 100 kg/m³

→ water is applied at a flow rate of

0.4 m³/min/m²

~~②~~ ~~Find total~~ hardness ~~in kg~~ ~~volume of~~

① Find total hardness to be removed in kg.

② volume of Ion exchange = $\frac{\text{Total hardness to be removed}}{\text{capacity of exchanger}}$

③ Surface area of Ion exchange = $\frac{Q}{\text{flowrate}} = \pi/4\, d^2$

⇒ dia of exchanger = ?

height of exchanger = $\frac{\text{volume of exchanger}}{\text{Area of exchanger}}$

(P1) Design an Ione exchanger to treat a flow of 5 MLD. with adsorption capacity of exchanger is 90 kg/m³ and a flow rate of 0.4 $m^3/min/m^2$. 0.4 (m/min) (Total hardness = 250 mg/l)

Sol:- Surface area of Ion exchanger $= \frac{Q}{\text{Flow rate}}$

$(\pi/4)\, d^2 = $ ~~5×10^6~~

Assuming 75 mg/l as acceptable.

Sol:- Total hardness to be removed $= 250 - 75$

$= 175$ mg/l.

[volume of Ion exchane $= \frac{175 (mg/l)}{90 (kg/m^3)} = \frac{175 \times 10^{-3} kg/l}{90 (kg)/m^3}$

$= 1.944 \times 10^{-3} \frac{m^3}{l}$

$= 1.944$]

→ Total hardness to be removed = Q * concentration of the hardness

$= 5 \times 175$

$= 875$ kg/day.

Area of exchanges $= \frac{Q}{\text{rate of flow}} = \frac{5 * 10^6 / 10^3 \times 24 \times 60}{0.4} \frac{(m^3/min)}{m^3/min/m^2}$

$= 8.68 m^2$

$\pi/4\, d^2 = 8.68$

$d = \sqrt{\frac{8.68 \times 4}{3.14}} = 3.32 m$

→ volume of Ion exchanger $= \frac{\text{Total hardness in kg}}{\text{capacity of exchanger}} = \frac{815}{90}$

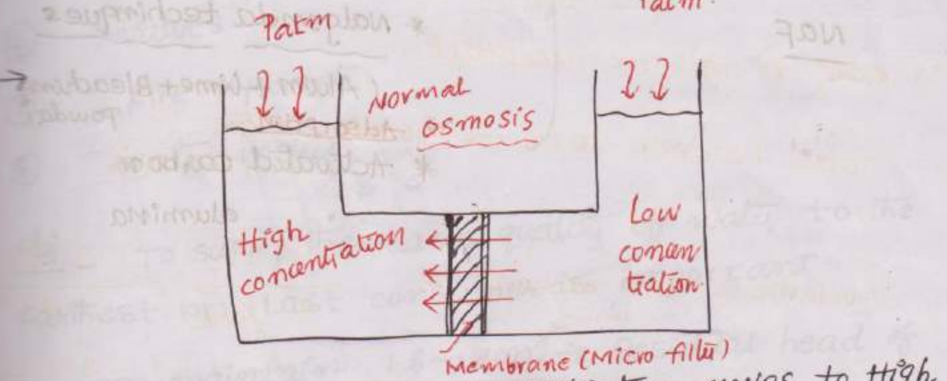
$= 9.72 m^3$.

∴ Height of exchanger $= \frac{\text{volume}}{\text{area}}$

$= \frac{9.72}{8.68} = 1.12 m$.

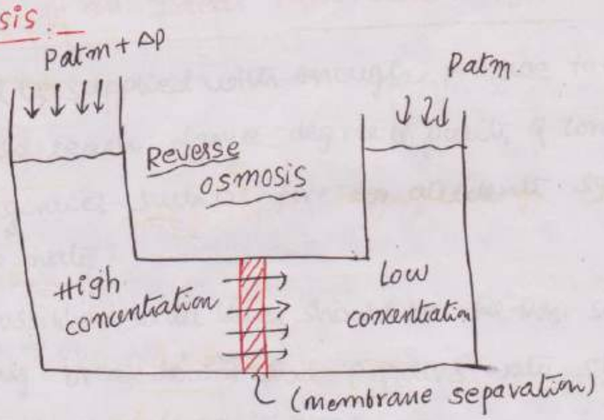
* Desalination [removed high conantation of salts & TDS]

① Reverse osmosis } → Membrane seperation techinque.
② Electrodialysis }
③ Distillation

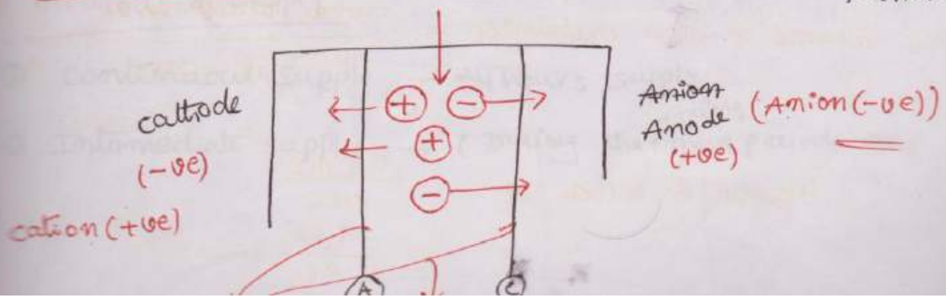


→ Normal process – Low conantration moves to High conentation (normal osmosis} (osmatic pressure).

* ~~Reverse~~ osmosis. _



* Electrodialysis. _ (Electric force is used to move the particles)



* Distillation :- ① Thermal Distillation - Fast but expansive
② solar " - slow (economical)

* Flouridation :-

→ Addition of flourine

NaF

* Deflouridation :-

→ Removal of flouridies.

* Nalgonda techinques

(Alum + lime + Bleaching powder)

→ Adsorption :-

* Activated carbon

" alumina.

9. Distribution system

① Network of pipes.
② pumps.
③ Distribution Reservoirs.
④ valves.
⑤ Fire Hydrants
⑥ water meters.

} Distribution system.

obj. - To supply the same quality of water to the farthest (or) Last consumer is important.

* To maintain $1.6 - 2m^2 \xrightarrow{\text{of water}}$ Residual head of

* Residual pressure Head [1.6 - 2m ⇒ 16 KN/m² - 20 KN/m²]

* Requirements of an Ideal Distribution system

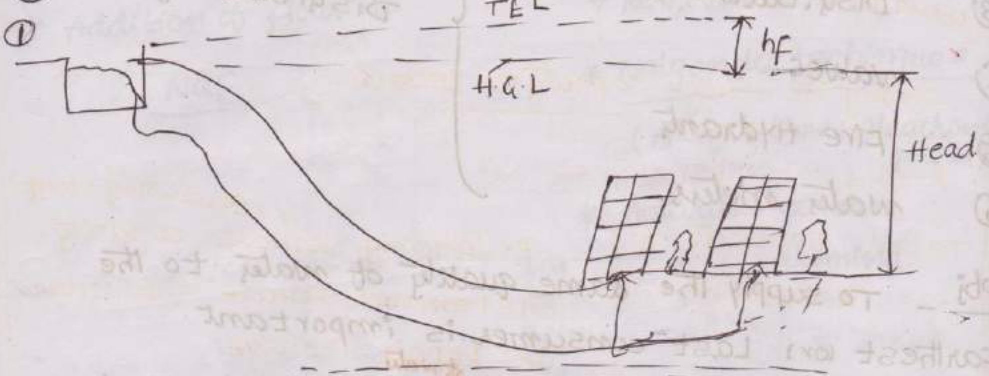
① water should be supplied with enough pressure to consumer.
② water should reach same degree of purity of consumer
③ During emergencies such as fire ~~or~~ accidents system should give water.
④ As far as possible water lines should be ~~far~~ free from sewer lines
⑤ Even during breakdowns and Repairs water should be reach the consumer (Realibility)

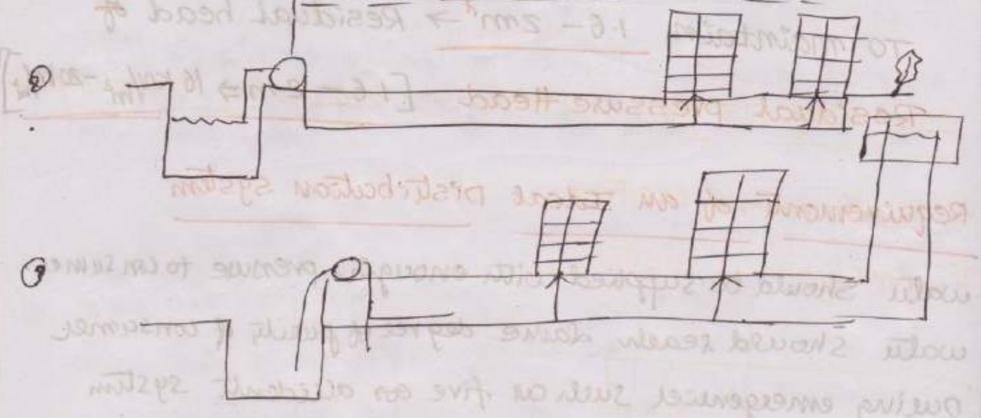
* methods of supply

① continuous supply - 24 hours supply
② Intermediate supply → (During the fixing time periods only

* Types of Distribution :-

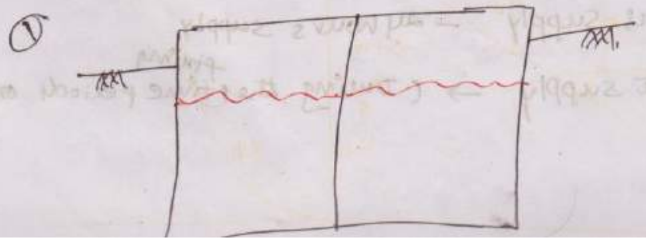
① Gravity Distribution.
② pressure Distribution.
③ Gravity & pressure Distribution.



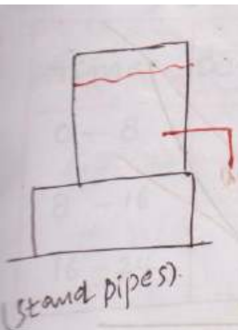


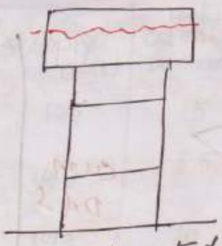
* Reserviors :- (To balance supply & demand).

① surface reservior (summer storage tanks)
② stand pipes.
③ Elevated Reservior



③


(Stand pipes).


(Elevated Reservior).

* Fixing the storage capacity of Reservior :-

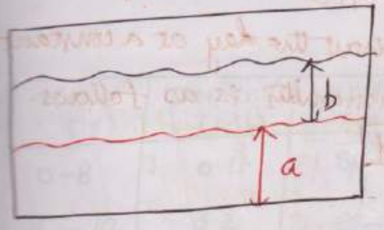
→ ① ⇒

Total capacity of Reservoir } : Balancing storage (Equalizing storage) capacity + Fire Demand storage + Brake down (or) Repair storage.

→ Balancing storage capacity (or) equalizing storage capacity:

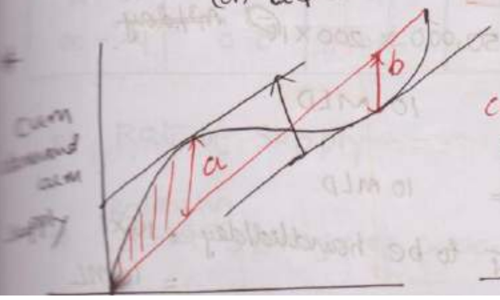
① Mass curve Method.

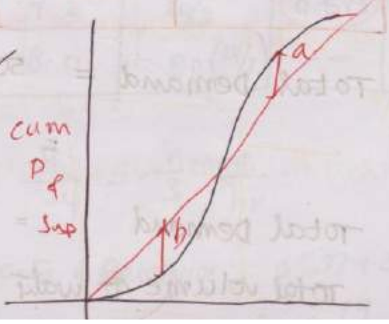
② Analytical Method.



(maximum reservoir capacity is a+b)
(or) a & b)

① mass curve





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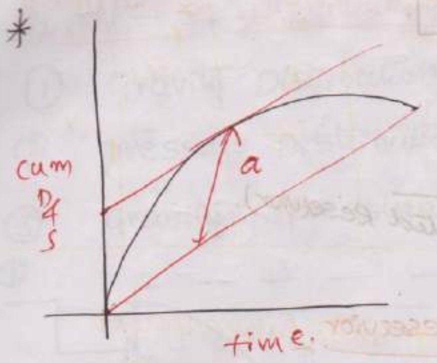
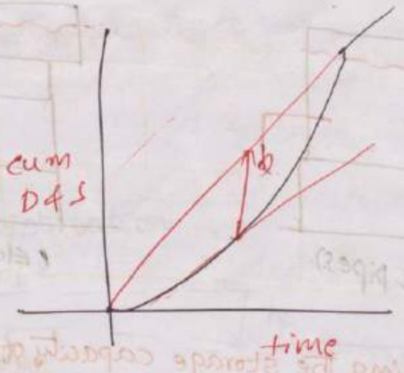


(max storage capacity a)



(max storage capacity b)

② Analytical Method :-

Time	Demand	supply	cum Demand	cum supply	surplus	deficit

mass curve method

(Analytical method)

(P) Find out equalizing storage capacity of reservior for a community of population 50,000. Supply at a rate of 200lpcd. water is supplied throughout the day at a constant rate. The Demand pattern of community is as follows.

	%ge of total Demand
0 – 8hr	50%
8 – 16hr	15%
16 – 24hr	35%

sol:- Total Demand = 50,000 × 200 × 10^{-3} ~~m³/day~~

= 10 MLD

Total Demand = 10 MLD.

→ Total volume of water to be handled/day = 10 × 1

= 10ML

⇒

Time	Demand (ML)	supply (ML)	(ML) cum Demand	(ML) cum supply	surplus (ML)	deficit (ML)
0 – 8	5	10/3	5	10/3	5/3	—
8 – 16	1.5	10/3	6.5	20/3	—	1/6
16 – 24	3.5	10/3	10	10	—	—

⇒ Rate of supply = $\frac{\text{Volume of water to be supplied}}{\text{duration of supply}}$

$= \frac{10}{24} = \frac{5}{12}$ mL/hr.

⇒ Balancing of capacity of Reservior = $\frac{5}{3} + \frac{1}{6}$

$= 11/6 = 1.833$ (mL)

(2-2)
(04) Total Demand $= \frac{50,000 \times 160}{10^6} = 8$ mLD

⇒ Total volume of water to be handled/~~by~~ day = 8×1 = 8 mL.

⇒

Time (hr)	Demand (ML)	supply (ML)	cumDemand (ML)	cum supply (mL)	deficit ~~surplus~~ (mL)	~~deficit~~ (mL) surplus
0-8	0.4	8/3 ~~8/5~~	0.4	8/3	---	2.26
8 – 10	3.2	2/3 ~~8/5~~	3.6	10/3	0.26	---
10 – 16	1.6	6/3 ~~8/5~~	5.2	16/3	---	0.133
16 – 20	2.0	4/3 ~~8/5~~	7.2	20/3	0.533	--
20 - 24	0.8	4/3 ~~8/5~~	8.0	8.0 (24/3)	---	---

⇒ Rate of supply $= \frac{8}{24} = \frac{1}{3} \frac{\text{ML}}{\text{hr}}$

⇒ Balancing ~~Bala~~ storage ~~of~~ capacity of Reservior = 0.533+2.26

= 2.79

Ex:- A town with a population 1,00,000 supplied at a rate of 200 lpcd of water. The breakup of demand is given as follows.

Time	lit/person (lpcd)	(%ge) Demand
0 – 6 AM	30	0.15
6 – 12 PM	80	0.4
12 – 6 PM	40	0.2
6 – 12 AM	50	0.25

→ water is supplied from 4 AM to 8 AM and again 4 PM to 8 PM at constant rate. Find the equalizing storage capacity of Reservior.

Sol:- Total Demand $= \frac{1,\cancel{00,000} \times 20\cancel{0}}{\cancel{10^6}}$

$= 20$ MLD.

volume of water to be supplied/day $= 20$ (ML)

Rate of supply $= \frac{20}{8} = 2.5$ mL/hr.

Time	(lpcd) Demand ~~(ML)~~	$\frac{\text{Pop} \times \text{Percapita}}{10^6}$ demand (mL)	supply (mL)	cum (Demand)	cum (supply)	Deficit	Surplus
0 – 6 AM	30	3	5	3	5	--	2
6 – 12 PM	80	8	5	11	10	1	--
12 – 6 PM	40	4	5	15	15	0	0
6 – 12 AM	50	5	5	20	20	0	0

* Blancing (or) equalizing storage capacity of Reservior.

$= 2 + 1 = \underline{3 \text{ML}}$

$= (3 \text{mL})$ of Rea

* Layouts of Distribution (or) Distribution Layouts :-

① Dead end Layout (Tree system).

② Grid Iron layout (or) system
[Raticulation system].

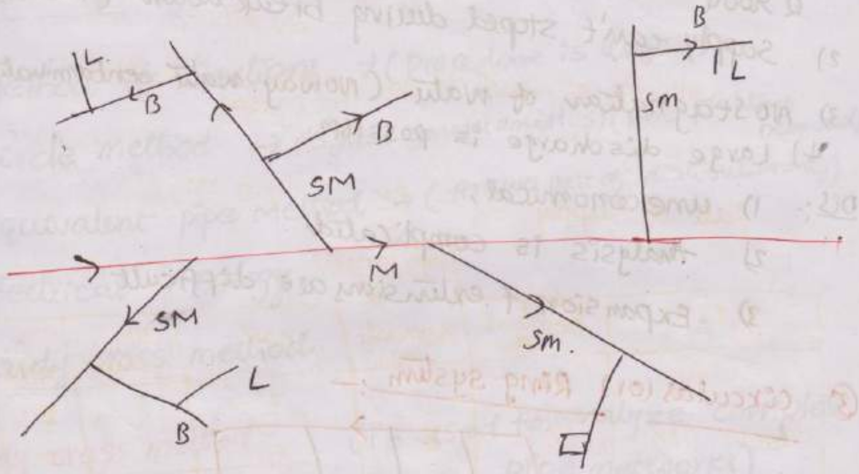
③ circular (or) Ring system

④ Radial system of layout

→ Dead end layout :- → irregular grown of system.

* [Main → sub main → Branches → Latral → House connection

→ hapzard (or) irregular pattern of roads.



Adv :-

→ ** This system is economical and expansion is very easy.

→ Design calculations are very simple.

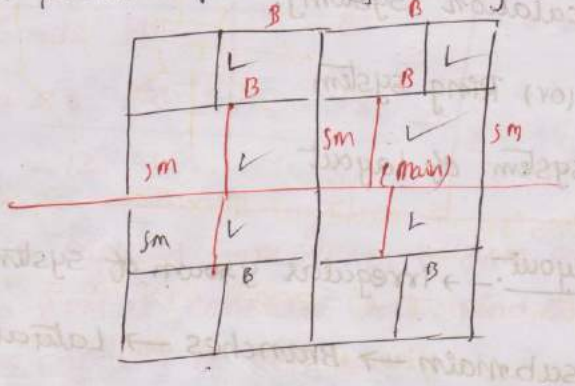
* Dis :- Repair work at one place other place don't get any water.

So many dead ends (chances of stagnation)

→ Fire fightings large discharge is not possible.

② Grid Iron layout :- (Raticulation system (or) inter laced system).

→ Grid pattern of Layout's (or) Roads such communities this pattern is possible eg. chandigarh, Gujarat (Gandhi nagar)



Adv:- 1) Every house is connected supply is more than 2 root

2) supply can't stoped during break down. (Reliable supply)

3) No stagnation of water (Noway water contaminated)

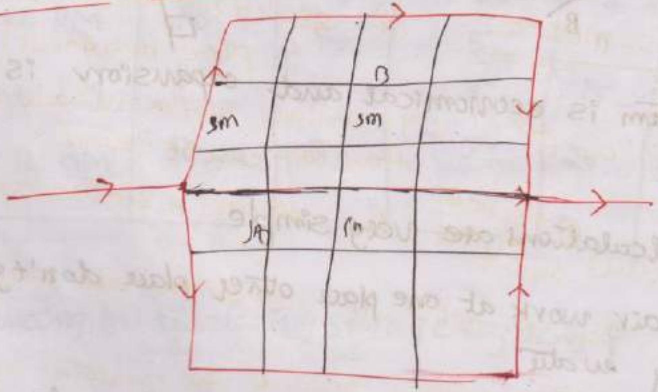
4) Large discharge is possible.

Dis:- 1) uneconomical,

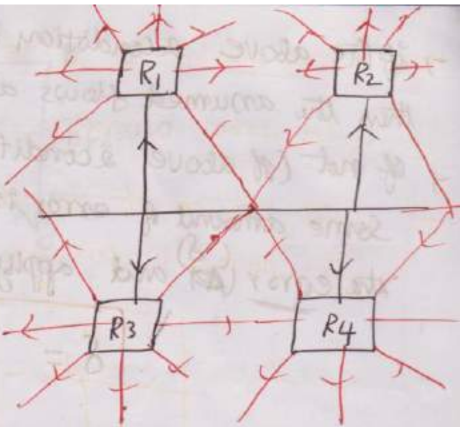
2) Analysis is complicated.

3) Expansion + extensions are difficult

③ Circular (or) Ring system :-



④ Radial system :-



* Analysis & Design of water Distribution system :-

→ Distribution system consist of complex pipe network. Therefore finding the hydraulic parameters to design the system is not that easy. So special techniques to are used to find pressure drop and as well as flow in each pipe.

① Method of Sections →(procedure is lengthy)

② circle method →(Small communities)(Fire fighting Demand)

③ Equivalent pipe Method →(Answer part of distribution only)

④ Electrical Analogy.

⑤ Hardy cross method

* Hardy cross method :-

(is used to analyze complex pipe networks)

$\boxed{H \propto Q^x}$ → By assuming the flow in each pipe Headloss can be found.

① $Q_{(in)} = Q_{(out)}$ ② Algebraic Sum of Head loss around a closed loop is zero. $[\Sigma H = 0]$

~~Hardy c~~ Then the following 2 conditions are verified.

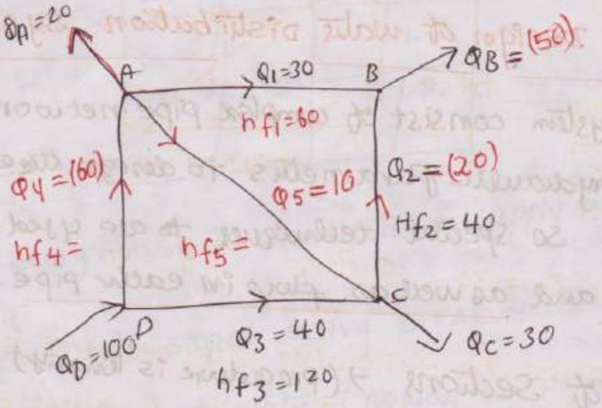
① At any Junction flow towards the Junction must be equal to flow out of the junction.

→ if the above 2 condition are Satisfied System is balanced then the assumed flows are correct flows.

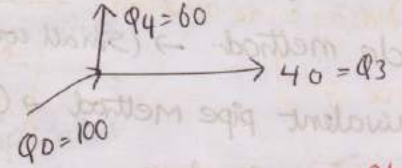
→ If not (If above 2 condition are not satisfied there is Some amount of error in assumed flows). Then ~~estimate~~ estimate the error (δ) and apply correction for the assumed flows.

$$\boxed{\delta = -\frac{\Sigma H}{x\,\Sigma\left|\frac{H}{Q}\right|}}$$

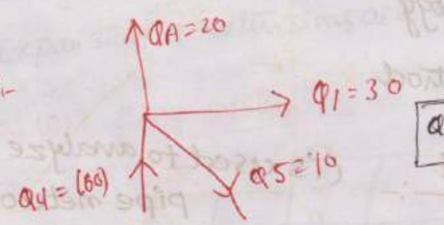
(03)



→ At D:-

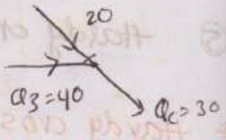


→ At A:-

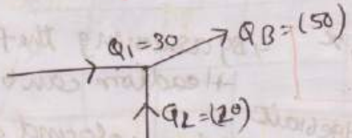


$\boxed{Q_5=10}$

→ At C:-



→ At B:-

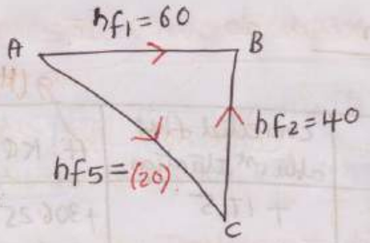


* To apply 2nd condition ΣH=0 . To follow sign convention

① clock wise flows and their corresponding head losses is taken as positive.

② anti clockwise flows and their corresponding head losses

At Loop(1):-



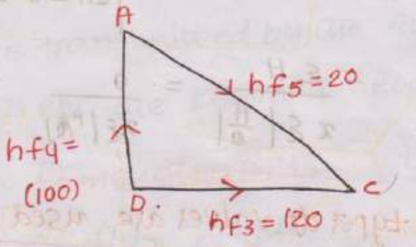
Loop (ABCA)

$\Rightarrow +hf_1 - hf_2 - hf_5 = 0$

$\Rightarrow 60 - 40 - hf_5 = 0$

$\Rightarrow \boxed{hf_5 = 20}$

$\Rightarrow$ Loop(ACDA)

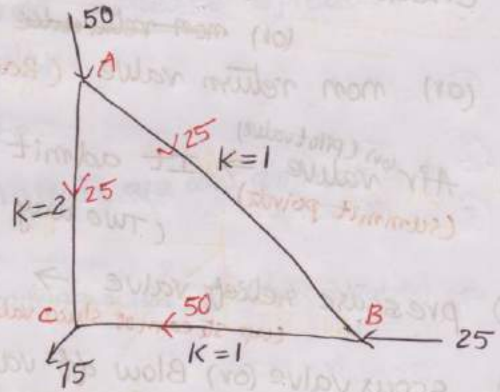


$\Rightarrow +(20) - 120 + hf_4 = 0$

$\Rightarrow \boxed{hf_4 = 100}$

$\Rightarrow Q_B = 50;\ Q_2 = 20;\ Q_4 = 60;\ Q_5 = 10.$

Example:- Analyze the following pipe networks shown below by Hardy cross method find flow in each pipe. take $x = 2$



Sol:- $\left[H \propto Q^x\right]$

$H = KQ^x$

$\boxed{H = KQ^2}$

$$\delta = -\frac{1875}{2(125)}$$
$$= -7.5$$

I^{st} iteration

pipe	K	assumed flow (Q)	$H: KQ^2$	$\lvert H/Q \rvert$	corrected flow
AB	1	+25	+625	+25	25−7.5 = 17.5
BC	1	+50	+2500	50	42.5
CA	2	−25	~~625~~ −1250	50	−32.5

II^nd Iteration

Pipe	K	corrected flow after 1st Iteration	$H : KQ^2$ (Head loss)	$\lvert H/Q \rvert$	corrected flows
AB	1	+ 17.5	+306.25	17.5	+ 17.5
BC	1	+ 42.5	+1806.25	42.5	+ 42.5
CA	2	− 32.5	− 2112.5	65	+ 32.5
			$\Sigma H = 0.0$	$\Sigma\lvert \frac{H}{Q} \rvert = 125$	

$$\delta = \frac{-\Sigma H}{x \Sigma \lvert \frac{H}{Q} \rvert} = \frac{0}{x\Sigma\lvert H/Q \rvert} = \frac{0}{2\times125} = 0$$

* Different types of valves are used in water distribution system

① sluice valve (or) Gate valve → To regulate & control the flow.
(At every Junction)(~~mains~~

② check valve (or) ~~Reflects~~ Reflux valve → which allow flow only in one direction.
(or) ~~non return valve~~
(or) non return valve. (Back-flow)

③ Air (or) (pilot valve) valve → It admit air and also expel air.
(summit points) (Two way air movement).

④ pressure relief valve → To control pressures.
(up stream of sluice valve)

⑤ scour valve (or) Blow off valve → to empty the water in pipe to clean before stopp
(low points)

11. solid waste Management

* The waste arising from the community which is essentially solid and discarded as useless (or) unwanted.

* solid waste cause - Roddent borne diseases
(Improper handling of solid waste).

* Diseases which are transimitted by the Roddents such as Rats, Mice, bats etc are known as Roddent borne diseases.

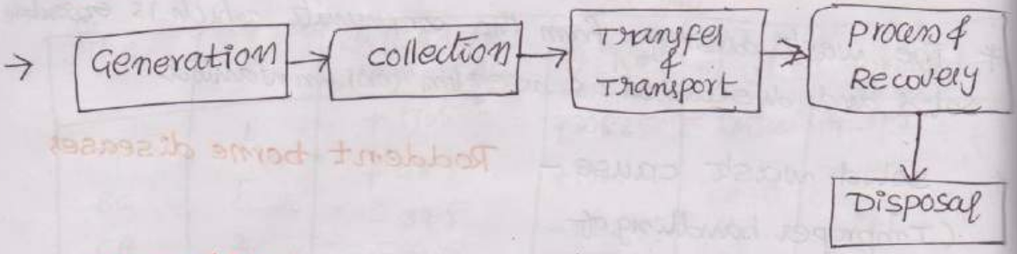
→ common Roddent borne diseases:-

* Diseases such as
(1) plague
(2) Hanta virus
(3) Lyssa virus
④ Leptosporosis etc
} transmitted by Roddents

→ usually Roddent borne disease spread in community by many ways.

① Through animal bite
② Drinking water & eating food are contaminated by Roddent waste.
3 Through physical contacting with Roddent waste.
③ Through parasite.
5 Breathing in air from the place contaminated by dry Roddent waste.

* Solid waste management Includes :-



→ Generation :- 0.4 - 0.8 kg/capita/day

→ collection :- Bin system.

→ Transfer & Transport :- Hauling system. (Trucks)

→ Process & Recovery :- Seggregate Heterogenous solids waste.

→ Disposal :-

* Broad classification of solid waste :-

① Municipal solid waste.

② Industrial solid waste → Ex:- Rubbish, ashes, special waste

③ Hazardous waste → Ex:- Hospital waste

* ① Municipal solid waste :-

(i) Residential waste ⟶ Examples :- food waste, rubbish, ashes etc.

(2) commercial waste ⟶ Ex:- Food waste, rubbish, ashes, construction & demolition waste

(3) open areas. ⟶ Ex:- rubbish, ashes, etc.

(4) Treatment plant waste Ex:- sludges.

* Hazardous waste :-

→ ignitable, Reactive } characteristics of Hazardous waste

→ Toxic

* Analysis of Solid waste.

1 Physical Analysis :-

ⓐ Identification of various substances from the heterogenous waste.

ⓑ Size of Individual components.

*ⓒ Moisture content of solid waste.

**ⓓ Density of the solid waste / specific gravity.

ⓒ Moisture content = $\frac{a-b}{a}\times 100$

$$\boxed{M.C = \frac{a-b}{a}\times 100}$$

ⓓ

$$\left[\frac{100}{\text{Sp. gravity (solidwaste)}} = \frac{\%ge\,x}{S_x} + \frac{\%ge\,y}{S_y} + \frac{\%ge\,z}{S_z} + ---\right]$$

x, y, z indicate component of solid waste.

$$\left[\frac{100}{e_{\text{solidwaste}}} = \frac{\%ge\,x}{e_x} + \frac{\%ge\,y}{e_y} + \frac{\%ge\,z}{e_z} + ---\right]$$

(P-68)

② $e = M/V = kg/m^3$

specific weight ⇒ density

$$\Rightarrow \frac{100}{e(MSW)} = \frac{50}{300} + \frac{30}{500} + \frac{10}{65} + \frac{\cancel{125}\,10}{125}$$

$$= 0.167 + 0.06 + 0.153 + 0.08$$

$$= 0.46$$

$$\Rightarrow \boxed{e(MSW) = 217 (kg/m^3)}$$

* chemical Analysis :-

ⓐ Proximate Analysis → (i) volatile (Biodegrable component present in water)

(i) volatile
(ii) ash
(iii) combustable
* (iv) Energy

ⓑ Elemental Analysis :- C, H, S, N, O.

** (Energy) Heterogenous Mix (MSW) [As discarded] : $\dfrac{\%x * E_x + \%y * E_y + \%z * E_z}{100}$

* Energy content on dry basis : Energy as discarded * $\dfrac{100}{100 - M.C}$

→ * Energy con on dry basis = Energy as discarded * $\dfrac{100}{100 - MC}$

→ Energy content ash free dry basis

= Energy as discarded * $\dfrac{100}{100 - \%M.C - \%ash}$

(P1)

(a) Enegrgy content = $\dfrac{15 \times 4{,}650 + 45 \times (16{,}750) + 10(16{,}300) + 10(32{,}600) + 10(6{,}500) + 5(18{,}600) + 5(700)}{100}$

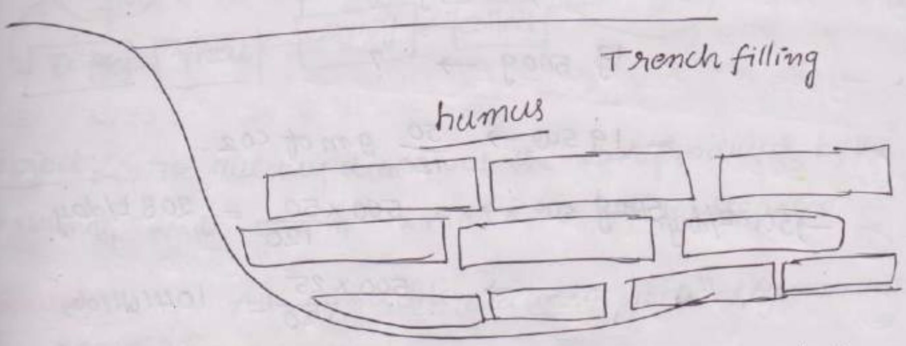
E. C = 14740 kJ/kg

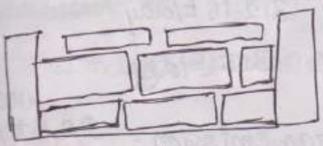
(b) Energy on dry basis = $14740 \times \dfrac{100}{100 - 21} = 18658.22$ kJ/kg

(c) Energy ash free = $14740 \times \dfrac{100}{100 - 21 - 5} = 19918.91$ kJ/kg

* Disposal Methods :-

(1) Land filling. → [Biodegradable waste]
↓
organic waste (change w.r.t time)





* → Lechate is produced in Land filling.

Area filling.

(2) Incineration → [combustible solids]

(3) pyrolisis. → [Absences of air]
(or)
(Thermal cracking) [plastic & rubber waste]
→ by products, Tar, oils etc.

(4) pulverization → [Inert (dry) waste]

(5) Sea disposal

(6) composting. → [Mixing human waste & Solid waste]
→ [Biodegrabledable Solid waste + Human waste (Night soil)]

→ ⓐ Indore Method :- Aerobically compost is produced

ⓑ Banglore method :- Anaerobically compost is produced

(P4) Green house gases – CO_2, CH_4.

$CO_2 + CH_4 \longrightarrow$

(MSW) 120g → 50 g of CO_2

→ 25g of CH_4

~~g~~ 500g → ?

1g SW → $\frac{50}{120}$ gm of CO_2

→ 500 t/day ~~500g~~ SW → $500 \times \frac{50}{120} = 208$ t/day

→ $500 \times \frac{25}{120} = 104.16$ t/day

Total = 208 + 104.16 = 312.16 t/day

≈ ~~313 g/day~~

∴ per capita greenhouse gas emission = $\frac{312.16 \cancel{t/day} \times 1000 \times 1000}{\cancel{1000000}}$

= 312.167 g/day

≈ 313 g/day.

(P5) $C_{50}H_{100}O_{40}N$; $C_aH_bO_cN_d$

a = 50; b = 100; c = 40; d = 1

→ molecular weight of $C_{50}H_{100}O_{40}N$

= 50(12) + 100(1) + 40(16) + 1(14) = 1354

→ $\frac{4(50) + 100 - 280 - 3}{8}$ CH_4 = 27.125 [(12) + 4(1)] = 434.

* 1354 part of SW produce = 434 parts of CH_4.
($C_{50}H_{100}O_{40}N$)

1 tonne of waste produce = $\frac{434}{1354} \times 1$ = 0.321 tons of methane

= 0.321 × 1000 = 321 kg

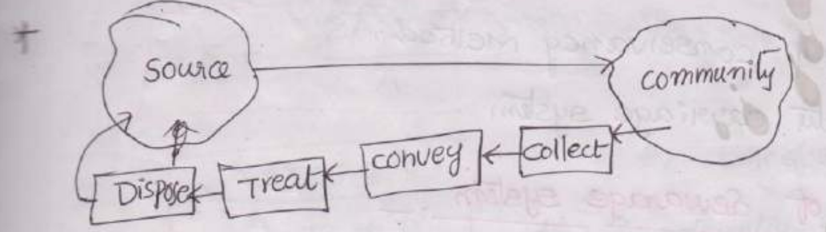
$\rho = m/V$ ~~Mass = ρ V~~ ⇒

$\boxed{V = m/\rho}$

V = $\frac{\cancel{32}\ \cancel{0.7167\ kg/m^3}}{321\ kg}$

V = 321

Waste water Engineering

*


* object :- To quickly drain out the waste produced by the community and ~~comm~~ to make it fit to disposal

* Sewage :- All forms of liquid waste produced by community is ~~produced by~~ known as sewage

ex :- Industrial, domestic, commerical & storm-water

* Sullage :- The less ~~off~~ offensive (dangerous) liquid waste produced by community is known as sullage.

ex :- Storm water, waste water from bath rooms, wash basins, etc.

* Dry weather flow :- (DWF) :-

→ Domestic waste water (sewage) + Industrial sewage.

* Wet weather flow :-

→ storm water produced by community is known as (WWF)

* Sewer :- conduit conveying sewage is known as sewer.

* Sewarage :- Networks of sewers employed in collection conveyance & disposal of sewage. Total system is known as sewarage.

* Methods of Sewage collection & Disposal

① Dry & conservancy Method.

② water carriage system.

* Types of Sewarage system :-

① separate system

② combined system.

③ Partially Separate & Partially combined system.
↓
(moderate amount of rainfall)

* Estatimation of Dry weather flow & wet weather flow (Discharge)

① DWF :-

$$\boxed{Q_{DWF} = \text{Population} * \text{per capita sewage flow}}$$

⇒ per capita sewage flow = per capita water supply * factor

factor = (%) water supply → Sewage

factor = 80%

$$\therefore \boxed{Q_{DWF} = \text{Population} * \text{percapita water supply} * \text{Factor}}$$

② WWF :- (storm water discharge)

→ Rational formula ($A < 5000\,ha$, $< 50\,km^2$)

R = Rain f
intensit
in (mm/

$$\boxed{q_{WWF} = \frac{AIR}{360}}$$

A - Area of catchment (in hectre)

I - Impeable coefficient

Q - storm discharge in (m^3/sec)

$$\boxed{I = \frac{\Sigma A_i I_i}{A}}$$

$$\boxed{R = \frac{25.4\,a}{t_c + b}}$$ (mm/hr)

t_c - time of concentration

t_c = time of entry + time of flow.

t_c --- (min).

$$\boxed{t_c = t_e + t_f}$$

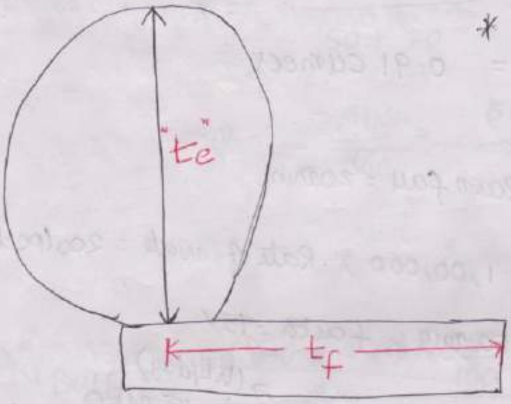
where a & b are constants whose value depends on duration of Rain

→ Rains of duration 5 mins to 20 mins.

$a = 30$; $b = 10$

→ If storm duration > 20 min. $a = 40$; $b = 20$

*



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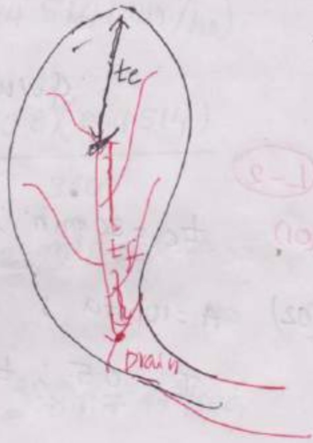


(L-1)

~~(8) A = 16 ha~~

Note:- If Rain fall duration is not given then for maximum discharge is taken as the time of concentration (tc)

Note:- If duration of storm is not given then for max "Q" [then duration of storm is taken as

* condition for Q_{max} (WWF) :-

Q is Q_{max} if duration of storm $\geq t_c$.

(L-1)

(18) $A = 16ha$;

$$I = \frac{\Sigma I_i A_i}{A} \Rightarrow K = \frac{\Sigma K A_i}{A}$$

$$\Rightarrow K = \frac{(0.80)(0.4) + (0.3)(0.2) + (0.3)(0.10)}{1}$$

$$K = 0.41$$

$$Q_{WWF} = \frac{AIR}{360} = \frac{16 \times 0.41 \times 500}{360}$$

$$= 0.91\ m^3/sec$$

$$\therefore Q_{WWF} = 0.91 \text{ cumecs}$$

(L-2)

(01) $t_c = 20\,min$; Rain fall $= 20\,min$.

(02) $A = 100\,Ha$; $P = 1,00,000$; Rate of wate $= 200\,lpcd$.

$I = 0.5$; $t_c = 50\,min$ factor $= 75\%$.

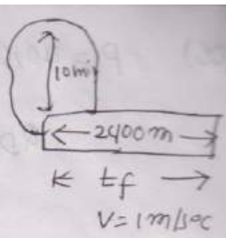
$$Q_{DWF} = 1,00,0\cancel{00} \times 200 \times 75/1\cancel{00} \xrightarrow{} (lit/day) = \cancel{15\,MLD}$$

$$Q_{WWF} = \frac{100 \times 0.5 \times \cancel{50}\ 14.514}{360} = 2.016\,m^3/sec.$$

$$Q_{DWF} = \frac{1,\cancel{0}\cancel{0},\cancel{000} \times 2\cancel{00} \times 75/1\cancel{00}\ (lit/day)}{1\cancel{000} \times 24 \times 6\cancel{0} \times 6\cancel{0}} = 0.1736\ m^3/sec$$

$$\left[R = \frac{25.4\ a}{t_c + b} = \frac{25.4 \times 40}{50 + 20} = 14.514\ mm/hr \right.$$

(03) $A = 50\,ha$; $t_e = 10$ minute ; $\phi^{I} = 0.8$.



Length of drain = 2400 m.

velocity of flow in drain = 1 m/sec

$Q = ?$

→ time of flow in drain = $\dfrac{\text{distance traveled in the drain}}{\text{velocity of flow in the drain}}$

$$= \frac{2400}{1} = \frac{2400}{60}$$

$$t_f = 40\,min.$$

$$\therefore \; t_c = t_e + t_f = 10 + 40 = 50\,min.$$

→ duration of storm : $t_c = 50$ min a:40 ; b: 20.

$$R = \frac{25.4(40)}{50+20} = 14.514\,(mm/hr)$$

$$Q = \frac{AIR}{360} = \frac{(50)(0.8)(14.514)}{360}$$

$$= 1.612\,m^3/sec$$

(04)

$$Q_{BWF} = \frac{5\cancel{0},\cancel{000} * 27\cancel{0} \times \frac{75}{100}}{1\cancel{000} \times 24 \times 6\cancel{0} \times 6\cancel{0}} = 0.117\,m^3/sec$$

$t_c = 25$ min:

$$R = \frac{25.4(40)}{25+20} = 22.577\,(mm/hr)$$

$$q_{WWF} = \frac{AIR}{\cancel{+0}360} = \frac{(150)(0.45)(22.577)}{360} = 4.233\,m^3/sec$$

∴ Total combined circular sewer flow

$= 4.35\,m^3/sec$

(06) $P = 40{,}000$; $A = 75\,ha$; $I = 0.70$

$$Q_{DWF} = \frac{2\cancel{40},\cancel{000} \times 1\cancel{20} \times 70/1000}{\cancel{1000} \times \cancel{24} \times 6\cancel{0} \times 6\cancel{0}} = 0.0388\ m^3/sec$$

21

$$Q\left[R = \frac{25.4 \times 40}{40 + 20} = 16.933\ mm/hr\right]$$

$$Q_{WWF} = \frac{75 \times 0.70 \times 16.933}{360} = 2.468\ m^3/sec$$

Total combined sewage = $2.4988 = 2.5\ m^3/sec$

(05) $$I = \frac{\Sigma I_i A_i}{A}$$

$$I = \frac{(0.9)(0.2) + (0.2)(0.85) + (0.05)(0.8) + (0.15)(0.4) + (0.35)(0.1) + (0.05)(0.05)}{1}$$

$$\cancel{I = \frac{0.4875}{1}}$$

$A = 36\,ha$

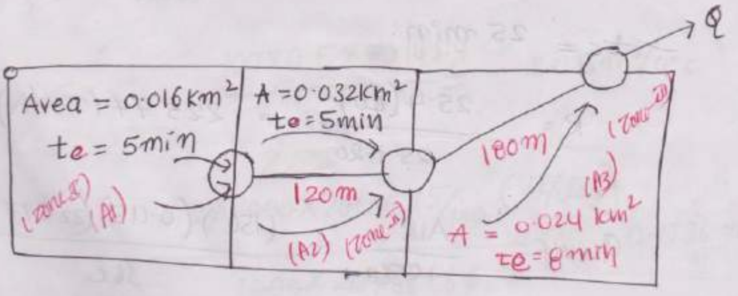
$R = 5\,cm/hr$

$R = 50\,mm/hr$

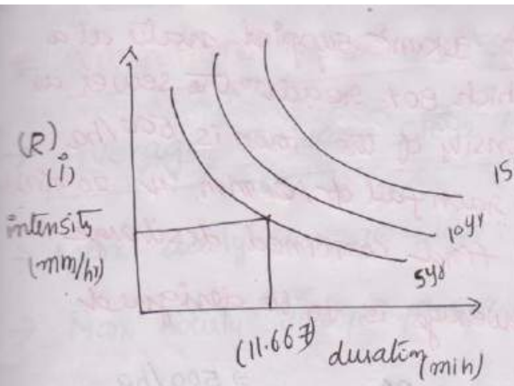
$$I = \frac{0.4875}{1} = 0.4875$$

$$Q_{WWF} = \frac{36 \times 0.4875 \times 5\cancel{0}}{36\cancel{0}} = 2.4375\ (m^3/sec)$$

(08)



* <u>Inlet time</u> :- time of entry ; "t_e"



→ zone-I :-

$$t_c = t_e + t_f$$

$$t_c = 5 + \frac{\text{Length of drain}}{\text{velocity of flow}} = 5 + \frac{\overset{5}{\cancel{300}}}{0.75} \times \frac{1}{\cancel{60}}$$

$$t_c = 11.667 \text{ min}$$

→ zone-II :- $t_c = 5 + \frac{\overset{3}{\cancel{180}}}{0.75} \times \frac{1}{\cancel{60}} = 9 \text{ min}$

→ zone III :- $t_c = t_e + t_f = 8 + 0 = 8 \text{ min}$

(which ever is maximum taken into account).

∴ Time of concentration choosen in the design = max t_c value among 3 zones

$t_c = 11.667$ min = duration of storm

~~(i) =~~ $R = 75$

$$\therefore Q = \frac{AIR}{360} = \frac{(\overset{7.2}{\cancel{0.072}})(0.3)(\overset{70}{\cancel{75}})}{360} = \cancel{45 \times 10^{-3}\ m^3/sec}$$

$$= 0.42 \text{ m}^3/\text{sec}$$

~~Q =~~ $A = \frac{A_1 + A_2 + A_3}{} = 0.072 \text{ km}^2$

$$= \frac{0.072 \times (1000)^2}{10^4}$$

$A = (7.2)$ ha

Ex:- A town with an area of 1 km² supplied water at a rate of 200 lpcd out of which 80% reach to the sewer as a sewage. The population density of the town is 500/ha. The town receives an avg rain fall of 10mm in 20 min. All of which are run off. find combined discharge for which a combined sewerage is to be designed.

Sol:- $$Q_{DWF} = \frac{\overset{50000}{\cancel{50000}} \times \cancel{200} \times \frac{8\cancel{0}}{1\cancel{00}}}{1\cancel{000} \times 24 \times 6\cancel{0} \times 6\cancel{0}}$$

⇒ 500/ha

= 1ha = $10^4\ m^2$

=

$1 km^2 = 10^6 m^2$

= ~~10~~

$1 km^2 = 100\ ha$

$$Q_{DWF} = 0.0925\ m^3/sec.$$

[1 km² = 100ha] [1ha = 500]

I = 1 (all of rain is runoff)

$$R = \frac{10}{\frac{20}{60}} \left(\frac{mm}{min}\right) = \frac{0.5}{\cancel{60}} \left(mm/min\right)$$

$$= 30\ mm/hr$$

$$Q_{WWF} = \frac{AIR}{360} = \frac{100 \times 1 \times 30}{360} = 8.33\ m^3/sec$$

$$Q_{total} = Q_{DWF} + Q_{WWF} = 8.43\ m^3/sec.$$

(~~Q = AV~~)

* Variations in sewage flow :-

→ Average sewage flow (Q) :-

→ Max daily sewage flow : 2 times the average sewage flow. = (2Q)

→ Max hourly sewage flow : 1.5 times the max daily sewage flow

= $1.5(2Q) = 3Q$

: 3 times the average daily sewage flow. (3Q)

→ Min daily sewage flow = $(2/3)^{rd}$ of average daily sewage flow

= $(2/3)(Q)$.

→ Min. hourly sewage flow = ½ minimum daily sewage flow.

= $\frac{1}{2} \times \cancel{2}/3\,Q = 1/3\,Q$.

= $\frac{1}{3}$ avg daily sewage flow.

2. Design of sewers

→ Sewers are designed as open channels. ~~through~~

* ~~Sewers are de~~ they are closed conduits at they are treated as open channels

→ using 'n' manning's formula most of the Sewers are designed. 99% ~~of~~ times sewage flow under gravity in sewer.

→ Any closed system is treated as open system if its Hydraulic gradient line coincide with free liquid surface because flow is gravity we are maintain velocity.

→ Sewers are gravity conduits therefore to maintain flow velocities in them their should be laid ~~on the~~ at a proper gradient. (They should design properly).

→ when sewers are designed for such a flow velocity Such that it doesn't allow settling (or) silting of the particles ~~in~~ inside it at the same time flow velocity shouldn't be too high.

v_{max} ↑ (scouring)

} (V)

v_{min} ↓ (Settling & silting) → clogging

** self cleansing velocity :— It is the min flow velocity at which no ~~settling~~ silting or settling of the particles occurs inside the sewer.

→ Any velocity less than ~~S~~ $V_{self\ cleansing}$ resulting into silting & settling of particle.

(min v flow) $\boxed{V_{self} = \sqrt{\frac{8K}{f}(s-1)gd}}$

where

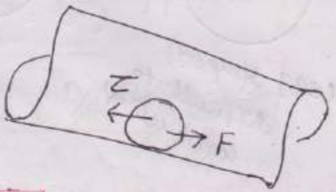
(Tractive force = frictional resistance)

k = character of sediment

f = friction factor

s = sp. gravity of the particle

d = dia of particle



*** $\boxed{V_{self} : 0.6 - 0.9 \ m/sec}$

* Non-scouring velocity

→ Max velocity of flow allowed in the sewer at which No scouring of sewer interior's will occur

Type of material (sewer)	Non-scouring velocities (m/sec)
① Earthen sewers	0.6 - 1.2
② Brick lined sewers	1.5 - 2.5
③ ** R.C.C & C.C sewers	2.5 - 3.0
④ stoneware "	3.5 - 4.5
⑤ C.I sewers (cast iron) **	4.0 - 5.0
⑥ vitrified glazed	4.5 - 5.5

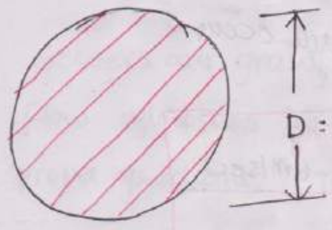
*  → Hydraulically more efficient when compared to other Geometries.

*

(egg shaped)
(difficult to construction)

** circular geometric shaped c/s are hydraulically more efficient over other cross sections.

case :- (i) when sewer's run full :- $[D = d]$



D = dia of sewer

d = depth of flow.

→ Area of c/s = $\pi/4 (D)^2$

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

$$R = D/4.$$

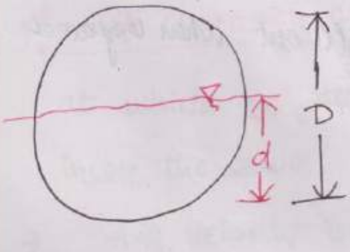
$$V = \frac{1}{n}(R)^{2/3} (S)^{1/2}$$

$$\boxed{Q = A \cdot V = \pi/4 (D)^2 \cdot \frac{1}{n} (D/4)^{2/3} \cdot (S)^{1/2}}$$

** case (I) :- (ii) Sewer's running (flowing) Half full :-

**

$[d = D/2]$



→ wetted area = Area of c/s

$$= \frac{\pi/4 (D)^2}{2} = \frac{\pi}{8}(D)^2$$

$$\rightarrow R = A/P = \frac{\pi/\cancel{8}(D^2)}{\frac{\pi D}{2}} = \frac{\cancel{\pi}D}{\cancel{2}4}$$

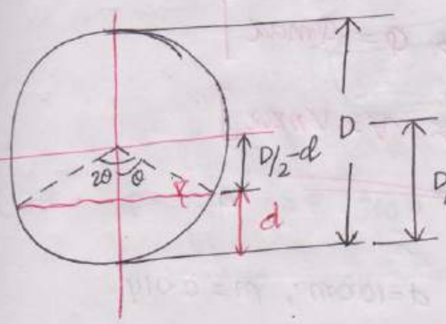
$* \; V = \frac{1}{n} \cdot R^{2/3} \cdot (S)^{1/2}$

Note :- when sewer's running full and as well as running ~~not~~ half full velocity flow in them is same (for given S & D is constant) but discharge is different.

$$\boxed{Q = AV = \frac{\pi}{8}(D^2) \times \frac{1}{n}\left(D/4\right)^{2/3} \times (S)^{1/2}}$$

case :- (iii) when sewer's running (flow) less than half full.

(when depth of flow ~~th~~ is less than D/2) $(d < D/2)$.



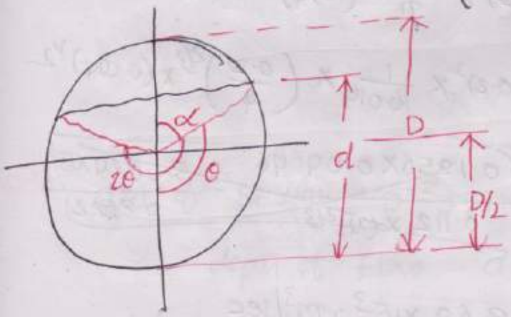
$$\boxed{P = 2r\theta}$$

$$\boxed{A = r^2 \left[\theta - \frac{\sin 2\theta}{2}\right]}$$

[wetted area]. (Area of c/s)

case :- (iv) when sewer running (flow) more than half full.

$(d > D/2)$



$$\boxed{P = 2r\theta}$$

$$\left[A = r^2\left[\theta - \frac{\sin 2\theta}{2}\right]\right.$$

(wetted area].

→ d/D - - - - q/Q, a/A, v/V, r/R, p/P

↓

0.1 - - - - - - - - - - -

0.2 - - - - - - -

0.3 - - - - - - - - - -

Note :- 1) It was found that by experiment velocity of flow is absolute maximum (best) when sewers are flowing at ~~0.85~~ depth of ~~0.85 times (Diameter) D~~ 0.81 diameter

$(d = \overset{0.81D}{\cancel{0.85D}})$

② velocity of flow in the sewes is maximum when compared to flowing full.

② Discharge in the sewer is maximum when sewer flowing at depth of flow 0.95 times diameter compared to flowing full.

$[d = 0.95D \rightarrow Q = Q_{max}]$

$[d = 0.81D \rightarrow V = V_{max}]$

(L-2)

(01) D = 20cm ; S = 0.004 ; d = 10cm ; n = 0.014

(Discharge is half full).

$D = \frac{2\cancel{0}}{10\cancel{0}} = 0.2$

$$Q = AV = \frac{\pi}{8}(D)^2 \times \frac{1}{n} \times (D/4)^{2/3} \times (S)^{1/2}$$

$$= \frac{3.14}{8}(0.2)^2 \times \frac{1}{0.014} \times \left(\frac{0.2}{4}\right)^{2/3} \times (0.004)^{1/2}$$

$$= \xcancel{\frac{0.1256 \times 0.04046}{0.112 \cancel{\times (4)^{2/3}}} = \frac{5.0824 \times 10^{-3}}{0.2822}}$$

$$Q = 9.62 \times 10^{-3} \ m^3/sec$$

$$Q = 9.6 \ lit/sec$$

(06) $d = 45cm;$ $P = 30,000$ D

$$Q = AV = \frac{\pi}{4}(D)^2 \times \frac{1}{n} \times \left(D/4\right)^{2/3} \times (S)^{1/2}$$

$$= \frac{\pi}{4}(0.45)^2 \times \frac{1}{0.012} \times \left(\frac{0.45}{4}\right)^{2/3} \times (S)^{1/2}$$

$$= 3.08\sqrt{S}$$ [$Q_{Design} = 3.5\, Q_{avg}$]

$$Q_{DWF} = \frac{3\cancel{0},\cancel{000} \times 15\cancel{0} \times \frac{80}{100}}{\cancel{1000} \times 24 \times 6\cancel{0} \times 6\cancel{0}} = 0.04167\ (m^3/sec)\ (Q_{avg})$$

3.5×0.04167

$= 0.145$ (Q design)

$$0.145 = 3.08\sqrt{S}$$

~~$S = 0.00229$~~
~~$S = 0.002$~~

$S = 2.229 * 10^{-3}$

$S = \frac{1}{448.5}$: 1 in 448.5

(07) $S = 1/360;$ $n = 0.011$

$$Q = AV = \frac{\pi}{4}(D)^2 \times \frac{1}{n} \times (D/4)^{2/3} \times (S)^{1/2}$$

$$= \frac{\pi}{4}(1.25)^2 \times \frac{1}{0.011} \times \left(\frac{1.25}{4}\right)^{2/3} \times \left(\frac{1}{360}\right)^{1/2}$$

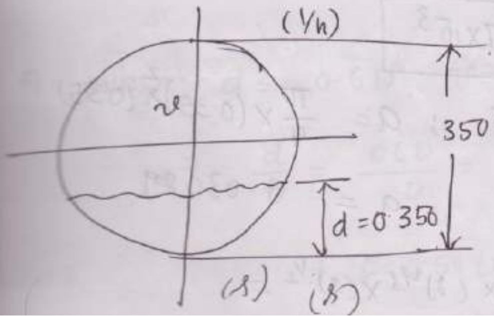
$$= \frac{3.14 \times (1.25)^2 \times 1 \times (0.46) \times (0.052)}{8 \times 0.011}$$

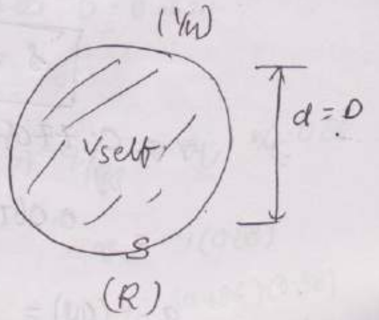
$Q =$ ~~2.70 m^3/sec~~ $1.35\ m^3/sec$

$Q = 1.33$

(08) dia of sewer "D" 350 mm ; 0.35 m

depth of flow $d = 0.35D.$





→ $V = \frac{1}{n} (R)^{2/3} (S)^{1/2}$ → flowing full.

$v = \frac{1}{n} (r)^{2/3} (s)^{1/2}$ → partially full.

(grade → slope)

$$V = V$$

$$\Rightarrow \cancel{\frac{1}{n}} (R)^{2/3} (S)^{1/2} = \cancel{\frac{1}{n}} (r)^{2/3} (s)^{1/2}$$

→ when $\boxed{d = 0.35 D}$

$$\frac{a}{A} = 0.315 \; ; \; \frac{p}{P} = 0.472 \; ; \; \left(\frac{r}{R}\right) = 0.7705$$

$$\left[\frac{(S)^{1/2}}{(s)^{1/2}} = \left(\frac{r}{R}\right)^{2/3} \right]$$

$$\Rightarrow \boxed{(s)^{1/2} = \left(\frac{R}{r}\right)^{2/3} (S)^{1/2}}$$

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

D = 350mm = 0.35m

$$0.8 = \frac{1}{0.014} \left(\frac{0.35}{4}\right)^{2/3} (S)^{1/2}$$

$$(S)^{1/2} = 0.0568.$$

~~$s = 0.0477$~~

~~$(s)^{1/2} =$ s fin~~

$$\boxed{s = 4.57 \times 10^{-3}.}$$

→ $r = 0.7705 * \frac{0.35}{4}$; $a = \frac{\pi}{4} \times (0.35)^2 \times (0.315)$

$= 0.0674$ $a = 0.03029$

$a \times \frac{1}{n} \times (r)^{2/3} \times (s)^{1/2} =$

(9A) * $V_{self} = V_{min} = \sqrt{\frac{8K}{f}(S-1)gd}$

$= \sqrt{\frac{8 \times 0.1}{0.03}(2.65-1)\,9.81 \times (1 \times 10^{-3})}$

$= 0.6~~8~~56$ m/sec

$V_{self} = V_{min} = 0.656$ m/sec.

* $V_{self} = 0.656 = \frac{1}{0.013} \times \left(\frac{1}{4}\right)^{2/3} \times (S)^{1/2}$

[R = D/4 : flowing half full]

$S = 4.61 \times 10^{-4} = 1/2165$

S = 1 in 2165

(10A) $Q = AV = \frac{\pi}{4}(D)^2 \times \frac{1}{n} \times (D/4)^{2/3} \times (S)^{1/2}$

$\Rightarrow 0.05~m^3/sec = \pi/4\,(D)^2 \times \frac{1}{0.013} \times \frac{D^{2/3}}{(4)^{2/3}} \times \left(\frac{1}{1000}\right)^{1/2}$

$= \frac{3.14}{4 \times 0.013} \times \frac{1}{(4)^{2/3}} \times ~~\frac{1}{4}~~ (0.0316) \times D^{8/3}$

$0.05 = \frac{3.029 \times D^{8/3}}{~~4~~}$

D = ~~0.2445~~ 0.36 m

~~D = 0.2~~ D = 0.36 m.

$V = \frac{1}{n}\left(\frac{0.36}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$

$= \frac{1}{0.013}(0.200) \times \left(\frac{1}{1000}\right)^{1/2}$

V = 0.486

⇒ when d = 0.6D. v = ? q = ?

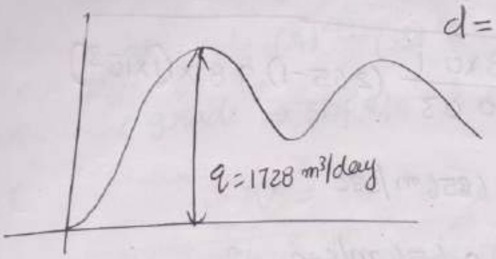
⇒ $\frac{d}{D} = \frac{0.6D}{D} = 0.6$ ⇒ $q/Q = 0.54$; $v/V = 0.88$

⇒ q = 0.54 (0.05)

v = V(0.88)

V = (0.486)(0.88)

[illegible] $D = 0.3m$ $S = 1:280$ ~~Qpeak~~ $q = 1728\ m^3/day$



$d = q = \frac{1728}{3600 \times 24}\ m^3/sec$

$= 0.02\ m^3/sec$

→ when sewer running full i.e $d = D$

$Q = AV$

$\left[R = D/4 \quad A = \pi/4\ D^2 \right.$

~~$Q = \pi/4\,(0.3)^2 * 1$~~

$Q = \pi/4\,(D)^2 \times \frac{1}{n} \times (D/4)^{2/3} \times (S)^{1/2}$

$Q = \pi/4\,(0.3)^2 * \frac{1}{0.015} * \left(\frac{0.3}{4}\right)^{2/3} \left(\frac{1}{280}\right)^{1/2}$

$Q = 0.05\ m^3/sec = 4327.29\ m^3/day$

$\Rightarrow q/Q_{full} = \frac{1728}{4327.29} = 0.4$

$\Rightarrow d/D = 0.5$

depth of flow $d = (0.5)(D)$

$= (0.5)(300) = 150mm$

$\boxed{d = 150mm}$

$\Rightarrow v/V_{full} = 0.8$

$\Rightarrow v = (0.8)\left(\frac{1}{0.015}\right)\left(\frac{0.3}{4}\right)^{2/3}\left(\frac{1}{280}\right)^{1/2}$

$v = (0.8)\,(0.05976)\,(0.1778)\,(66.667)$

$v = 0.5668\ m/sec$

$\boxed{v = 0.57\ m/sec}$

P14 $D = 300\,mm$, $S = \frac{1}{400}$ $v_{full} = 0.7\,m/s$ (full condition)

$\Rightarrow$ $D = 600\,mm$, $S = \frac{1}{200}$; $v_{mean} = ?$ (half full condition)

$$S = 2 \times \frac{1}{400} = \frac{1}{200}.$$

$$\Rightarrow \left[\begin{aligned} Q &= \pi/4\,(D)^2 \times v_{full} \\ &= \pi/4\,(0.300)^2 \times (0.7) \\ Q_f &= 0.049\ m^3/sec \end{aligned}\right]$$

$\Rightarrow$ $[v_{full} = v_{mean}]$ $\Rightarrow V = \frac{1}{n}(R)^{2/3}(S)^{1/2}$

(velocity remain constant)

→ In this problem velocity is not constant. (D) & (S) are changed.

$$\Rightarrow \frac{1}{n} = \frac{v_1}{(R_1)^{2/3}(S_1)^{1/2}} = \frac{v_2}{(R_2)^{2/3}(S_2)^{1/2}}$$

$$\Rightarrow \frac{0.7}{\left(\frac{0.300}{4}\right)^{2/3}\left(\frac{1}{400}\right)^{1/2}} = \frac{v_2}{(0.6/4)^{2/3}\left(\frac{1}{200}\right)^{1/2}}$$

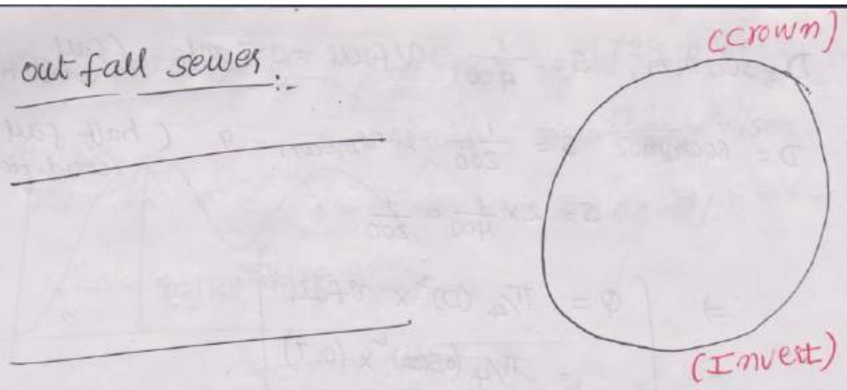
$$= \frac{0.7}{(0.075)(0.05)} = \frac{v_2}{(0.28)(0.0707)}$$

$$\Rightarrow (186.667)(0.28)(0.0707) = v_2$$

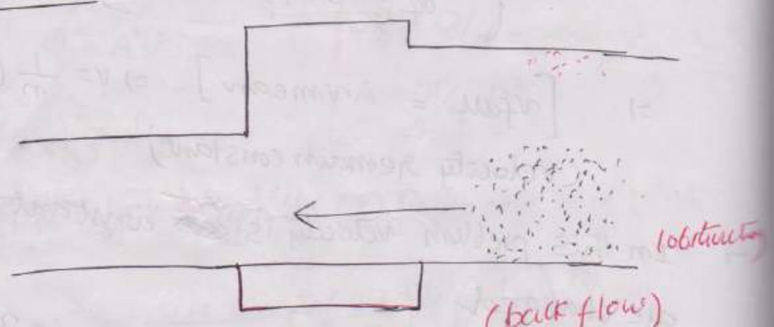
$$v_2 = 1.57\ m/sec$$

* Lateral sewer Branch sewer main sewer (Trunk sewer)

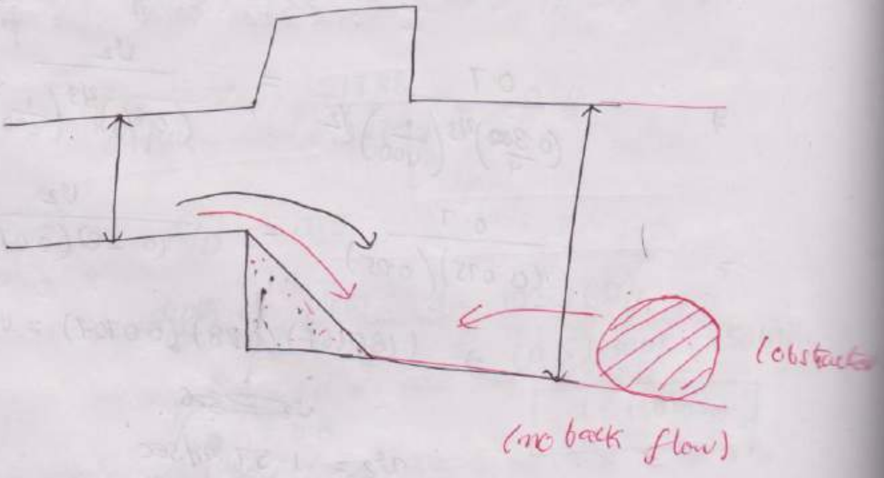
* out fall sewer :-



* Invert matching



* crown matching



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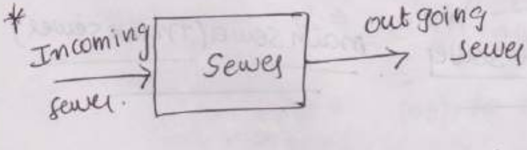


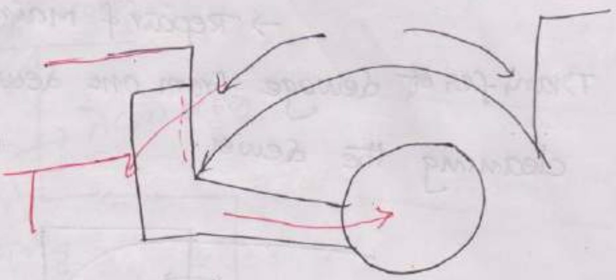
(transition → smaller to larger)

* ** Self cleansing velocity depends only in the tractive force. (Independent of slope, velocity

* Sewer appartenamus:— ↓↓↓

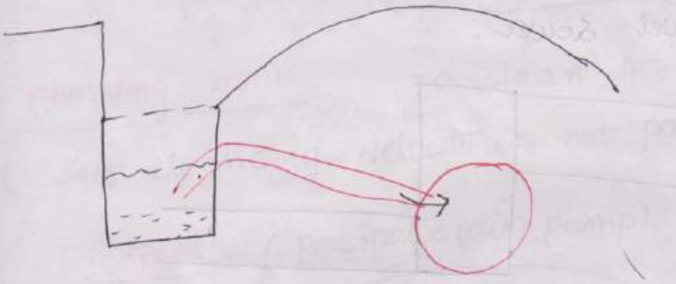
→ ① Inlet

② Catch basin

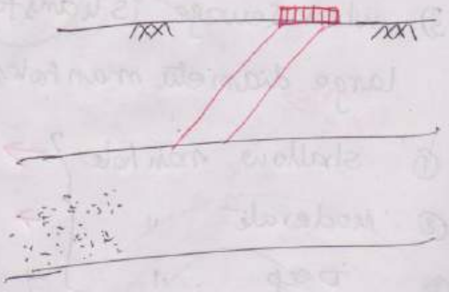


→ Inelet:— collect water from road surface & admit same in to storm water sewer.

→ catch basin:— special Inlet which collect storm water from road and detain it for some time & admit storm water in to storm water sewer.



③ clean out:—



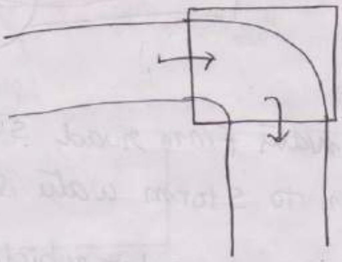
→ cleaning the sewer.

→ To ease sewage flow by inserting rod a provi~~ded~~sion is made.

④** Man hole :– (Inspection
→ Repair & Maintainence of sewer)

→ Transfer of sewage from one sewer to other.

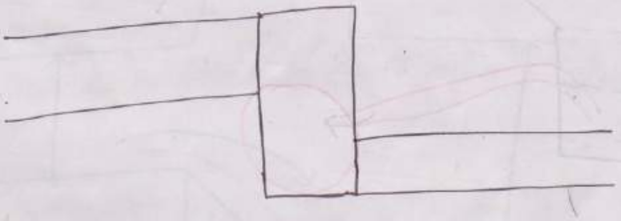
→ cleaning the sewer.



→ ~~when sewage~~ In addition to above manhole facilitate the following.

1) To change the direction of sewage flow.

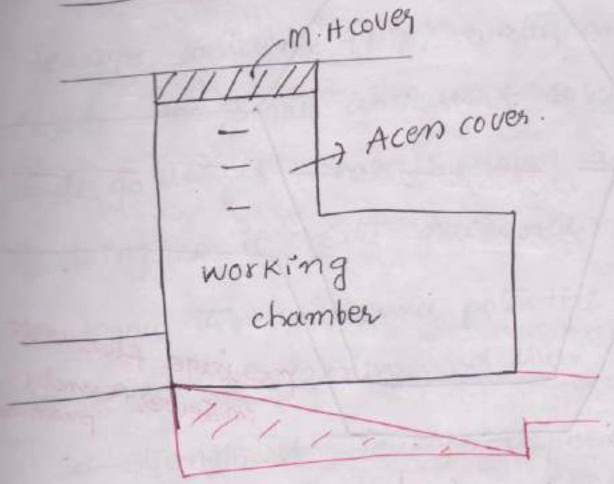
2) when ever sewage dropdown to high level sewer to the ~~lea~~ low level sewer.



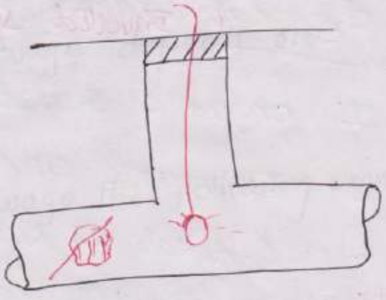
3) when sewage is transfer from small diameter to large diameter manholes are constructed.

① shallow man hole → depth of M.H ≤ 0.9m
② moderate " → " " 0.9 – 1.5m
③ Deep " → " " > 1.5m
- working chamber
- Access chamber

→ Deep manhole :-

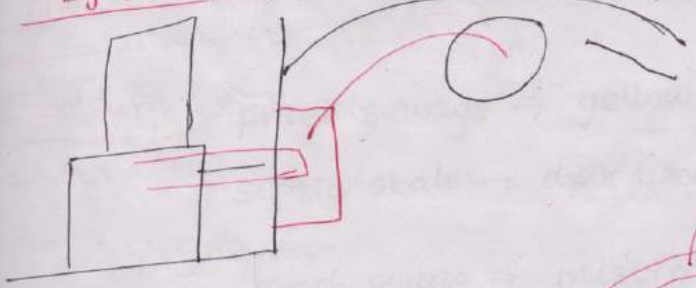


⑤ Lamp hole :-

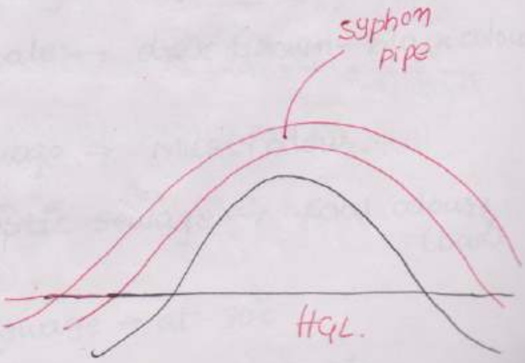


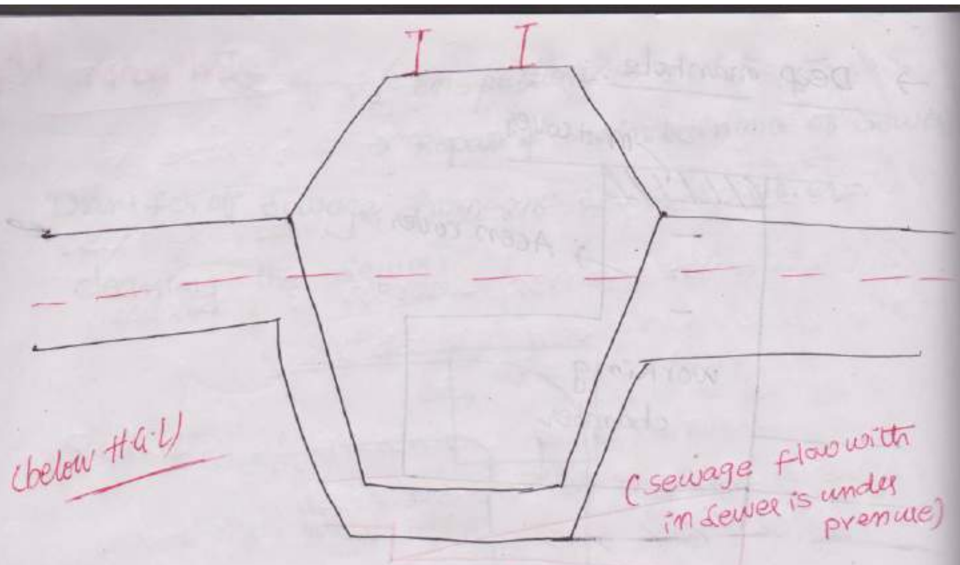
⑥ Flushing tank :- To clean the sewer.
(self cleansing velocity is not possible).

⑦ Ejectors :- (pnematic (air) pump).



⑧ Inverted syphon :-





(Inverted Syphon)

3. Characteristics of Sewage

→ Sewage contains 99.9% water and small portion of solids. The small amount of solids present in sewage under go changes what is known as "decomposition".

→ It doing so it create nuisance."

→ To know the nuisance potential of a sewage. sewages are ~~examined~~ exam in and their strength is found.

→ ~~So strength of sewage depends on~~
(or)
Nuisance potential of sewage depends on strength of sewage.

→ To find out the strength of sewage the following examinations are conducted on sewage

① physical Examination
② chemical Examination

→ To know state of sewage & condition of sewage.
→ fresh sewage (stale or septic sewage. "stale"

① physical Examination

ⓐ colour :- Fresh sewage → yellow - light brown.
septic stale → dark brown - black colour.

ⓑ odour - Fresh sewage → Musti odour.
Stale & septic sewage → foul odours. (bad)

ⓒ Temperature :- Fresh sewage → at 30°c
Septic & stale sewage > 30°c.

④ Turbidity :- fresh sewage → less turbid
→ stale & septic sewage → Highly turbid

* Decomposition : oxidation + Reduction

oxidation : aerobic decomposition
(decomposition which occurs in the Presence of air).

Reduction : anaerobic decomposition.
(decomposition which occurs in the abs of air.

* chemical Examination of waste :-

1. organic substances → ** Biodegradable. / → Non-Biodegradable

2. Inorganic substances.
(Alkalinity causing substances)
(carbonates, bicarbonates, chlorites, nitrogen etc).
Ca, mg, S

→ Nuisance $\propto$ strength of waste $\propto$ organic content of the waste.
$\propto$ BOD_5

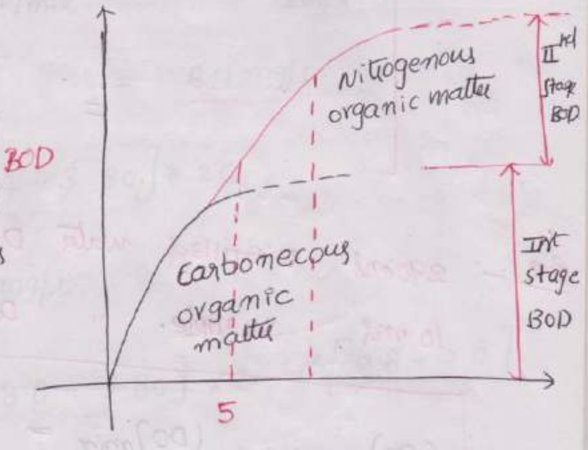
* organic matter is so complex made up of proteins, carbohydrate, oils, fats etc. There fore finding all these substances in waste is not possible but by oxidizing these substances either chemically (or) biologically →(micro organisms) it is possible to quantify the organic strength of waste

* oxygen Demand
** ① BOD – Bio chemical oxyg Dem
* ② COD –
③ TOD
④ ThOD

- Definition :- (BOD) It is the amount of oxygen Demanded by the microorganisms to decompose Biodegradable organic matter present in the sewage under aerobic conditions.

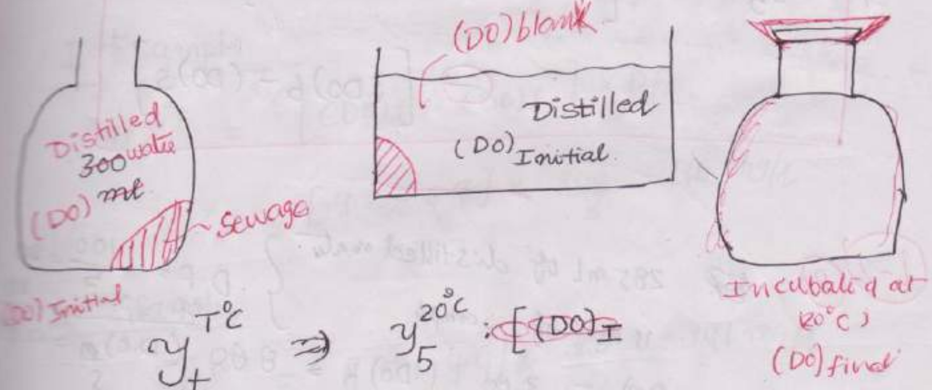
- BOD Test :-

(65-80% of organic matter oxidized composed other 20% takes Infinite time. so is taken as 5 days BOD



- [Test conducted at 20°c for 5 days]

- Test procedure :-



$y_t^{T^\circ C} \Rightarrow y_5^{20^\circ C} : [\cancel{(DO)}_I$

$$\boxed{y_5^{20^\circ C} = \left[(DO)_{Initial} - (DO)_{final}\right] * \text{Dilution factor}}$$

* $y_5^{20°c} = \left[(DO)_{Initial} - (DO)_{final}\right] * DF$.

$$\Rightarrow \boxed{\text{Dilution factor} = \frac{300}{\text{ml of sewage sample tested}} = \frac{100}{(\%)\text{ sewage sample in dilution}}}$$

gef

Ex. - 290 ml · Distilled water DO : 8 ml

10 ml sample. " DO . 0.5 ml

$$\boxed{(DO)_{Initial} = (DO)_{mix} = \frac{V_D(DO)_D + V_S(DO)_S}{V_D + V_S}}$$

$$\Rightarrow \boxed{y_5^{20°C} = \left[(DO)_{blank} - (DO)_{final}\right] * DF \quad \ominus \left[(DO)_b - (DO)_S\right]}$$

(L-2) (P2) Ex. 285 ml of distilled water } D·F = $\frac{100}{5} = 20$
15 ml of sample } DF = 300/15 = 20

$(DO)_{final} = 3.80$; $(DO)_b = 8.80$ $(D.O)_S = 0.80$

$\Rightarrow$ ~~$y_5^{20°c}$~~ = [

$\rightarrow$ $(DO)_{final} = 3.80$ mg/l ; $(DO)_D$; $(DO)_b = 8.8$ mg/l

$(DO)_S = 0.8$ mg/l.

→ 285 ml of distilled water with Dissolved oxygen = 8.8 mg/l

mixed with 15ml sewage sample DO = 0.8 mg/l.

$$(DO)_{Initial} = (DO)_{mix} = \frac{285 \times 8.8 + 15 \times 0.8}{285+15}$$

$$= 8.4 \text{ mg/l.}$$

* $y_5^{20^\circ C} = [8.4 - 3.80] * 20$

$y_5^{20^\circ C} = 92$ mg/l.

* $y_5^{20^\circ C} = [8.8 - 3.80] \times 20 - [8.8 - 0.8]$

$= 100 - 8$

$y_5^{20^\circ C} = 92$ mg/l

(9) I^st^ sample :-

$y_5^{20^\circ C} = [(DO)_I - (DO)_F] \times DF$

$= [9.2 - 6.9] \times \frac{300}{5} = 138$ mg/l.

II^nd^ sample

$y_5^{20^\circ C} = [9.1 - 4.4] * \frac{300}{10} = 141$ mg/l.

III 3^rd^ sample :-

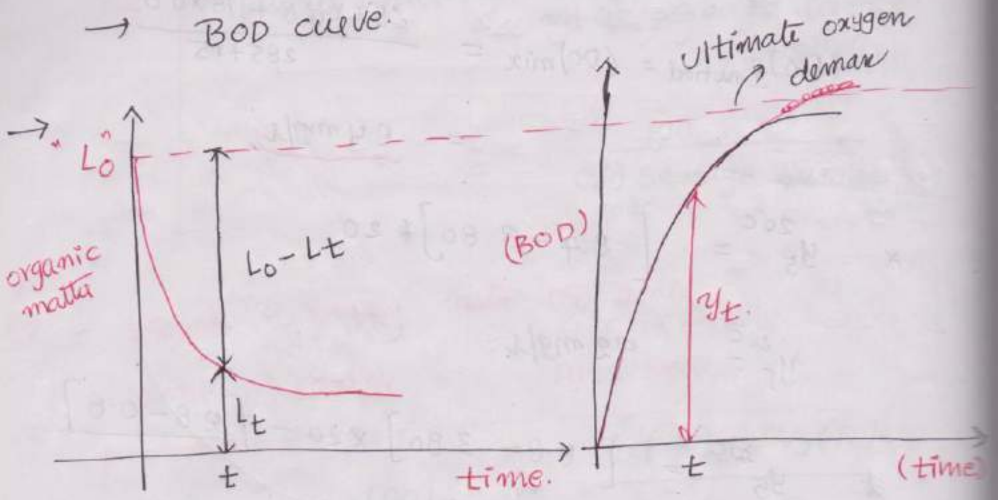
Test failed final DO. zero.

⇒ $y_5^{20^\circ C} = \frac{138+141}{2} = 139.5$ mg/l

* Mathematical model for BOD

→ organic matter curve

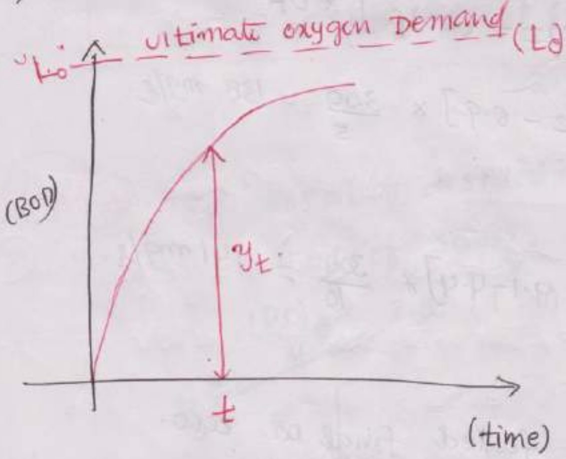
→ BOD curve.



→ L_0 – Initial amount of organic matter present in water.

L_0 – ultimate BOD

→ ultimate oxygen Deamd = L_0.



$$\boxed{\frac{dL}{dt} \propto L_t}$$

$$\Rightarrow \frac{dL}{dt} = -KL_t$$

$$\Rightarrow \cancel{\frac{dL}{dt}} \cdot \frac{dL}{L_t} = -K\,dt$$

$$\Rightarrow \int \frac{dL}{L_t} = \int -K\,dt$$

$$\ln[L_t] = -Kt + C \longrightarrow (I)$$

→ Apply boundary conditions to find 'C'.

$$\text{at } t = 0, \quad L_t = L_0$$

$$[L_0] = 0 + C \Rightarrow C = \ln[L_0]$$

$$\ln[L_t] = -Kt + \ln[L_0]$$

$$\Rightarrow \ln\left[\frac{L_t}{L_0}\right] = -Kt$$

$$\frac{L_t}{L_0} = e^{-Kt}$$

$$*** \boxed{L_t = L_0 e^{-Kt}}$$

(organic matter remain unoxidized in time "t")

→ $$y_t = L_0 - L_t$$

$$y_t = L_0 - L_0 e^{-Kt}$$

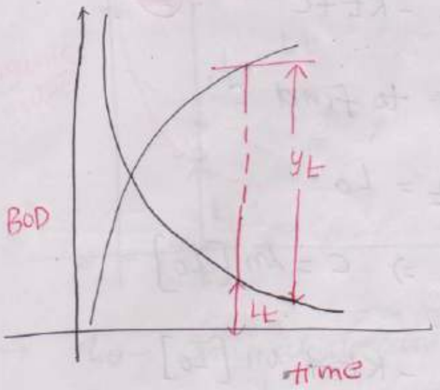
$$*** \boxed{y_t = L_0 (1 - e^{-Kt})}$$

BOD at any time

$$* \quad \boxed{y_t^{T^\circ C} = L_0\left[1 - e^{-K_T t}\right]}$$ → BOD at any time "t" and temperature

$$\boxed{K_T = K_{20}\left[1.047\right]^{T-20}}$$

$$\boxed{L_t = L_0 e^{-Kt}}$$ → organic matter present at any time "t".



$$* \quad \boxed{y_5^{20^\circ C} = \left[(DO)_I - (DO)_f\right] * DF = L_0\left[1 - e^{-K_T * t}\right]}$$

K = BOD rate constant : $\frac{1}{day}$ (or) d^{-1}.

K (base e)

K (base 10) : $\underline{K * 2.3}$(base e)

Ⓟ Ultimate BOD, L_0 = ?

Volume of waste water sample = 6ml.

$(DO)_S = 0$

Distilled water = 294 ml

$(DO)_D$ = 8.6 mg/l.

$(DO)_{final}$ = 5.4 mg/l ; K_{20} = 0.25 d^{-1} (base e)

(

$$\Rightarrow (DO)_{Initial} = (DO)_{mix} = \frac{V_D (DO)_D + V_S (DO)_S}{V_D + V_S}$$

$$= \frac{294 * 8.6 + 6 * 0}{294 + 6}$$

$$= 8.428 \text{ mg/l}.$$

$$y_5^{20^\circ C} = \{(DO)_I - (DO)_f\} * DF$$

$$D.F = \frac{300}{6} = 50$$

$$y_5^{20^\circ C} = [8.428 - 5.4] * 50 = 151.4 \text{ mg/l}.$$

(or)

$$y_5^{20^\circ C} = [(DO)_b - (DO)_f] * DF - [(DO)_B - (DO)_I]$$

$$= [8.6 - 5.4] * \frac{300}{6} - [8.6 - 0]$$

$$y_5^{20^\circ C} = 151.4 \text{ mg/L}.$$

$$* \quad y_t^{T^\circ C} = L_0 [1 - e^{-K_T t}]$$

$$y_5^{20^\circ C} = L_0 [1 - e^{-K_{20} * 5}]$$

$$K_{20} = K$$

$$\Rightarrow 151.4 = L_0 [1 - e^{-0.25 * 5}]$$

* Ultimate BOD, $\boxed{L_0 = 212.19 \text{ mg/l}.}$

(P04) 5 day 30°c BOD of a Sewage sample is

$y_5^{30°c} = 110$ mg/l.

$K_D(20) = 0.1/\text{day}$ (base 10)

$y_5^{20°c} = ?$

* L_0 is independent of time & temperature.

L_0 remains constant for a given waste.

$$\cancel{\frac{L_0}{y_5^{30°c}(1-e^{kt})}} \quad \left[L_0 = \frac{y_5^{30°c}}{1-e^{-K_{30}\times 5}} = \frac{y_5^{20°c}}{1-e^{-K_{20}*5}} \right]$$

$$\left[\frac{110}{1-e^{-0.364*5}} = \frac{y_5^{20°c}}{1-e^{-0.23\times 5}} \right]$$

$K_{20} = 0.1\,d^{-1}$ (base 10)

$K_{20} = 2.3 * 0.1 = 0.23\,d^{-1}$ (base e)

$K_T = K_{20}[1.047]^{T-20}$

$K_{30} = 0.23(1.047)^{30-20} = 0.364\,d^{-1}$ (base e)

* $y_5^{30°c} = L_0\left[1-e^{-K_{30}*5}\right]$

$110 = L_0\left[1-e^{-0.364*5}\right]$

$L_0 = 131.268$ mg/l.

* $y_5^{20°c} = L_0\left[1-e^{-K_{20}*5}\right]$

$= 131.268\left[1-e^{-0.23\times 5}\right]$

$$\boxed{y_5^{20°c} = 89.7 \text{ mg/l}}$$

(05) y_5 $y_1^{30°c} = 110 \, mg/l$

$y_5^{20°c} = ?$ $K_{(20)} = 0.1/d$ (base 10)

$K_{20} = 2.3 \times 0.1 \, d^{-1} = 0.23 \, d^{-1}$ (base e)

$\Rightarrow K_{30} = K_{20} (1.047)^{T-20}$

$K_{30} = 0.23 (1.047)^{30-20} = \underline{0.364 \, d^{-1}}$

$y_1^{30°c} = L_0 (1 - e^{-K_{30} \times 1})$

$110 = L_0 (1 - e^{0.364 \times 1})$

$\boxed{L_0 = 360.527 \, mg/l}$

$* \; y_5^{20°c} = L_0 \left[1 - e^{-K_{20} * t}\right]$

$= 360.527 \left[1 - e^{-0.23 \times 5}\right]$

$\boxed{y_5^{20°c} = 246.37 \, mg/l.}$

(08) $y_5 = 600 \, mg/l$; $K_{20} = 0.23 \, d^{-1}$ (base e)

$(BOD)_u \Rightarrow L_0$? (unoxidised $(BOD)_u$ for 20 days) ?

$\Rightarrow 600 = L_0 \left[1 - e^{-0.23 \times 5}\right]$

$\Rightarrow L_0 = 878.01 \, (mg/l)$

$\therefore L_t = L_0 e^{-Kt}$

$L_{20} = (878.01)(e^{-0.23 \times 20})$

$= 8.825 \, mg/l.$

$\therefore$ proportional of BOD Ultimate remain unoxidised

$= \underline{8.825} \times 100 = 1\%$

(P10) $y_5 = 190\ mg/l$. $K = 0.01 h^{-1}$ (base e)

$L_0 = ?$ $K = \frac{0.01}{h}$

$= 0.01 \times 24$

$= 0.24\ d^{-1}$

$$y_5 = L_0\left[1 - e^{-K_T \times t}\right]$$

$$190 = L_0\left[1 - e^{-0.24 \times 5}\right]$$

$L_0 = 271.89\ mg/l$. (Ultimate BOD)

(P11)

$y_5^{20°C} = 180\ mg/l$; $K_{20} = 0.18\ d^{-1}$

$$y_5^{20°C} = y_{2.5}^{T°C}$$

$$\cancel{L_0}\left[\cancel{1-e}^{+K_{20}\times 5}\right] = \cancel{L_0}\left[\cancel{1-e}^{+K_T \times 2.5}\right]$$

$$K_{20} \times 5 = K_T \times 2.5$$

~~$\frac{0.18\times5}{2.5} = K_T$~~

$$\Rightarrow \cancel{K_{20}} \times 5 = \cancel{K_{20}}\ (1.047)^{T-20} * 2.5$$

$$5 = (1.047)^{T-20} * 2.5$$

$$\Rightarrow \frac{5}{2.5} = (1.047)^{T-20}$$

$$\Rightarrow 2 = (1.047)^{T-20}$$

$$\ln(2) = (T-20)\ln(1.047)$$

$$\Rightarrow 0.693 = (T-20)(0.0459)$$

$$T = 15.09 + 20$$

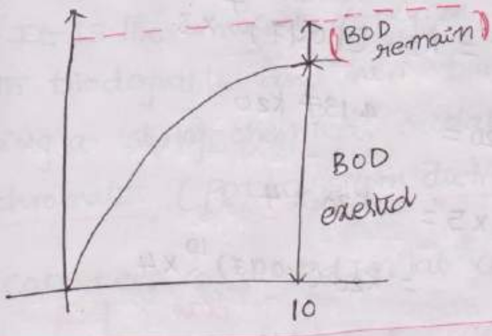
$$\boxed{T = 35.09°C}$$

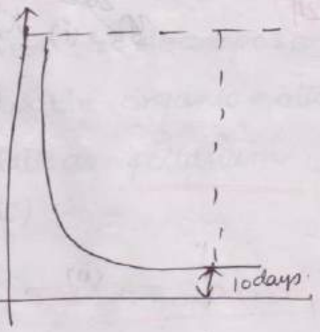
$$\ln 5 = \ln(T-20)\ \ln(1.047 \times 2.5)$$

$$T = 35.09\ °C$$

$$\boxed{T = 35.0°C}$$

(12) $y_3 = 75$ mg/l , $K_{20} = 0.345$





→ Amount of BOD remaining = amount of organic matter remaining

⇒ $110 = L_0\left[1-e^{-0.345*3}\right]$

⇒ $L_0 = 116.32$ mg/Lt

$$\boxed{L_{10} = L_0 e^{-K*t}}$$

⇒ BOD remaining after 10 days ⇒ $L_{10} = L_0 e^{-K*10}$

$L_{10} = (116.32)e^{-0.345\times10}$

$$\boxed{L_{10} = 3.69 \text{ mg/Lt}}$$

(P21) $y_5^{20°C} = 250$ mg/l

⇒ $\boxed{y_5^{20°C} = y_t^{30°C}}$

⇒ $\cancel{L_0}\left[\cancel{1}-\cancel{e}^{-K_{20}\times5}\right] = \cancel{L_0}\left[\cancel{1}-\cancel{e}^{-K_{30}\times t}\right]$

$+K_{20}\times5 = K_{30}\times t$

⇒ $\cancel{K_{20}}\times5 = \cancel{K_{20}}\,(1.047)^{\overset{(10)}{30-20}}\times t$

$t = 3.158$ days

$$\boxed{t = 3.16 \text{ days}}$$

P24

~~$y_5^{20°c}$~~ (i) $K_{20} \times 5 = K_{27} \times 3$

$K_{20} \times 5 = K_{20}\,(1.047)^7 \times 3$

$5K_{20} = 4.137\,K_{20}$

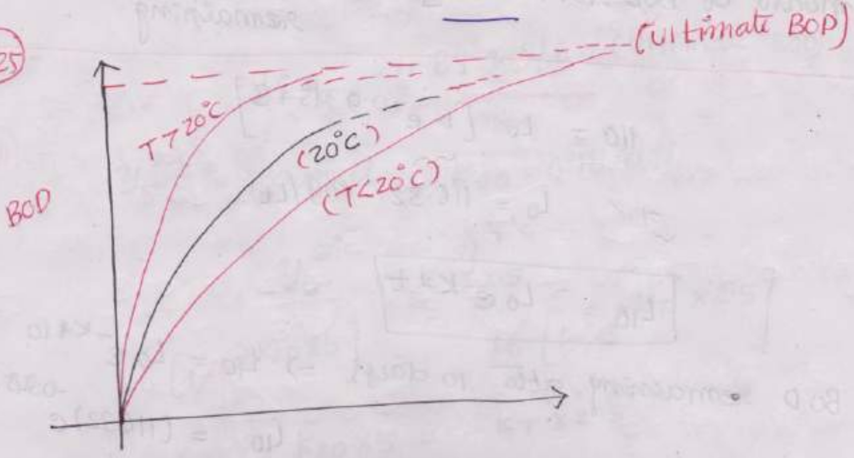
(ii) $K_{20} \times 5 = K_{30} \times 4$

$= K_{20}\,(1.047)^{10} \times 4$

$5K_{20} = 6.33\,K_{20}$

$5K_{20} = \underline{\quad}$

P25



P26

$y_1^{20°c} = 150\ mg/l$

$K_{20} = 0.23\ d^{-1}$ (base e)

$y_5^{20°c} = ?$

1) $y_1^{20°c} = L_0(1 - e^{-K_T \times t})$

$150 = L_0(1 - e^{-0.23 \times 7})$

$L_0 = 187.47$

2) $y_5^{20°c} = L_0(1 - e^{-K_t \times t})$

$= 187.47\,(1 - e^{-0.23 \times 5})$

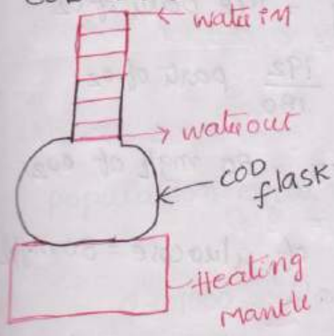
$$\boxed{y_5^{20°c} = 128.11\ mg/l}$$

$$\boxed{y_5^{20°c} = 128\ mg/l}$$

* COD :- (chemical oxygen Demand)

→ It is the amount of oxygen required to decompose both biodegrable and non biodegradable organic matter using a strong chemical oxidatent such as pottasium - dichromate. (pottassium dichromate)

* COD test conducted in lab using Reflux apparatus



* Reagents

1. potassium dichromate ↓ ($K_2Cr_2O_7$) (oxidising agent).
2. conc. H_2SO_4. (To main acidic condition & main temperature)

*3. silver sulphate - catalyst.

4. Mercuric sulphate → Inhibitor

→ Along with sewage sample.

* Heat~~ange is~~, the sample (2 hours).

* Titration :- → Titrant - Ferrous Ammonium sulphate

→ Indicator - Ferroin.

* TOD :- It is the amount of oxygen required to oxidice ~~the~~ biodegradable organic matter, non biodegradable organic matter ~~at~~ and along with them few of the inorganic chemical substances.

* * * $\boxed{TOD > COD > BOD}$

* ThOD :- (Theoritical oxygen Demand) :- It is used to find the amount of oxygen required using the chemical relation ship existing ~~the~~ among the given ~~substances~~

Ex:- Find ThoD of glucose 75 mg/l in waste water sample. The following chemical reaction is given.

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

Sol:- Mol. wt of $C_6H_{12}O_6 = 6\times12 + 12\times1 + 6\times(16) = 180$.

mol. wt of $6O_2 = 6[2(16)] = 192$.

180 parts of glucose demanding = 192 parts of O_2.

1 part of glucose = $\frac{192}{180}$ parts of O_2.

75 parts of glucose = $\frac{192}{180}\times75 = 80$ mg/l of O_2

∴ O_2 demand of 75 mg/l of glucose = 80 mg/l.

* ~~$\frac{BOD}{COD}$~~ $\frac{COD}{BOD}$: 1.5 – 2 ⇒ waste is biodegradable

⇒ $\frac{BOD}{COD}$: 0.5 – 0.67 → waste water is biodegradable.

* Population equivalent

⇒ $$\boxed{\underset{(kg/day)}{\text{Total strength of waste}} = \underset{(MLD) \times 10^6}{Q} \times \underset{(mg/l)}{y}}$$ ~~lit/day~~

→ As per Indian condition, percapita BOD contribution usually ranges from 80 – 90 gm/capita/day.

* $$\boxed{\text{Total strength of waste} = \text{population} * \text{per capita BOD.} \qquad (Q\times y) =}$$

∴ $$\boxed{\text{population equivalent} = \frac{\text{Total strength of waste}}{\text{Per capita BOD.}}}$$

(P06) $Q = 80 \times 10^6 \ l/d = 80 \times 10^3 \ m^3/d$

$y_5 = 285 \ mg/l$ $\qquad = \frac{80 \times 10^3}{24 \times 60 \times 60} \ m^3/sec$

Percapita BOD = 75 g/day/per $\qquad Q = 0.925 \ m^3/sec$

$Q = 80 \ mLD$

$\therefore$ population equivalent $= \frac{\text{Total strength of waste}}{\text{per capita BOD}} = \frac{Q \times y}{\text{per BOD}}$

$$= \frac{80 \times 285}{75 \times 10^{-3}} \left(\frac{kg/day}{kg/person/\cancel{day}} \right)$$

$\therefore$ population equivalent $= 304000$.

(P18) $Q = 1000 \ m^3/day$; $BOD = 162 \ mg/l = y$

$BOD = 80 \times 10^{-3} \ kg/person/day$.

$Q = \cancel{10^6} \ 1 \ mLD = \frac{10^6 \ L/day}{10^6} = 1 \ mLD$.

$\therefore$ population equivalent $= \frac{1 \times 162}{80 \times 10^{-3}} = 2025$

* Relative stability — It is the ratio b/w amount of oxygen remaining in a waste to amount of oxygen required to meet the first stage BOD.

$$\boxed{S_r = 100 \left[1 - 0.794^{t} \right]}$$

(P07) $S_r = 100 \left[1 - (0.794)^{12} \right]$

$S_r = 93.72$.

Treatment of waste water

→ Ⓘ Preliminary Treatment
Ⓘ Ⓘ Primary Treatment
Ⓘ Ⓘ Ⓘ ** Secondary Treatment
Ⓘ Ⓥ Tertiary Treatment

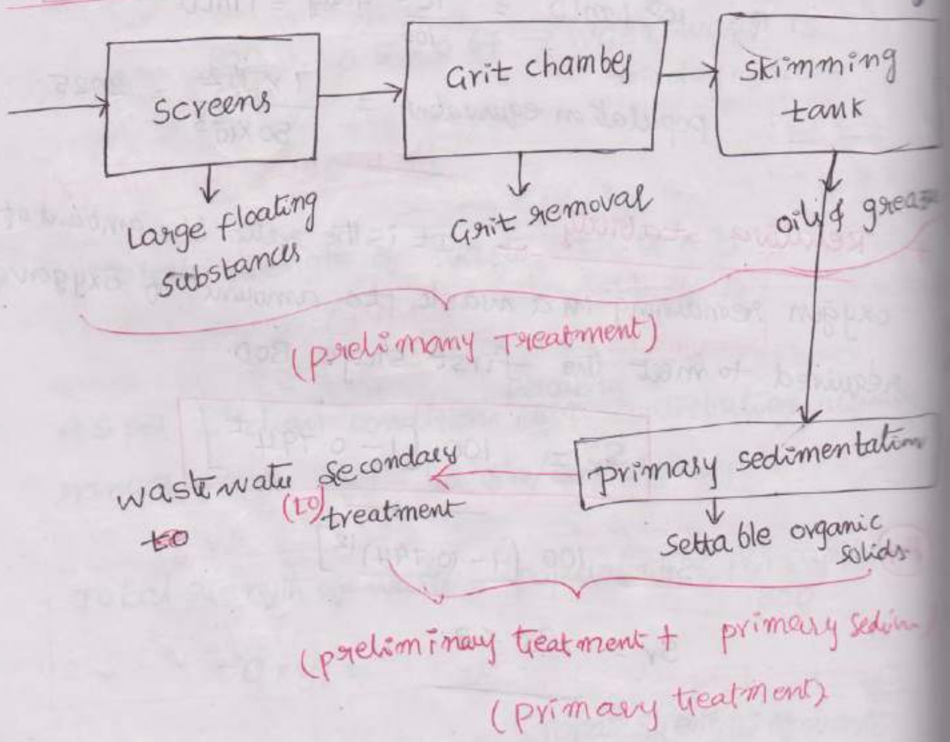
① Preliminary Treatment :- Preparatory process.

② Primary Treatment :- Settleable organic solids.

③ Secondary Treatment :- soluble BOD.

④ Tertiary Treatment :- Recycling

* Diagram :-



4. primary Treatment of sewage

* ① screens :-

→ screens device is used to remove large floating substance such as waste cloth, paper, wooden pieces, cark, glass bottles etc.

→ screen is a device with openings of uniform size. floating objects they are to large to openings therefore they are retained by the screen device.

→ Based on size of the openings.

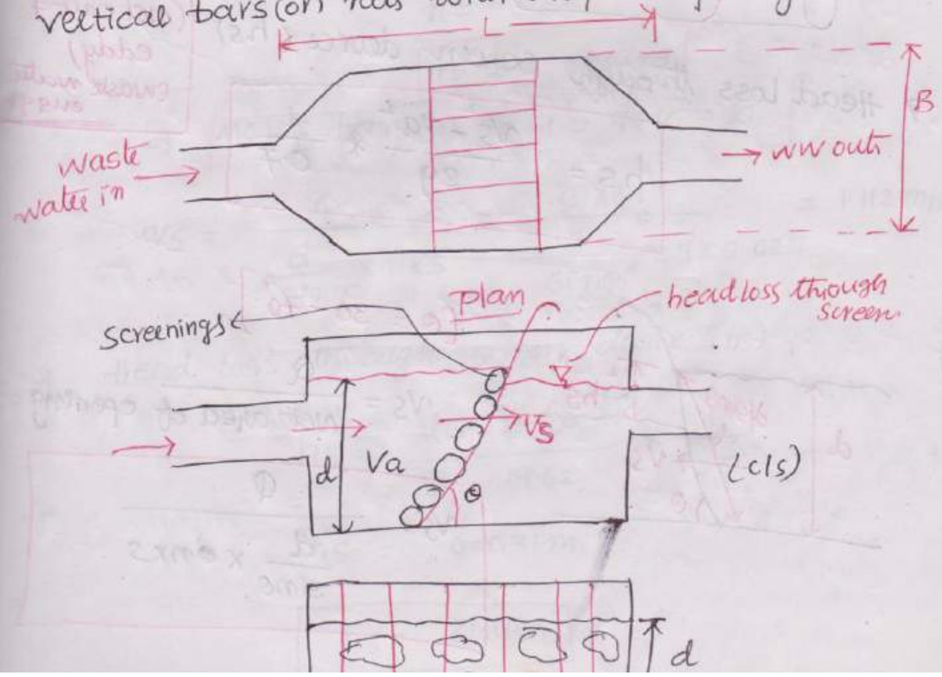
(1) coarse screen [size of opening > 50 mm]

(2) medium screen [size of opening 6mm - 40 mm]

(3) fine screen [size of opening 3mm - 6mm]

↓
frequent of choking is possible

→ screen ~~is a~~ device is made up of number of parell vertical bars (or) rods with uniform spacing.



* Design Information :- (Screen Design)

→ ① Approach velocity ("v_a") ⇒ [0.6 – 1.2 (m/s) Generally]

→ c/s area of screen device (B×d) = $\frac{Q}{v_a}$

– Depth of flow = 0.8 m – 1 m.

* Let n = no of spacings.

S = size of each spacing &

ϕ = diameter of bar.

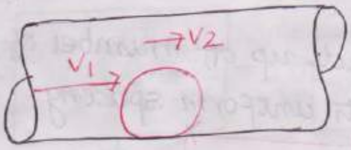
$$\boxed{B = n * S + (n+1)\phi}$$

(n+1) = no of bars

usually S = 25 mm ; ϕ = 10 mm.

② Head Loss due to obstruction :-

$[V_2 > V_1]$

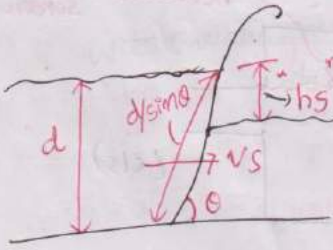


→ Head loss through screen device (h_s)

$$\boxed{h_s = \frac{v_s^2 - v_a^2}{2g} * \frac{1}{0.7}}$$

Text book (metcalf & eddy) (waste water engg)

*



$[\theta = 30 - 70°]$

$$v_s = \frac{Q}{\text{Net area of opening}}$$

$$\boxed{v_s = \frac{Q}{\frac{d}{\sin\theta} \times n \times s}}$$

Example :- Design a screen device for a flow of 25 MLD with $v_a = 0.9$ m/s. assume liquid depth = 1m, size of each spacing 25 mm, $\phi = 10$mm also find out head loss through screen chamber if it is provided 60° to horizontal

Sol :- c/s area of screen device $= \frac{Q}{v_a}$

$$Q = 25\,MLD = \frac{25\times10^6}{10^3\times24\times60\times60}$$

$$Q = 0.289\ m^3/sec$$

$$\therefore\ B\times d = \frac{0.289}{0.9} = 0.321\ m^2$$

$$B = 0.321\ m;\quad d = 1m$$

$S = 25mm$, $\phi = 10mm$; n = no of spacing

$$\cancel{0}321 = n\times25 + (n+1)(10)$$

$$= 25n + 10n + 10$$

$$321 = 35n + 10$$

$$n = 8.88$$

$$\boxed{n \approx 9\ \text{spacing}}$$

$\Rightarrow$ [no. of bars $\Rightarrow$ $n+1 = 9+10 = 10$]

$$v_s = \frac{Q}{\frac{d}{\sin\theta}\times n\times s} = \frac{0.289}{\frac{1}{\sin60^\circ}\times9\times0.025} = 1.112\ m/sec$$

* Head loss through screen device (h_s)

$$h_s = \frac{(1.112)^2-(0.9)^2}{19.62}\times\frac{1}{0.7}$$

$$h_s = 0.031m.$$

$$\boxed{h_s = 31mm}$$

② Grit chamber

→ * Grit is composed of

* ① Inorganic suspended solids.

[dia < 0.2mm]

[sp.gravity ≥ 2.65]

Eg.:- * [It consists of sand, silt, clay, cynder, broken glass pieces, Metal fragments e.t.c]

* ② organic & non biodegradable suspended solids

[size (dia) > 2mm] [sp.gravity (S) = 1.05-1.1]

Eg.:- [coffee grounds, Tea grounds, egg shells, bone chips etc]

→ Grit particles are removed by using Grit chamber

→ Grit chamber is a long, narrow, rectangular channel with increased dimensions ~~decelerate~~ deccelerate flow velocities giving raise to settlement of grit particles from sewage flow.

→ usually we maintain.

$$v_H = 0.2 - 0.4 \text{ m/sec}$$

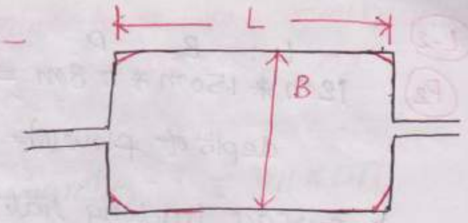
** $$\boxed{V_H = 0.3 \text{ m/sec}}$$

* A proportional flow weir is provided at the outlet of the grit chamber.

** slight Increase in flow velocity leads to scouring of settled grit.

** slight decrease in v_H leads to settlement of non targeted particles.

* Design of Grit chamber :-



→ Long narrow rectangular channel.

L = 7.5m – 20m

B = 2.5m – 7m

depth (d) = 2 – 3m

$\boxed{v_H = 0.3\ m/sec}$

→ Modified Hazen's formulae :-

$$\left[\underset{(cm/sec)}{v_s} = 60.6\,(S-1)\,\underset{cm}{d}\ \frac{3\overset{Temp^\circ C}{T}+70}{100} \right]$$

→ Detention time : 1 min – 3 min.

* $\boxed{\text{volume of grit chamber : } Q * DT}$

– Assume Depth of flow.

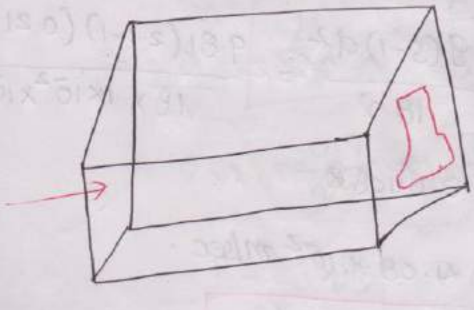
**→ $\boxed{\text{surface area of Grit chamber} = \dfrac{\text{volume of grit chamber}}{\text{depth of grit chamber}}}$

→ Surface area : L * B.

L : B = 3 : 1

L = 3B

(proportional weir)



(L-2)

(P2) L : B : D

12m * 1.50m * 0.8m = Dimensions.

depth of flow (Q) = 720 m^3/hr.

→ surface loading rate : $\frac{Q}{\text{surface are}}$: $\frac{Q}{L*B}$

$$= \frac{\frac{720}{24\times60\times60}}{12\times1.5} = \frac{720}{12\times1.5}$$

$= 40\ m^3/hr/m^2$

$= 40000$ lt/hr/m^2.

⇒ Volume = Q * DT

$$DT = \frac{\text{volume}}{Q} = \frac{12\times1.50\times0.8}{\frac{720}{60}}$$

DT = 1.2 min

(P4) $Q = 3\ m^3/sec$; $v_H = 0.3$ m/sec. (not given but default)

$$\boxed{\text{cross sectional area} = \frac{Q}{V_H}}$$

$$= \frac{3}{0.3} = 10 m^2.$$

(P5) sp. gravity = 2.7 ; size = 0.21 mm.

$\nu = 1 * 10^{-2}\ cm^2/sec$.

$$V_S = \frac{g(S-1)d^2}{18\nu} = \frac{9.81(2.7-1)(0.21)10^{-3}}{18\times1\times10^{-2}\times10^{-4}}$$

$V_S = 0.0408$

$V_S = 4.08 * 10^{-2}$ m/sec.

$$\boxed{V_S = 4.08\ cm/sec.}$$

Example :- Design a Grit chamber for a flow 20 MLD with a horizontal flow velocity 0·3 m/sec and DT : 1 min. Assume length to width ratio as 3 : 1.

Sol :- $\boxed{\text{Length of the grit chamber } L = v_H \times DT}$

$$L = 0.3 \times 1 \times 60$$

$$L = 18\,m.$$

$$L : B = 3 : 1$$

$\cancel{B = \frac{3l}{L}}$. $B = \frac{L}{3} = \frac{18}{3} = 6\,m.$

$\left[\frac{L}{B} = \frac{3}{1}\right]$

$\left[B = L/3\right]$

→ c/s area : $\frac{Q}{v_H}$

$$Q = 20\,MLD = \frac{20 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.231\,m^3/sec.$$

$$B \times H = \frac{0.231}{0.3} = 0.77\,m^2$$

$$H = \frac{0.77}{6} = 0.129.$$

→ provide 1m minimum depth.

Page-18

(18) Length = 7·5 m; $v_H = 0.3\,m/s$; $d = 0.9\,m$; $S = 2.5$

$g = 9.80\,m/s^2$, $\mu = 1.002 \times 10^{-3}\,N\text{-}s/m^2$ at 20°C.

$e_w = 1000\,kg/m^3$. (removed 100% efficiency)

$$\boxed{\frac{H}{V_S} = \frac{L}{v_H}}$$

$$\Rightarrow \frac{0.9}{v_S} = \frac{7.5}{0.3}$$

$$v_S = 0.036\,m/sec.$$

$$\therefore \left[v_s = \frac{g(s-1)d^2}{18\nu} \right] \qquad \left[\nu = \frac{\mu}{e} = \frac{1.002\times10^{-3}}{1000} \right]$$

$$\left[s = \frac{e_p}{e_w} \right]$$

$$\therefore v_s = \frac{g(e_p - e_w)d^2}{18\mu}$$

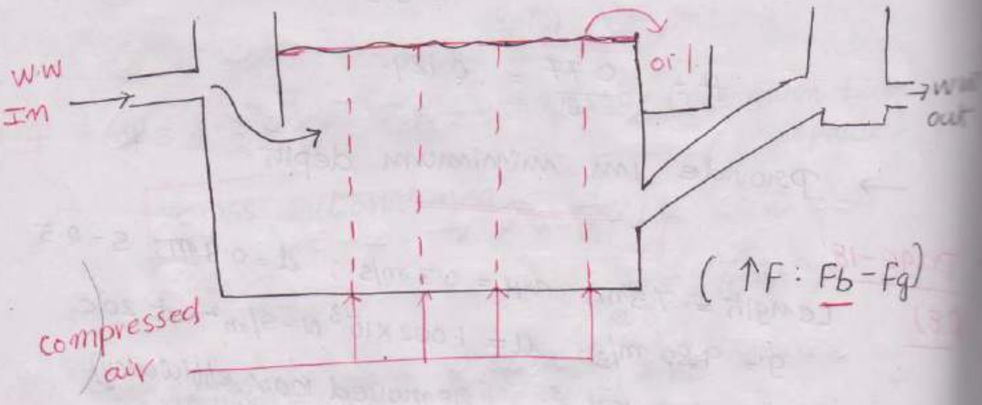
$$0.036 = \frac{9.81(2500-1000)(d)}{18\times1.002\times10^{-3}}$$

∴ diameter of the particle ~~(d)~~ = 0.21×10^{-3} m

$$\boxed{(d) = 0.21\,mm}$$

* Skimming tank (floatation unit $\overset{\text{or}}{\text{tank}}$) (buoyant force is used) :-

→ used to remove oil & grease present in waste water



$(\uparrow F : F_b - F_g)$

=) Detention time = 3-5 min.

* surface area $A_s = 0.00622 \frac{Q}{V_r}$

$L * B$ = surface area 'A_s'

$$\boxed{A_s = 0.00622 \frac{q}{V_r}}$$

V_r = liquid rise velocity = 0.25 m/min

Q = flow rate in m^3/day.

* Primary sedimentation tank :-

(primary clarifier).

→ used to remove organic settleable solids.

It capture 70% of settleable solids (Biodegradable organic solids capture & 30% BOD is removed in waste water).

→ primary sedimentation tank used to employee to dealing waste water follows type-III settling is also known as Hindered settling

→ organic solids → flocculent particles.

** Flocculent particle settlement in concentrated suspension.

→

* Surface Loading Rate

SLR (or) SOR

$v_0 = 30-50\ m^3/day/m^2$

$\downarrow$ surface area $\propto \frac{1}{v_0} \uparrow$

* Detention time :- 1.5 - 2 hrs.

* $\boxed{\text{Surface area } \frac{\pi}{4} d^2 = \frac{Q}{v_0}}$

Depth : 2.5 - 3.5

* Secondary Treatment :-

→ Biodegradable suspended solids which escape from primary sedimentation tank as well as solulable biodegradable organic matter (soluble BOD).

* Soluble BOD is removed by :-

1. physico-chemical treatment method.
2. Biological treatment method.

→ ① Micro screening.
② chemical absorption.
③ adsorption.
④ Filtration.
⑤ chemical coagulation.
⑥ Dialysis etc.

} High cost options

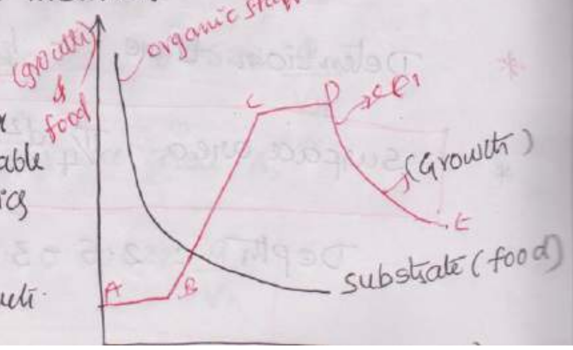
* $\boxed{\frac{COD}{BOD} : 1.5-2}$ → waste water can be biologically tretable.

* Biodegradable waste better it can be treated by biological treatment methods rather than physico-chemical treatment methods.

* * principle :-

→ Microorganism + complex biodegradable organics

→ simple & stable end products.



* Microorganisms + complex Biodegradable organic ⟶ simple & stable end products

→ AB – Lag growth

BC – ~~Expansion~~ Exponential growth.

CD – stationary growth.

DE – Declining growth.

* Micro organisms :–

→ Based on O_2 utilization of microbes.

① Aerobic organisms → survive only in the presence of O2.

② Anaerobic organisms → survives in the absence of external O2 source.

③ facultative organisms → survive both in presence (or) absence of O2.

→ Based on food habits :–

1. Autotraphic organisms. Eg– Algae
   ↓
   doesn't depend on other (or) External food source.
2. Hetrotrophic organisms. Eg:– Bacteria

* Based on the organism employed in decomposing the waste water treatment is broadly classified into two categories. (Biological treatment)

① Aerobic treatment.

② Anaerobic treatment.

* Aerobic treatment :-

$$\left.\begin{array}{l}\text{complex}\\\text{organic}\\\text{matter}\end{array}\right\} + \text{Bacteria} + O_2 \rightarrow CO_2 + NH_3 + H_2O + \text{Energy}.$$

$$\text{Energy} + \text{bacteria} + O_2 \longrightarrow \underbrace{C_5H_7NO_2}_{\text{(New microbial cell)}}.$$

(very fast) - Adv

(It produce so much amount of biomass) - Dis

* Anaerobic treatment :-

→ Slow process. *(Biogas production) is based on this process).

$$\Rightarrow \left.\begin{array}{l}\text{complex}\\\text{organic}\\\text{matter}\end{array}\right\} + \text{Bacteria} \longrightarrow CH_4 + CO_2 + H_2S + \text{Energy}.$$

$$\Rightarrow \text{Energy} + \text{bacteria} \longrightarrow \underbrace{C_5H_7NO_2}_{\text{New microbial cell}}$$

* In general ~~whit~~ waste waters are treated Aerobically and then disposed off.

→ The by-products produced from aerobic treatment treated anaerobically and then dispose.

5· Activated sludge Process

* Aerobic treatment of waste waters :—

① suspended culture system.

Eg:— [Activated sludge process]

② Attached culture system.

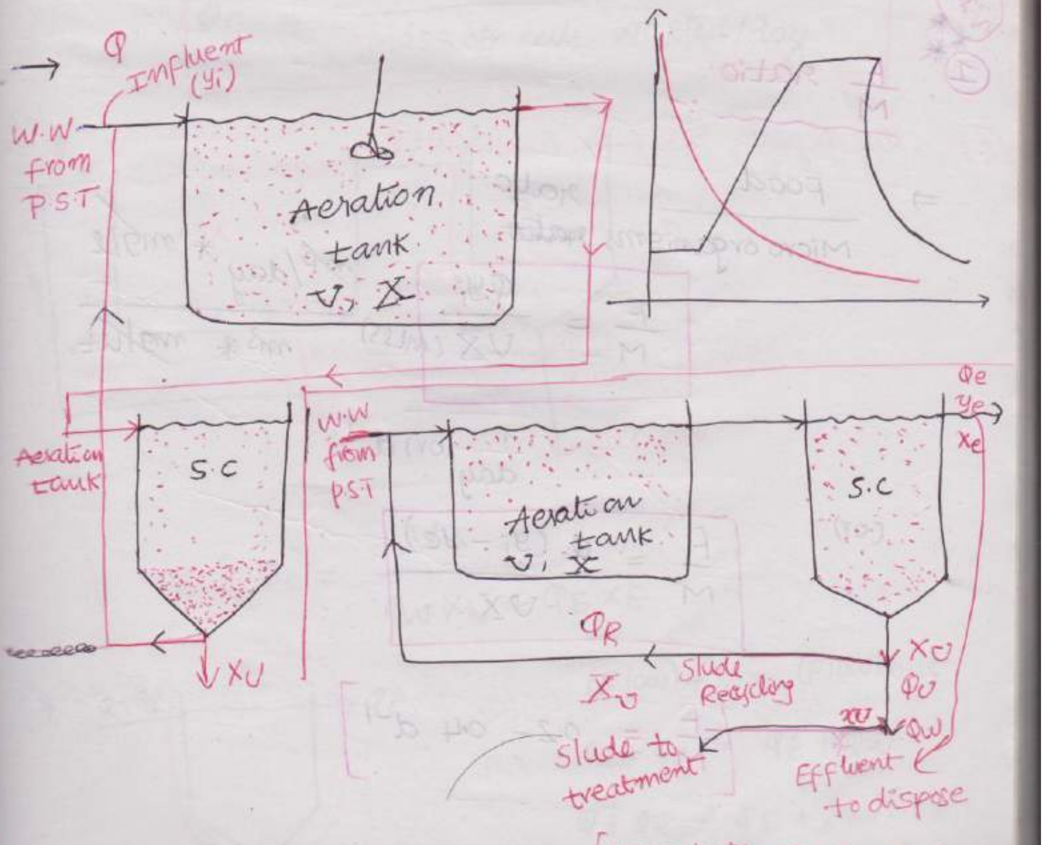
Eg.— [Trickling Filters]

① Activated sludge process

→ works on the principle of suspended culture system.

* 2 reactors :— ① Aeration tank.

② Secondary settling tank.



[concentration is same of

* Design parameters of Activated sludge process

⇒ y_i = BOD of Influent.

V = Volume of aeration tank.

X = MLSS (Mixed liquor suspended solids).

y_e = effluent BOD. (mg/l)

(solids) X_e = MLSS in effluent. (mg/l)

X_U = MLSS in under flow (settled mass).

Q_U = under flow rate in (m^3/sec)

Q_R = flow rate of recycled sludge.

Q_W = flow rate of waste sludge.

(V.Imp) *** ① $\frac{F}{M}$ ratio :-

⇒ $\frac{\text{Food}}{\text{Micro organisms}}$ ~~ratio~~ ratio.

$$\boxed{\frac{F}{M} = \frac{Q y_i}{V X \text{ (MLSS)}}} \qquad \frac{\cancel{m^3}/day * mg/l}{\cancel{m^3} * \cancel{mg/lit}}$$

$$\frac{1}{day} \text{ (or) } d^{-1}$$

(or)

$$\boxed{\frac{F}{M} = \frac{Q(y_i - y_e)}{VX}}$$

$$* \left[\frac{F}{M} = 0.2 - 0.4 \, d^{-1}\right]$$

② volumetric Loading rate (or) organic Loading rate :-
($\forall_L$)

$$\boxed{\forall_L = \frac{Q y_i}{X}}$$

[Mass food applied for unit volume of reactor]

units :- kg of BOD/day/m^3

~~③~~ [$\forall_L$ = 0.3-0.6 kg of BOD/day/m^3]

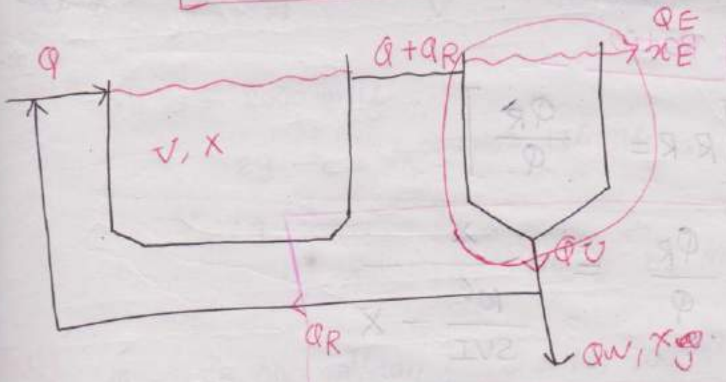
**(V.I) ③ (θ_c) Mean cell residence time (MCRT) (θ_c")

→ ~~Avg life of organism.~~

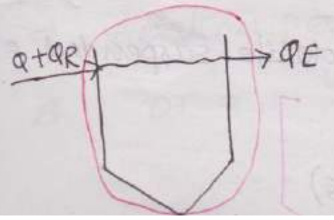
→ sludge age : Avg life period of organism.

$$\boxed{\theta_c = 4-15 \text{ days.}}$$

$$\boxed{\theta_c = \frac{\text{Mass of cells in the reactor}}{\text{Mass of cells wasted/day.}}}$$



$$" \theta_c" = \frac{VX}{Q_W X_U + Q_E x_E}$$

* 

$(Flow)_{In} = (Flow)_{out}$.

$Q_1 + Q_2 = Q_E + Q_W$

$Q + Q_R = Q_E + (Q_W + Q_R)$

**
*

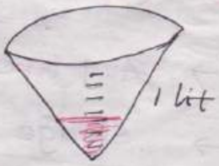
$$\boxed{\theta_c = \frac{VX}{Q_w X_u + Q_E X_E} = \frac{VX}{Q_w X_u + (Q - Q_w) X_E}}$$

④ ~~Det~~ Detention time :-

$$\theta\,(DT) = \frac{\text{volume of areation tank}}{Q}$$

$$\theta = 4 \text{ to } 8\,hrs$$

⑤** SVI (Sludge volume Index)
*



$$(SVI) = \frac{\rightarrow \text{Volume occupied in (ml)}}{\text{1 gm of MLSS settling for 30 mins from 1 liter of sewage sample (gm)}}$$

$$\left[SVI : 50 - 150\ ml/gm\right]$$

(SVI = $\frac{200\,ml}{200\ [illegible]}$ [illegible]

⑥ Recycling Ratio :-

$$\left[R \cdot R = \frac{Q_R}{Q}\right]$$

$$\boxed{\frac{Q_R}{Q} = \frac{X}{\frac{10^6}{SVI} - X}}$$

$$\left[\frac{Q_R}{Q} : 0.25 - 0.5\right]$$

* MLVSS – Mixed liquor volatile suspended solids

$$\left[\frac{F}{M} = \frac{Q y_i}{V\,(MLVSS)}\right]$$

Level-2

(01) $Q = 50 \times 10^6$ l/d ; BOD $= 180$ mg/l ; $\forall_L = 550$ gm BOD/m^3
(y_i)

$Q = 50$ MLD.

$$\forall_L = \frac{Q y_i}{V}$$

$$550 \times 10^{-3} = \frac{50 \times 180}{V}$$

$$V = 16363 \text{ m}^3.$$

(02) $Q = 50$ MLD ; $y_i = 180$ mg/l ; MLSS $= 1800$ mg/l.

$\frac{F}{M} = 0.5 (d^{-1})$ $V = ?$

$$\Rightarrow \frac{F}{M} = \frac{Q y_i}{V \times (\text{MLSS})}$$

$$\Rightarrow (d^{-1})\, 0.5 = \frac{10^3 \times \overset{\text{MLD}}{50} \times 180 \text{ mg/l}}{V (1800) \text{ (mg/l)}} \quad \frac{\text{m}^3/\text{day}}{}$$

$$\Rightarrow V = 10{,}000 \text{ m}^3$$

03) MLSS $= 2000$ mg/l

2g → ~~1,000 ml~~ 176 ml

1g → ?

$\Rightarrow \underline{1g} = \frac{176}{2} = 88$ ml/gm.

(04) $Q = 35{,}000$ m^3/day ; $V = 10{,}900$ m^3 ; $y_i = 250$ mg/l

$y_e = 20$ mg/l ; MLSS $= 2{,}500$ mg/l $= X$.

$X_e = 30$ mg/l ; $X_U = 9{,}700$ mg/l ; $Q_W = 220$ m^3/day

$\Rightarrow$ Aeration period $=$ D.T

$$DT = \frac{\text{volume of aeration tank}}{Q}$$

$$= \frac{1090\cancel{0}}{3500\cancel{0}} \; \frac{\text{m}^3}{\text{m}^3/\text{day}} \text{ (day)}$$

$$DT = \frac{10900}{35000} \times 24$$

$$DT = \underline{7.47\ hr.}$$

(05)

$$\frac{F}{M} = \frac{Qy_i}{VX} = \frac{35\cancel{000} \times 25\cancel{0}}{109\cancel{00} \times 25\cancel{00}}$$

$$= 0.321\ d^{-1}$$

(06)

$$\boxed{\eta = \frac{y_i - y_e}{y_i} * 100}$$

$$\eta = \frac{250-20}{250} \times 100$$

$$\boxed{\eta = 92\%}$$

* * *

$$\boxed{\text{sludge age (MCRT)} \quad \theta_c = \frac{VX}{Q_W X_U + (Q - Q_W) X_E}}$$

$$\left[\frac{m^3 (mg/l)}{m^3/day \cdot mg/l}\right] = days$$

(07)

$$\theta_c = \frac{10900 \times 2500}{220 \times 9700 + (35000 - 220) \times 30}$$

$$\boxed{\theta_c = 8.58\ days}$$

(09) $1g \rightarrow 200\ ml \Rightarrow SVI = 200$ only.

(10) $V = 400\,m^3$; $MLSS = 1000\,mg/l$

$$\text{Amount of MLSS} = 400 \times 1000 \times \frac{1000}{10^6} \; (m^3)\left(\frac{mg}{lit}\right)$$

$$= 400\ kg.$$

$$\boxed{\text{mass of MLSS in reactor} = VX}$$

$-Q_w)X_E$

$] =$ days

$\frac{mg}{lt})$

⑫ ~~Aeration period $= \frac{\text{volume}}{Q}$~~

$= \frac{30\times14\times4.3}{0.0796}\ \frac{m^3}{(m^3/s)}$

~~$= 0.262$~~ [illegible]

DT = 6.30 hr

$$\frac{F}{M} = \frac{0.0796\times130\times24\times60\times60}{\cancel{0.262}\ 1806\times\cancel{2100}\ 1500}$$

$\Rightarrow$ ~~$F/M = 0.235\,d^{-1}$~~ $F/M = 0.33\,d^{-1}$

$\Rightarrow$ ~~$SVI = \frac{230\,(ml/l)}{}$~~

$$\Rightarrow SVI = \frac{\text{volume occupied in (ml)}}{1\text{gm of MLSS}}$$

$$SVI = \frac{230}{2.1} = 109.52$$

$$\Rightarrow \frac{Q_R}{Q} = \frac{X}{\frac{10^6}{SVI} - X}$$

$$\frac{Q_R}{(0.0796\times130\times24\times60\times6)} = \frac{2100}{\frac{10^6}{109.52} - 2100}$$

$$\boxed{Q_R = 2054.20\ m^3/day}$$

[~~1hr = 3600sec~~]

[1hr = 3600sec]

$*$ Aeration period $= \frac{\text{Volume}}{Q} = \frac{30\times14\times4.3\ (m^3)}{0.0796\ (m^3/s)}$

$= 6.30\ hr$

(DT = 6.30 hr)

(13) $SVI = \frac{\quad}{2.8}$ $\underline{12.8}$

⑮ $Q = 1\ MLD$; $y_i = 200\ mg/l$ $\quad Q = \cancel{1000}\ L/D$

$V = 200\ m^3$; $x_e = 50\ mg/l$ $\quad = 10^6\ L/D$

$Q = 10^3\ (m^3/day)$

$X = 2000\ mg/l$

$$DT = \frac{V}{Q} = \frac{200\ (m^3)}{10^3\ (m^3/day)} = 0.2\ days$$

$$DT = 4.8\ \cancel{day}\ hours$$

⑯ ∴ completely mixed, $Q_u = Q_R$

$Q_w = 0$

$$\left[\theta_c = \frac{VX}{Q_w X_u + (Q - Q_w) X_u}\right]$$

$$\theta_c = \frac{200 \times 2000}{0 + (1000 - 0)(50)}$$

$$\theta_c = \cancel{000}\ 8\ days$$

$$\boxed{\theta_c = 8\ days}$$

(18) $\frac{F}{M} = \frac{Q y_i}{V X} \Rightarrow \frac{F}{M} = \frac{(\cancel{20.833}\ 12000)(150)}{(4000)(2000)}$ $\quad \left(1\ \cancel{hour}\ day / 24\ hour\right)$

$$\Rightarrow F/M = \frac{(m^3/day)(\cancel{mg/l})}{(m^3)(\cancel{mg/l})}$$

$$F/m = \left(\frac{1}{day}\right)$$

$$F/m = 0.225\ days.$$

~~⑯~~ $\left[\boxed{M = VX}\right.$ $\quad \left[\frac{2000}{10^{-3}} \frac{mg}{m^3}\right]$

$$\cancel{M = (4000)(m^3)(2000)\ mg/l}$$

$$\cancel{M = (4000)(2000) \times 10^{-3}}$$

(19) $\theta_C = \dfrac{\text{Mass of cells in reactor}}{\text{Mass of cells } \cancel{\text{for}} \text{ wasted/day}}$

mass of cells wasted/day $= \dfrac{\text{mass of cell in reactor}}{\theta_c}$

=) mass of cells waste/day $= Q_w X_U + (Q - Q_w) X_E = \dfrac{VX}{\theta_c}$

$[X_E = 0]$

$$= \frac{(4000)(m^3)(2000)(mg/l)}{10 \ (day)}$$

$$= \frac{(4000)(10^3) \times (2000) \times \frac{1}{10^6}}{10} \quad \frac{\cancel{lit} * kg/lit}{day}$$

$$= 800 \ kg/day$$

∴ mass of cells wasted/day = 800 kg/day.

(20) 4000 mg = ~~4000 B ml~~ 1000 ml =) 1 ml = $\frac{4000}{1000}$ = 4 mg.

~~[illegible]~~

$SVI = \frac{200}{4} = 50$

, For convential activated slude proam (ASP)

$\boxed{\text{MLSS : } 1500 - 3000 \ mg/l}$

F/M : $0.2 - 0.4 \ d^{-1}$

V_L : $0.3 - 0.6$ kg of BOD/m³/day.

θ_c : 4 – 15 day , θ : 4–8 hr.

SVI : 50 – 150

$\frac{Q_R}{Q}$: 0.25 – 0.5

X_U : 9000 – 11000.

$SUI = 88 \ ml/gm$

$$\boxed{X = \frac{1}{SVI} \ gm/ml}$$

$$X = \frac{1}{88} * \frac{1000}{\frac{1}{1000}} = \frac{1}{88} \times 10^6$$

$$\underline{X = 11364 \ mg/l}$$

Example :- Data pertaining to activated slude process given below.

→ flow rate : $10000 \ m^3/day$.

y_i : 150 mg/l.

y_e : 20 mg/l

MLSS (X) : 3000 mg/l.

⇒ MLSS in waste slude (X_u) : 10000 mg/l

$F/M = 0.25 \ d^{-1}$

$\theta_c = 10$ days.

⇒ Find the following (i) volume of aeration tank (ii) efficiency of BOD removal (iii) mass of solids wasted per day (iv) volume of solids wasted per day. (v) Recycling Ratio. (vi) Dentention time

Sol:-

$$\frac{F}{M} = \frac{Q y_i}{V X} \Rightarrow 0.25 = \frac{\overset{(m^3/day)}{(10,000)}(150)}{V(3000)}$$

$$\Rightarrow V = \frac{500 m^3}{0.25}$$

$$\Rightarrow V = 2000 \ m^3$$

(ii) $$\eta = \frac{y_i - y_e}{y_i} \times 100$$

$$\eta = \frac{150 - 20}{150} \times 100$$

$$\eta = \frac{130}{150} \times 100 = 86.67\%$$

(iii) mass of cells wasted/day

$$= \frac{VX}{\theta_c} = \frac{(2000)(3000)\times10^{-3}}{10}$$

$$Q_w \times U = 600 \text{ kg/day}.$$

(iv) ** volume of solids wasted ~~per~~/day =

$$\boxed{V/t = Q_w} \quad \left[Q_w = \frac{\cancel{8}m}{X_U}\right]$$

$$Q_w = \frac{600}{10000} = \frac{\text{kg/day}}{\text{mg/lit}}$$

$$= \frac{600\times10^6}{10000} \cdot \frac{\text{mg/day}}{\text{mg/lit}} = (\text{lit/day})$$

$$= \frac{6\cancel{00}\times10^{\cancel{6}}}{\cancel{10000}} \times \frac{1}{\cancel{1000}}$$

$$= 60 \text{ m}^3\text{/day}$$

$$\boxed{Q_w = 60 \text{ m}^3\text{/day}}$$

(v) sludge volume Index $= \dfrac{10^6}{X_U}$

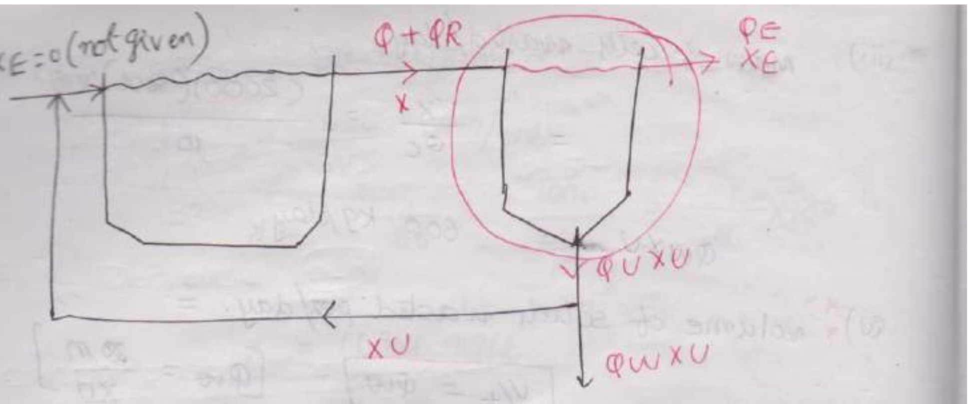
$$SVI = \frac{10^6}{X_U} = \frac{10^6}{10{,}000} = 100 \text{ ml/gm}.$$

$$\frac{Q_R}{Q} : \frac{X}{\frac{10^6}{SVI} - X} = \frac{3000}{\frac{10^6}{100} - 3000}$$

$$\frac{Q_R}{Q} = 0.428$$

$$\boxed{\frac{Q_R}{Q} = 0.428}$$

* $X_E = 0$ (not given)



$$\Rightarrow \quad (\text{mass})_{In} = (\text{mass})_{out}$$

$$(Q+Q_R)\,X = Q_E X_E + Q_U X_U$$

$$(Q-Q_W)X_E + (Q_W+Q_R)X_U$$

$$\Rightarrow \quad (Q+Q_R)\,X = (Q_W+Q_R)X_U$$

mass balance operation →

$$\therefore \boxed{(Q+Q_R)\underline{X} = (Q_W+Q_R)X_U}$$

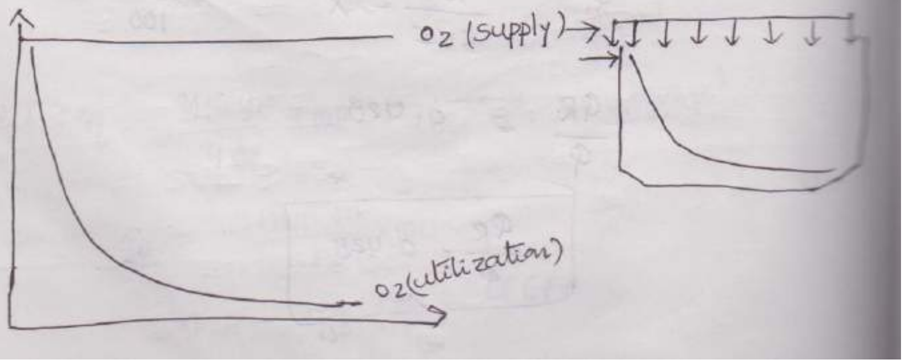
$$\Rightarrow \quad (10000+Q_R)\,3000 = (60+Q_R)\,10000$$

$$Q_R = 4200 \text{ m}^3/\text{day}$$

$$\frac{Q_R}{Q} = \frac{42\cancel{00}}{100\cancel{00}} = 0.42$$

$$\therefore \boxed{\frac{Q_R}{Q} = 0.42}$$

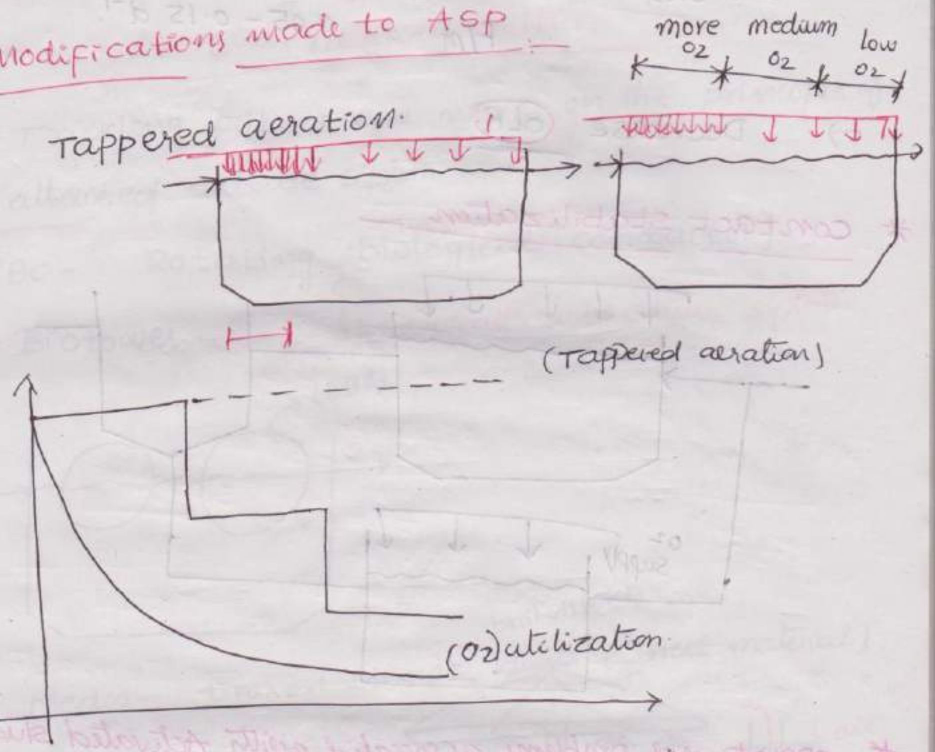
*



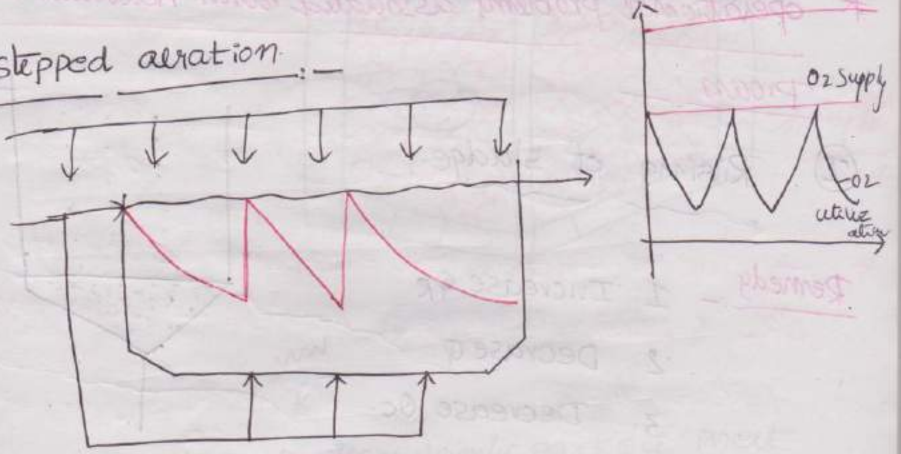
* Activated sludge process constant amount of O_2 is supplied.

* Modifications made to ASP :-

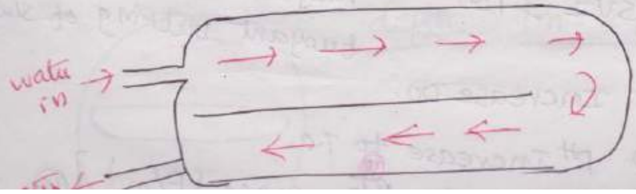
1. Tappered aeration.



② Stepped aeration :-



③ Extended aeration :-

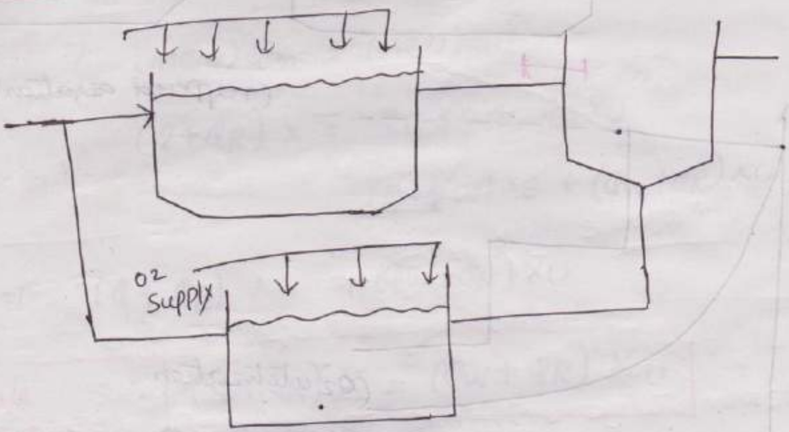


→ Increase Detention time; DT : 18 - 24 hr.

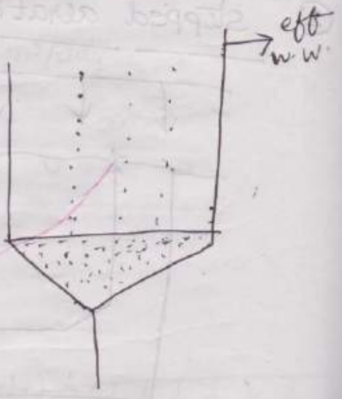
Decrease F/m ratio to
F/m : 0.05 - 0.15 d^{-1}.

→ Decrease OLR

* contact stabilization :-



* operational problems associated with Activated sludge process :-



① Rising of sludge :-

Remedy :- 1. Increase Q_R

2. Decrase Q

3. Decrease θ_c.

② Bulking of sludge :- (more number of dead cells they are absorb water and buoyant bulking of sludge)

SVI ≥ 150

Remedy :- ① Increase DO.

② pH Increase to 7.0.

③ Lower to slude volum Inden (SVI ≈100)

④ Decrease (F/M) ratio.

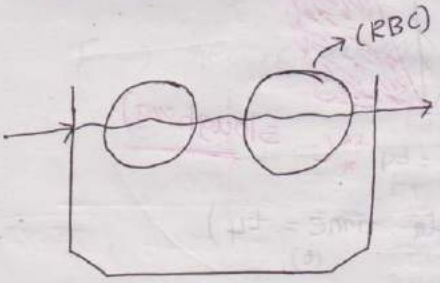
6. Trickling filters

→ Trickling filters ~~are~~ works on the principle of attached culture system.

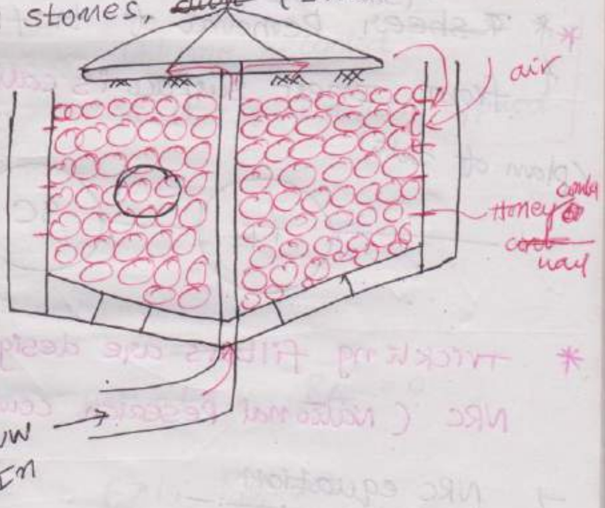
→ (RBC - Rotating biological contactor)

→ Biotower.

} standard attached culture system.

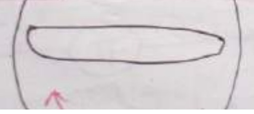


→ Media - broken stones, ~~dust~~ broken bricks (Inert material)

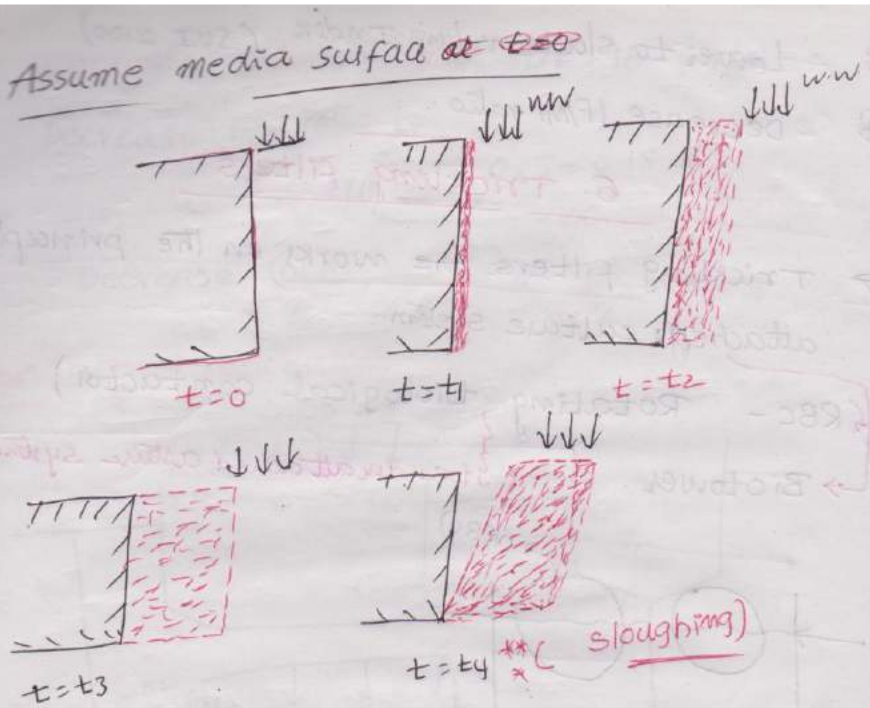


→ T.F consist of Randomly packed inert media in a circular reactor of dia 3m - 60m

depth :- 1m - 24m

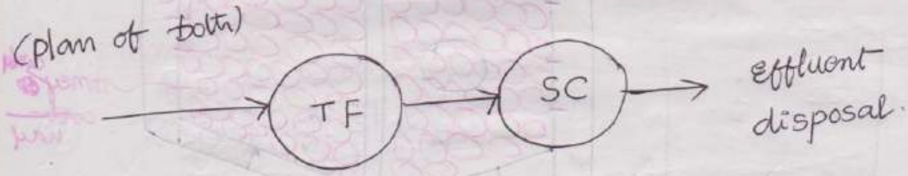


* Assume media surface ~~at t=0~~



(cycle is repeated after time = t_4)
(t)

** ~~I shear~~ (Sheared) Removal of biofilm by the waste water
* from Inert surface is called sloughing



* Trickling filters are designed based on NRC (National Research council of USA) equation.

→ NRC equation :-

efficiency of Trickling filter.

$$\boxed{\eta = \frac{y_i - y_e}{y_i} \times 100 = \frac{100}{1+0.0044\sqrt{\frac{Q \cdot y_i}{V \cdot F}}}}$$

L-2

* $\frac{Q \cdot y_i}{VF}$ = organic Loading rate (or) (BOD Loading rate)

= kg/day/ha-m

$V \rightarrow$ volume of Trickling filter $\rightarrow$ Ha·m.

$Q \rightarrow$ MLD

$y_i \rightarrow$ mg/l.

$F \rightarrow$ recirculation factor.

$$\boxed{F = \frac{1 + R/I}{(1 + 0.1\, R/I)^2}}$$

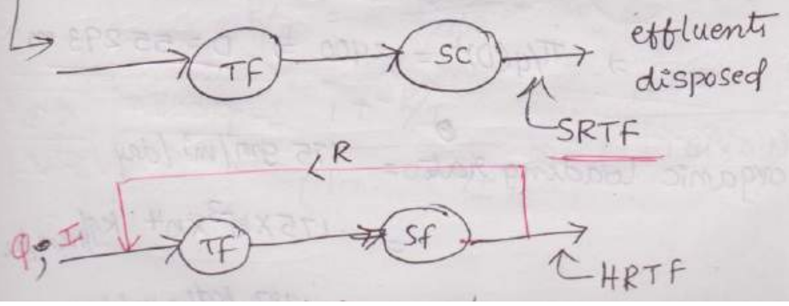
$R/I \rightarrow$ recirculation ratio.

$$\boxed{\frac{R}{I} = \frac{\text{volume recycled}}{\text{volume of Influent applied}}}$$

Based on "F"

TF classified into

1. standard rate T·F $F = 1$, $R/I = 0$.
2. High rate T·F ; $F > 1$, $R/I > 0$.



(L-2)

(01) $y_i = 200\ mg/l$

$y_e = 40\ mg/l$

$$\eta = \frac{200-40}{200} \times 100$$

$$\boxed{\eta = 80\%}$$

(02) $OLR = \frac{Q \cdot y}{V} = 0.175\ kg/m^3/day$; $y_i = 150\ mg/l$

$= 0.175 * 10^4\ kg/ha\text{-}m/day$

$[~~1m^3 = 10^4~~]$ $= 1750\ kg/ha \cdot m/day$

$[1 ha \cdot m = 10^4 m^3]$

$[1 m^3 = \frac{1}{10^4} ha]$

$$\eta = \frac{150 - y_e}{\cancel{y}\,150} \times 100 = \frac{100}{1 + 0.0044\sqrt{\cancel{1750 \times 150}}}$$

$$\Rightarrow \boxed{y_e = 23.3\ mg/l}$$

(03) $Q = 6 MLD$; $y_i = 150\ mg/l$

$d = ?$ $V = ?$; surface loading rate $= 2500\ l/m^2/day$

↓

(Hydraulic loading rate)

Surface area of trickling filter $= \frac{Q}{SLR}$

$$= \frac{6 \times 10^6}{2500} : 2400\ m^2$$

$\Rightarrow \pi/4 (D)^2 = 2400 \Rightarrow \underline{D = 55.293\ m}$

* organic loading rate $= 175\ gm/m^3/day$

$= 175 \times 10^{-3} \times 10^4\ kg/ham\ ~~bu~~$

$1750\ kg/ha\ m/$

$$\eta = \frac{100}{1+0.0044\sqrt{1750}} = 84.45\%$$

$$\Rightarrow \quad \eta = \frac{y_i - y_e}{y_i} \times 100$$

$$\frac{84.45}{100} = \frac{\cancel{100}\ 150 - y_e}{150}$$

$$y_e = 23.32\ mg/l.$$

$$\therefore \quad \frac{Q y_i}{V} = 1750\ kg/ha{\cdot}m/day$$

$$\frac{6 \times 150}{1750} = V$$

$$V = 0.514\ ha\text{-}m$$

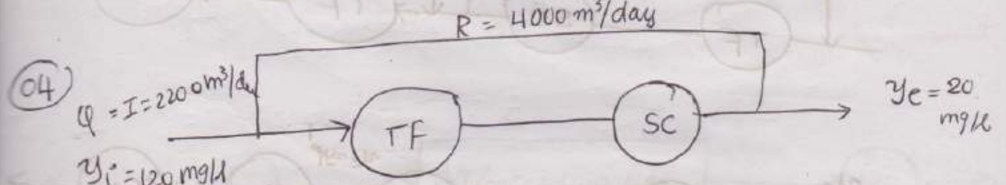
$$V = 0.514 \times 10^4\ m^3$$

$$V = 5140\ m^3.$$

$$\therefore \quad \text{Depth of trickling filter} = \frac{\text{Volume of TF}}{\text{Surface area of TF}}$$

$$= \frac{5140}{2400} = 2.14\ m.$$

(04)



$$\therefore \quad R/I = \frac{4000}{2200} = 1.81$$

$$F = \frac{1 + R/I}{(1 + 0.1\,R/I)^2} = \frac{1+1.81}{(1+1.81 \times 0.1)^2} = 2.01$$

$$\eta = \frac{y_i - y_e}{y_i\cancel{y_e}} \times 100 = \frac{100}{1 + 0.0044\sqrt{\frac{Q \cdot y_i}{V \cdot F}}}$$

$$\Rightarrow \frac{120-20}{120} \times 100 = \frac{100}{1 + 0.0044\sqrt{\frac{2.2 \times 120}{V \times 2.01}}} = \frac{100}{1 + 0.0044\sqrt{\frac{131.34}{V}}}$$

$Q = 2200\ m^3/day$

$Q = 2.2\ mLD.$

$\Rightarrow 0.833 =$

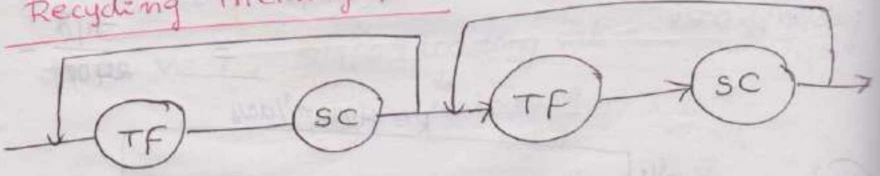
$\Rightarrow 83.33 =$

$V = 0.0633\ Ha\text{-}m.$

$$\boxed{V = 635.7\ m^3}$$

* Single stage Trickling filters :-

* standard rate, two stage Trickling filter, Recycling Trickling filter (or) multistage Trickling filter



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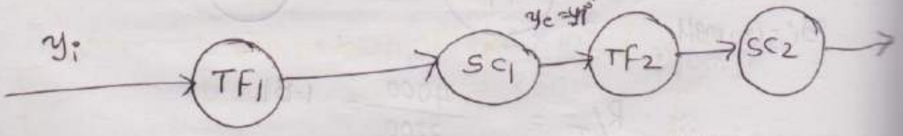


$$\eta_1 = \frac{100}{1 + 0.0044\sqrt{\frac{Q y_i}{V F}}} \ ; \ \eta_2 = \frac{100}{1 + \frac{0.0044}{1 - \eta_1}\sqrt{\frac{Q y_i'}{F' V'}}}$$

100

1+0.0044

$\sqrt{\frac{131.34}{v}}$

* operational problem associated with Trickling Filter

① Psychoda Problem (Filter fly nuisence)

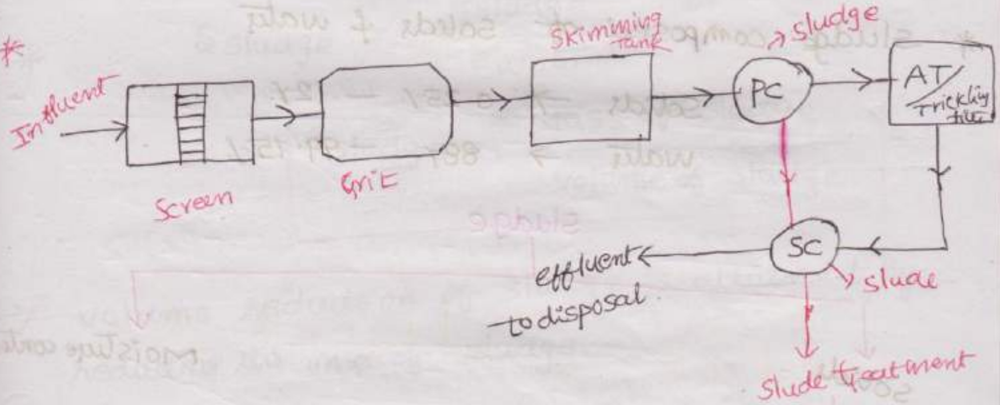
② ponding

* Secondary clarifier (or) settling tanks follows Type-IV settling. [compression settling (or) zone settling].

(Settles layer by layer).

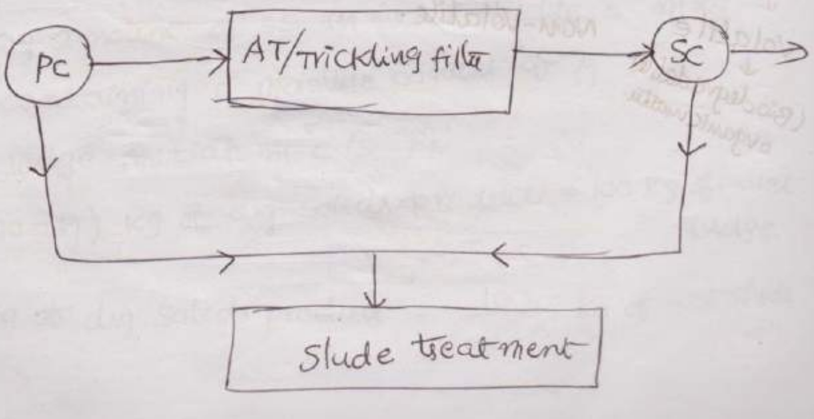
* Design is based on Solids flux analysis.

*



Trickling filter

*



$\sqrt{\frac{Q y_i'}{F' V'}}$

7. sludge Digestion

* sludge treatment ① volume reduction.
② strength reduction.

→ Volume reduction & strength reduction of sludges are attained by the followings.

① sludge thickening. → concentration of sludge.

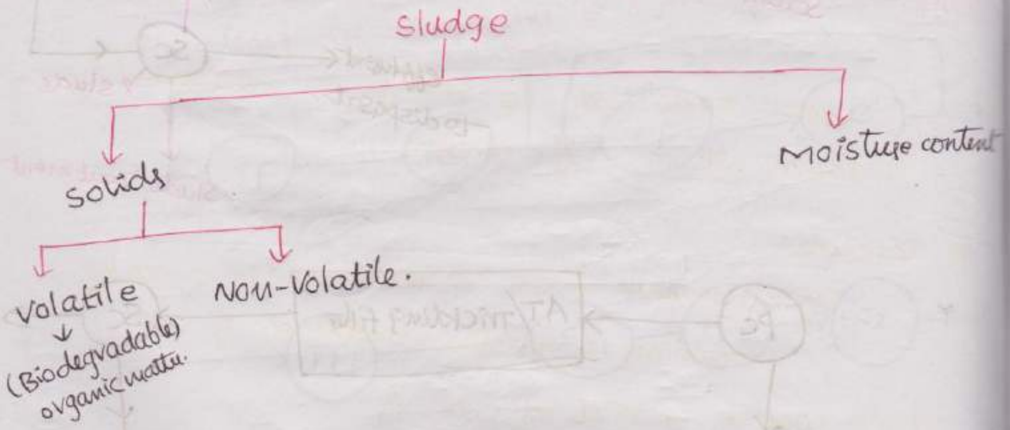
*② De Anaerobic digestion → strength reduction.
(or)
sludge

③ sludge conditioning → to improve drainatility.

*④ sludge dewatering & drying → volume reduction

* sludge composed of solids & water

Solids → 0.25% — 12%
water → 88% — 99.75%



* Mass-Volume relation of sludge

→ Solids :—

$$\Rightarrow \boxed{\frac{100}{S_{solids}} = \frac{\text{\%ge of volatile}}{S_v} + \frac{\text{\%ge of non-volatile}}{S_{NV}}}$$

Specific gravity of solids (S_{solids}) = ?

$$* \boxed{\frac{100}{S_{sludge}} = \frac{\text{\%ge of solids}}{S_S} + \frac{\text{\%ge of moisture content}}{S_{m.c}}}$$

$\Rightarrow S_{sludge} = ?$

$$* \quad S_{sludge} = \frac{e_{sludge}}{e_{water}}$$

$$\boxed{e_{sludge} = \frac{\text{Mass of sludge}}{\text{Volume of sludge}}}$$

→ Volume reduction of sludge is attained by reducing the m.c of sludge.

* Assume

Dry amount of SS in waste sludge = m kg.

containing a moisture content of P_1

→ If sludge initial m.c is P_1.

$(100 - P_1)$ kg of dry solids produce = 100 kg of wet sludge.

$\Rightarrow$ 1kg of dry solids produce = $\frac{100}{100-P}$ kg of wet slude

∴ m kg of dry solids produce $= \boxed{\frac{100}{(100-P_1)} * m}$ kg of wet sludge

∴ Mass of wet sludge at m.c, $P_1 = \frac{100}{100-P_1} * m$.

$$\boxed{\rightarrow \text{volume of wet sludge at m.c, } P_1 = \frac{100}{100-P_1} * \frac{m}{e_{sludge}}}$$

$$\boxed{* \text{ volume of sludge at mc } P_1 \text{ be } V_1 = \frac{100}{100-P_1} * \frac{m}{e_{sludge_1}}}$$

* volume of sludge at mc P_2 be $V_2 = \frac{100}{100-P_2} * \frac{m}{e_{sludge_2}}$

→ If $e_{sludge_I} = e_{sludge_2}$

$$\Rightarrow \frac{m}{e_{sludge}} = \frac{\cancel{100}}{\cancel{100-P}} = \frac{(100-P_1)V_1}{100} = \frac{(100-P_2)V_2}{100}$$

$$\Rightarrow \frac{m}{e_{sludge}} = (100-P_1)V_1 = (100-P_2)V_2$$

$$\therefore ** \quad \boxed{V_2 = \frac{(100-P_1)V_1}{(100-P_2)}}$$

Problem

(P6) $V_2 = \frac{(100-98)X}{(100-96)} = \frac{2x}{4}$

$$\boxed{V_2 = \frac{X}{2}}$$

(P7) $V_2 = 0.5V$; $V_1 = V$

$V_2 =$

(L-2)

(P3) $V_2 = \frac{(2)V_1}{8} = \frac{1}{4}V_1$

$V_2 = \frac{V_1}{4} = 0.25V_1$

% decrease in volume $= \frac{V_1 - V_2}{V_1} \times 100$

$= \frac{V_1 - 0.25V_1}{V_1} \times 100$

$= \frac{0.75V_1}{V_1} \times 100$

$= 75\%$

(P5) $V_2 = \frac{1}{4}(V) = 0.25V_1$

% decrease in volume

$= \frac{V_1 - 0.25V_1}{V_1} \times 100$

$= 75\%$

(P10) Solids content = 2% ; $S_{\text{~~sludge~~ solids}} = 2.2$; $\rho_w = 1000\,kg/m^3$

$$\left[S_{sludge} = \frac{\rho_{sludge}}{\rho_{water}} \right]$$

⇒ moisture content = 98%

$$\Rightarrow \left[\frac{100}{\rho_{sludge}} = \frac{\%\text{ge of solids}}{\rho_{solids}} + \frac{\%\text{ge of m.c}}{\rho_{water}} \right]$$

$S.S = 2.2 \Rightarrow \rho_w * S_S = 2200\,kg/m^3 = \rho_{solids}$

$$\frac{100}{\rho_{sludge}} = \frac{2}{2200} + \frac{98}{1000}$$

$$\left[\rho_{sludge} = 1011\,kg/m^3 \right]$$

$$* \quad \frac{100}{S_{sludge}} = \frac{\%\text{ solids}}{S_S} + \frac{\%\text{ m.c}}{S_{m.c}}$$

$$\frac{100}{S_{sludge}} = \frac{2}{2.2} + \frac{98}{1}$$

$S_{sludge} =$

$\rho_{sm} = S_{sludge} \times \rho_w =$

(P11) $V_2 = \frac{\cancel{V_1}}{2} = \frac{(100-P_1)}{(100-P_2)} * V_1$ [ρ_{sludge} is constant]

$\Rightarrow \frac{1}{2} = \frac{100-98}{100-P_2}$

$100 - P_2 = 4$

$P_2 = 96\%$ (m.c)

⇒ solids content is $\underline{4\%}$

(or)

$\left[V_1 = \frac{100}{(100-P_1)}\left(\frac{m}{\rho_{sludge_1}}\right) ; V_2 = \frac{100}{(100-P_2)} \frac{m}{(\rho_{sludge})_2}\right.$

$\left. m = (100-P_1) V_1 \rho_{s_1} = (100-P_2) V_2 \rho_{s_2} \right]$

(P12) $V_2 = \frac{(100-98)}{(100-96)} * P$

$= \frac{2P}{4}$

$\boxed{V_2 = P/2}$

(P1) $Q = \cancel{5P}\ 4.5$ MLD $S.S = 275$ mg/l.

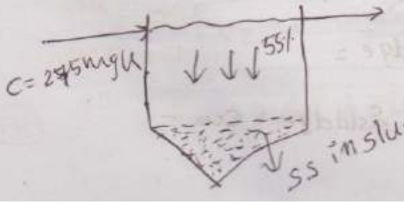
⇒ removed suspended solids = 55%.

[%ge of removal = 55%.]

→ suspendend solids in sewage (sludge) $= \frac{55}{100} \times 275$

$= 151.25$ mg/l.

⇒ S.S in sludge = S.S removed ~~in~~ from sewage flow



SS in sludge = SS

$= \frac{55}{100} \times 275 = 151.25$ mg/l

→ mass of sludge produced per day $= \frac{100}{100-P_1} \times m$

m = mass of dry suspended solids

→ Total mass of dry suspended solids = $Q \times$ concen of S.S
(MLD × mg/l)

$= 4.5 \times 151.25$

$= 680.625$ Kg.

* mass of sludge produce/day $= \frac{100}{(100-P_1)} \times m$

$= \frac{100}{100-96} \times 680.625$

$\boxed{\text{Mass of sludge produce/day} = 17015.625 \text{ Kg/day.}}$

ii) $S_{sludge} = 1.02 \Rightarrow \rho_{sludge} = S_{sludge} \times \rho_w$

$= 1.02 \times 1000 = 1020 \text{ Kg/m}^3$

Volume of sludge $= \frac{100}{(100-96)} * \frac{680.625}{1020}$

$\boxed{\text{Volume of sludge} = 16.68 \text{ m}^3.}$

~~Ex~~ ~~* strength reduction~~

Ex:- An activated sludge process 1 MLD of secondary sludge has to be returned to keep the required MLSS concentration in the aeration tank. This sludge has a water content m.c of 99%. If the sludge w.c is reduced to 98%. what volume of sludge to be recycled?

a) 0.25 MLD
~~b)~~ 0.5 MLD
c) 0.75 MLD
d) 1 MLD

sol:- $V_2 = \frac{100-99}{100-98}$ (1) MLD

$V_2 = \frac{1}{2}$ (MLD) = 0.5 MLD

* strength reduction of sludge

↳ (Removal of BOD of sludge)

→ ① Anaerobic digestion. digestion occurs in 2 stages :—

① Acid fermentation. → I st stage

② Methane fermentation. → II nd stage.

I st stage :—

sludges → Acid formers ⟶ Acids.
(anaerobic bacteria)

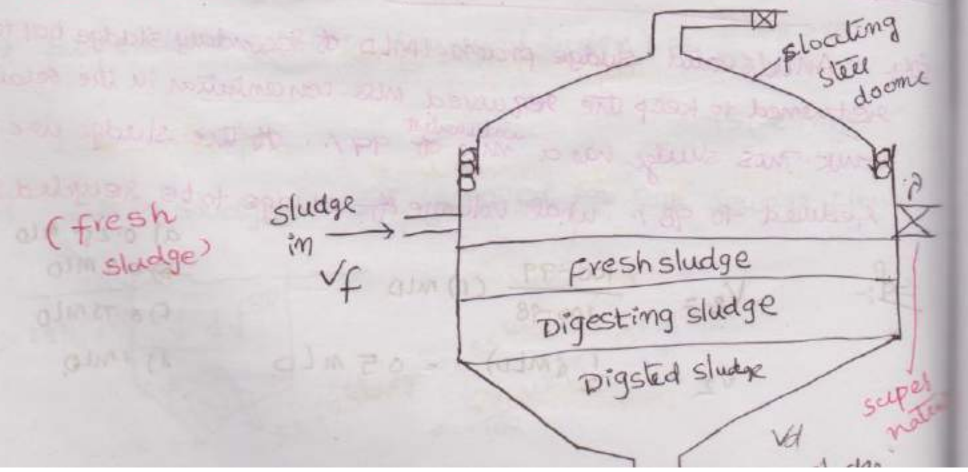
Acids ⟶ { propionic acid, Acetic acid., Butyric acid }

II nd stage :—

→ Acids → Methane formers ⟶ gases → { CH_4, CO_2, H_2S }
(anaerobic bacteria)

* Anaerobic sludges are Anaerobically reacted by a reactor is known as "sludge digster"

* sludge digster :— (Anaerobic reactor)



→ Based on temperature micro organisms

→ psychrophilic — temp < 10°c

→ mesophilic — 10°- 40°c

→ Thermophilic — 45°- 60° (temp resistant bacteria)

* under normal conditions — Mesophilic organisms (40-70) days

* Thermophilic organisms — 20-30 days

\+ Design :—

① capacity of digester (volume of digester).

$$\boxed{V = \left[V_f - \tfrac{2}{3}(V_f - V_d)\right] t}$$

$$\boxed{V = \left[\frac{V_f + V_d}{2}\right] t}$$

$$\therefore V_f = \frac{(100 - P_T)}{(100 - P_1)} \times \frac{m}{\rho_{sludge\,1}}$$

P_1 = M.C of fresh sludge

$$V_d = \frac{(100 - P_Z)}{(100 - P_2)} \times \frac{m}{\rho_{sludge\,2}}$$

t = digesting period (1 to 1.5 month)

** * $$\boxed{\text{Rate of gas production} = 0.9\ m^3/1\ \text{Kg of VSS destroyed}}$$

CH_4 = 70%

CO_2 = 25%

Remainings = traces.

$$\boxed{* \ \text{Energy content of } CH_4 = 5800 \ K\cdot cal/m^3}$$

(P3)

$$\frac{100}{S_{sludge}} = \frac{\%\,Solids}{S_s} + \frac{\%\,m.c}{S_{m.c}}$$

$$\frac{100}{1.02} = \frac{5}{S_s} + \frac{95}{1}$$

$$\Rightarrow S_s = 1.645$$

$$\boxed{S_{solids} = 1.645}$$

→ Fresh sludge (Raw sludge) :-

$$S_{sludge} = 1.02$$

$$\rho(sludge)_1 = 1020 \ kg/m^3$$

→ Digsted sludge (m.c = 85%)

$$\frac{100}{S_{sludge}} = \frac{\%\,solids}{S_S} + \frac{\%\,mc}{S_{m.c}}$$

$$\frac{100}{\cancel{1.02}\ S(sludge)} = \frac{15}{1.645} + \frac{85}{1}$$

$$\Rightarrow S(sludge) = 1.0625$$

$$\rho(sludge)_2 = 1062.5 \ kg/m^3$$

∴ Q = 20MLD ; SS in sewage flow = 300 mg/l.

S.S in sludge = 300 × 0.65 = 195 mg/l.

∴ Total mass of dry solids/day = Q × concentration of S.S in slud

= 20 × 195

= 3900 kg/day.

$$\therefore V_f = \frac{100}{(100-P_1)} \times \frac{m}{(e_{sludge})_1}$$

$$= \frac{100}{100-95} * \frac{3900}{1020}$$

Volume of fresh sludge produce/day $\Big\} = 76 \cdot 47 m^3$.

→ volume of digsted sludge :-

$$V_d = \frac{100}{100-P_2} \times \frac{m}{(e_{sludge})_2}$$

$$= \frac{100}{100-85} \times \frac{3900}{1062 \cdot 5}$$

$$= 24 \cdot 47 \ m^3/day.$$

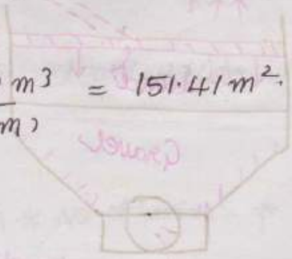
* Assuming linear reduction.

$$\text{capacity of digester} = \left[\frac{V_f + V_d}{2}\right] t$$

$$V = \left[\frac{70 \cdot 47 + 24 \cdot 47}{2}\right] 30$$

$$V = 1514 \cdot 10 m^3.$$

*⇒ Assuming depth of digester 10m. find the diameter of digester required-



$$Area = \frac{1514 \cdot 10 \ m^3}{10 \ (m)} = 151 \cdot 41 m^2.$$

$$A = \pi/4 \, (d)^2$$

$$d^2 = \frac{(151 \cdot 41)(4)}{3 \cdot 14}$$

$$d = 13 \cdot 88 m$$

⑨ Suspended solids = 200 mg/l

90% of Suspend solids are removed

= 200×0.9 = 180 mg/l.

70% Volatile matter = 180×0.7 = 126 mg/l

65% Volatiles are destroyed — 0.9 m^3/kg

= 126×0.65 = 81.9.

Total flow = 1 MLD.

→ Total amount of gas = 81.9×0.9 = 73.71 m^3/kg

65% of CH_4 gas = 47.9115 m^3/kg

(or)

Gas produced = $[(200\times0.9)*0.7]*0.65]*1*0.9$

= 73.71 m^3/kg.

65% of CH_4 gas = 73.71×0.65 = 47.9115 m^3/kg.

∴ Fuel value of gas = Energy * Volume of gas

= 47.91×5200

= 249139 K cal/.

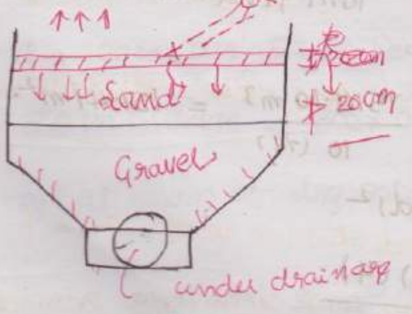
[Total VSS destroyed = Q×VSS destroyed

1×81.9 = 81.9 kg/day]

* sludge dewatering & drying :-

(sludge drying beds) :- open solar sand beds

⇒



B = 3m – 8m

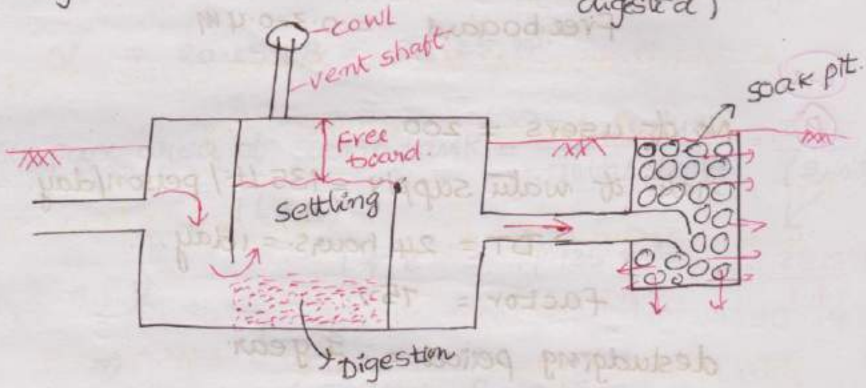
L = 30m – 80m.

8. Design of septic Tanks

→ Septic tanks employed unsewered areas.

→ septic tank is a settling tank provided with long detention ~~time~~ peroid, with extra provision for digestion of settled solids. (Solids Anaerobically digested)

⇒



(biological reactor)

* Volume of septic tank = Settling + volume required for volume required to accomodate settled solids.

* settling zone

Settling zone of septic tank is designed based on Detention time.

DT : 24 hrs to 48 hrs.

** Rate of sludge production : 30-40 Lit/capita/year.

* [Volume of sludge produce b/w cleanings (desludging) (Desludging period)

= Rate of sludge production * No. of users * Desludging (or) cleaning period.]

* Total volume = volume of settling zone + volume of sludge zone.

$L : B = 2 : 1$

** liquid depth = 1m – 2m.

Avg Head = 1.5m.

free board = 0.3-0.4 m

(L-2)

(P) No. of users = 200

rate of water supply = 135 Lt / person/day.

DT = 24 hours. = 1 day.

factor = 75%.

desludging period = 1 year

Rate of deposition of sludge = 40 lit/person/year

$D = 2.0\,m$

free board = 0.3 m;

$L/B = 3:1$

~~rate of~~ waste water = $0.75 \times 135 = 101.25$ Lt/person/day

$\Rightarrow$ q = no. of users * rate of watersupply * factor

$= 200 \times 135 \times 0.75$ lit/day

$$q = \frac{200 \times 135 \times 0.75}{10^3} = 20.25\ m^3/day.$$

$\Rightarrow$ volume of settling zone = q * DT

$= 20.25 * 1$ day

$= 20.25\ m^3$

$\Rightarrow$ volume of sludge zone

$\Rightarrow$ V = Rate of sludge production × no of users * desludging period.

=) volume of sludge zone = 40 × 200 × 1 lit

$= \frac{40 \times 200 \times 1}{10^3} m^3$

$= 8 m^3$.

* Total volume of septic tank = $(\text{volume})_{\text{settling}}$ + (volume) sludge

$V = 20.25 + 8 = 28.25 \, m^3$.

→ surface area of septic tank = $\frac{\text{Total volume}}{\text{Total depth}} = \frac{28.25}{(2-0.3)} \swarrow = \frac{28.25}{1.7}$

(L * B)

=> L * B = ~~14.125 m²~~ 16.617 m²

L = 3B

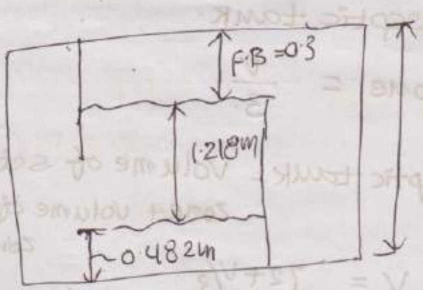
=> L = ~~6.509m~~ 7.06 m, B = ~~2.17m~~ 2.35m.

* liquid depth = $\frac{\text{volume of settling zone}}{\text{surface area}}$

= 20.25 / ~~14.125~~ 16.617 = ~~1.433m~~ 1.218 m

=) depth of sludge zone = 1.7 − 1.218 = 0.482 m

[Note:- depth of septic tank excluding FB = 2 − 0.3 = 1.7m]



(02) L : B = 2.25 : 1

liquid depth = 2m

F.B = 300mm

Desludging Interval = ?

Trench area (soak pit) = ?

no. of users = 300.

water supply = 100 lpcd

factor = 80% = 0.8.

→ Rate of sludge production = 0.04 m^3/capita/yr.

Detention time = 3 days.

* Desludging is done when the tank is $\frac{1}{3}^{rd}$ full of sludge.

Hydraulic Loading = 100 Lt/m^2/day.

Q = no. of users * Rate of water supply * factor.

= 300 × 100 × 0.8

Q = 24 m^3/day.

settling zone :-

volume of settling zone; $Q \times DT$

$= 24 \times 3 = 72 m^3$

volume of sludge zone :-

let V : volume of septic tank.

Volume of sludge zone = $\frac{V}{3}$.

⇒ Total volume of septic tank = Volume of settling zone + volume of sludge zone.

$V = 72 + V/3$

$\frac{2V}{3} = 72$

$\Rightarrow$ volume of sludge $= V/_3 = 108/_3 = 36\,m^3$.

* Volume of sludge = Rate of sludge Production × no. of users × desluding period

$36 = 0.04 \times 300 \times$ desluding Interval.

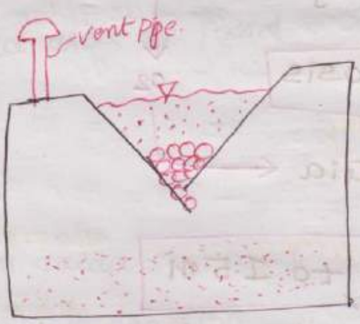
$\therefore$ Desluding Interval $= \dfrac{36}{0.04 \times 300} = 3$ years.

* ~~Sur~~ Area of percolating trench $= \dfrac{Q}{H \cdot L \cdot R}$

$$= \frac{300 \times 100 \times 0.8 \ \text{lit/day}}{100 \ \text{lt/m}^2\text{/day}}$$

$$= 240\,m^2$$

* If no. of users are more than 300 Imhoff tanks are preferred ~~than~~ to ~~the~~ septic tanks.



9. oxidation ponds

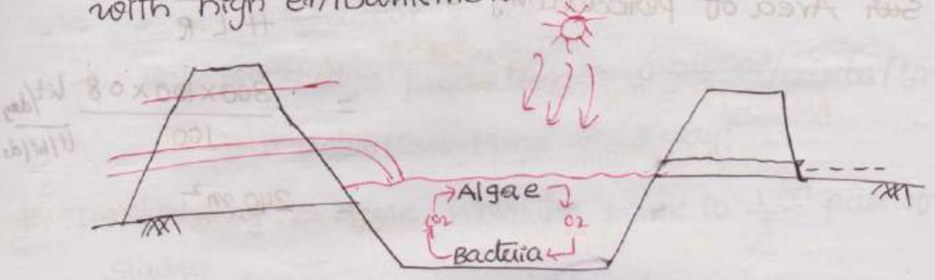
[waste stabilization ponds]

→ It is also biological reactor.

→ Low cost waste water treatment unit.

* oxidation pond is a aerobic waste stabilization pond.

* It is a shallow dug earthen pond provided with high embankment.



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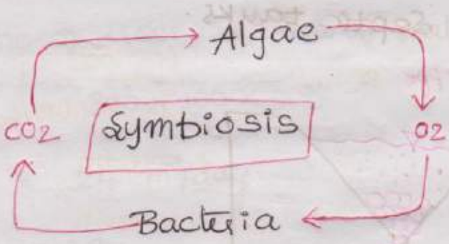


* Depth : 1m to 1.5m.

* Area depend on the latitude of places.

*** Surface area of pond = $\frac{\text{BOD applied to pond}}{\text{BOD Loading rate}}$
(or)
(organic loading rate)

* Total BOD applied to pond = $Q \times y_i$
(kg/day) (MLD) (mg/l)

* BOD Loading rate (or) organic Loading rate

(based on latitude)

→ OLR – (kg of BOD/ha/day).

* DT = 2 weeks to 6 weeks.

$$\boxed{t = \frac{1}{k} \ln \frac{y_i}{y_e}}$$

Problems

(Po5) persons = 10,000 ; Sewage flow $Q = 200$ l/day

$y_i = 300$ mg/l ; OLR = 310 kg/ha/day.

Total BOD applied = $(2\times10^{-4})(2)(300) = 600$ kg/day

$$Q = P \times S = \frac{10{,}000 \times 200}{10^6} = 2\text{ MLD}$$

$$\therefore \text{ Surface area of pond} = \frac{600 \text{ kg/day}}{310 \text{ kg/day/ha}}$$

$$= 1.935 \text{ ha}$$

$$\approx 2 \text{ hectare}$$

(Po2) Design oxidation pond $L = ?$ $B = ?$ $D = ?$

$$\Rightarrow Q = \frac{10{,}000 \times 150}{10^6} = 1.5 \text{ MLD}$$

$$\therefore \text{ Surface area of pond} = \frac{1.5 \times 300}{300} = 1.5 \text{ ha } \cancel{\text{kg/day}}$$

$$= 1.5 \text{ ha}$$

$$= 1.5 \times 10^4 \text{ m}^2$$

$L : B = 4 : 1$

$L = 4B$ $\Rightarrow L \times B = 1.5 \times 10^4$

$\Rightarrow 4B^2 = 1.5 \times 10^4$

$L = 244.95$ m . $B = 61.23$ m.

$$t = \frac{1}{K} \ln \frac{y_i}{y_e}$$

$$K = 0.1 \times 2.3 = 0.23 d^{-1} \text{ (base)}$$

$$t = \frac{1}{0.5} \ln\left(\frac{300}{30}\right) = 10.01 \text{ days}$$

∴ volume of oxidation pond $= Q \times DT$

$$= \frac{1.5 \times 10^6}{10^3} \times 10$$

$$= 15000 \, m^3.$$

∴ Depth of oxidation pond (liquid depth) $= \frac{\text{volume of pond}}{\text{Area of pond}}$

$$= \frac{15000}{15 \times 10^4}$$

$$= 1m$$

∴ Depth = 1m

(Pd) Population = 10,000 ; $\overset{\text{percapita BOD}}{\cancel{\ }}$ = 40 g/day

wate = 100 lpcd ; factor = 80%.

Sewage flow = 100 × 0.8 = 80 lpcd

DT = ? y_e = 80% of BOD removal achieved (or) not

[DT = V/Q]

$$Q = \frac{10,000 \times 100 \times 0.8}{10^6} = 0.8 \, MLD.$$

Total BOD = $Q \times y_i$ = population * per capita BOD.

$$\Rightarrow 0.8 \times y_i = 10,000 \times 40 \times 10^{-3}$$

$$(kg/day) \times y_i =$$

$$\boxed{y_i = 500 \, mg/l}$$

⇒ BOD removal efficieny $= \frac{y_i - y_e}{y_e} \times 100$

$$80 \Rightarrow \frac{500 - y_e}{\;} \times 100$$

$\therefore$ effluent BOD = 100 mg/l → effluent can be used for irrigation

→ surface area of oxidation pond $= \dfrac{Qy_i}{\text{BOD loading rate}}$

$$= \frac{0.8 \times 500}{200}$$

$$= 2\,ha$$

surface area of oxidation pond $= 2 \times 10^4\, m^2$.

$L : B = 4 : 1$

$\boxed{L = 4B.}$

$\Rightarrow \quad L \times B = 2 \times 10^4$

$4B^2 = 20000$

$B = 70.71\,m$; $L = 282.84\,m$.

$\therefore$ Detention time $= \dfrac{\text{volume of pond}}{Q} = \dfrac{L \times B \times d}{Q}$

$$= \frac{70.71 \times 282.84 \times 2m}{0.8 \times 10^6/10^3}$$

$$= 50 \text{ days}$$

** IN Normal fresh water bodies Excess ~~to much amount~~ of growth of algae leads to death of water body.

(This problem is known as Eutrophication)

10. Disposal of Effluents

* Treated effluents can be disposed by 2 methods

(i) Disposal by dilution. (disposing into freshwater body).

(ii) Disposing on Land
(or)
Land Disposal.

→ As per IS1974

Effluent disposal (discharge) standards

①	Domestic w.w	Industrial w.w
BOD	≤ 20 mg/l.	≤ 30 mg/l.
COD	—	≤ 250 mg/l.
TSS	≤ 100 mg/l.	—
oil & grease	≤ 10 mg/l	≤ 10 mg/l.

(i) Disposal by dilution –

favourable

① There must be enough water in the water body for diluting the waste.

② where sewage can be disposated fresh.

③ Receiving waters should have enough Dissolved oxygen.

*** ④ There should not be any community using water immediately on the down stream of point of disposed.

*

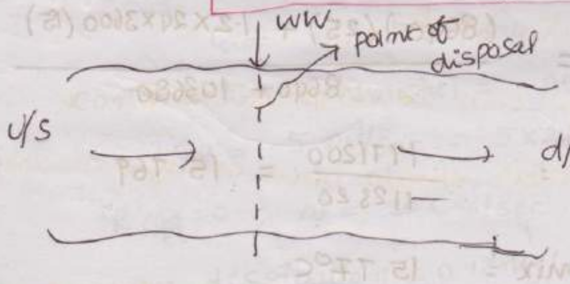
Dilution factor	Type of treatment recommended for domestic sewage
> 500	No Treatment
300 – 500	Preliminary Treatment.
150 – 300	Primary Treatment
< 150	Thorough Treatment [primary treatment followed by secondary treatment].

* when w.w disposed into water body the remaining objectanable matter present in the waste after treatment (is ~~taking care of the~~) removed by the water body is known as "self purification".

* Self purification of water body is due to :–

① Dilution. (concentration is decreased).

$$\boxed{C_{mix} = \frac{Q_R C_R + Q_w C_w}{Q_R + Q_w}}$$



(2) Dispersion (spread)

Air currents helps in dispersion

(3) sedimentation.

(4) oxidation.

(5) Reduction

(6) sunlight.

problems (L-2)

(P01) $Q_W = 12{,}000\ m^3/d$; $y_i = 50\ mg/l$

$Q_R = 40{,}000\ m^3/d$; $y_e = 3\ mg/l$.

Q ~~$C_{mix} = Q_W C_R + Q_R C$~~

$$C_{mix} = \frac{Q_W y_W + Q_S y_S}{Q_S + Q_W}$$

$$= \frac{(12{,}000)(50) + (40{,}000)(3)}{40000 + 12000}$$

$$\boxed{C_{mix} = 13.85\ mg/l}$$

(P12)

$$C_{mix} = \frac{(200)(50) + 8(500)}{550} = 25.4\ mg/l.$$

(P13)

$$C_{mix} = \frac{(8640)(25) + 1.2 \times 24 \times 3600\,(15)}{8640 + 103680}$$

$$= \frac{1771200}{112320} = 15.769$$

$$C_{mix} = 15.77^{\circ}C$$

(04)

(a) $(BOD)_{mixture} = \dfrac{(12{,}000)(50)+(40{,}000)(3)}{52{,}000}$

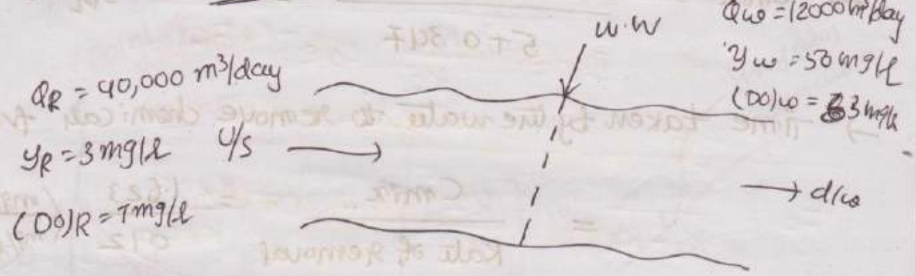
$= 13.85$ mg/l. (y_{mix})

~~b~~ (c) D.O. of the mixture $= \dfrac{(12{,}000)(2)+(40{,}000)(7)}{52{,}000}$

$= 5.846$ mg/l.

$(K = 0.23)$

~~(b) Ultimate B.O.D~~



(b) $y_{mix} = L_0(1-e^{-Kt})$

$13.85 = L_0(1-e^{-0.23\times 5})$

$\boxed{L_0 = 20.26 \text{ mg/l}}$ ⇒ ultimate BOD

(09) Rate of dissipation = 0.12 mg/l/hr

$Q_w = 30\times 10^6$ lit/day $= 30000$ m³/day

concentration (chemical) $= 25$ mg/l. $= C_w$

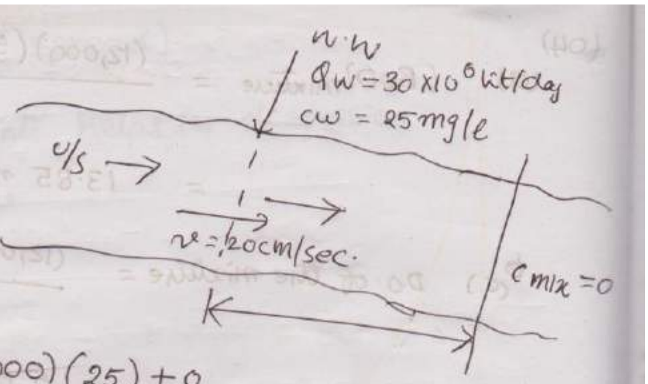
$Q_R = 5$ m³/sec $= 5\times 24\times 3600 = 432000$ m³/day

$C_R = 0$; $v = 20$ cm/sec $= 0.2$ m/sec.

⇒ uniform dissipation $= 0.12$ mg/l/hr.

$Q_R = 5\ m^3/sec$

$C_R = 0$



$$\Rightarrow C_{mix} = \frac{(30000)(25) + 0}{(30000) + (432000)} =$$

$$\rightarrow C_{mix} = \frac{5 \times 0 + 0.347 \times 25}{5 + 0.347} = 1.623\ mg/l$$

→ Time taken by the water to remove chemicals from water

$$= \frac{C_{mix}}{\text{Rate of removal}} = \frac{1.623}{0.12} \left(\frac{mg/l}{mg/l/hr}\right)$$

$$= 13.525\ hr.$$

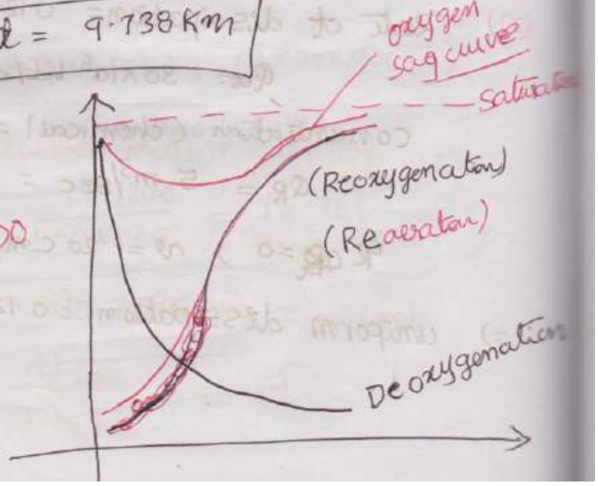
$t = 13.525\ hr$

* Distance after which chemical residue persist

$$v = d/t \Rightarrow d = 0.20 \times 3600 \frac{cm}{hr} \times 13.525\ hr$$

$d = 9.738$ Km.

$$\boxed{d = 9.738\ Km}$$



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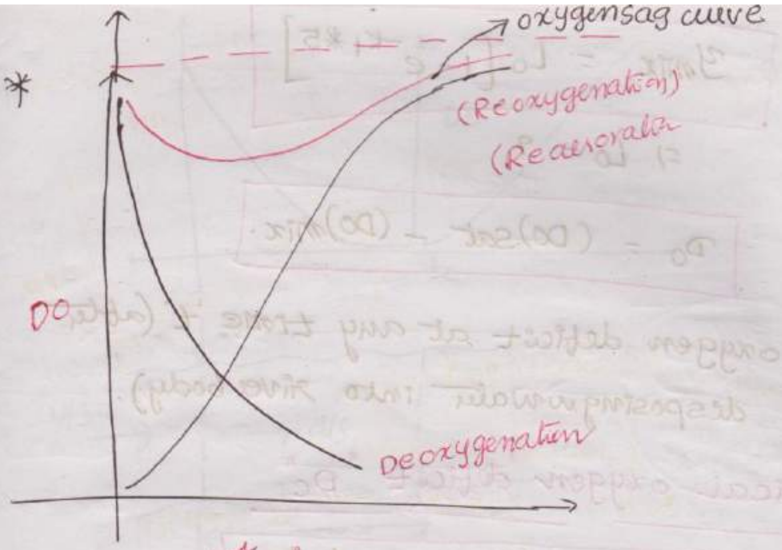

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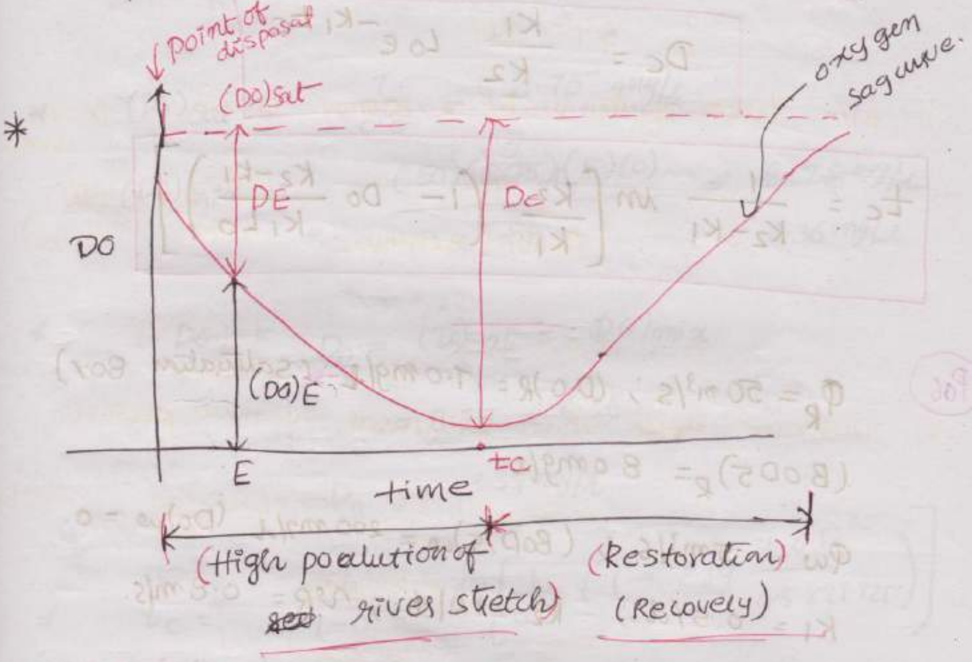


* streeter - phelphs equation

K_1 : Deoxygenation constant : d^{-1}

K_2 : Reoxygenation constant : d^{-1}

* Deficit at any time (t)

$$\boxed{D_t = \frac{K_1 L_0}{K_2 - K_1}\left[e^{-K_1 t} - e^{-K_2 t}\right] + D_0 e^{-K_2 t}}$$

$$\boxed{y_{mix} = L_0\left[1 - e^{-k_1 * 5}\right]}$$

$\Rightarrow L_0 = 9$

$$\boxed{D_0 = (DO)_{sat} - (DO)_{mix}.}$$

$\Rightarrow D_t$ = oxygen deficit at any time 't' (after disposing wwater into river body).

(ii) Critical oxygen deficit "D_c"

$$\boxed{D_c = \frac{k_1}{k_2} L_0 e^{-k_1 t_c}}$$

$$\boxed{t_c = \frac{1}{k_2 - k_1} \ln\left[\frac{k_2}{k_1}\left(1 - D_0\frac{k_2 - k_1}{k_1 L_0}\right)\right]}$$

(P06) $Q_R = 50\ m^3/s$; $(D.O)_R = 7.0$ mg/l → (saturation 80%)

$(B.OD_5)_R = 8.0$ mg/l.

$Q_w = 5\ m^3/s$; $(BOD)_5)_w = 200$ mg/l $(DO)_w = 0$.

$k_1 = 0.5/d$; $k_2 = 1.0/d$; $v_R = 0.8$ m/s.

* Minimum DO occurs where deficit is "DO" is max.

* (DO) is minimum in river after disposal, where (DO) deficit is maximum.

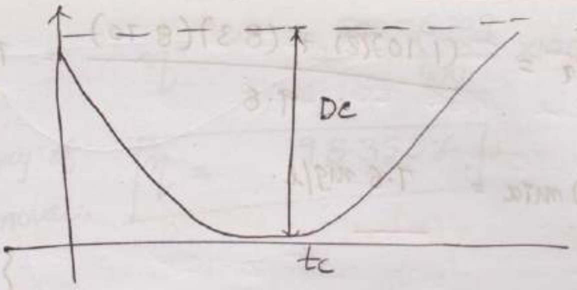
max DO deficit D_c occurs at critical time "t_c"

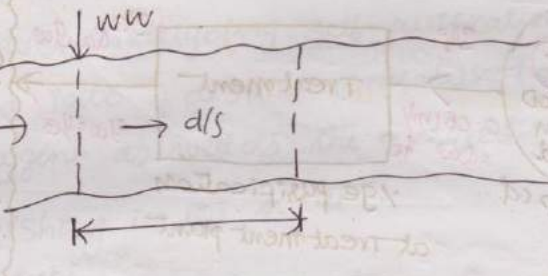
$$y_{mix} = \frac{(50)(8) + (5)(200)}{55} = 25.45$$

$$25.45 = L_0(1 - e^{-k_1 \times 5})$$

= 27.725 mg/l

*





* $(DO)_{sat} = \frac{7}{0.8} = 8.75 \text{ mg/l}.$

$(DO)_{mix} = \frac{(50)(\cancel{8.75}\, 7)+(5)(0)}{55} = \cancel{8.75\text{ mg}}/l$

$= 6.36 \text{ mg/l}$

* ~~DO~~ = $D_0 = (D)_{sat} - (DO)_{mix}$

$= 8.75 - 6.36$

$D_0 = 2.39 \text{ mg/l}.$

$\Rightarrow t_c = \frac{1}{1-0.5} \ln\left[\frac{1}{0.5}\left(1 - 2.39\, \frac{1-0.5}{0.5 \times 27.725}\right)\right]$

$t_c = 1.205$ days.

$v = d/t \Rightarrow d = 0.8 \times 1.205 \times 3600 \times 24$

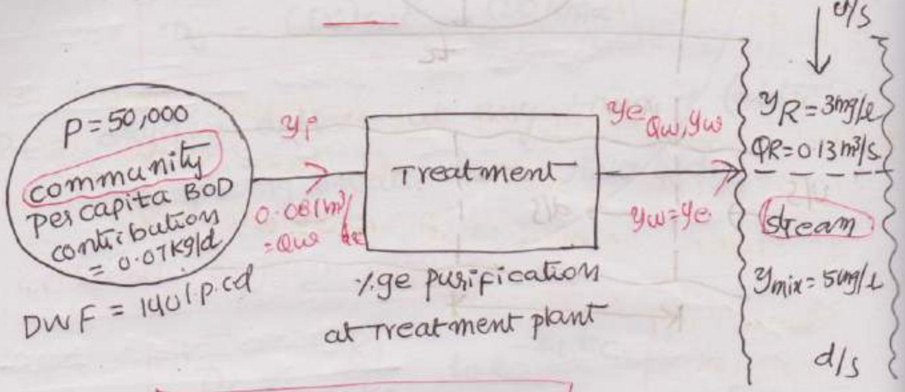
$\Rightarrow$ d = 83.28 Km.

$\boxed{d = 83.2896 \text{ Km}}$

(03) $$(DO)_{mix} = \frac{(1.10)(2)+(8.3)(8.70)}{9.8} = 7.59$$

$$(DO)_{mix} = 7.6\ mg/l.$$

(P05)



percentage purification →

$$\boxed{\eta = \frac{y_i - y_e}{y_i} \times 100}$$

$$y_{mix} = \frac{Q_R y_R + Q_W y_W}{Q_R + Q_W}$$

$\Rightarrow$ Q_{DWF} = Q_W = population × percapita sewage flow

$$Q_W = \frac{50,000 \times 140}{10^3 \times 24 \times 60 \times 60} = 0.081\ m^3/sec$$
$$= 7\ MLD$$

$$~~y_{mix}~~\ 5 = \frac{(0.13)(3)+(0.081)(y_W)}{0.13+0.081}$$

$$\boxed{y_W = 8.209\ mg/l\ ;\ y_e}$$

$\Rightarrow$ Total BOD = $Q\,y_i$ = population × per capita BOD
(kg/day) (MLD) (mg/l)

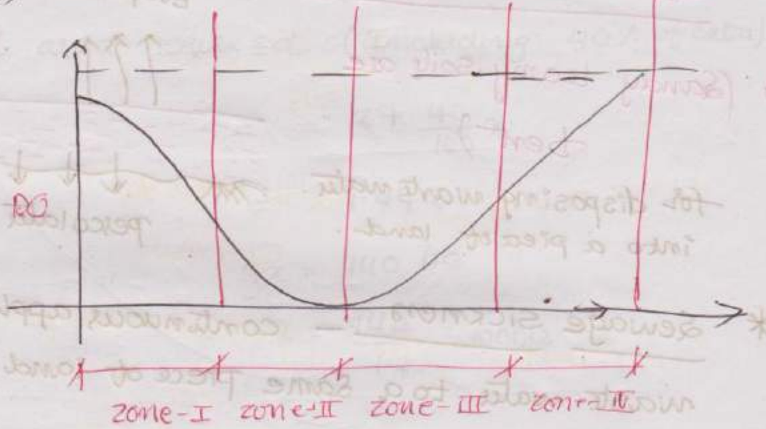
= $(7)(y_i)$ = 50,000 × 0.7

$$\boxed{y_i = 500\ mg/l}$$

$$\eta = \frac{500 - 8.209}{500} \times 100$$

efficiency of BOD removal. $\boxed{\eta = 98.358\%}$

* The river undergoing self purification process can be divided into 4 distinct zones based on the availability of oxygen as well as the aquatic organisms flourishing in the water. (present)



ⓐ Zone-I :- zone of Degradation
(DO Levels decrease by 40%) (oxidation)

→ Except fish all other organisms disappear.

ⓑ zone-II :- zone of active decomposition.
(DO levels reduced to zero). (Anaerobic conditions prevail).

→ fish also disappear.

→ foul odours are released

→ Heavy pollution.

ⓒ zone-III :- zone of recovery.

→ (DO) levels rise to 40%.

→ fish appear.

→ ~~zor~~

ⓓ zone-IV :- clear water zone.

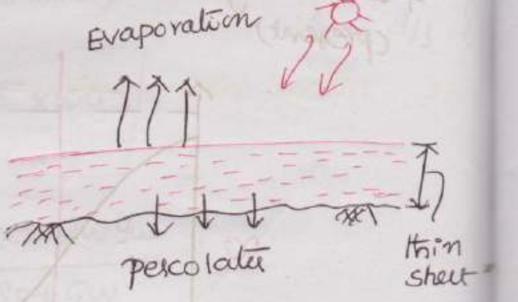
→ Recovery is said to be atomsphere.

→ Do levels rise to original, all aquatic organisms appear.

* Land disposal :-

→ (Sandy loamy soils are best)

for disposing waste water into a piece of land.



* Sewage sickness :- continuous application of waste water to a same piece of land.

* ~~The amount of area~~

* Area of land required for sewage disposal

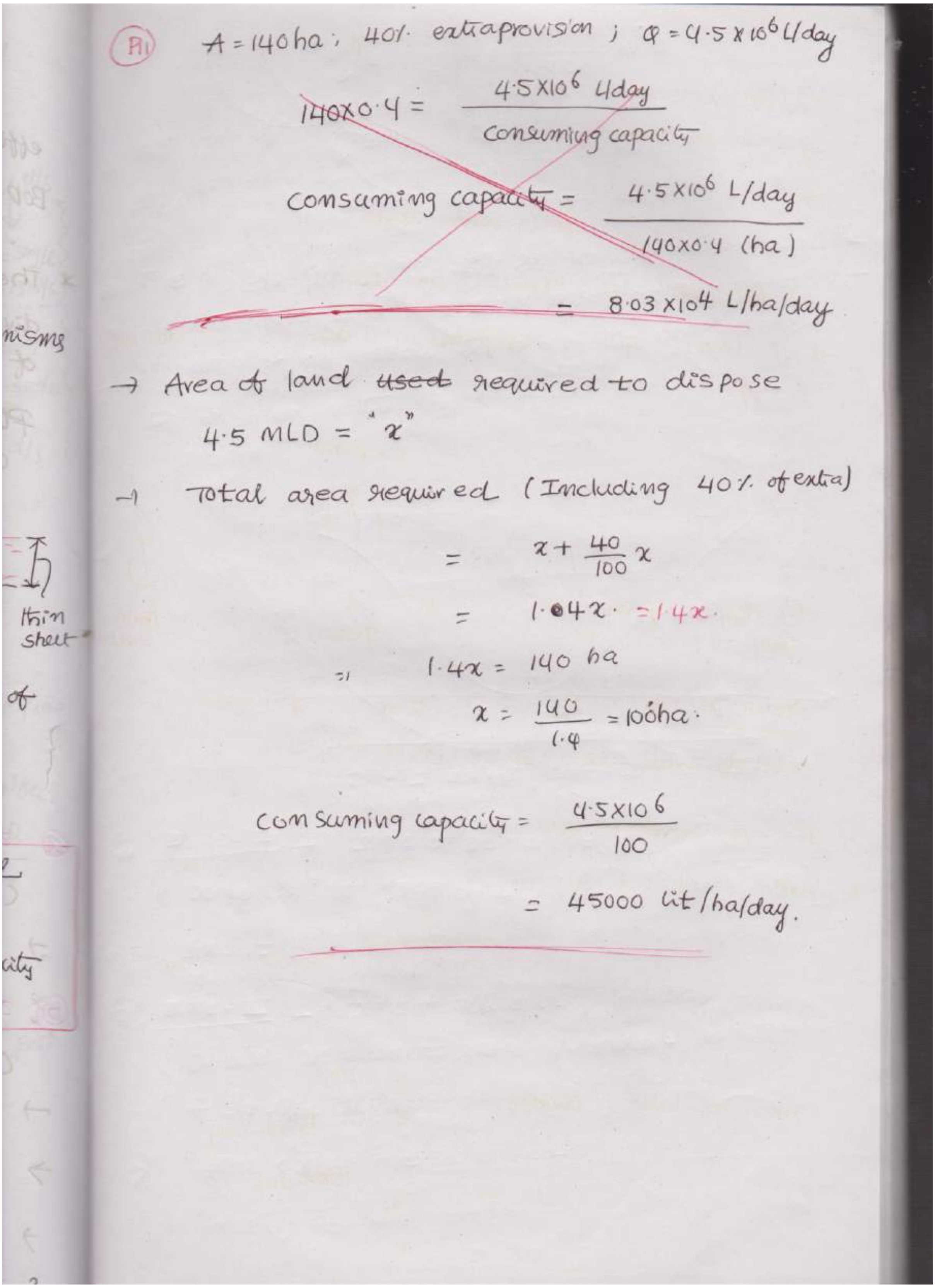
$$= \frac{Q}{\text{consuming (or) absorbing capacity of soil}}$$

(P10)

$$\text{Area of land required} = \frac{8 \text{ MLD}}{80000 \text{ lit/ha/day}}$$

$$= \frac{8 \times \cancel{10^6}\, 10^2 \times 10^4}{8\cancel{0000}} \text{ (ha)}$$

$$= \frac{800}{8}$$



(P1) $A = 140\,ha$; 40% extraprovision ; $Q = 4.5 \times 10^6\ L/day$

~~$140 \times 0.4 = \frac{4.5 \times 10^6\ L/day}{\text{consuming capacity}}$~~

~~consuming capacity $= \frac{4.5 \times 10^6\ L/day}{140 \times 0.4\ (ha)}$~~

~~$= 8.03 \times 10^4\ L/ha/day$~~

→ Area of land ~~used~~ required to dispose 4.5 MLD = "x"

→ Total area required (Including 40% of extra)

$$= x + \frac{40}{100}x$$

$$= 1.04x \cdot = 1.4x.$$

$$\Rightarrow 1.4x = 140\ ha$$

$$x = \frac{140}{1.4} = 100ha.$$

consuming capacity $= \frac{4.5 \times 10^6}{100}$

$= 45000$ lit/ha/day.