Water Treatment.

→ Water treatment is essentially a removal process. Contiminants present in water are removed either by
ⓐ unit operation ⓑ Unit processes.

Unit operation:- contimination removal by physical forces is known as unit operation.

Unit Process:- contimination removal by chemical or biological forces is known as unit processes.

Surface Water treatment:-

Raw water → Plain sedimentation → Coagulation → Fitration → Disinfection → Wholesome water.

- Plain sedimentation ↓ Suspended particles
- Coagulation ↓ Colloidal particles
- Fitration ↓ Dissolved organic substances
- Disinfection ↓ Pathogen.

Ground Water treatment:-

Ground water → Aeration → Softening → Filtration → Disinfection ~~softenin~~ → Ground water to usage.

- Aeration: O_2 ↓ in; ↓ CO_2, H_2S
- Softening ↓ Hardeness
- Filtration ↓ Dissolved organic substance.
- Disinfection ↓ pathogen.

Plain Sedimentation.

→ Plain Sedimentation is the first unit operation employed to remove suspended particles from water.

→ All particles whose specific gravity is greater than specific gravity of water have a tendency to settle down, but turbulence in water and flow velocity of water offer resistance to particle settlement therefore they remain in suspension.

→ particle seperation from water controlling turbulence and flow velocity there by settlement by virtue of gravity force is known as plain sedimentation.

Plain sedimentation follows type-I settling.

Type I. settling deals with the discrete particle settlement in dilute suspension.

Terminal settling velocity - (V_s)

$$\boxed{V_s^2 = \frac{\frac{4}{3} \cdot g \left(\rho_p - \rho_w \right) d}{C_D \cdot \rho_w}}$$ → Stokes law for settling velocity.

ρ_p = Mass density of particle.

ρ_w = Mass density of water.

d = dia of particle.

C_D = co-eff. drag.

$C_D = \frac{24}{Re}$ → Laminar $Re < 1$.

$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$ → Transition $Re = 1$ to 10^4

$C_D = 0.4$ → Turbulent $Re > 10^4$

For laminar

ific

For laminar flow

$$C_D = \frac{24}{Re} \;;\; Re = \frac{\rho_w V_s \cdot d}{\mu} \Rightarrow C_D = \frac{24\mu}{\rho_w \cdot V_s \cdot d}.$$

$$\boxed{V_s = \frac{g(\rho_p - \rho_w) \cdot d^2}{18\mu}.}$$

$$\boxed{V_s = \frac{g(S-1)d^2}{18\nu}.}$$

μ = Dynamic viscosity of water.
ν = Kinematic viscosity of water.
S = specific gravity of particle

$$\boxed{S = \frac{\rho_p}{\rho_w}}$$

Hazen formula for V_s.

$$\boxed{V_s = 418(S-1)d^2\left[\frac{3T+70}{100}\right]}$$

V_s = mm/sec.
d = mm.
$T = {}^oC$: temp of water

Q) Find terminal settling velocity of a particle of diameter 0.018 mm with $S_G = 2.65$. settling from water whose co-efficient of dynamic viscosity 1. centi poise.

$$V = \frac{g(\rho_p - \rho_w) \cdot d^2}{18\mu} = \frac{9.81(2650-1000) \times (0.018 \times 10^{-3})^2}{18 \times 10^{-3}} \times 10^3$$

$= 0.29$ mm/sec.

Q) A particle of dia 0.02 mm and $S_G = 2.7$ settling from water whose kinematic viscosity 1 centi poise.

$$V = \frac{g(\rho_p - \rho_s) \cdot d^2}{18\mu} = \frac{g(S-1)}{18\nu} \times d^2$$

$= 9.81 \times (2.7-1) \times (0.02 \times 10^{-3})^2$ m/sec

For laminar flow

$$C_D = \frac{24}{Re} \; ; \; Re = \frac{\rho_w V_s \cdot d}{\mu} \Rightarrow C_D = \frac{24\mu}{\rho_w \cdot V_s \cdot d}.$$

$$\boxed{V_s = \frac{g(\rho_p - \rho_w) \cdot d^2}{18\mu}}$$

$$\boxed{V_s = \frac{g(S-1)d^2}{18\nu}}$$

μ = Dynamic viscosity of water.
ν = Kinematic viscosity of water.
S = specific gravity of particle

$$\boxed{S = \frac{\rho_p}{\rho_w}}$$

Hazen formula for V_s.

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$$V = \frac{g(\rho_p - \rho_w) \cdot d^2}{18\mu} = \frac{9.81(2650-1000) \times (0.018 \times 10^{-3})^2}{18 \times 10^{-3}} \times 1$$

$= 0.29$ mm/sec.

(Q) A particle of dia 0.02 mm and $S_G = 2.7$ settling from water whose kinematic viscosity 1 centi poise.

$$V = \frac{g(\rho_p - \rho_s) \cdot d^2}{18\mu} = \frac{g(s-1) \times d^2}{18\nu}$$

$$= \frac{9.81 \times (2.7-1) \times (0.02 \times 10^{-3})^2}{18 \times 10^{-6}} \text{ m/sec}$$

$= 3.7 \times 10^{-4}$ m/sec $= 0.37$ mm/sec.

(Q) Find terminal settling velocity for a particle of dia 0.03mm with SG = 2.65 settling from water @ 20°C.

$$V_s = 418(S-1)d^2\left(\frac{3T+70}{100}\right)$$

$$= 418(2.65-1)(0.03)^2\left(\frac{3\times20+70}{100}\right)$$

$$= 0.8\ mm/sec.$$

P-25
Q-8) $d = 0.025mm$; $S_G = 2.65$

$\nu = 0.01 cm^2/sec = 0.01\times10^{-4} m^2/sec$

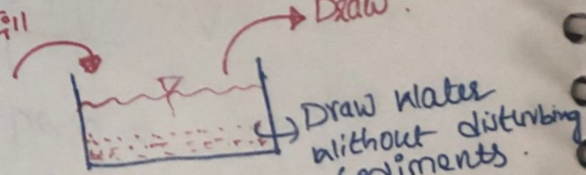
$$V_s = \frac{g(s-1)d^2}{18\nu}$$

$$= \frac{9.81(2.65-1)\times(0.025\times10^{-3})^2}{18\times0.01\times10^{-4}}$$

$$= 0.56\ mm/sec = 0.056\ cm/sec.$$

Sedimentation tank's (or) settling tanks (or) clarifiers.

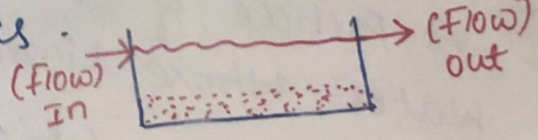
→ The place where suspended particles are seperated from water by controlling turbulence & flow velocity is known as sedimentation tank.



Types of Sedimentation tanks.

Types of settling tanks.

1. Draw and Fill type settling tanks (Out dated)
2. Continuous flow type settling tanks. (Preferrable)



@ Horizontal flow rectangular settling tanks.
ⓑ Radial flow circular settling tanks

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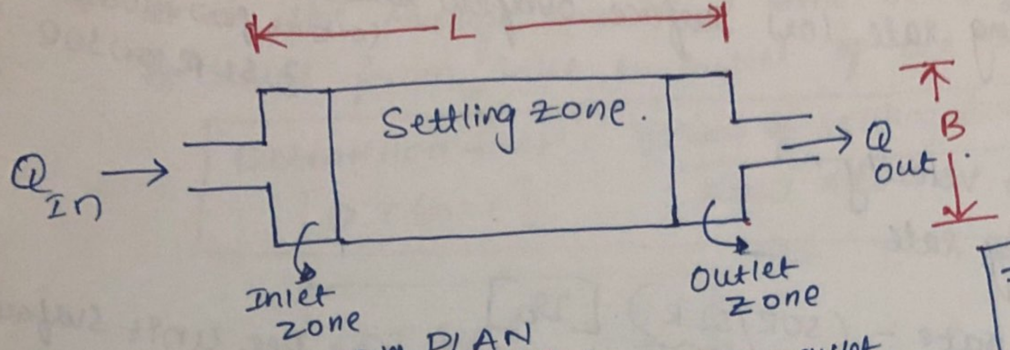
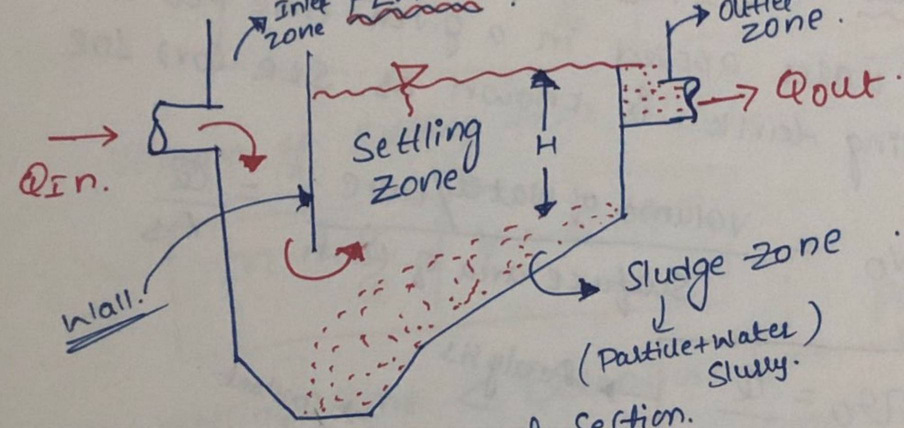
Horizontal flow rectangular settling tanks.



PLAN.



Longitudinal Section.

Design

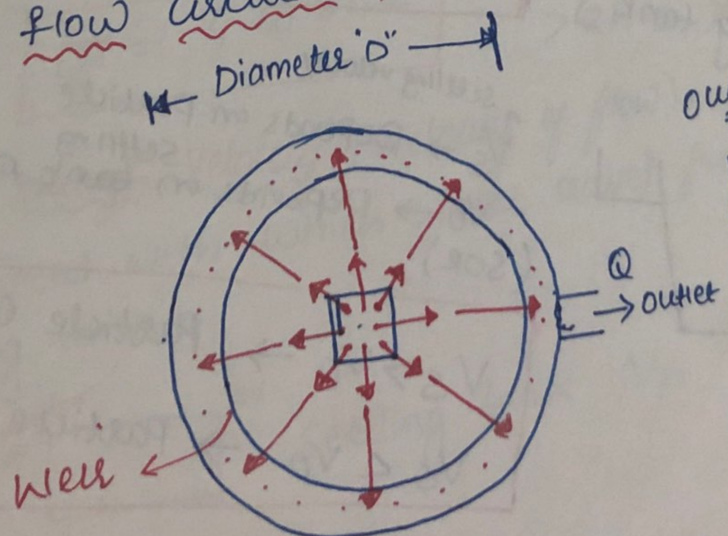
We need to find

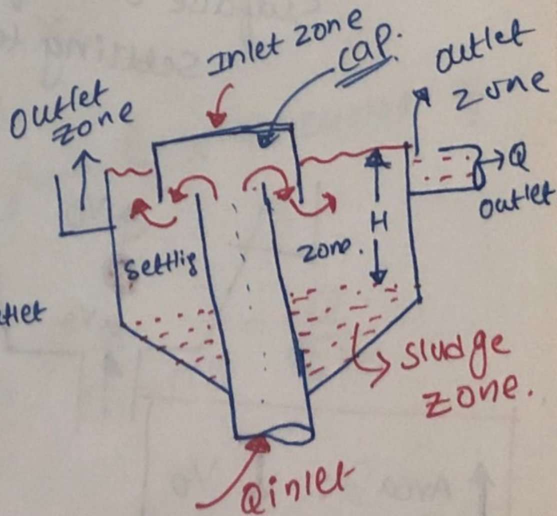
L = Length

B = Breadth

H = Height

Radial flow circular settling tanks.





Design Parameters of settling tank.

1. Surface loading rate (or) surface overflow rate (or) Hydraulic loading rate (or) over flow velocity } SLR (or) SOR.
2. Detention.
3. Flow through velocity.
4. Weir loading rate.

1. Surface overflow rate :- (SOR/SLR). [v_0]

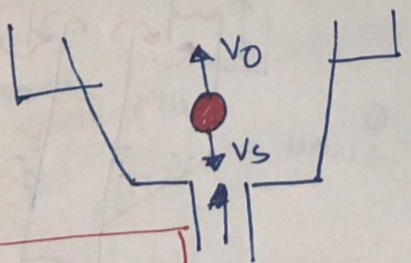
→ volume of water applied in a given time per unit surface area of settling tank. is known as SLR (or) SOR.

$$SLR/SOR = V_0 = \frac{\text{volume of water/time}}{\text{Surface area of tank}} = \frac{Q}{A_s}$$

$$\boxed{v_0 = \frac{Q}{A_s}} \rightarrow \text{Analysis}$$

Surface area of settling tank } ⇒ $\boxed{A_s = \frac{Q}{V_0}} \rightarrow$ Design

constant



V_s → Depends on Particle. (settling velocity)

V_0 → depends on settling tank Area. (SOR)

$V_s > V_0$ →	Particle capture.
$V_s < V_0$ →	Particle Escape

↑ Area	: ↓ V_0
↓ Area	: ↑ V_0

SLR (or) SOR

V_0 = 500 to 750 lit/hr/m^2.

V_0 = [10 to 20 m^3/day/m^2]

Surface area (plan area) of Rectangular tank = L × B

" " " circular tank = $\frac{\pi}{4} \times d^2 \times H$.

2. Detention time (or) Retention time (or) Hydraulic Detention time :

→ It is the Average theoritical time taken by the water to travel from inlet to outlet of the settling tank.

$$\boxed{\text{Detentition time } [DT \text{ (or) } t] = \frac{\text{Volume of settling tank}}{\text{Flow rate}}}$$

$$\boxed{DT \text{ (or) } t = \frac{V}{Q}}$$

Volume of settling tank = $\boxed{V = Q \times DT}$

$$\boxed{DT = \frac{V}{Q} \quad \Big| \quad V = Q \times DT}$$

* Particle settling time < Detention time → Particle capture.
* particle settling time > Detention time → particle escape.

$\boxed{DT = 4 \text{ to } 8 \text{ hrs}}$ < 4hrs ✓   > 8hrs ✗.

3. Flow through Velocity (Velocity of flow).

Speed with which water travel from inlet to outlet of Settling tank.

Important *

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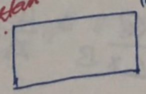

Settling tank $V_H = \frac{Q}{c/s \text{ area}} = \frac{Q}{B \times H}$.

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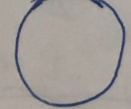


Settling tank $V_r = \frac{Q}{\int_{r_1}^{r_2} 2\pi r\, dr \cdot H} = \frac{Q}{2\pi (r_2 - r_1) H}$.

Flow through velocity V_H (or) V_r } ⇒ 0.2 to 0.9 m/min (0.3 m/min)

Weir loading rate: (WLR)

Discharge per unit length of weir is known as WLR.

$$\boxed{WLR = \frac{Q}{\text{Length of weir}}}$$

Particle removal efficiency: ("η")

Particle removal efficiency of ith particle $\eta_i = \frac{v_{si}}{v_o} \times 100$

* $v_{si} \geq v_o \rightarrow$ 100% removal.
* $v_{si} < v_o \rightarrow$ partial removal.

Overall removal of particles from settling tank. $\}$ $\eta_{overall} = \sum P_i \eta_i$

P_i = percentage of i^{th} particle in water.

Conditions for 100% removal.

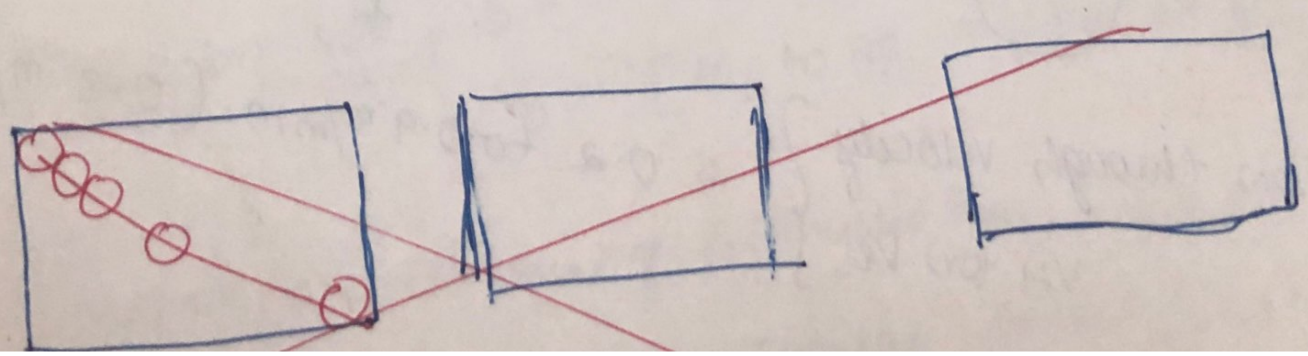
$$DT = \frac{\cancel{V}}{Q} = \frac{L \times \cancel{B \times H}}{\cancel{B \times H} \times V_H}$$

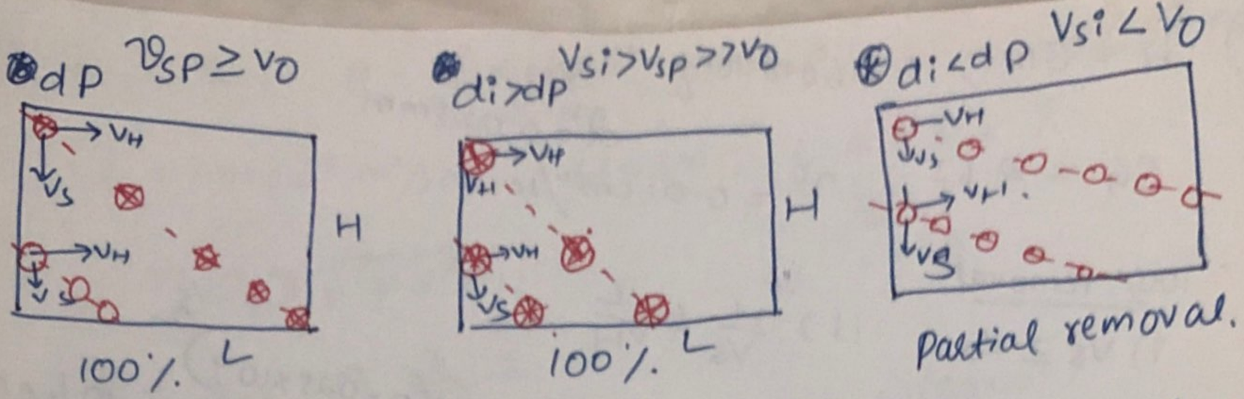
i) $v_{si} \geq V_o$

2). $\frac{H}{V_s} \leq \frac{L}{V_H}$

Eg = $\frac{H}{V_s} \leq \frac{L}{V_H} \Rightarrow \frac{H}{V_s} = \frac{L}{V_H}$.

$V_s = V_H \times \frac{H}{L} \Rightarrow \frac{Q}{B\cancel{H}} \times \frac{\cancel{H}}{L} \Rightarrow \frac{Q}{L \times B} = \frac{Q}{A_s} = V_o$.





Note: 1.

1. Partial removal only depend on surface of settling tank.
2. partical removal is independent of depth i.e Depth does not Play any role in particle removal.

$$\boxed{\begin{gathered}\eta \propto \frac{1}{v_0} \\ v_0 \propto \frac{1}{\text{surface area}}\end{gathered}}$$

CRPQ

1. $B = 6\text{ m}$; $L = 15\text{m}$; $H = 3$; 2MLD; $= 2\times10^6$ L/Day.

$\Rightarrow V_0 = \dfrac{2\times10^6}{24 \times 15 \times 6} = 926$ L/hr/m².

2.) $D.T = \dfrac{V}{Q} = \dfrac{6\times15\times3 \text{ m}^3}{\dfrac{2\times10^6 \times 10^{-3}\text{ m}^3}{24}} = 3.24$ hrs.

3). $Q = 1.8\times10^6$ L/D. ; $t = 4$ hours :

$t = \dfrac{V}{Q}$. $\Rightarrow V = t \times Q$. $\Rightarrow \dfrac{1.8\times10^6}{10^3\times24} \times 24 \Rightarrow 300\text{ m}^3$.

volume of Settling tank.

4) $SOR = V_0 = 500$ lit/hr/m² and $L:B = 4:1$.

surface area of Settling tank. } $L\times B = \dfrac{Q}{v_0} \Rightarrow \dfrac{1.8\times10^6/24 \text{ lit/hr}}{500 \text{ lit/hr/m}^2} = 150\text{m}^2$

$L:B = 4:1$. $L = 4B$; $B = L/4$

$L\times B = 150\text{m}^2$

$L\times\frac{L}{4} = 150 \Rightarrow L = \sqrt{150\times4} = 24.5\text{ m}$.

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(5) $H = 3m$; $L = 60m$ long. $V_H = ?$

$d = 0.025mm$.

$SG = 2.65$; $\nu = 0.01 cm^2/sec$.

100% removal

i) $V_S \geq V_0$ ii) $\frac{H}{V_S} \leq \frac{L}{V_H}$.

$$V_s = \frac{g(s-1)d^2}{18\nu} = \frac{9.81(2.65-1)(0.025\times10^{-3})^2}{18\times0.01\times(\frac{1}{100})^2} . m/sec$$

$$= 5.62\times10^{-4} m/sec$$

$$\Rightarrow \frac{H}{V_s} = \frac{L}{V_H}$$

$$\frac{3}{5.62\times10^{-4}} = \frac{60}{V_H}.$$ $\Rightarrow$ Flow velocity $V_H = 0.0112 m/sec$.

(6) $Q = 10^6 \ m^3/day$. $v_s = 20 m/day$. (100% remova).

Surface area $= \frac{10^{\cancel{5}} m^3/\cancel{day}}{20 m \cancel{day}} \Rightarrow 5000 m^2$.

For 100%. $V_S \geq V_0$.= $V_S = V_0 = 20 m/day$.

(8) $v_0 = 121000$ lit/hr/m² ; $d = 0.03$ mm ; $\nu = 0.897$ mm²/sec

$= \frac{121000\times10^{-3} m^3}{60\times60} =$ $\Rightarrow$ $v_s = \frac{9.81\times(2.65-1)\times(0.03\times10^{-3})^2}{18\times0.897\times10^{-6}}$.

$v_s = 9.02\times10^{-4}$

$$\eta = \frac{V_s}{V_0}\times100 \Rightarrow 27.07\%$$

(1) $G = 2.$

$\nu =$

(11) $G = 2.3$ $Q = \frac{100\times10^6\times10^{-3}}{24\times60\times60} = 1157\ m^3/day$ $d = 50\times10^{-6}\ m$

$\nu = 1.01\times10^{-6}\ m^2/sec.$ $H = 3m$; $L:B = 3:1$

$\frac{L}{B} = \frac{3}{1}$

$L = 3B.$

$V_s = 1.8\sqrt{g.d(s-1)}$

$\frac{H}{V_s} = \frac{L}{V_H} \Rightarrow \frac{3}{1.3} =$

$$v_s = \frac{g(s-1)d^2}{18\nu} = \frac{9.81\times(2.3-1)(50\times10^{-6})}{18\times1.01\times10^{-6}}$$

$$= 1.75\times10^{-3}\ m/sec.$$

For 100% removal

$v_s \geq v_o \Rightarrow v_o = v_s = 1.75\times10^{-3}\ m/sec.$

Surface are of settling tank $= L\times B = \frac{Q}{v_o}$.

$$L\times B = \frac{\frac{100\times10^6}{10^3\times24\times60\times60}}{1.75\times10^{-3}} = 661.14m^2$$

$L\times B = 661.4m^2$

$3B\times B = 661.14\ m^2 \Rightarrow 3B^2 = 66.141$

$\Rightarrow B = 14.84\ m.$

$L : 3B \Rightarrow 44:53m.$

$$D.T = \frac{V}{Q} = \frac{L\times B\times H}{100} = \frac{44.53\times14.84\times3}{\frac{100\times10^6}{10^3\times24}} \frac{m^3}{m^3/hr}$$

$\Rightarrow 0.47$ hrs.

(12) $L\times B\times H = 100\times50\times3m$; $Q = 100000\ m^3/day$

SOR, $V_o = ?$ $d = ?$ $S = 2.65\ gm/c.c.$

$m^3/m/day$ (100% removed) $\nu = 1.02\times10^{-2}\ cm^2/sec$

For 100%.

$V_s \geq V_o$

$V_o = V_s = 20\ m^3/m^2day$

$$v_o = \frac{Q}{A} = \frac{Q}{L\times B} = \frac{1000000}{100\times50} = 20\ m^3/m^2/day.$$

$SG =$

$$\frac{20}{24\times60\times60} = \frac{9.81\left(\frac{2.65}{1}-1\right)d^2}{18\times1.02\times10^{-2}\times10^{-4}\ m^2/sec} \Rightarrow d = 1.6\times10^{-5}\ m = 0.016mm$$

(13) $H = 3m$; $B \times H = 900 m^2$, $Q = 8000 m^3/d$; $t = 20°c$.
$\mu = 10^{-3} kg/m\text{-}s$ & $\rho = 1000 kg/m^3$.
$d = 0.01$; $G = 2.65$.

* Proportionality means.

$$SLR : V_0 = \frac{Q}{Surface} = \frac{8000}{900} \frac{m^3/day}{m^2} : 8.88 \, m/day \Rightarrow \frac{8.88}{24 \times 60 \times 60}$$

$$= 1.02 \times 10^{-4} \, m/sec$$

$$V_s = \frac{g(\rho_p - \rho_w) \cdot d^2}{18 \mu} \; ; \; \rho_p = S \times \rho_w = 2.65 \times 1000 = 2650 \, kg/m^2$$

$$= \frac{9.81(2650 - 1000) \times (0.01 \times 10^{-3})^2}{18 \times 10^{-3}}$$

$$= 8.99 \times 10^{-5} \, m/sec.$$

proportion removed : $\eta = \frac{V_s}{V_0} \times 100 = \frac{8.99 \times 10^{-5}}{1.02 \times 10^{-5}} \times 100$

$\Rightarrow$ 87.5%.

(14) $L = 20m$; $W = 10m$; $H = 3m$.
$Q = 4MD$; $\mu = 1.002 \times 10^{-3} \, N \cdot s/m^2$; dia = 100% removed
$\rho_w = 998.2 \, kg/m^2$. $G = 2.65$

$$SOR ; V_0 = \frac{Q}{A} = \frac{Q}{L \times B} = \frac{4 \times 10^6}{20 \times 10} \frac{m^3/day}{m^2} = \frac{m^3}{m^2 \cdot day}$$

$$= 20 \, m^3/day/m^2.$$

(15) $V_s = V_0 = 20 m^3/day/m^2 = 20 m/day = \frac{20}{24 \times 60 \times 60} \, m/sec$

$$= 2.31 \times 10^{-4} \, m/sec.$$

$$V_s = \frac{g(\rho_p - \rho_w) d^2}{18 \mu} \qquad \rho_p = S \times \rho_w = 2.65 \times 998.2 = 2645.23 \, kg/m^3$$

$$2.31 \times 10^{-4} = \frac{9.81(2645.23 - 1000) d^2}{18 \times 1.002 \times 10^{-3}}$$

$d = 1.6 \times 10^{-5} m$ ∴ $0.016 \, mm = 16 \times 10^{-3} \, mm$

(16)

$\eta_i = \frac{v_{si}}{v_0} \times 100$	Particle	v_{si} %ge of particles	v_s mm/sec	SOR
$\eta_1 = \frac{0.1}{0.5} \times 100 = 20$	1	10	0.1	0.5
$\eta_2 = \frac{0.2}{0.5} \times 100 = 40$	2	60	0.2	0.5
$\eta_3 = \frac{1}{0.5} \times 100 = 200 \simeq 100\%$	3	30	1	0.5

$v_0 = 43.2 \frac{m^3}{m^2 d}$

$v_0 = 43.2\ m/day$

$= \frac{43.2 \times 1000}{24 \times 60 \times 60} \frac{mm}{sec}$

$= 0.5\ mm/sec.$

$\eta_{overall} = \Sigma P_i n_i$

$= \frac{10}{100} \times 20 + \frac{60}{100} \times 40 + \frac{30}{100} \times 100$

$\Rightarrow 2 + 24 + 30$

$\eta. \Rightarrow \underline{\underline{56}}\ \%.$

(17) $S.O.R = v_0 = 30 \frac{m^3}{day \cdot m^2}$; $G = 2.65$, $\rho_w = 1000$

$v_s = v_0 = 100\%$ removal

$\mu = 0.001\ N.s/m^2.$

$$\frac{30 \times \cancel{1000}}{24 \times 60 \times 60} = \frac{g(\rho_p - \rho_w) \cdot d^2}{18 \cdot \mu}$$

$$= \frac{9.81(2650 - 1000) \cdot d^2}{18 \times 0.001}$$

$d = 1.96 \times 10^{-5}\ m$

$= 0.0196\ mm \simeq 0.02\ mm.$

(18) $d = 0.10mm$; ia of particle present; $Q = 0.01\ m^3/s$, $g = 9.8$, $SG = 2.65$,

$\nu = 1.0105 \times 10^{-2}\ cm^2/s$. $d = 0.06mm$.

$$v_s = \frac{g(S-1)d^2}{18\nu} = \frac{9.8(2.65-1) \cdot (0.06 \times 10^{-3})^2}{18 \times 1.0105 \times 10^{-2} \times \frac{1}{(100)^2}}$$

$= 3.2 \times 10^{-3}\ m/sec.$

Forr 100% removal.

$V_s \geq V_0$ $= V_0 = V_s = 3.2 \times 10^{-3}\ m/sec$

surface are of settling tank $= \frac{Q}{V_0} = \frac{0.01}{3.2 \times 10^{-3}} = \frac{m^3/sec}{m/sec} = 3.12\ m^2.$

19.. $40\ m^3/m^2/d$ = S.O.R

$\rho = 1000\ kg/m^3$; $\rho_p = 2650$; $\eta = 90\%$.

$g = 9.81$; $\nu = 1.10 \times 10^{-6}\ m^2/s$. (9)

$S = \frac{\rho_p}{\rho_w} = \frac{2650}{1000} = 2.65$

$$\frac{36 \times}{24 \times 3600} = \frac{9.8(2.65-1)d^2}{18 \times 1.10 \times 10^{-6}}$$

$$\eta = \frac{V_{si}}{V_0} \times 100 \Rightarrow 90 = \frac{V_{si}}{40} \times 100$$

$V_{si} = \frac{90}{100} \times 40 = 36\ m^3/m/day$

$= \frac{36}{24 \times 60 \times 60}$

$d \Rightarrow 2.25 \times 10^{-5}\ m$

$= 2.25 \times 10^{-5} \times 10^{6}\ m$

$\boxed{1\,m = 10^6\,\mu}$

$d = 22.58\ \mu$.

(20) $v_0 = 32.5\ m^3/m^2\text{-}day$

$L = 32.5\ m$ $\quad L_{weir} = 75\ m$.

$B = 8$

$H = 2.25\ m$

$v_0 = \frac{Q}{L \times B} = \quad Q \Rightarrow 32.5 \times 32.5 \times 8 \quad \times \frac{m^3}{m^2\text{-}day} \times m^2$

$\Rightarrow 8450$

Weir loading $= \frac{Q}{L} \Rightarrow \frac{8450}{75} \Rightarrow 112.66\ m^3/day/m^2$

Length of weir for same tank, then take "B"

(9) $d = 26m$ $\quad$ $DT = ?$

$H = 2.1m$ $\quad$ $WLR = ?$

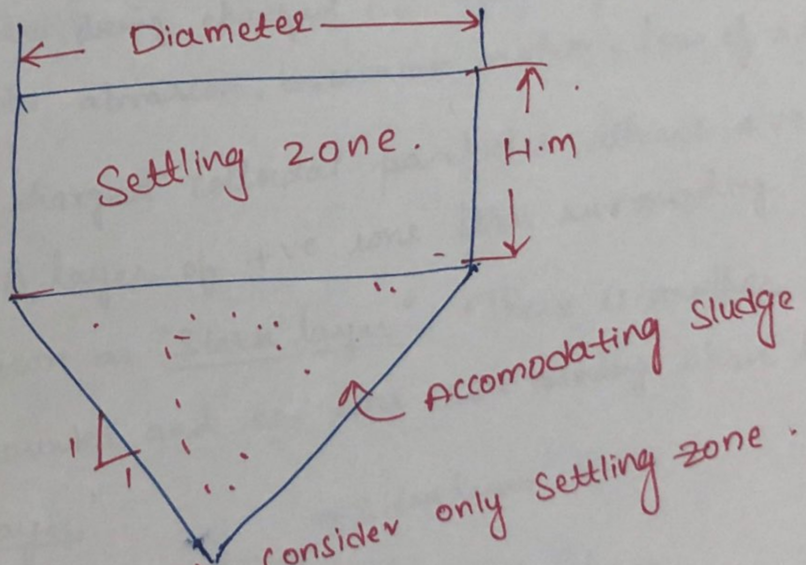
$Q = 13000\ m^3/day$.

$$D.T = \frac{\text{volume of tank}}{Q} = \frac{\frac{\pi}{4} \times D^2 \times H}{13000} = \frac{\frac{\pi}{4}(26)^2 \times 2.1}{13000}$$

$$= 2.05\ hrs$$

$$\simeq 2.41\ hrs.$$

(10) $$WLR = \frac{Q}{\text{Length of weir}} = \frac{Q}{\pi D} = \frac{13000}{\pi(26)} = 159\ m^3/day/m.$$



* We have to consider only Settling zone.

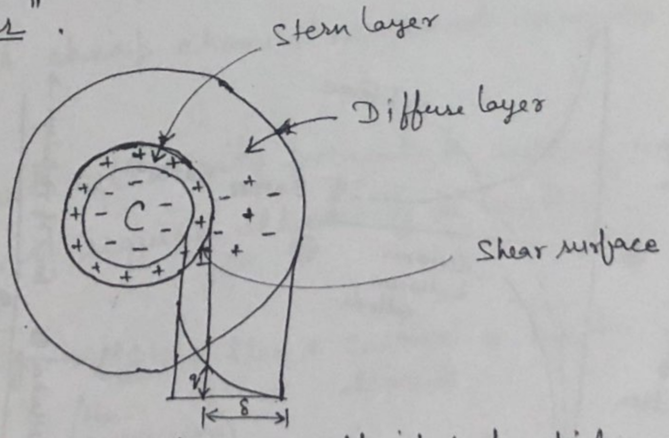
11/ Sedimentation aided with coagulation

26/8/18 (13)

- Sedimentation aided with coagulation is accelerated sedimentation process aimed to capture colloidal substances present in the water. It can also capture suspended solids ($< 50\ \mu m$), which escape from plain settling operation.

colloidals = -vely charged

- Colloids are charged particles. Most of the colloids carry "-ve" charge. Their surface being charged i.e. they aquire charges on their surface due to abrasion, brownian motion, loss of atoms etc.
- Negatively charged colloidal particles attract +ve ions present in water. A layer of +ve ions form surrounding colloidal surface known as "Stern layer". There is another layer of ion containing counter and co- ions surrounding stern layer known as "diffuse layer".



- These two layers surrounding the colloidal particle give stability, known as "electronic double layer".
- Stability is the strength of colloids.
- Colloidal stability - The measure of colloidal stability is "zeta potential"

$$\boxed{\text{Zeta Potential, } \zeta = \frac{4\pi q \delta}{D}}$$

q: charge on shear surface

δ: thickness of diffused layer

D: Dielectric constant

water they must be

stabilize colloids

of water.

are

Common coagulants

Trivalent aqua

high coagulati

chemical subs

1> Alu

2> Fe

3> F

4>

— Therefore to capture colloids from water they must be destabilized.

— Addition of certain chemicals to water to destabilize colloids is known as <u>coagulation</u> or <u>chemical conditioning</u> of water.

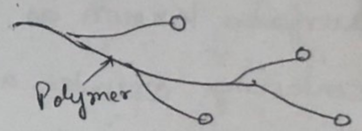
— Chemical substances used to destabilize colloids are known as <u>coagulants</u>.

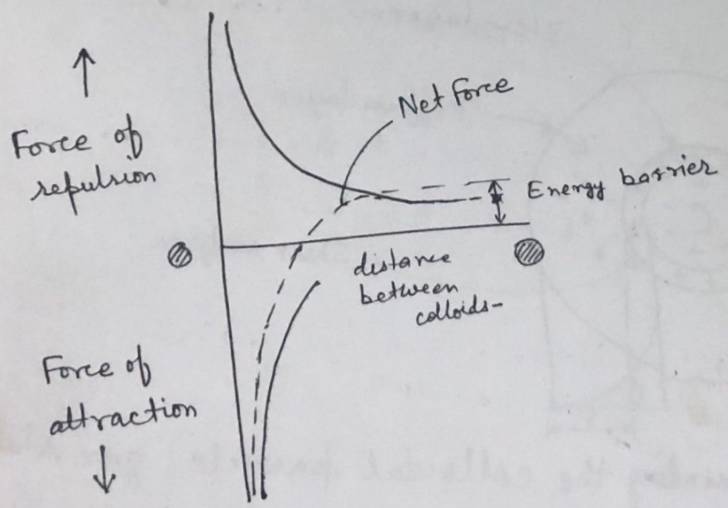
Mechanisms of coagulation (destabilization)

1.) Compression of electronic double layer
2.) Adsorption and charge neutralization.
3.) Entrapment in the precipitate or Sweep coagulation.

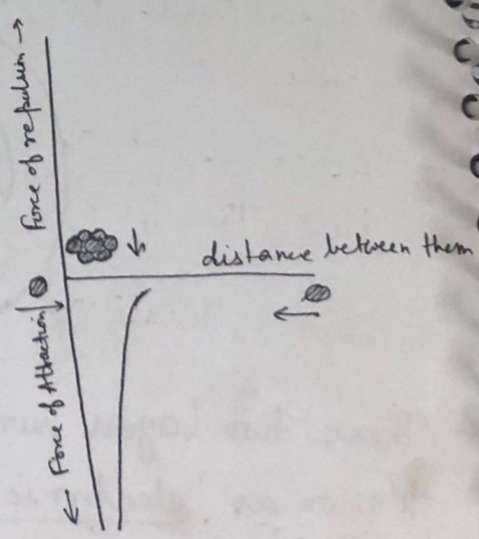
DLVO theory

4.) Interparticle bridging (by adding certain chemical polymers as coagulants)





Before coaggulation



After coagulation.

Coagulation ⟶ Flocculation ⟶ Sedimentation.
(chemical conditioning) (Physical conditioning) (growth of colloids)

Common coagulants

Trivalent aqua metallic cationic substance thought to have very high coagulating powers and used as coagulants. The following chemical substances are used as coagulants.

1.) Aluminium Sulphate (Alum)

2.) Ferrous Sulphate (Copperas)

3.) Ferric sulphate and ferric chloride (chlorinated copperas)

4.) Sodium aluminate.

Aluminium Sulphate (Alum)

- Alum is known as universal coagulant.
- Alum produce effective floc in water when pH of water is 6.5 to 8.5.
- Besides producing floc it also remove colour, odour and improve taste of water. Coagulating water with alum is economical because alum is cheap chemical compound easy to store and handle.
- Alum react with alkalinity present in water and produce floc. Therefore, it require alkalinity in water.

$$\text{Alum} + \text{Alkalinity} \rightarrow \underbrace{\text{NCH}}_{\text{(Non-Carbonaceous Hardness.)}} + \text{floc} + \text{Carbon dioxide} + \text{water}.$$

- Alum impart hardness and water become corrosive due to decrease in pH.

$$Al_2(SO_4)_3 \cdot 18H_2O + 3\,Ca(HCO_3)_2 \longrightarrow 3\,CaSO_4 + 2\,\underbrace{Al(OH)_3}_{\text{(floc)}} \downarrow + 6CO_2 + 18\,H_2O$$

Mol. wt. of alum = 666

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

— The

des

mol. wt. of $3\,CaCO_3 = 3 \times 100$

— Add

is kn

required (as $CaCO_3$) $= \dfrac{3 \times 100}{666} \times$ dose of alum.

— Chemical

known a

deficiency = Alkalinity Required – Alkalinity Present

$\rightarrow CaO + CO_2$

Quicklime (used as external alkali)

$CaO = 40 + 16 = 56$

required (as $CaCO_3$) $= \dfrac{56}{100} \times$ (Alkalinity deficiency in water.)

Mechanisms of

1.) Compression of e

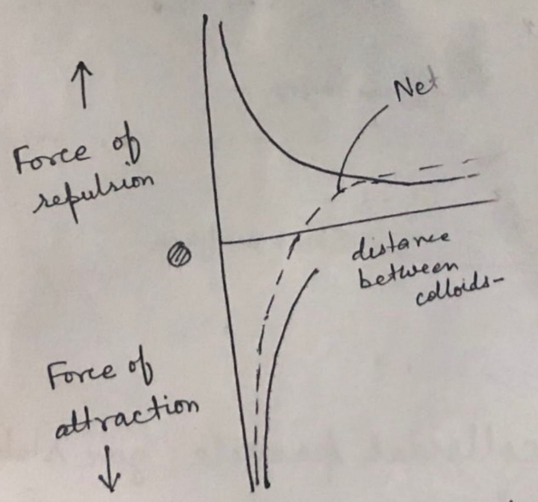
2.) Adsorption and

3.) Entrapment in th

4.) Interparticle brid

10^6 l/day

g/L.



Before coagulation

× dose of alum

20

as $CaCO_3$

g/day as $CaCO_3$

/day as $CaCO_3$

Coagulation → Flocculation →

(chemical conditioning) (Physical conditioning)

... colloids)

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

Mol. wt. of $3\,CaCO_3 = 3 \times 100$

$$\boxed{\text{Alkalinity required (mg/L as } CaCO_3) = \frac{3 \times 100}{666} \times \text{dose of alum.}}$$

$$\boxed{\text{Alkalinity deficiency} = \text{Alkalinity Required} - \text{Alkalinity Present}}$$

$CaCO_3 \rightarrow CaO + CO_2$

$CaO \rightarrow$ Quicklime (used as external alkali)

Mol. wt of $CaO = 40 + 16 = 56$

$$\boxed{\text{Dose of CaO required (as mg/L of } CaCO_3) = \frac{56}{100} \times (\text{Alkalinity deficiency in water.})}$$

P-32 Q-2

$Q = 10$ MLD $= 10 \times 10^6$ l/day

Alkalinity present $= 6$ mg/L.

Alum required : 20 mg/L

$$\text{Alkalinity required} = \frac{3 \times 100}{666} \times \text{dose of alum}$$

$$= \frac{3 \times 100}{666} \times 20$$

$$= 9 \text{ mg/L as } CaCO_3$$

$$= 9 \times 10 \times 10^6 \text{ mg/day as } CaCO_3$$

$$= 90 \times 10^6 \text{ mg/day as } CaCO_3$$

3.) Alkalinity deficiency = 9 − 6 = 3 mg/L as $CaCO_3$.

Dose of CaO required = $\frac{56}{100} \times 3$ = 1.68 mg/L as CaO

$= 1.68 \times 10 \times 10^6$ mg/day

$= 1.68 \times 10 \times 10^6 \times 365$ mg/year

$= 6132 \times 10^6$ mg/year.

$$\boxed{\underset{(kg/day)}{\text{Total amount of any substance 'x'}} = \underset{MLD}{Q} * \underset{(mg/L)}{\text{Conc. of } x} = \underset{MLD}{Q} * \underset{(mg/L)}{\text{dose of } x}}$$

Total quicklime required = Q * dose of quicklime.

= 10 × 1.68

= 16.8 kg/day

Total quicklime required / annum = 16.8 × 365 = 6132 kg/year

$= \underline{6132 \times 10^6}$ mg/year

4.) Q = 12 MLD

Alum required = 14 ppm.

CO_2 gas = ?

Total quantity of Alum = Q × dose of Alum

= 12 × 14 kg/day

= 168 kg/day

666 gm of alum = 6 × 44 gm of CO_2.

168 kg/day of alum = $\frac{6 \times 44}{666} \times 168$ kg/day of CO_2

= 66.59 kg/day

= 5.55 mg/L.

3.) Alkalinity deficiency = 9 − 6 = 3 mg/L as $CaCO_3$.

Dose of CaO required = $\frac{56}{100} \times 3$ = 1.68 mg/L as CaO

= $1.68 \times 10 \times 10^6$ mg/day

= $1.68 \times 10 \times 10^6 \times 365$ mg/year

= 6132×10^6 mg/year.

$\boxed{\text{Total amount of any substance 'x' (kg/day)} = Q * \text{Conc. of } x \; (\text{MLD} * \text{mg/L}) = Q * \text{dose of } x \; (\text{MLD} * \text{mg/L})}$

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168 kg/day of alum = $\frac{6 \times 44}{666} \times 168$ kg/day of CO_2

= 66.59 kg/day

= 5.55 mg/L.

666 parts of alum produce = 6×44 parts of CO_2

1 part of alum " $= \frac{6 \times 44}{666}$ " "

14 mg/L of alum " $= \frac{6 \times 44}{666} \times 14 = 5.55$ mg/L.

Q.12) $Q = 3.5\ m^3/min = 3.5 \times 10^3\ l \times \frac{60 \times 24}{day} = 5.04$ MLD

Alum dosage = 25 mg/L

Total alum required = $5.04 \times 25 = 126$ kg/day

Alum required in 30 days = $30 \times 126 = 3780$ kg

Ferrous sulphate (Copperas)

Ferrous sulphate is cheaper than alum. It produce floc only in conjunction with hydrated lime. It is effective only when pH > 8.5. It does not produce floc in coloured water. Therefore colour is a constraint.

Ferrous Sulphate + hydrated lime → NCH + floc + water

$$FeSO_4 \cdot 7H_2O + Ca(OH)_2 \longrightarrow CaSO_4 + \underbrace{Fe(OH)_2}_{floc} \downarrow + 7H_2O$$

$$Ca(OH)_2 \longrightarrow CaO + H_2O$$

Molecular wt of $FeSO_4 \cdot 7H_2O = 56 + 32 + 4 \times 16 + 7 \times 18 = 278$

$$\boxed{\text{Dose of } CaO \text{ required} = \frac{56}{278} \times \text{dose of Ferrous Sulphate}}$$

Q. 5) Total quantity of ferrous sulphate =

5) $Q = 12 \text{ MLD}$

Dosage = 10 mg/L.

Total quantity of Ferrous sulphate = 12×10 = 120 kg/day.

278 parts of $FeSO_4 \cdot 7H_2O$ require = 56 part of CaO

10 mg/L " " " $= \frac{56}{278} \times 10$

$= 2.014$ mg/L of CaO.

Total quantity of lime = $Q \times$ Dose

$= 12 \times 2.014 = 24.17$ kg/day

Ferric Sulphate and Ferric Chloride (Chlorinated copperas)

Copperas reacted with chlorine to produce chlorinated copperas.

They are very effective (i.e. produce good floc) when water pH > 8.5 & pH < 6.5

And colour is not a constraint.

$$6\,FeSO_4 \cdot 7H_2O + 3Cl_2 \rightarrow \underset{\text{(ferric sulphate)}}{2Fe_2(SO_4)_3} + \underset{\text{(ferric chloride)}}{2FeCl_3} + 42H_2O$$

$$Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 3CaSO_4 + \underbrace{2Fe(OH)_3}_{\text{floc}} \downarrow$$

$$2FeCl_3 + 3Ca(OH)_2 \rightarrow 3CaCl_2 + \underbrace{2Fe(OH)_3}_{\text{floc}} \downarrow$$

Sodium Aluminate ($Na_2Al_2O_4$)

Independent of pH i.e. @ any pH produce floc.

expensive chemical. It also require alkalinity to produce floc.

$$Na_2Al_2O_4 + Ca(HCO_3)_2 \longrightarrow \underbrace{CaAl_2O_4}_{\text{floc}} \downarrow + Na_2CO_3 + CO_2 + H_2O$$

Optimum dose of coagulent

Coagulent dose at which maximum removal of colloids occur is known as optimum dose of coagulant.

Optimum dose of coagulent is conducted by Jar test using Jar test apparatus.

Jar test

by applying force	– Orthokinetic flocculation.
on own	– Parakinetic flocculation

Rapid Mixing

(Chemical conditioning)

1 to 3 min

rotate @ 100 to 120 rpm.

Slow mixing

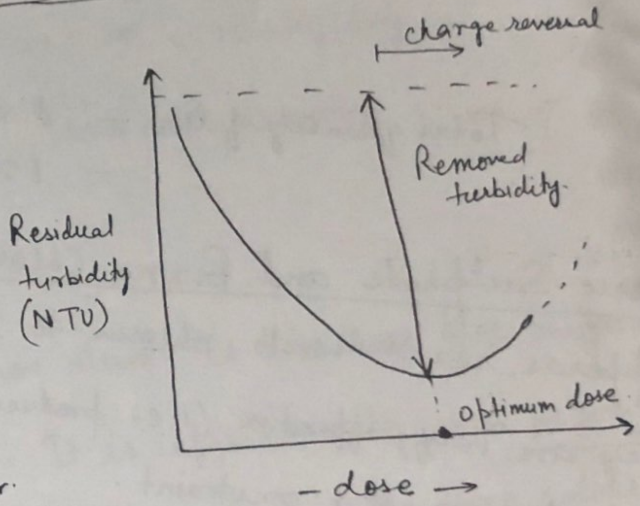
(Physical conditioning)

1 to 3 rpm.

20 to 30 min.

Sedimentation

Allow the floc to settle for next 30 min to 1 hr.



27/8/17

Clarifloculator

Clarifloculator is a reactor where coagulation, flocculation and sedimentation is carried out.

Clarifloculator consists —

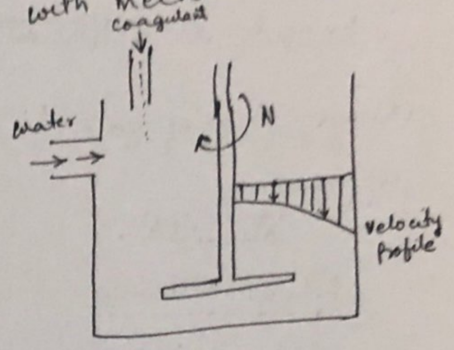
1.) Rapid mixing unit (flash mixer)

2.) Flocculator (Slow mixing unit)

3.) Settling tank.

Rapid mixing unit or flash mixer

For blending coagulant with water rapid mixing unit is employed. It consists a square or circular tank with mechanical mixing device.



Design of rapid mixing unit

Design of rapid mixing unit is carried out based on.

1. Detention time   2. Velocity Gradient

Detention time (D.T. or t)

$$DT = 1 \text{ to } 3 \text{ min.}$$

Volume of rapid mixer $= Q * D.T.$

Assume depth, $H = 1 \text{ to } 1.5 m.$

Surface Area, $A_s = \frac{Volume}{H}$

For square tank, $A_s = B * B$

$\Rightarrow B = ?$

For circular tank $A_s = \frac{\pi}{4} D^2$

$\Rightarrow D = ?$

Velocity Gradient 'G.'

Velocity gradient is the measure of degree of mixing.

$G \propto$ Degree of mixing $\propto$ Turbulance

$G = 700 \text{ to } 1000 \text{ sec}^{-1}$ → Provide good degree of mixing.

$$\boxed{G = \sqrt{\frac{P}{V\mu}}}$$

P: Power in watt

V: Vol. of mixing unit in m^3

μ = Coeff. of dynamic viscosity Ns/m^2.

G = velocity gradient in sec^{-1}.

$N \rightarrow rpm$

$\omega \rightarrow \frac{2\pi N}{60}$

$v = \omega \times r$

$P = F \times v$

$P = \frac{C_D A \rho_w v^2}{2} \cdot v = \frac{C_D \cdot A \rho_w v^3}{2}$

$$\boxed{G \propto P \propto v \propto \omega \propto N}$$

$$\boxed{G \propto \frac{1}{V}}$$

P-33 Q-8

$V = 2\,m^3$

$G = 600\,sec^{-1}$

$\mu = 1 \times 10^{-3}\,Ns/m^2$.

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

$$P = \mu V G^2 = 1\times10^{-3} \times 2 \times 600^2$$

$$= 720\,W$$

Q.6.

$Q = 3000\,m^3/hr$

$t = 20$ min.

$G = 40\,sec^{-1}$

$\mu = 1.0087\times10^{-3}\,Ns/m^2$.

$L' = 2.$ $d = 0.4B.$

Vol. of flocculator $= Q \times t$

$= 3000 \times \frac{20}{60} = 1000\ m^3.$

$1000 = L \times B \times D$

$1000 = 2B \times B \times 0.4B$

$B^3 = \frac{1000}{2 \times 0.4}$

$B = 10.77\ m.$

$L = 21.54\ m.$

$D = 4.31\ m.$

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

$P = \mu V G^2 = 1.0087 \times 10^{-3} \times 10.77 \times 21.54 \times 4.31 \times 40^2$

$= 1613.69$ Watt

1.> $Q = 28800\ m^3/day$

$\rho_w = 1000\ kg/m^3$

$\nu = 10^{-6}\ m^2/s.$

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

Dose of alum = $35\ mg/l$

$DT = 2\ m.$

Vol. of rapid mixer $= V = Q \times DT.$

$= \frac{28800}{24 \times 60} \times 2 = 40\ m^3.$

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

$P = V \mu G^2 = V \rho_w \nu G^2$

$= 40 \times 1000 \times 10^{-6} \times 900^2 = 32400\ W.$

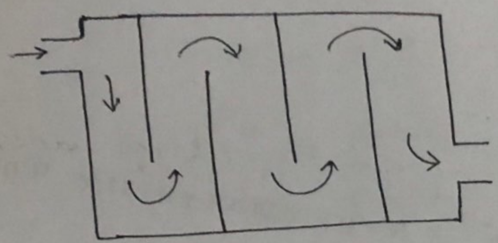
Flocculator

Flocculator is a slow mixing unit. To have orthokinetic flocculation for the growth of floc, flocculator is employed.

There are two types of flocculators.

1) Hydraulic flocculator (obsolete)

2) Mechanical flocculator



Plan of hydraulic flocculator

Hydraulic flocculators are obselete, they donot produce floc of our choice. Mechanical flocculators are preferred to hydraulic flocculators.

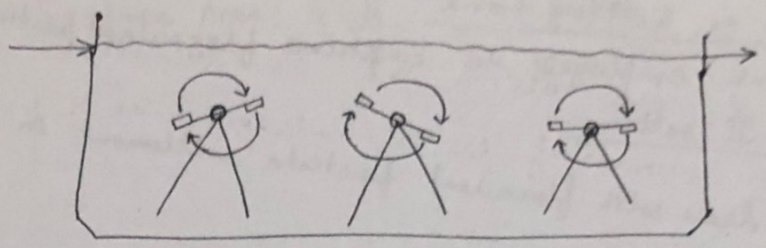
Mechanical flocculator

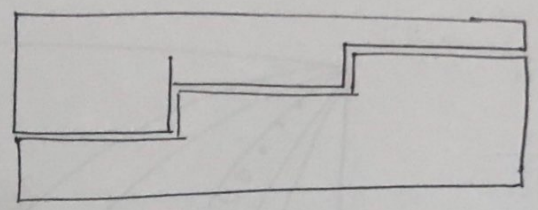
Mechanical flocculator is a rectangular tank provided with paddle rotors or drum rotors to induce small scale turbulence. Size of floc produced depends on a non-dimensional number. "Gt". A Gt value ranges from 10⁴ to 10⁵ usually produce larger and denser floc. But the following combinations of Gt only produce floc.

1) $G \uparrow$ $t \downarrow$ → Smaller and denser floc produced

2) $G \downarrow$ $t \uparrow$ → Larger and lighter floc produced.

$\boxed{Gt = \text{velocity gradient} \times \text{Detention time.}}$





tapered flocculation

Note- Tapered flocculation is employed to get large and dense floc.

Design Parameters

1.) Detention time

A DT of 20 min to 40 min is required.

Volume of flocculator $L \times B \times H$ } $V = Q \times DT.$

$H = 2\text{ m to } 4\text{ m}$

Surface Area $L \times B = \frac{V}{H}$

$L : B \Rightarrow L = ?\ ,\ B = ?$

2.) Velocity gradient

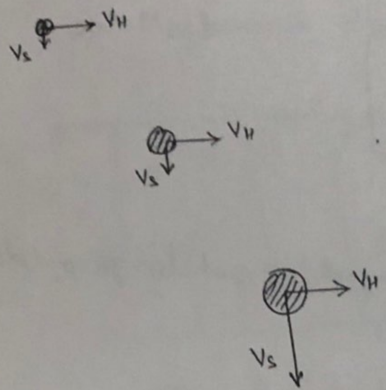
$G = 20 \text{ to } 80\ sec^{-1}$

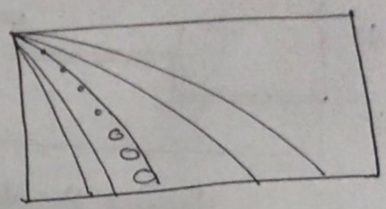
$$G = \sqrt{\frac{P}{V\mu}}$$

Sedimentation tank or Settling tank

Sedimentation tank employed to capture flocculant particles and follows Type-II settling.

Type-II settling deals with flocculant particle settlement in dilute suspension.





→ Flocculent particle settle much faster than discrete particle.
Trajectory of particle motion is non linear.

Design Parameter

1.) SLR or SOR or V_o = 20 to 30 $m^3/day/m^2$

2.) D T. = 2 to 4 hr

P-33 / Q-9

$Q = 4.2\ m^3/min. = 252\ m^3/hr.$

$V_o = 0.2\ mm/s.$

$H = 3.5\ m$

$D.T. = \frac{H}{V_o} = \frac{3.5 \times 10^3}{0.2} \frac{\cancel{sec}}{\times 3600} h = 4.86\ hr.$

$V = Q \times DT. = 252 \times 4.86 = 1224.72$

$A_s = \frac{V}{H} = \frac{1224.72}{3.5} = 349.52 = 350\ m^2$

9.) Surface

9.) Surface Area, $= \frac{Q}{V_0} = \frac{4.2/60}{0.2 \times 10^{-3}} = 350 m^2$. 20

Scanned with CamScanner

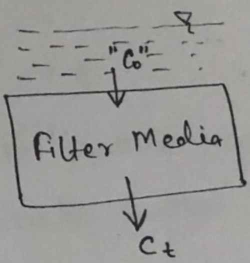
Filtration

Filtration - Method of passing water through a stationery bed of granular media is known as filtration. Media usually known as filter media react and retain impurities and yield impurities free water.

Media such as,-

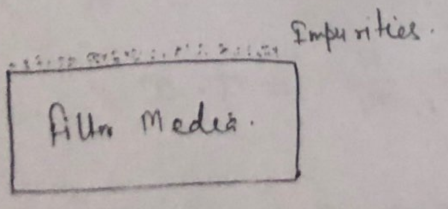
1. Anthracite coal
2. silica sand
3. Garnet

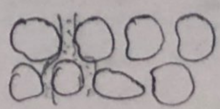
only capable of reacting with impurities and they only used as filter media.

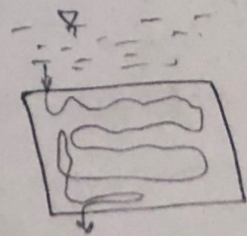


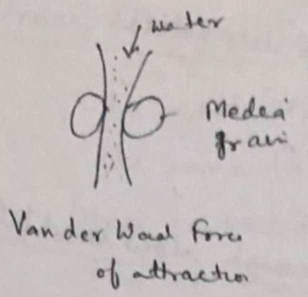
Mechanism of filteration

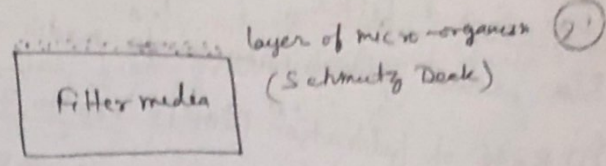
1.) Mechanical Strain
2.) Sedimentation
3.) Impact (by inertia)
4.) Interception (Vandar waal force)
5.) Biological metabolism











Filters

The place where filter media is packed and water is passed is known as filters.

Types of filters

Filters are classified based on.

(i) Rate of filtration or Loading rate. (ROF)

Volume of water filtered in unit time per unit surface area of filter is known as rate of filtration (ROF).

a.) Slow filters – ROF is very low

b) Rapid filters – ROF is very high.

(ii) Based on force with which filtration occur.

(a) Gravity filter – Gravity force

(b) Pressure filter – Pressure force

(iii) Based on number of filter media employed

(a) Single media filters

(b) Double or Dual media filters

(c) Multi or Mixed media filters.

Slow Sand filter

Slow sand filters are single media gravity type slow filters

*① Rate of filtration (ROF) = 100 to 200 lit/hr/m^2.

*② Particle removal efficiency η = 98 to 99%.

Note- Coagulated water should never pass through slow sand filters.

No pre-treatment of water is required and post treatment is optional.

Components of slow sand filter

1) Filter Box : open water tight rectangular tank.

Size = 100 m^2 to 2000 m^2

Depth = 2.5 m to 3.5 m

Bed Slope = 1 in 100

2) Filter media

Clean river sand is used as filter media.

thickness = 90 to 110 cm

*Effective size, D_{10} = 0.2 to 0.35 mm.

*Uniformity Coefficient $C_u = \frac{D_{60}}{D_{10}}$ = 1.8 to 3

(well graded sand)

3) Gravel Bed

Below sand bed, gravel bed is laid.

Thickness of gravel bed = 30 to 75 cm.

Size = 3 mm to 60 mm. (well graded gravel)

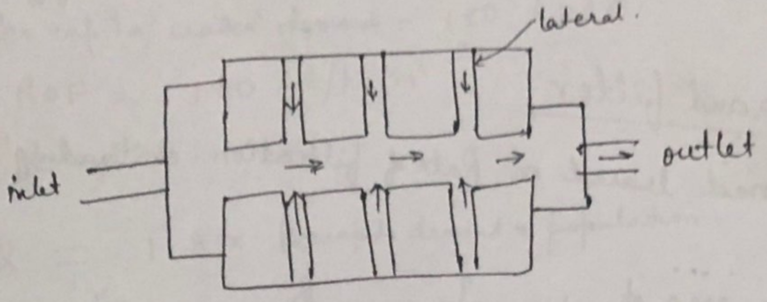
– Support sand bed and also prevent escape of sand grains along with filtered water.

4) Under

4) Under Drainage System

To collect filtered water from gravel bed and drain the same to outlet.

Open central drain with laterals on either side with a spacing 2 m to 5 m c/c provided below gravel bed.

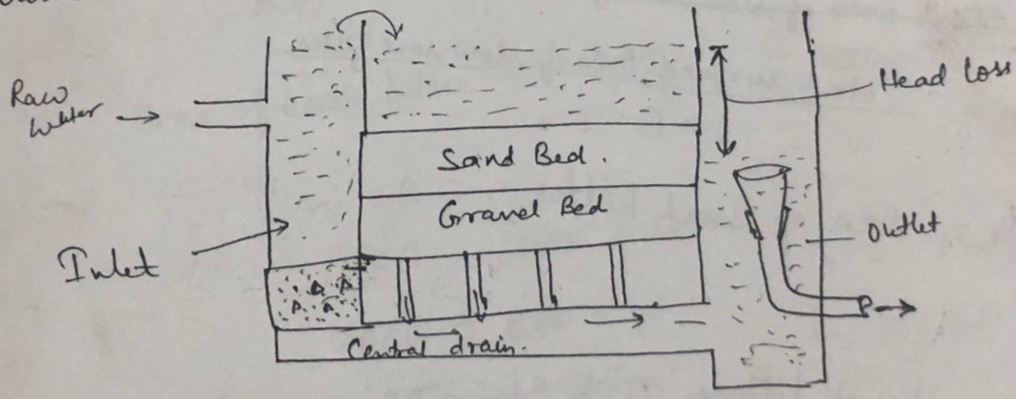


Plan at bottom

5) Inlet and outlet

Inlet – to apply water uniformly over sand bed:

Outlet – to collect filtered water at constant rate.



Longitudinal Section

When filters are in operation, initial head loss : 10 cm to 15 cm.

Filters are operated till, final head loss = 90% of thickness of filter media
i.e 70 cm to 90 cm

Once filters reach final head loss, slow sand filters are cleaned or washed. It reaches above condition once in every 1 month to 3 month.

Frequency of cleaning of slow sand filter = once in every 1 to 3 month

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→ top 1.5 to 3 cm is scrapped off upto 50 cm thickness of sand layer is remaining.

Slow sand filters are cleaned or washed by scrapping top 1.5cm to 3 cm layer of sand.

Percentage of filter water is used in cleaning or washing = 0.2 to 0.6% of filtered water

P-39
Q-1

Design of slow sand filter

Filters are designed based on Rate of filtration or loading rate.

$$\left.\begin{array}{l}\text{Total surface area of} \\ \text{slow sand filter required}\end{array}\right\} = \frac{Q}{ROF}$$

Method 1

fix the size of each filter i.e. L and B

Find the number of filters $n = ?$.

~~Total area of slow sand filter.~~

$$n = \frac{\text{Total surface Area of slow sand filter}}{L * B}$$

$L*B$ = Area of each filter.

Method 2

Fix number of filters 'n'.

Find size of each filter.

$L = ?$ $B = ?$.

$$\text{Area of each filter} = L \times B = \frac{\text{Total surface area}}{n}$$

$L:B$,

$L = ?$

$B = ?$.

Note - Provi

Note - Provide 1 or 2 extra filter units as stand by.

No. of filters provided = $n + 1$ or 2.

n = no. of filters in operation.

P-39

Q-1

Population = 50,000

Per capita water demand = 150 lpcd.

ROF = 180 lit/hr/m².

$L = 2B$.

$$Q = 1.8 \times \text{Percapita demand} \times \text{population}$$

$$= 1.8 \times 150 \times 50{,}000 \ \text{l/day}$$

$$= \cancel{13500000} = 13.5 \times 10^6 \ \text{l/day}$$

$$= \frac{13.5 \times 10^6}{24} = 562500 \ \text{l/hr.}$$

Total Surface Area

$$A_s = \frac{Q}{ROF} = \frac{562500}{180} = \cancel{3750\ m^2}.\ 3125\ m^2$$

$$\text{Size of each filter} = \frac{3750}{5} = \cancel{750\ m^2}\ 625$$

$L = 2B$

$L \times B = \cancel{750}\ 625$ $\qquad B = 17.67$ m

$2B \times B = \cancel{750}\ 625$ $\qquad L = 35.35$ m

$\cancel{B = 19.36\ m}$

$\cancel{L = 38.73\ m}$

Provide 6 filters each of size ~~[illegible]~~ 35.35 m × 17.67 m out of which 1 act as stand by

[illegible]

Total surface Area of slow sand filter = $\frac{Q}{ROF}$

= [illegible] = [illegible] m^2

No. of filters = [illegible] = 10.41 or 11. Ans

Rapid Sand filters (RSF)

- Rapid Sand filters are single media gravity type rapid filters.

Rate of filtration, ROF = 3000 to 6000 lit/hr/m²

Particle removal efficiency, η = 80 to 90%

- Pre and post treatment of water is mandatory

2/9/17

Components of Rapid Sand filter

1) **Filter Box** : open water tight rectangular tank

Size of filter box: 10 m² to 80 m²

depth = 2.5 to 3.5 m.

Bed Slope : 1 in 100

2) **Filter media** : clean river sand is used as filter media

thickness of filter bed : 60 to 90 cm

*Effective size D_{10} : 0.35 mm to 0.55 mm

*Uniformity coefficient $C_u = \frac{D_{60}}{D_{10}}$ = 1.2 to 1.8

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Rapid Sand filter (RSF)

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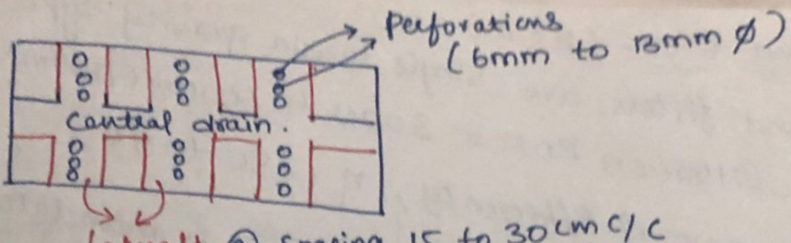
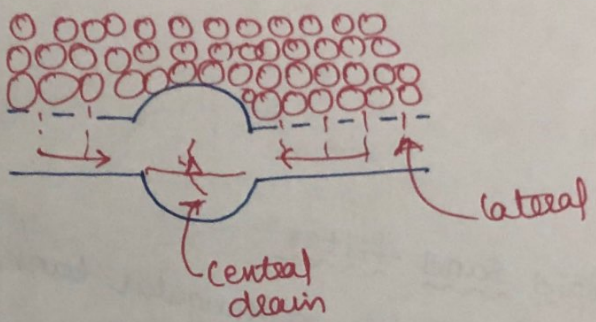
Components of rapid sand filter:-

1. Filter box:- open water-tight rectangular tank.
   - → Size of filter box: $10m^2$ to $80m^2$.
   - → Depth : 2.5m to 3.5m.
   - → Bed slope : 1 in 100.
2. Filter Media : Clean river sand is used as filter media.
   - → Thickness of filter bed = 60 to 90cm.
   - * Effective Size D_{10} = 0.35mm to 0.55mm
   - * Uniform co-efficient C_u: $\frac{D_{60}}{D_{60}}$ = 1.2 to 1.8
3. Gravel bed:- Support sand bed, Prevent escape of sand along with filtered water.
   - → Also help in cleaning (or) washing filter.
   - → Thickness of gravel bed = 60cm to 90cm.
   - Well graded gravel size 3mm to 40mm.
4. Under drainage System:-
   - → Closed central manifold drain provided with laterals on either side to collect filtered water.
   - → It also helps in cleaning (or) washing filter.



Plan @ bottom



IES

Design of underdrainage system:

Total area of perforations required = 0.2% of area of each filter

$$= \left[\frac{0.2}{100} \times L \times B\right]$$

Total area of laterals required = 2 times the total area of perforation

Total area of central drain required = 2 times the total area of laterals

$$\boxed{\frac{\text{Length of lateral}}{\text{dia of lateral}} \ngtr 60.}$$

5. Inlet and out let:

Inlet → To apply water uniformly over sand bed to drain wash water from filter.

Outlet → Central drain itself acts as an out let

6. Other components:

ⓐ Wash water troughs → To collect and drain wash water from top.

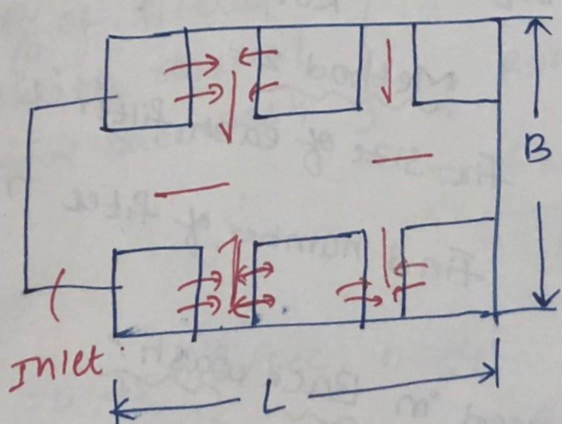
ⓑ Air pump → To carryout air wash of filter.

ⓒ Valves → To operate filter and to clean (or) wash filter.

ⓓ Nephelometer → To measure turbidity

ⓔ Venturi → Rate control device.

ⓕ Manometer → To measure head loss.



→ Initial head loss: 10 to 15 cm

Filters operated till:

1. Terminal head loss = 3m

2. Turbidity break through = 2.5 NTU.

→ Based on anyone of the above criteria filter's are cleaned (or) washed.

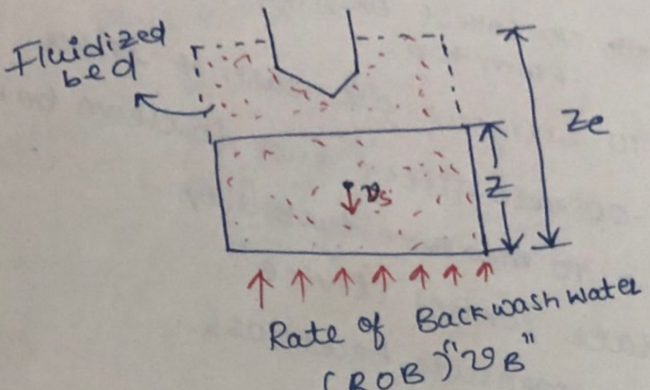
→ The above conditions occur once in every 24hr to 48hr.

Frequency of cleaning (or) washing: once in 24hr to 48 hr.

(3)

→ Rapid sand filters are cleaned (or) washed by "Back washing".

Percentage of water required for back washing } 2% to 6% of filtered water



Design of Rapid sand filter :-

Total surface area of RSF required : $\frac{Q}{RoF}$.

Method 1:

Fix number of filters "n"

Find size of each filter.

L =   B =

Method 2:-

Fix size of each filter "L" & "B".

Find number of filter n = ?

Percentage of filtered water used in Back wash?

% of filtered water used in backwash } $\frac{\text{Volume of filtered water used in back washings}}{\text{Volume of water filtered between back washing}} \times 100$

Volume of filtered water used in back wash = RoB × DOB × Area of each filter

volume of water filtered between backwashing = RoF × DoF × Area of each filter.

ROB (or) V_B = Rate of back wash.
DOB = Duration of back wash.
DOF = Duration of filtration between back washes

(3) $Q = 24 MLD$; $5 m^3/hr/m^2 = ROF$

$= 24 \times 10^6 \times \cancel{60} \times 24$

$1 m^3 = 1000 L$.

1 Day = 24 hr

$$RSF = \frac{\frac{24 \times 10^6 \times 10^{-3}}{24}}{5} \quad \frac{\frac{L \cdot m^3}{m^3 \, hr}}{hr/m^2} \quad m^2$$

$R.S.F = 200 m^2$

Area of each filter $\Rightarrow \frac{L \times B}{n} = \frac{200}{1} = 200 m^2$

$L \times B = 200 m^2$
$L : B = 2 : 1 \Rightarrow L = 2B$
$2B \times 2B = 200$
$B = 10m$; $L = 20m$.

~~(b) ROB =~~

(b) % of filtered water required for backwash $\Bigg\} = \frac{ROB \times DOB \times (L \cancel{\times} B)}{ROF \times DOF \times (\cancel{L} \times B)}$

$$= \frac{6 \times ROF \times \frac{10}{60}}{ROF \times (24 - \frac{10}{60})} \times 100 = 4.19 \%.$$

(4) $Q = 0.25 m^3/sec$; $n = 4$
$ROF = 5 m^3/m^2/hr$, $ROB = 10 l/m^2/sec$.
$L : B = 2 : 1$ $\qquad L : B = ? : ?$
Flow rate in each wash water trough = ?
No. of troughs / filter = ?

$$R.S.F = \frac{Q}{ROF} = \frac{0.25 \times 60 \times 60}{5} \quad \frac{m^3/hr}{m^3/m^2 \, hr} = 180 m^2.$$

Area of each filter $(L \times B) = \frac{180}{4} = 45 m^2$

$L \times B = 45 m^2$; $L = 2B$
$2B \times B = 45$; $B = \sqrt{45/2} = 4.74 m$

$\boxed{L = 9.48 m}$

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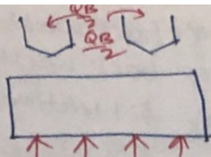
(6)



Q_B : $ROB = v_B = 10\ lit/m^2/sec$.

$Q = A \times v_b$

$= L \times B \times v_b$

$= 45 \times 10$ $lit/m^2.sec \times m^2$

$\boxed{Q_B = 450\ lit/sec}$ (or) $\boxed{0.45\ m^3/sec}$

Flow rate in Each Wash water trough $\left(\frac{Q_B}{2}\right)$ $= \frac{0.45}{2} = 0.225\ m^3/sec$

(8) $ROF = 200\ m^3/m^2.d$; $Q = 0.5\ m^3/s$. $1\ day = 24 \times 60 \times 60$

Area of each filter $L \times B = 50\ m^2$.

$R.S.F = \frac{0.5 \times 24 \times 60 \times 60}{200} = 216$.

(9) $50 = \frac{216}{n} \Rightarrow n = \frac{216}{50} = 4.32 \simeq 5$ (6)

(10) $Q = 1\ m^3/sec$; $n = 14$

~~R.S.F~~ Each filter surface area $= 50\ m^2$. $1\ Day = 24 \times 60 \times 60\ sec$

$ROF =$

$\Rightarrow 50 \times (14 \cdot 2) = R.S.F = 600\ m^2$

$ROF = \frac{Q}{R.S.F} = \frac{1}{600}$ $\times \frac{m^3/sec}{m^2} = \frac{m^3}{m^2 \times sec}$

$= \frac{24 \times 60 \times 60}{600} = 144\ m^3/day/m^2$.

Kinetics of filtration

1. Head loss during filtration-

Carmen & kozney equation.

$$\boxed{H_f = \frac{f z v^2}{g d} \frac{(1-n)}{n^3}}$$

f = friction factor
z = Thickness of filter media (sand)
v = Superficial velocity (ROF)
d = size of sand grain.
n = Porosity of sand bed.

$$f = \frac{150(1-n)}{Re} + 1.75$$

$$\boxed{Re = \frac{\rho_w \cdot v \cdot d}{\mu} \phi = \frac{v \cdot d}{\nu} \cdot \phi}$$

ϕ = shape factors.

2. Head loss during back wash "H_B":-

$$\boxed{H_b = z(1-n)(s-1) = z_e(1-n_e)(s-1)}$$

s = Specific gravity of sand.
z_e = Thickness of expanded bed.
n_e = porosity of expanded bed.

$$\boxed{\frac{z_e}{z} = \frac{1-n}{1-n_e}}$$

3. Rate of back wash (ROB) v_B-

$$\boxed{v_B = v_s (n_e)^{4.5}}$$

v_s = Settling velocity and sand grains.

$$\boxed{v_s = \frac{g(s-1)d^2}{18\nu} \rightarrow \text{for laminar flow}}$$

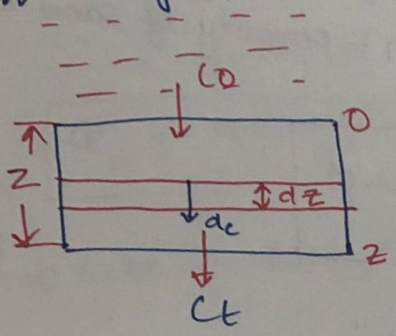
Stokes

$$\boxed{v_s^2 = \frac{4}{3} \frac{g(\rho_p - \rho_w)d}{C_D \cdot \rho_w}} \rightarrow \text{for another flow conditions.}$$

Iwasaki and Isaku equation :-

$$\boxed{\frac{dc}{dz} \propto c}$$

This equation is used to relate concentration of impurities removed, thickness of filter media and efficiency of filter.



$$\frac{dc}{dz} = -\lambda \cdot c$$

$$\int_{C_o}^{C_t} \frac{dc}{c} = \int_0^z -\lambda \cdot dz$$

λ = filter constant.

$$\boxed{\lambda = \frac{1}{z} \ln \frac{100}{100-\eta} = \frac{1}{z} \ln \frac{C_o}{C_t}}$$

$$\boxed{\eta = \frac{C_o - C_t}{C_o} \times 100}$$

(5) $v = 3\, m/hr$ $Z = 0.6\, m$; $d = 0.5\, mm = 0.5\times10^{-3}$

$S = 2.65$, $\phi = 0.8$ $n = 0.4$; $\nu = 1\times10^{-6}\, m^2/sec$.

Sol $Re = \frac{3\times 0.5\times10^{-3}}{1\times10^{-6}} \times 0.8 \;\frac{m/hr}{m^2/sec}$ = ~~0.41~~. = 0.328 1hr = 60×60 sec.

$f = \frac{150(1-0.4)}{0.33} + 1.75$ = ~~221.26~~ ~~309.06~~ = 274.47

$H_f = \frac{f\cdot Z\cdot v^2}{g d}\;\frac{(1-n)}{n^3}$

$H_f = \frac{274.47 \times 0.6 \times \left(\frac{3}{3600}\right)^2}{9.81\times 0.5\times10^{-3}} \times \frac{(1-0.4)}{(0.4)^3} = 0.219\, m.$

$\boxed{H_f \Rightarrow 21.8\, cm}$

(6) $d = 0.65\, mm = 0.6\times10^{-3}$; $Z = 65\, cm = 0.65\, m$; $D = 1.3\times10^{-2}\, cm^2/sec$

$S = 2.66$, $n = 0.42$

$v_B = v_s (n_e)^{4.5}$

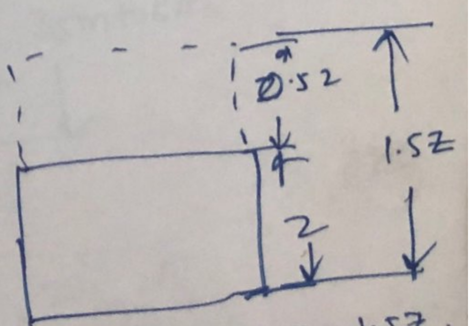
$v_s = \frac{g(s-1)d^2}{18\nu} = \frac{9.81(2.66-1)\times(0.6\times10^{-3})^2}{18\times 1.3\times10^{-2}\times10^{-4}\, m^2/sec}$

$n_e = 0.613$

$v_s = 0.294$

$v_B = 0.294(0.613)^{4.5}$

$\boxed{v_B = 0.032}$ m/sec.



$Z_e = Z + 0.5Z = 1.5Z.$

$\frac{Z_e}{Z} = \frac{1-n}{1-n_e}$ $\boxed{n_e = 0.613}$

$\frac{1.5Z}{Z} = \frac{1-0.4}{1-n_e}$

$H_b = Z(1-n)(s-1)$
$= 0.65(1-0.42)(2.66-1)$

$\boxed{H_b = 0.6258}$

⑦ $\cancel{z} = 0.05\,m$ $\quad \eta_1 = 90\%$.

$\eta_2 = 99\%$.

Sol: $\lambda = \frac{1}{z_1} \ln \frac{100}{100-\eta_1} = \frac{1}{z_2} \ln \frac{100}{100-\eta_2}$.

$$\frac{1}{0.05} \ln \frac{100}{100-90} = \frac{1}{z_2} \ln \frac{100}{100-99}.$$

$$\boxed{z_2 = 0.01\,m}$$

Pressure filters (Swimming pool) (Gated communities) (hospitals)
[Other than drinking water] (paper pulp industries) (Generating steam)

→ Pressure filter's are rapid sand filters where filtration is carried out under a ~~press~~ head of 30 to 70m of water [300 to 700 kN/m2].

When large quantities of water required with reasonable quality in short period of time then pressure filters are employed.

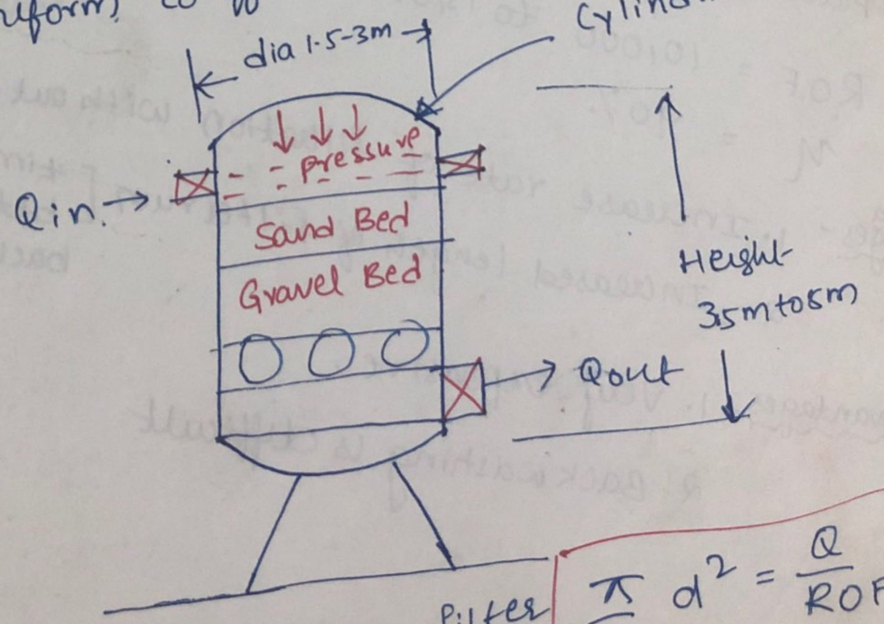
They are widely used at.
i) Swimming pools.
ii) Hospitals.
iii) Industries.
iv) private buildings etc.,

→ Rate of filtration : 6000 to 15000 lit/hr/m2. (2-5 times R.S.F; 60-150 time S.S.F)

→ particle removal efficiency η = 60 to 70%

→ Effective size D_{10} = 0.5 to 0.7mm

→ uniform co-efficient C_u = 1.2.



Surface area of pressure filter

$$\frac{\pi}{4} d^2 = \frac{Q}{ROF}$$

$$d = \frac{4}{\pi} \times \frac{Q}{ROF}.$$

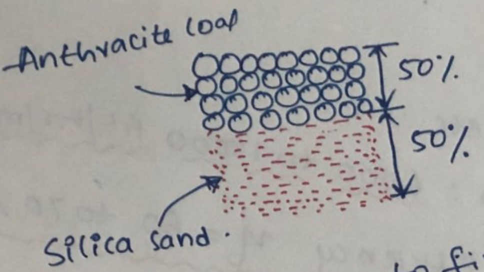
Dual [illegible]dia filters (or) Double Media filters

→ Dual media filters are rapid sand filters where two filter media employed in single filter.

Normally used filter media are.

1. Anthracite coal
   ↓
   $D_{10} = 0.9$ to 1.1 m
   $S = 1.4$ to 1.5.
   50%

2. Silica Sand.
   ↓
   $D_{10} = 0.5$ mm
   $S = 2.65$.
   50%.



→ Filtration is from coarse to fine [∵ coarser anthracite placed on top and fine silica sand placed at bottom]

ROF = 10,000 to 15,000 lit/hr/m3.

η = 90%.

Advantages:-
1. Increase rate of filtration without compromising "η"
2. Increased length of filterrum [time interval between backwashing increases]

Dis Advantages:
1. Very expensive.
2. Back washing is difficult

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50%

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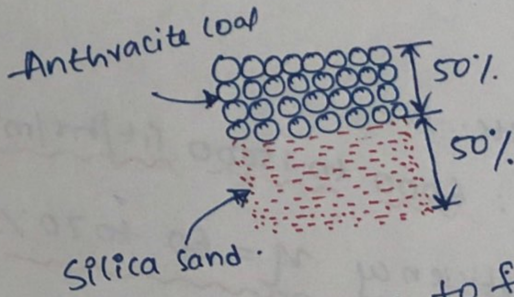
$S = 2.65$

50%.



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ROF = 10,000 to 15,000 lit/hr/m3.

η = 90%.

Advantages:- 1. Increase rate of filtration without compromising "η"

2. Increased length of filter run [time interval between backwashing increases]

Dis Advantages: 1. very expensive.

2. Back washing is difficult

Multimedia (or) Mixed up media filters.

→ Multimedia filter is a Rapid Sand filter where 3 filter media Packed in a single filter.

1. Anthracite coal → $D_{10} = 0.9$ to $1.1mm$ → $S = 1.4$ to 1.5 → 60%
2. Silica sand → $D_{10} = 0.5mm$ → $S = 2.65$ → 30%
3. Garnet (Green sand) → $D_{10} = 0.1$ to $0.15mm$ → $S = 4.2$ to 4.5 → 10%

Filtration is from coarse to fine.

ROF = 15000 to 20000 lit/hr/m2. $\eta = 90\%$.

Advantages:-

i) Increased ROF
ii) Increased length of filters.

Disadvantages

i) very Expensive
ii) Difficult to backwash.

Disinfection.

→ Disinfection is the method of destroying disease causing organisms known as pathogens present in water and render water safe to drink.

Disinfection destroys the existing germs (pathogens) (Microorganisms) and also fight against future possible potential contaminants.

Disinfectants :- Substances used to carryout disinfection are known as disinfectants.

* IES.

Requirements of an ideal disinfectant :-

1. Effective & Efficient Removal.
2. Fast rate of removal.
3. Should destroy only organisms and should be safe to human.
4. It should have enough residual power.
5. Should be of such nature that they can be easily detected in water.

Mechanisms of Disinfection.

1. By damaging cell wall, organisms are destroyed.
2. By destroying protoplasm, organisms are inhibited.
3. By alteration of cell wall permeability, organisms are destroyed.
4. By precipitating enzymes, nutrients etc.. organisms are inhibited.

Methods of disfection:-

1. Physical Methods.
   (a) By heat energy. ex: Boiling
   (b) By light energy. ex: U.V. rays.

2. Chemical Methods.
   (a) Excess lime treatment
   (b) Treatment with metal ions.
   (c) Treatment with potassium Permanganate.
   (d) Treatment with ozone.
   (e) Treatment with halogen group of chemicals.

Boiling:- Rising the temperature of water above 80°c to destroy organisms by damaging the cell wall.

→ ~~Boiling remove~~

Advantages
→ 1. Effective and efficient removal 2) fast rate of removal.

Disadvantages
1. No residual power 2. produce precipitates in water.
3. Expensive method.

~~practised only.~~
This Method can't be used in bulk water treatment.
Adviced to boil & drink during epidemics.

UV ray trea

→ U.V. rays
have go
in to
Adv destr
→ (1) U.V.
rem
(3)

Dis A
(1)
→ Th

UV ray treatment :- [U.V = Ultra Violet]

→ U.V. rays in the wave length ranging from 250 to 260 n.m have got very high destructive powers. They penetrate in to cell of microorganisms and attack protoplasm and destroy organisms.

Adv

→ ① U.V. rays have got instant kill, ② effective and efficient removal.

③ No secondary problems such as taste, odour, toxicity, Precipitates etc. in water for any amount of UV rays exposure.

Dis Adv

① No residual power.

→ The amount of destruction in water depends on intensity of U.V. rays and their time of exposure given by the following equation.

$$\boxed{\ln \frac{N_t}{N_0} = -K \cdot I \cdot t}$$

N_t = Number of organisms remain in water at time 't'

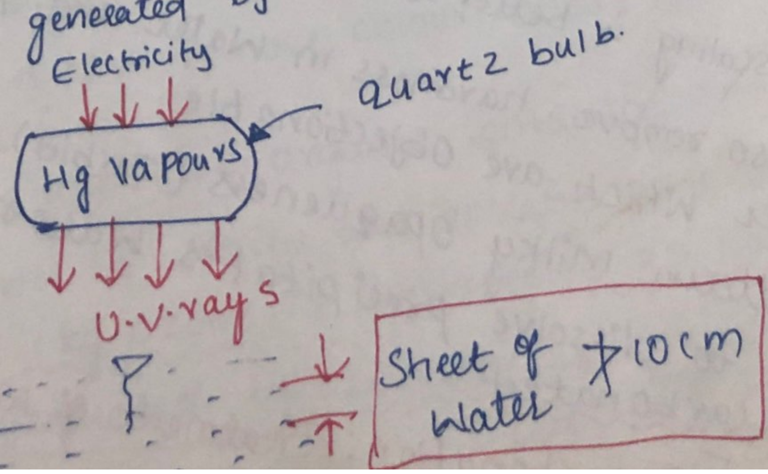
N_0 = Initial number of organisms.

I = Intensity of U.V. rays in $\mu W/cm^2$.

t = time of exposure of U.V. rays in "sec"

K = rate constant.

→ U.V. ray's are generated by U.V. ray equipment



eg) Find the time of exposure required to reduce organisms from 10^6 to 100 by exposing to U.V. rays of intensity $35\ \mu W/cm^2$. Take $K = 6\times10^{-3}\ cm^2/\mu\text{-}w\text{-}sec$.

$$\ln\left(\frac{N_t}{N_o}\right) = -K \cdot I \cdot t$$

$N_t = 100$

$N_o = 10^6$

$I = 35$

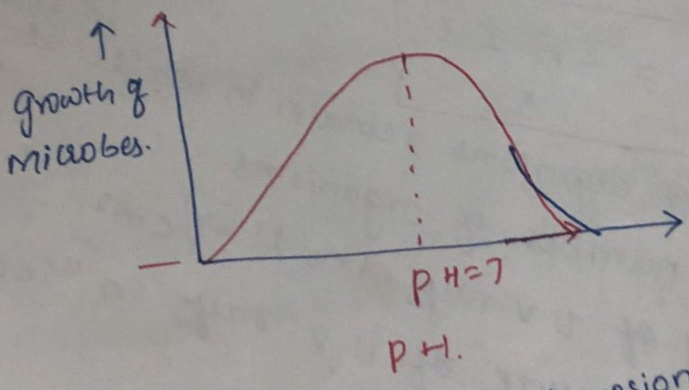
$$\ln\left[\frac{100}{10^6}\right] = -6\times10^{-3}\times 35 \times t$$

$$\boxed{t = 43.85 \text{ seconds}}$$

Excess lime treatment:-

→ By adding excess lime to water, PH of water is increases.

When PH > 9.5 → 99.9% of removal of organisms occur.



→ If we reduce PH value → corrosion takes place.

→ If we increase PH value → Scaling occurs.

* scaling is better than corrosion.

→ Lime also remove hardness in water and produce Precipitates in water which are objectionable.

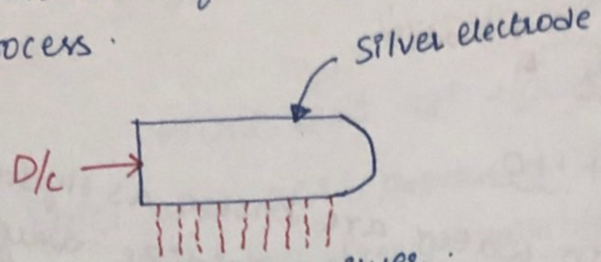
Water attain milky opaqueness (Turbid)

→ Therefore to dissolve precipitates water must be "recarbonated".

[Recarbonation: Treatment of water with CO_2]

Treatment with metal ions :-

- → Silver and copper have got very high inhibiting power.
- → Silver has got more power then copper.
- → Treatment of water with silver is known as "electrokatadyn" process.



Actuated silver.

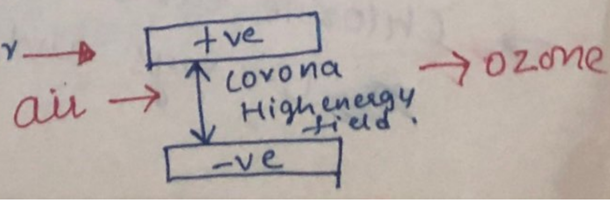
- → A silver dose of 10 to 20 ppb sufficient to destroy organism
- → Very expensive method.
- → Not recommended to bulk water treatment.

Treatment with potassium permanganate ($KMnO_4$)

- → Potassium permanganate is a powerful oxidant and oxidize anything present in reduced state including micro organisms but it is very slow. Takes 24hr to 48hr time to destroy organisms.
- → Rural ~~areas~~ wells are disinfected by this method.

Treatment with ozone :-

- → Disinfection of water with ozone is known as "Ozonization"
- → The most happening method of disinfection in the world.
- → ozone destroy organisms instantly and for any amount ozone dose No secondary problems.
- → ozone has got little residual power.
- → ozone can also remove colour, odour and improve taste of water.
- → ozone also oxidize organic contamination of wastes.
- Disadv → ozone cannot be stored and operated just before use.
- → To generate 1kg ozone it consume 0.82 kw-hr power.
- → ozone is generated by ozonator →



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Ozone → unstable molecule of oxygen

→ When ozone (O_3) is added to water it produce hydroxyl free radicals.

$$O_3 + H_2O \longrightarrow 2HO_2 \quad \leftarrow \text{free radical}$$

$$O_3 + HO_2 \rightarrow 2O_2 + HO$$

→ HO_2 and HO produced in water are known as Hydroxyl free radicals are powerful oxidants, oxidize any substances presence in reduced state including microbes.

→ This method is very expensive in India due to power shortage. Yet to use in bulk water treatment.

Treatment with halogen group of Chemicals substances.

→ Iodine, Bromine and Chlorine used as disinfectants. But Iodine and Bromine available only in the form of Pellets (or) Tablets.

→ Because of Non availability in bulk quantities not been used.

→ Chlorine is widely used to disinfect waters.

****

Chlorine :-

→ Addition of Chlorine (or) it's compounds to disinfect water is known as "Chlorination".

→ Disinfection with chlorine is economical. Chlorine is cheap economical compound.

very high residual power.

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→ Chlorine has got very high residual power.

→ ~~It is slower~~

→ Chlorine takes time to destroy organism, not as fast as U.V. rays and ozone.

→ When Chlorine is added to water, Chlorine first hydrolizes then it ionizes and produce free Chlorine in water.

$$Cl_2 + H_2O \rightarrow \underset{\text{Hypochlorous}}{HOCl} + \underset{\text{Hydrochloride.}}{HCl} \rightarrow \text{Hydrolization}$$

$$HOCl \overset{\text{"pH"}}{\rightleftharpoons} H^+ + OCl^- \rightarrow \text{Ionization}$$

→ HOCl and OCl^- produced in water together known as free Chlorine (or) freely available Chlorine.

→ HOCl and OCl^- produced, diffuse in to cell of organisms and form chlorotoxic substances which precipitates enzymes, nutrients and destroy organisms.

→ HOCl is more powerful than OCl^-. (Because of charge containing for OCl^-)

→ But HOCl and OCl^- produced depend on pH.

$$\boxed{\begin{array}{l} pH < 7.5 \rightarrow HOCl > OCl^- \\ pH > 7.5 \rightarrow OCl^- > HOCl. \end{array}}$$

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

$$\boxed{\% \; HOCl = \frac{1}{1 + \frac{OCl^-}{HOCl}} \times 100.}$$

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

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

$$\boxed{\% \; HOCl = \frac{1}{1 + \frac{K}{H^+}} \times 100} \rightarrow \boxed{\begin{array}{l|l} OCl^- \propto \frac{1}{H^+} & H^+ \propto \frac{1}{pH} \\ HOCl \propto H^+ & \end{array}}$$

9. $K_1 = 2.7 \times 10^{-8}$ mol/lit

$\%$ HOCl = 90

pH = ?

$$\% HOCl = \frac{1}{1+\frac{K_1}{H^+}} \times 100$$

$$90 = \frac{1}{1+\frac{2.7\times10^{-8}}{H^+}} \times 100$$

$H^+ = 2.43\times10^{-7}$ mol/lit

$$pH = \log_{10}\frac{1}{H^+} = \log_{10}\frac{1}{2.43\times10^{-7}} = 6.6$$

12. Fraction HOCl = ?

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

$K_1 = 2.5\times10^{-8}$ mol/lit

$$\text{Fraction HOCl} = \frac{1}{1+\frac{K_1}{H^+}} = \frac{1}{1+\frac{2.5\times10^{-8}}{10^{-7}}}$$

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

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Forms of Chlorine :-

→ Chlorine is added to water in any one of the following forms.

1. Hypochlorites
2. Chloramines.
3. Chlorine gas.
4. Chlorine dioxide

Hypochlorites:- Addition of Chlorine to water in the form of hypochlorites is known as "hypochlorination"

These are two types of Hypochlorites.

1. Calcium hypochlorite.
2. Sodium hypochlorite.

Calcium Hypochlorite :- [Bleaching Powder B.P.]

→ B.P contains 30 to 35% of Chlorine.

$$\boxed{Cl_2 \text{ dose} = B.P \text{ dose} \times \% \, Cl_2 \text{ in } B.P}$$

$$\boxed{B.P \text{ dose} = \frac{Cl_2 \text{ dose}}{\% \, Cl_2 \text{ in } B.P}}$$

Sodium Hypochlorite :- (10% to 15% of Cl_2)

→ Contains less amount of Chlorine

Therefore, it is not used.

Therefore, Bleaching powder is very economical

Adv - i) Chlorination with Bleaching powder
ii) Produce free Cl_2.

Dis Adv. i) It does not dissolve quickly in water.
ii) lose strength when exposed to air (or) light.
iii) cause odour & taste problems in water.
iv) It also cause toxicity.

02) Chlorine dosage = 0.2 ppm. Population = 20,000

% Chlorine in B.P = 30%. demand = 150 lit.

$$B.P\ dosage = \frac{Cl_2\ dosage}{\%\ Chlorine\ in\ BP}$$

Total BP

$$Q \Rightarrow \frac{20,000 \times 150}{10^6} \Rightarrow \frac{3 \times 10^6\ L/d}{10^6} \Rightarrow 3\ MLD.$$

Chlorine dosage $\Rightarrow 0.2 \times 3 \Rightarrow 0.6$ kg.

$$BP\ dosage = \frac{0.6}{0.3} = 2\ kg/day.$$

13) $Q = 50 \times 10,000\ l/d$

$= 0.5$ MLD.

Cl_2 dose $= 0.5 \times 2 = 1$ kg

$$B.P = \frac{1}{0.2} = 5\ kg/day.$$

Chloramines :-

→ Chlorine react with ammonia and produce chloramines with water.

$Cl_2 + H_2O \rightarrow HOCl + HCl$.

$HOCl + NH_3 \rightarrow NH_2Cl + H_2O$

$HOCl + NH_2Cl \rightarrow NHCl_2 + H_2O$

$HOCl + NHCl_2 \rightarrow NCl_3 + H_2O$

→ NH_2Cl (Mono Chloramine), $NHCl_2$ (Dichloramine) are powerful than NCl_3 (Tri Chloramines) but formation depend on pH

pH > 8 → only NH_2Cl form

pH = 5 to 8 → both NH_2Cl & $NHCl_2$ form.

pH = 4.4 to 5 → only $NHCl_2$ form

pH < 4.4 → only NCl_3 form.

Adv.

1. Persist

2. Quick

3. Does

4. For

Nc

Dis adv

→ T

Note

→ C

C

Adv:-

1. persist very long in water.
2. Quickly dissolve in water.
3. Does not lose power when exposed to air (or) light.
4. For any dose of Chloramines no secondary problems (No odour, No taste, No toxicity etc...)

Dis adv:-

→ It is little slower than other forms of chlorine.

Note:-

→ Chlorine in the form of Chloramines known as combined Chlorine or Combinedly available chlorine.

Chlorine gas :- (Cl_2 gas) :-

→ Amber coloured pungent smell suffocating gas 2½ times heavier than air quickly dissolve and produce free Chlorine in water. Most sought after (preferred) form of chlorine at this point of time.

→ Cl_2 added in the form of gas but storage and shipping (transport) in liquid form

$$Cl_2 \text{ gas} \underset{\text{Remove pressure}}{\overset{\text{apply pressure}}{\rightleftharpoons}} \text{liquid } Cl_2.$$

→ Free Cl_2 present in water if react with organic substance produce THM (Tri halo methanes) such as chloroform, Bromoform etc.. which are carcinogenic & cause cancer.

→ Therefore to overcome this adjust Chlorine dose in such a way that it does not produce free chlorine (Cl_2) residual > 0.2 mg/l.

→ Free Cl_2 residual in drinking water = 0.1 to 0.2 mg/l.

Free Cl_2 residual < 0.1 mg/l → No future protection

Free Cl_2 residual > 0.2 mg/l → THM risk.

Chlorine dioxide :- Instant removal of organisms

→ Independent of pH.

→ No THM risk for any dose.

→ No secondary problems (colour, taste etc) in water.

→ It is unstable therefore generated just before use & very Expensive.

Chlorine demand of water :-

→ Chlorine first react with Iron (Fe^{2+}) and Manganese(Mn^{+}) present in water then it react with ammonia in water and finally react with micro organisms and destroying. In doing so some amount of Cl_2 consumed.

→ Total Cl_2 consumed in reacting with above is known Chlorine demand of water.

After meeting Cl_2 demand of any excess Cl_2 remain that appear as residual Cl_2.

$$\boxed{Cl_2 \text{ demand} = Cl_2 \text{ dose} - \text{Residual } Cl_2}$$

Q) 600 kg of bleaching powder consumed per month to Chlorinate 10 MLD of water we have a Cl_2 residual of 0.2 PPM find Cl_2 demand of water. If the bleaching Powder contains 35% of Cl_2.

Sol :- B.P = 600kg per month $= \frac{600}{30} = 20$ kg/day.

Q = 10 MLD

Cl_2 demand = ?

% Cl_2 in B.P = 35%.

Cl_2 residual = 0.2 PPM

Total B.P = Q * dose of B.P

20kg/day = 10 × dose of B.P

dose of BP $= \frac{20}{10}$.

= 2 mg/l.

Cl_2 dose $= 2 * \frac{35}{100} = 0.7$ mg/l.

Cl_2 demand = Cl_2 dose - Residual Cl_2

= 0.7 − 0.2 = 0.5 mg/l.

Q) $Q = 20{,}000\ m^3/day = 20{,}000 \times 10^3 \times \frac{1}{10^6}$ MLD = 20MLD.

Total Cl_2 usage = 8 kg/day ; Residual Cl_2 = 0.15mg/l.

Cl_2 dosage = ? ; Cl_2 demand = ?.

Total Cl_2 usage = Q * dose of Cl_2 : 8 (kg/day)
MLD (mg/l)

20 * dose of Cl_2 = 8 (kg/day)

dose of Cl_2 $= \frac{8}{20}$ mg/l = 0.4mg/l.

Cl_2 demand = Cl_2 dose − Residual = 0.4 − 0.15 = 0.25 mg/l.

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Kinetics of disinfection [Chlorination] -

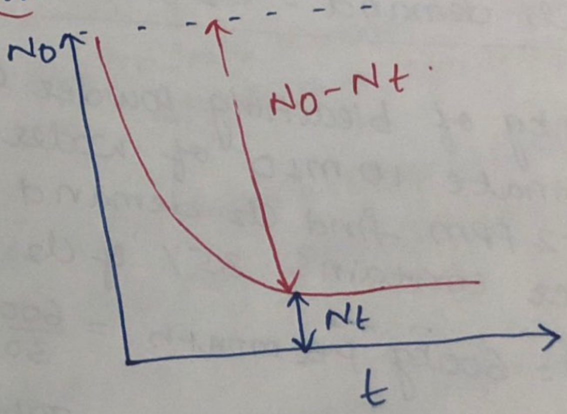
$$\boxed{\left.\begin{array}{l}\text{Percentage removal of} \\ \text{organisms}\end{array}\right\} \text{"}\eta\text{"} = \frac{N_0 - N_t}{N_0} \times 100}$$

N_0 = Initial number of organisms.

N_t = No. of organisms remained after time "t".

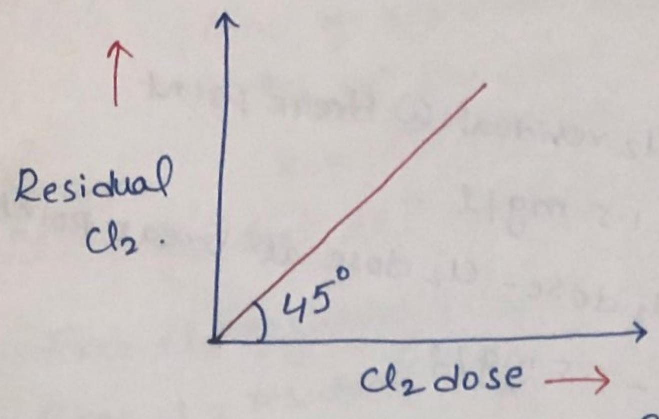
$$\boxed{\log(\text{Removal}) = \log_{10}(N_0) - \log_{10}(N_t)}$$

Chicks law for disinfection. :-



Break point Chlorination:- ← Free from ammonia.

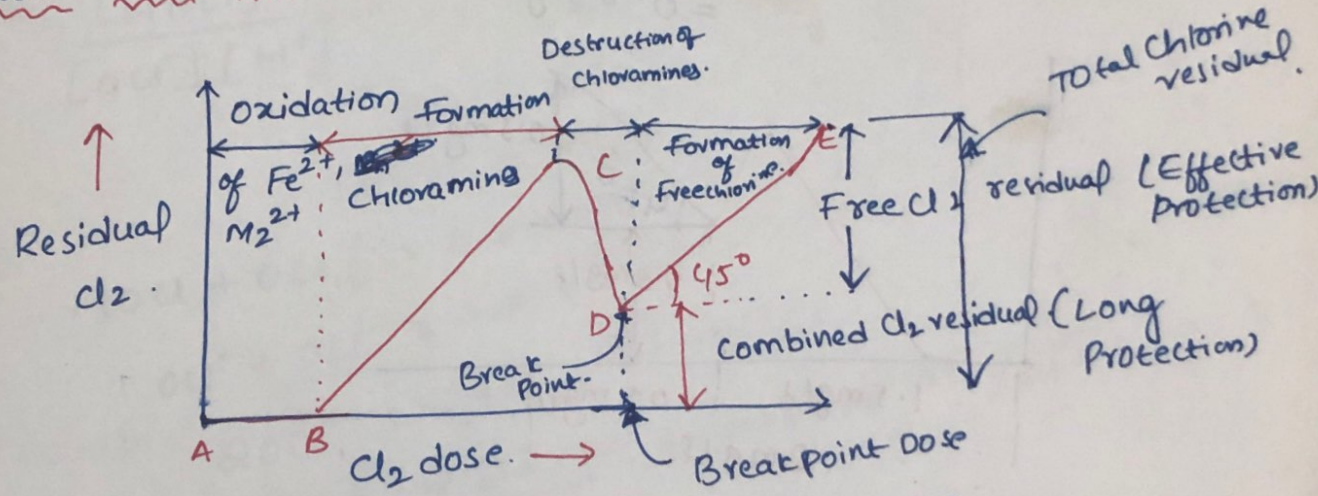
Water free from Cl_2 demand.



Cl_2 demand = Cl_2 dose − Residual Chlorine.

0 = Cl_2 dose − Residual chlorine.

Water with Cl_2 demand.



→ Dose should be added after Break Point.

Cl_2 demand = Cl_2 dose @ break point.

Combined Cl_2 residual = Cl_2 residual at break Point.

Free Cl_2 residual = Cl_2 dose − Cl_2 dose @ break Point.

Total Cl_2 residual = combined Cl_2 residual + Free Cl_2 residual.