AIR-1 Notes

Pages: 448

Environmental Engineering

Handwritten notes by

Kartikay Kaushik

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IES Master classroom Student

Environmental Engineering

① Water Supply and Treatment → (a) Source
*(b) Quality Parameter
*(c) Treatment
(d) Distribution
} 40%

② Sewage Treatment → (a) Sewage collection
*(b) Characteristics
*(c) Treatment
(d) Disposal.
} 55%

③ Air Pollution
④ Solid waste
⑤ Noise Pollution
} 5%

Ch-① Water Supply & Treatment

Q- A ~~scientif~~ synthetic sample of water is prepared by adding 100 mg of Kaolinite, 200 mg glucose, 168 mg of NaCl, 120 mg of $MgSO_4$ and 111 mg of $CaCl_2$ to 1 litre of pure water. Find the concentration of Total solids and Fixed Dissolved solids in mg/L

↓ Inorganic Dissolved solids.

Total solids = 100+200+168+120+111 = 699 mg/L

Kaolinite → Inorganic SS
Glucose → Organic Dissolved
NaCl, $MgSO_4$, $CaCl_2$ } Inorganic Dissolved

So, Fixed Dissolved Solids = 168+120+111 = 399 mg/L

→ <u>Molecular weight</u>	→ <u>Equivalent wt</u>
→ $CaCO_3 = 100$	→ $CaCO_3 = 100/2 = 50$
→ $Ca^{2+} = 40$	→ $Ca^{2+} = 40/2 = 20$
→ $Al^{2+} = 27$	→ $Mg^{2+} = 24/2 = 12$
→ $Mg^{3+} = 24$	→ $Al^{3+} = 27/3 = 9$
→ $Al_2(SO_4)_3 \cdot 18H_2O = 666$	→ $Al_2(SO_4)_3 \cdot 18H_2O = 666/6 = 111$
→ $OH^- = 17$	→ $OH^- = 17$
→ $CO_3^{2-} = 60$	→ $CO_3^{2-} = 30$
→ $HCO_3^- = 61$	→ $HCO_3^- = 61$

→ $\text{Moles} = \dfrac{\text{Weight in gram}}{\text{Molecular weight}}$

→ $\text{Milli moles} = \dfrac{\text{Weight in mg}}{\text{Molecular weight}}$

→ $\text{No of gram equivalent} = \dfrac{\text{Weight in grams}}{\text{Equivalent weight}}$

→ $\text{Milli eq} = \dfrac{\text{Weight in mg}}{\text{Equivalent wt}}$

→ No. of gram eq = No of moles × Valency.

$$\overset{\text{Valency}=6}{Al_2(SO_4)_3} + 3\,\overset{\text{Valency}=2}{Ca(HCO_3)_2} \longrightarrow 3\,\overset{\text{Valency}=2}{CaSO_4} + 2\,\overset{\text{Valency}=3}{Al(OH)_3} + 6\,CO_2$$

1 mole ↓ 6 g-eq   3 mole ↓ 6 gm-eq → 3 mole ↓ 6 gm-eq   2 mole ↓ 6 gm eq

$$\boxed{\text{1 gm-eq of Anything} \equiv \text{1 gm-eq of any other thing}}$$

$$\boxed{333\text{ gm of } Al_2(SO_4)_3 \cdot 18H_2O \equiv 150\text{ gm of } CaCO_3}$$

→ Normality : N = No of gm-eqs / litres

→ Molarity : M = No. of moles / Litres

→ 1 mL of 0.02 N H_2SO_4 ≡ 1 mg of $CaCO_3$.

⇒ Chemical Kinetics

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

1	0	0
1 − x	x	x

depends on temperature

mole/Litre

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

Reaction constant

$$k = \frac{x^2}{1-x}$$

⇒ Alkalinity

Q- A water sample contains 100 mg/L of CO_3^{2-} and 75 mg/L of HCO_3^- at a pH of 10. Calculate alkalinity exactly at 25°C and approximate the alkalinity by ignoring $[H^+]$ and $[OH^-]$

$pH = 10 \Rightarrow [H^+] = 10^{-10}$ mol / litre ≡ 10^{-7} meq/L as $CaCO_3$ ≡ 5×10^{-6} mg/L as CaCO

$pOH = 4 \Rightarrow [OH^-] = 10^{-4}$ mol / litre ≡ 10^{-4} gm-eq / litre = 0.1 meq/Litre

≡ 0.1 meq/l as $CaCO_3$

≡ 5 mg/L as $CaCO_3$

So, Exact Alkalinity = $\frac{100}{30} \times 50 + \frac{75}{61} \times 50 + 5 \cancel{+} 5 \times 10^{-6} \cong 233.142$ mg/L as $CaCO_3$

Approximate Alkalinity = $\frac{100}{30} \times 50 + \frac{75}{61} \times 50 + 5 = 233.142$ mg/L as $CaCO_3$

After neglecting $[H^+]$ and $[OH^-]$ = 228.142 mg/L as $CaCO_3$.

Q. A 200 mL sample of water has initial pH = 10. 11 mL of 0.02 N H_2SO_4 is required to reduce the pH to 8.3. and 30 mL of 0.02 N H_2SO_4 is required to titrate the sample to pH of 4.5. Find out the total alkalinity of water in mg/L as $CaCO_3$ and also find the alkalinity species.

→ pH = 10 ⇒ ~~p~~$[OH^-] = 10^{-4}\ \frac{mol}{litre}$ ≡ 5 mg/L as $CaCO_3$ ~~×5 = 25 mg/L~~

↳ Caustic Alkalinity.

→ $[OH^-] + \frac{1}{2}[CO_3^{2-}] = \frac{11\ mg}{200\ mL}$ as $CaCO_3$ = 55 mg/L as $CaCO_3$

⇒ $[CO_3^{2-}] = (55 - 5) \times 2 = 100$ mg/L as $CaCO_3$

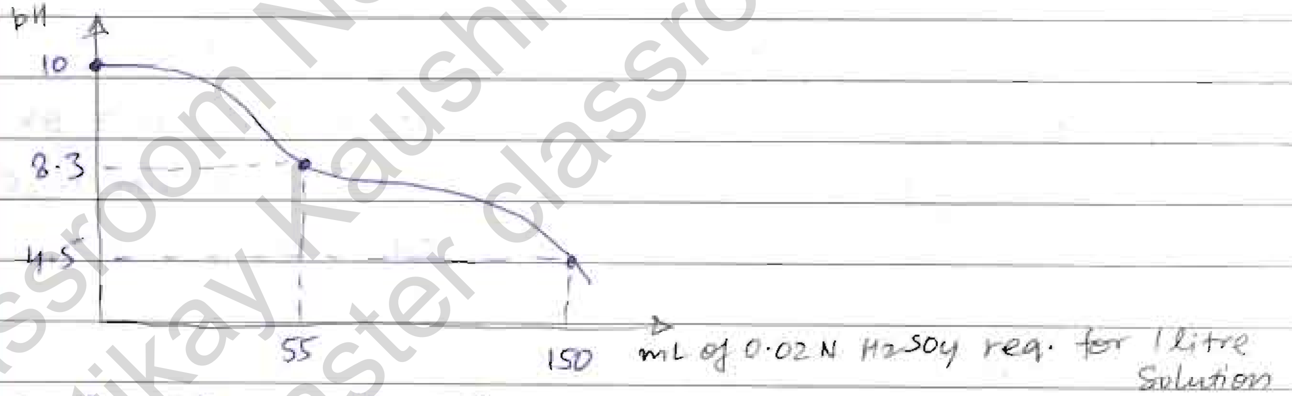
↳ Carbonate Alkalinity

⇒ $[HCO_3^-] = 150 - 5 - 100 = 45$ mg/L as $CaCO_3$.

Total Alkalinity

↳ Bicarbonate Alkalinity.

Approximate Approach

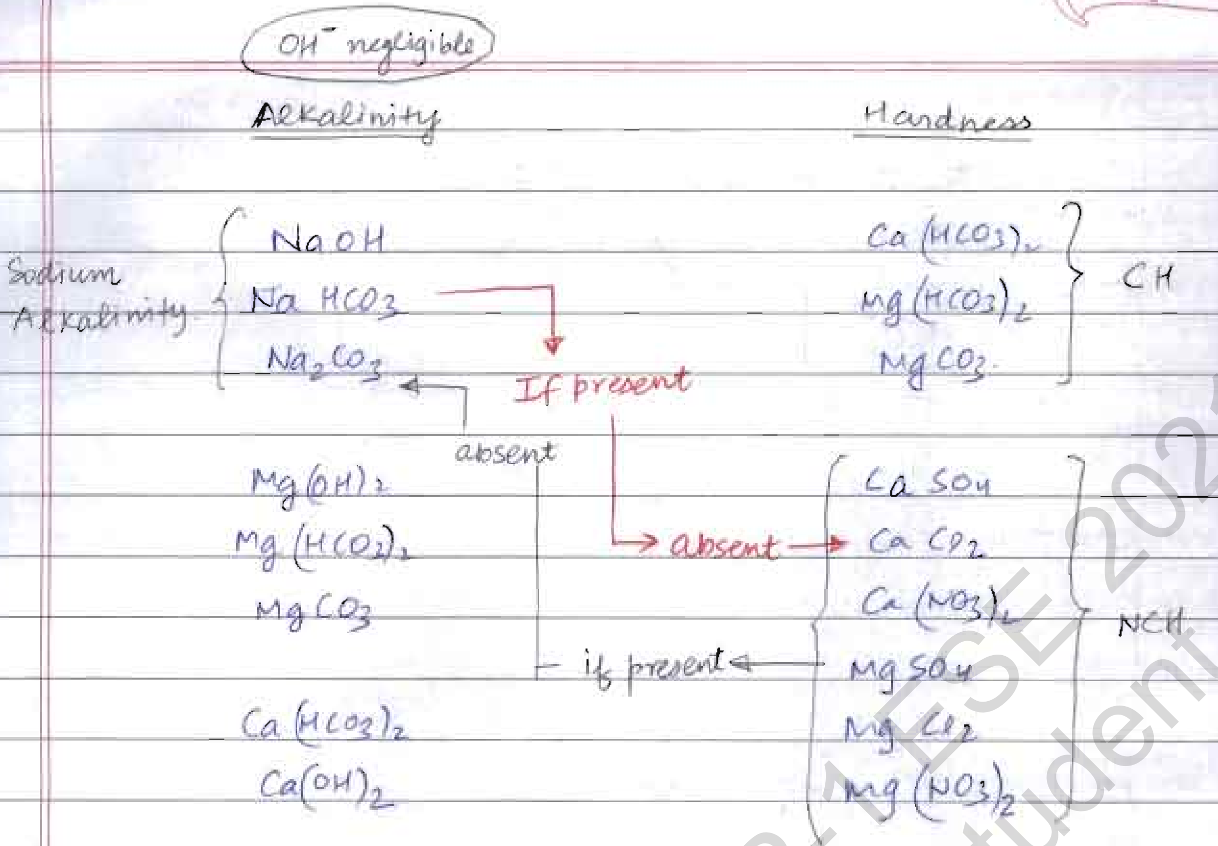


∴ $[HCO_3^-]$ and $[CO_3^{2-}]$ are the predominant species

⇒ $[OH^-] = 0$

⇒ $\frac{1}{2}[CO_3^{2-}] = 55$ ⇒ $[CO_3^{2-}] = 110$ mg/L as $CaCO_3$

⇒ $55 + [HCO_3^-] = 150 - 55$ ⇒ $[HCO_3^-] = 40$ mg/L as $CaCO_3$.



$$CH = \min\{TH, \text{Alkalinity}\}$$

$$NCH = [TH - \text{Alkalinity}]$$, take zero if −ve

⇒ Hardness

Q Water contains the following dissolved ions: $[Na^+] \rightarrow 56$ mg/L, $[Ca^{2+}] = 40$ mg/L, $[Mg^{2+}] \rightarrow 30$ mg/L, $[Al^{3+}] \rightarrow 3$mg/L and $[HCO_3^-] = 190$ mg/L, $[Cl^-] = 165$ mg/L and pH=7. Find TH, Alkalinity, CH and NCH.

→ $\text{Alkalinity} = \frac{190}{61} \times 50 = 155.74$ mg/L as $CaCO_3$

* at pH=7, majority of alkalinity causing species are in the form of HCO_3^-

→ $TH = 50 \times \left(\frac{40}{20} + \frac{30}{12} + \frac{3}{9}\right) = 4.833 \times 50 = 241.67$ mg/L as $CaCO_3$

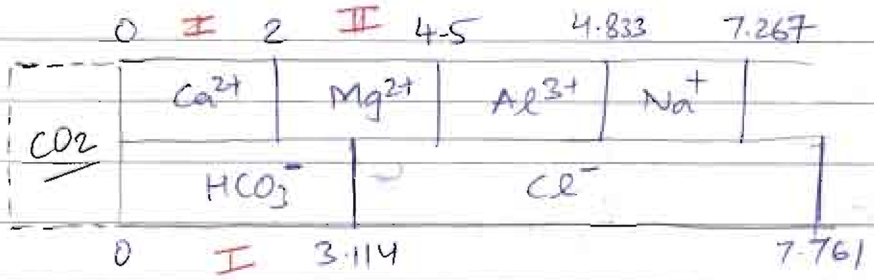
→ $CH = \min\{TH, \text{alkalinity}\} = 155.74$ mg/L as $CaCO_3$

$NCH = TH - \text{Alkalinity} = 241.67 - 155.74 = 85.93$ mg/L

↓

NCH is present
Hence, Na-Alkalinity is absent
So, Na will not combine with $[HCO_3^-]$ present

⇒ Bar chart



⇒ MPN

Q- Multiple Tube Fermentation Test was conducted on a sample of water and the result of analysis for confirmed test are as given below:

Sample size	No. of Positive results out of 5-tubes
10 mL	4
0.1 mL	3
0.01 mL	1

MPN / 100 mL can be obtained from the following chart:

for 10 mL, 1 mL and 0.1 mL

Combination of positive	MPN / 100 mL
4-2-1	26
4-3-1	33
2-1-0	7

Ans → 33 × 10 = 330

So MPN = 330 / 100 mL

Q-

Sample size	No. of +ve result
10 mL	4
1 mL	2
0.1 mL	1
0.01 mL	0

⇒ None of the dilutions have all 5 +ve

⇒ Select least diluted with middle result +ve.

⇒ MPN = 26 / 100 mL

Q⇒ Water sample having particle distribution as shown below:

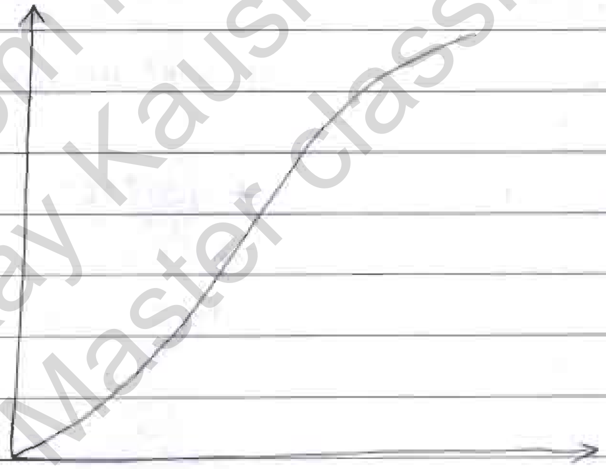
Size	Quantity	Settling velocity in m/s	fraction removed
0.1 mm	10%	0.2	4/7
0.2 mm	20%	0.25	5/7
0.3 mm	15%	0.3	6/7
0.4 mm	5%	0.35	1
0.5 mm	30%	0.40	1
0.6 mm	20%	0.5	1

→ Overflow rate of tank is 0.35 mm/s. Find the efficiency of the tank.

$$\eta = \frac{\frac{4}{7} \times 0.1 + \frac{5}{7} \times 0.2 + \frac{6}{7} \times 0.15 + 0.55}{1}$$

$$= 0.8786 \Rightarrow 87.86\%$$

⇒ For continuous distribution of particles,



Q- Determine the overall removal for a sedimentation tank having the following data:

Particle size	Wt fraction greater in size	% removal	% finer
0.1 mm	0.1	100	0.9
0.08 mm	0.15	100	0.85
0.07 mm	0.40	100	0.60
0.06 mm	0.7	100	0.30
0.0597mm		100	0.2965
0.04 mm	0.93	44.87	0.07
0.02 mm	0.99	11.22	0.01
0.01 mm	1.00	2.80	0

Overflow rate = 32.6 ~~time~~ m /day Gs of particles = 1.2

Dynamic viscosity = 1.027 centiPoise, $\rho_w = 0.997 g/cm^3$

Use stoke's law to find out the settling velocity.

Find out the overall efficiency.

$$v_s = \frac{(\gamma_s - \gamma_w) d^2}{18\mu} = \frac{\gamma_w (G_s - 1) d^2}{18\mu}$$

For $v_s' = 32.6$ m/day

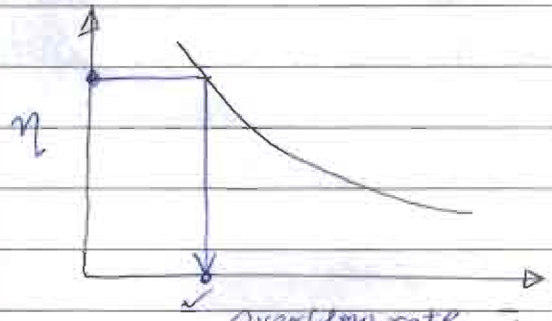
$d = 0.0597$ mm

So particles of size > 0.0597 mm will be removed completely

$$\text{Removal Efficiency} = \left[(1 - 0.2965) + (0.2265 \times 0.7244) + (0.06 \times 0.2804) + (0.01 \times 0.0701) \right] \times 100\%$$

$= 88.51\%$

⇒ Design of settling tank



$$\text{Overflow rate} = \frac{Q}{LB} = \frac{\text{Discharge}}{\text{Plan Area}}$$

① $\frac{Q_{design}}{\text{Overflow rate}} = \frac{1.8\, Q_{avg}}{\text{Overflow rate}} = \text{Plan Area} < \begin{matrix} L \times B \\ \frac{\pi D^2}{4} \end{matrix}$

② Adopt L/B ratio ⇒

③ Find L, B.

④ Take $t_d = \frac{LBH}{Q_{design}}$ ⇒ Find H

⇒ For circular tanks, weir loading rate can also govern the Diameter of tank as $\boxed{\pi D = \frac{\text{Discharge}}{\text{weir loading rate}}}$

⇒ Coagulation

Q. A water treatment plant treating 10 MLD of water requires 20 mg/L of filter Alum ($Al_2(SO_4)_3 \cdot 18H_2O$). The water has 6 mg/L of alkalinity as $CaCO_3$. Find the total Alkalinity requirement in kg/day matching the filter alum as $CaCO_3$.
Also calculate the quantity of quick lime required in kg/year.

Total alkalinity requirement $= \frac{20}{111}$ meq/L

$= \frac{20}{111} \times 50 \frac{mg}{L} = 90.09$ kg/day as $CaCO_3$.

Alkalinity present $= \frac{6}{50}$ meq/L

Alkalinity required $= \frac{20}{111} - \frac{6}{50} = \frac{167}{2775}$ meq/L $= \frac{167}{2775} \times 29 \frac{mg/L}{CaO}$

⇒ 6150.41 kg/year ~~⇒ 172211.6 kg/year~~

Q- A coagulation treatment plant with a flow of 0.5 m³/s is ~~the~~ dozing alum at 23 mg/L and no other chemicals are being added Raw water Suspended solid concentration is 37 mg/L and effluent Suspended solid conc. is 12 mg/L. Sludge solid content is 1% The specific gravity of sludge solid is 3.01. What volume of sludge must be disposed off every day.

→ SS conc in sludge = 37−12 = 25 mg/L

$$= 25 \times 0.5 \times 10^3 \times 86400 \times 10^{-6} = 1080 \frac{kg}{day}$$

→ Alum ppt in sludge = $\frac{23}{\cancel{111}} \times 0.234 \times 0.5 \times 10^3 \times 86400 \times 10^{-6}$

$$= 232.5 \frac{kg}{day}$$

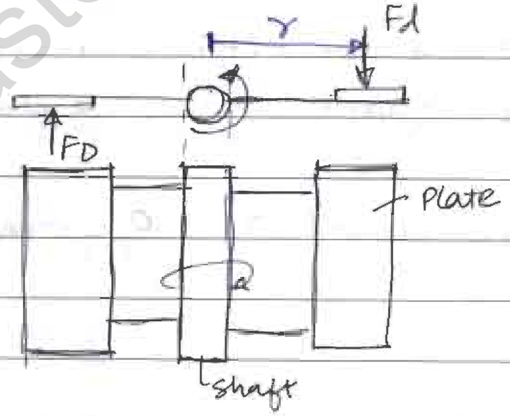
→ Total Solid in sludge = 1312.5 kg/day.

$$\frac{W_s}{W_w + W_s} = 0.01$$

W_w = 129937.5/day

So, V = 130.374 m³/day

⇒ Calculation of G value



Q A flocculation chamber is 30 m long, 12 m wide and 4.5 m deep is to treat 75 MLD of water. It is equipped with 12 m long, 0.3 m wide paddles ~~panels~~ supported parallel to and moved by 4 horizontal shafts which rotate at a speed of 2.5 rpm. The centre line of the paddle is 1.8 m from the shaft which is at the mid depth of the tank. 2 Paddes are mounted on each shaft. If the mean velocity of water is $\frac{1}{4}^{th}$ of the velocity of pedal, find:

(a) Power consumption

(b) Time of Flocculation

(c) G, temporal mean velocity gradient.

Take $\nu = 1.31 \times 10^{-6}$ ~~kg~~ m^2/s and C_d for pedal = 1.8

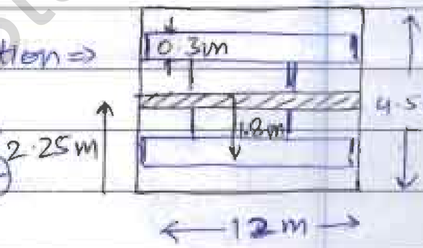
$$P = F_D \cdot V_r = \frac{1}{2} C_D \rho A V_r^3$$

for 1 shaft

$$= \frac{1}{2} \times 1.8 \times 1000 \times (2 \times 0.3 \times 12) \times (0.75 \times 0.4712)^3$$

$$= 286 \text{ W}$$

x-section ⇒



$V_p = \omega r = 0.4712$ m/s

(a) Power consumption = 4×286 = 1144 W

(b) Time of flocculation = $\frac{30 \times 12 \times 4.5}{75 \times 10^6 \times 10^{-3}} \times 86400$ = 31.104 min.

(c) $G = \sqrt{\frac{P}{\mu V}} = 23.22 \text{ s}^{-1}$

⇒ Backwashing

Say $Q_{avg} = 24 \times 10^5$ l/day

→ if backwashing takes 30 min., backwashing is done everyday, and 5% of filtered water is used for backwashing.

$$Q_{design} = \frac{1.8 \times 24 \times 10^5 + 0.05(24 \times 10^5)}{23.5} \text{ l/hr}$$

→ if backwashing is done after 48 hrs.

$$Q_{design} = \frac{(1.8 \times 48 \times 10^5) + 0.05\,(48 \times 10^5)}{47.5}\ l/hr$$

⇒ Design Steps

① $\frac{Q_{design}}{\text{Rate of filtration}}$ = Plan Area

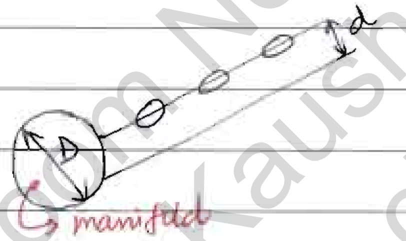
↳ 2-20 m/hr = 2000 to 20000 l/hr/m² of plan Area

② $n = 1.22\sqrt{Q_{design}} + 1$ ↳ Standby

③ Obtain size of 1 unit

④ $\frac{L}{B}$ = 1.25 to 1.33 and adopt depth b/w 3 to 4 m

⇒ Design of Under drainage system



To be determined:

① D
② d
③ hole size
④ hole spacing
⑤ no. of holes on each lateral drain.

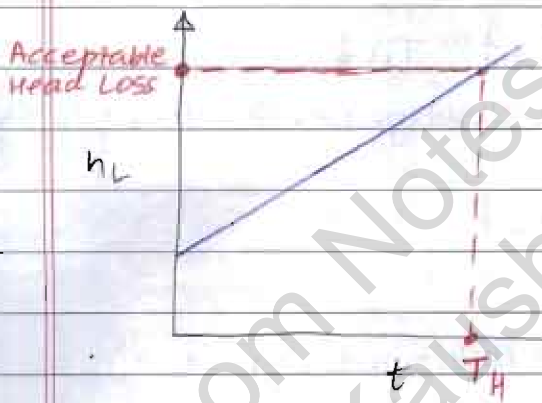
⇒ Sand incrustation means formation of hand coating on the surface of sand. It occurs due to deposition of sticky materials coming from the sedimentation tank in the form of precipitates which do not settle in the sedimentation tank. This will lead to increase in overall size of sand. Can be avoided by Carbonation (addition of CO_2) which dissolves ppts like $CaCO_3 \rightarrow Ca(HCO_3)_2$ and $Mg(OH)_2$ to $MgCO_3$. Done after sedimentation and before filtration. Sodium hexametaphosphate may be added to keep $CaCO_3$ in dissolved form.

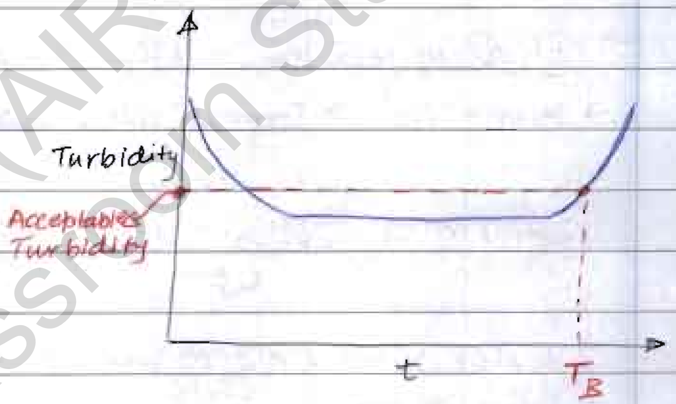
⇒ Bumping of filter → Due to blockage of the under-drainage perforations backwash application will be non-uniform and hence more water can be added at a particular location at high velocity which causes the sand in localised location to boil up and also gravel to rise to the surface.

To avoid it air scouring of the under-drain is done to open up the clogged perforations.

⇒ When to do Backwashing?

① Particle Breakthrough } in rapid sand filter
② Head Loss





→ The time at which cleaning of filter should start = min $\{T_H, T_B\}$

→ As more impurities are trapped, resistance against motion increases and hence, head loss increases.

→ As more impurities are trapped, pore size decreases and velocity of flow through pores increases, thus shearing action increases and impurities trapped on sand grain may get dislodged and thus turbidity in effluent starts increasing.

⇒ Effect on T_B and T_H of various parameters in flow

① Effect of increase in filter depth $T_B \uparrow$, $T_H \downarrow$

Since more depth of sand is available, there is greater opportunity for particles to be attached to sand grains, $T_B \uparrow$

(b) Since more depth of sand will lead to greater head loss → $T_H \downarrow$

② → <u>Effect of increase in porosity</u> $T_B \downarrow$ $T_H \uparrow$

→ There is lesser opportunity of contact with grains $T_B \downarrow$

→ There is lesser resistance against flow $T_H \uparrow$

③ <u>Effect of increase in velocity of flow</u> $T_B \downarrow$ $T_H \downarrow$

→ Increase in shearing action → $T_B \downarrow$

→ Greater loss at higher velocity → $T_H \downarrow$

④ <u>Effect of increase in influent particle concentration</u> $T_B \downarrow$ $T_H \downarrow$

→ Greater conc. of influent ⇒ early choking ⇒ increased velocity of flow

⑤ <u>Effect of increase in floc strength</u> $T_B \uparrow$ $T_H \downarrow$

→ Strong floc ⇒ Stronger attachment with sand grains ⇒ difficult to shear off

⑥ <u>Effect of increase in collector dia</u> $T_B \downarrow$ $T_H \uparrow$
(Bigger size of sand grain dia)

→ Lesser surface are of sand particles ⇒ lesser attachment → $T_B \downarrow$

→ losses are less, pore size being larger ⇒ $T_H \uparrow$

⑦ <u>Effect of Non-Addition of Coagulant</u> $T_B \downarrow$ $T_H \uparrow$

→ Attachment with sand grain is not efficient due to lack of coagulation → $T_B \downarrow$

→ Lesser loss through filter media since impurity collection is less.