17/07/19 Environmental Engineering (MI40001)

— BKPrusty

Impacts of Mining on Environment :-

- Water gets polluted (both surface & Underground)
- Water table gets down in surrounding areas
- Air pollution
- Degradation of land
- Forest Land degradation
- ~~Dis~~
- Aesthetic pollution

18/07/19

→ Mass & Energy Balance :-

For Liquids :- concentration is expressed as moles per litre of mixture, can also be expressed in ppm (= 1g/m³ = 1mg/L)

Eg1 :- Flouride concentration in drinking water is increased to help prevent tooth decay by adding sodium Flouride, However excessive flouride may cause mottling of the teeth. The maximum dose of flouride allowed is 0.053 mM/L. If sodium flouride is purchased in 25 kg bags, how many gallons of water would a bag treat.

NaF (23+19)
42 g/Mole.

For 1 litre 0.053 mM

$$\frac{25\times10^3}{42} = 595.23 \text{ moles}$$

Volume of water required $= \dfrac{595.23\times 1}{0.053\times10^{-3}} = 11.23\times10^{6}$ Litres

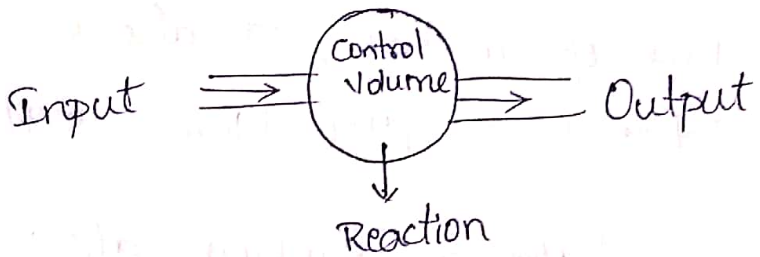
1 Gallon = 3.785 Litres

No. of Gallons $= \dfrac{11.23\times10^{6}}{3.785} = 2.97\times10^{6}$ Gallons

For Gases :- Units are 1ppm (by volume), $\frac{mg}{m^3}$

$PV = nRT$ (for conversion of ppm to $\frac{mg}{m^3}$)

→ Mass Balance :-

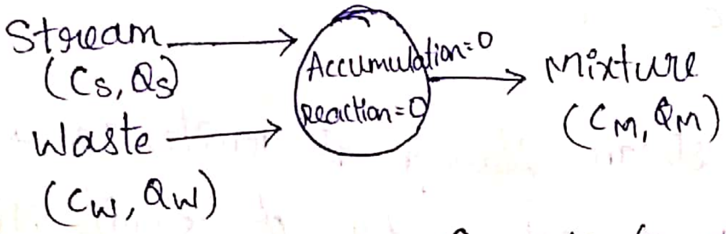


Input rate + Reaction rate = Output rate

Reaction → Generation (+)
Reaction → Decay (−)

* Conservative pollutants (Mass remains same in a Control volume), Non Conservative pollutants (Mass changes in a Control volume)

* Steady state Conservative system:
  - Input rate = Output rate
  - constant accumulation rate



Mass Balance eqn :- $(C_s \times Q_s) + (C_w \times Q_w) = (C_M \times Q_M)$

$$Q_s + Q_w = Q_M$$

$$\Rightarrow C_M = \frac{C_s Q_s + C_w Q_w}{Q_M}$$

$$C_M = \frac{C_s Q_s + C_w Q_w}{Q_s + Q_w}$$

Zero Order Reactions :- $C = K$

First Order Reactions : $C = C_0 e^{-kt}$

Second Order Reactions:

• Homework : Give an example of second order reaction & derive rate equation

Eg :- $2NO_2 \longrightarrow 2NO + O_2$

$$\frac{1}{C} = \frac{1}{C_0} + kt$$

Derivation :- $2A \longrightarrow P$

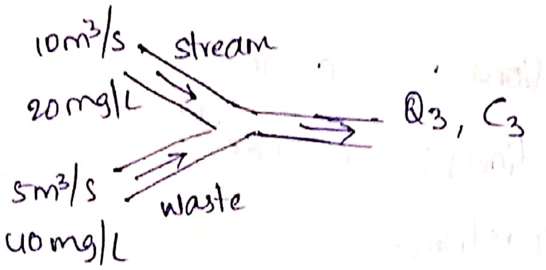
$$-\frac{d[A]}{dt} = k[A]^2 \Rightarrow -\frac{d[A]}{[A]^2} = k\,dt$$

$$\frac{1}{[A]} = kt + C \quad \left[\text{at } t=0,\ C = \frac{1}{[A_0]}\right]$$

$$\frac{1}{[A]} = \frac{1}{[A_0]} + kt$$

$$\frac{1}{C} = \frac{1}{C_0} + kt$$

19/07/19 Eg: A stream flowing at $10\,m^3/s$ has a tributary feeding into it with a flow of $5.0\,m^3/s$. The stream concentration of chloride upstream of the junction is 20.0 mg/L and the tributary chloride concentration is 40.0 mg/L. Treating chloride as a conservative substance and assuming mixing of two streams, find the downstream chloride concentration.



$$Q_1 + Q_2 = Q_3 \Rightarrow Q_3 = 10+5 = 15\,m^3/s$$

$$Q_1C_1 + Q_2C_2 = Q_3C_3$$

$$10\times20 + 5\times40 = 15\times C_3$$

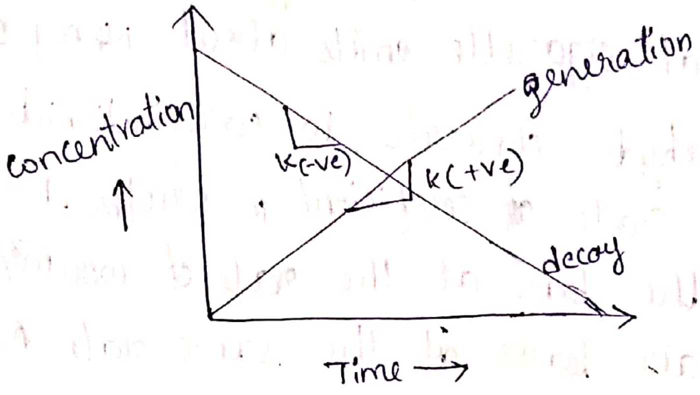
$$\frac{400}{15} = C_3 \Rightarrow C_3 = 26.6\ mg/L$$

* Batch system with Non-Conservative pollutants :-

There is no contaminant flow into or out of a batch system. Yet the contaminants in the system undergo chemical, biological or nuclear reactions fast enough and they are treated as non-conservative substances.

* zero-Order reaction :- (Eg:- Evaporation of water in different volume)

Rate of reaction $R = k[C]^0 = k$.



* First order reaction :-

Rate of reaction $R = k[C]^1$

$$\frac{d[C]}{dt} = -k[C]$$

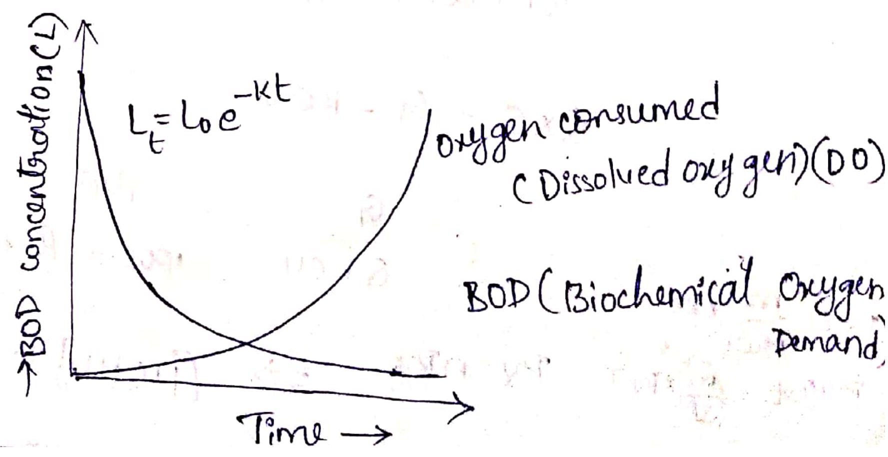
$$\frac{d[C]}{[C]} = -k\,dt$$

$$\ln c = -kt + \ln c_0$$

$$\ln c/c_0 = -kt$$

$$c = c_0 e^{-kt}$$

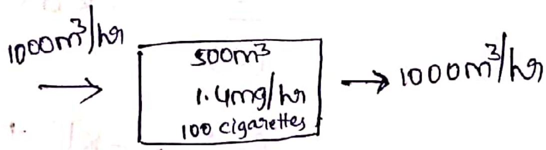
Eg: Biochemical degradation process (reactions)



'k' depends on Temperature

25/07/19

Eg: A bar with a volume $500m^3$ has 50 smokers in it, each smoking 2 cigarettes per hour. An individual cigarette emits about 1.4 mg of Formaldehyde (HCHO). Formaldehyde converts to carbondioxide with a reaction rate ~~of~~ coefficient $k = 0.40/hr$. Fresh air enters the bar at the rate of $1000\ m^3/hr$. and stale air leaves it the same rate. Assuming complete mixing, estimate the steady state concentration of Formaldehyde in the air. At 25°C and 1 atm of pressure, how does the result compare with the threshold for eye irritation of 0.05 ppmv?



$$C = C_0 e^{-kt}$$

Input rate + Generation rate = Output rate

Input rate = 0

Generation rate = $2 \times 50 \times 1.4 = 140\ mg/hr$

$$Q \times C = G - KCV$$

$$C = \frac{G}{Q + CV} = \frac{140}{1000 + (0.4 \times 500)} = 0.117 mg/m^3$$

$P \times V = \frac{m}{Mwt} \times R \times T$

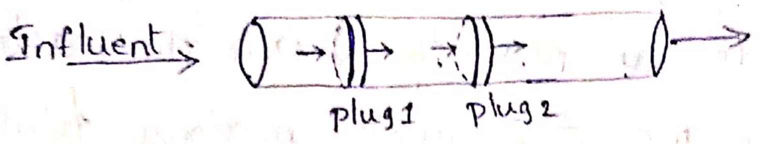
$P \times Mwt = \frac{m}{V} \times R \times T$ c

$PV = nRT$

$$\Rightarrow [HCHO] = \frac{C \times 24.4}{Mole.wt} = \frac{0.117 \times 24.4}{30}$$

$= 0.095 ppm$

→ Plug flow reactor :-



$$\frac{dM}{dt} = \frac{d(in)}{dt} - \frac{d(out)}{dt} + V\frac{dc}{dt}$$

Because of no mass. echange $d(in) = d(out) = 0$

$$\frac{dM}{dt} = 0 - 0 + V\frac{dc}{dt}$$

For a first order decay reaction, $V\frac{dc}{dt} = -kCV$

$$C_{out} = C_{in}e^{-kt}$$

$$C_{out} = C_{in}e^{-k\frac{V}{Q}}$$

Eg 1.7 from Masters & Ela :-

$L = 4.75\ km$

$A = 20m^2 \Rightarrow V = 20 \times 4.75 \times 10^3$

$V = 95 \times 10^3\ m^3$

$K = 10000/km/hr$

$$C_{out} = 7 \times e^{-\frac{10000}{1km\ hr} \times \frac{95 \times 10^3}{700\ m^3}}$$

$$= 7 \times e^{-\frac{10000}{10^3 \times 60} \times \frac{95 \times 10^3}{700}}$$

$$= 7 \times e^{-\frac{950}{42}}$$

$$C = C_0 - Kt$$

$$= 7 - \frac{10000}{10^3 \times 60} \times \frac{95 \times 10^3}{700}$$

Eg 2.7 : A waste water treatment plant must disinfect its affluent behaviour discharging the water flow to an near by stream. The waste water contains 4.5×10^5 fecal coli form colony forming units (CFU) per litre. The maximum permissible fecalcoliform concentration that may be discharged is 2,000 fecalcoliform CFU/L. It is proposed that a pipe carrying the waste water be used for disinfection process. Determine the length of pipe required if the linear velocity of the waste water in the pipe is 0.75 m/s. Reaction rate constant = $0.23\ min^{-1}$ (Assume steady state plug)

$C_{in} = 4.5 \times 10^5\ CFU/L \rightarrow$ [pipe] $\rightarrow C_{out} = 2000\ \frac{CFU}{L}$

$V_{in} = 0.75\ m/s$ $\quad \longleftarrow l = ? \longrightarrow \quad$ $V_{out} = 0.75\ m/s$

$K = 0.23\ min^{-1}$

$$C_{out} = C_{in} e^{-K V/Q}$$

$$= C_{in} e^{-K \times \frac{L \times A}{V \times A}}$$

$$= C_{in} e^{-\frac{KL}{V}}$$

$$2000 = 4.5 \times 10^5 \times e^{-\frac{0.23}{60} \times \frac{L}{0.75}}$$

$$\ln\left(\frac{2000}{4.5 \times 10^5}\right) = \frac{-0.23 L}{60 \times 0.75}$$

$$-5.42 = -\frac{23}{4500} \times L$$

$$L = 1060.43\ m$$

26/07/19

→ National Ambient Air Quality Standards :

Thermal NOx = Nitrogen is produced from Natural Air.

Fuel NOx = Results from the oxidation of nitrogen compounds that are chemically bound to the fuel.

TLV for NOx = 5 ppm — NOx is more Toxic (Brown colour)

TLV for CO = 50ppm

- NO_2 combines with the Haemoglobin of the blood (300,000 times than O_2) to form an extremely stable compound.

Homework: 1. Acid rain because of NOx, lead to Eutrophication. And what are the Environmental impacts because of Eutrophication.

2. Discuss the health effects of VOC (atleast two)

* Smog - Smoke + Fog
* Photochemical smog = NOx + Smoke + Fog

01/08/19

* Ozone → Ground level ozone (harmful)
  → Stratospheric ozone

Homework: Study briefly describe PAN & PBN, PCAH
How they are produced, sources, physiological effects, permissible limit.

- difference b/w TLV & Maximum allowable conc.

→ Particulate Matter (Dust):-

(PM_{10}) 1 µm - 10µm ⇒ Respirable particular matter

0.005 - 100µm ⇒ Particulate Matter

1 µm - 10000 µm ⇒ Dust

0.03 µm - 0.3µm ⇒ Fumes

$PM_{2.5}$ (1µm - 2.5µm) ⇒ harmful

** Homework:- Discuss Respiratory system and its protection system in stopping dust from entering & its Diagram with the examples like Silicosis Asbestosis **

02/08/19

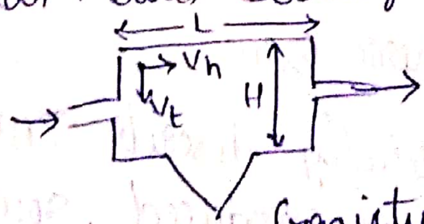
→ Ammonia:-

Uses:- 1) Fertilizers
2) Refrigeration agent
3) disinfecting agent

Anhydrous ammonia is lighter than air and will rise to the roof, but moistured ammonia settle down on the floor.

→ Benzene:-

→ Particular Matter Settling



Gravity settler.

Time taken to cover the length (t_l) = $\frac{L}{V_h}$

Vertical distance covered by, particle in time (t_l)

$$= V_t \times \frac{L}{V_h}$$

For full seperation, $H \leq \frac{V_t L}{V_h}$

If $H > \frac{V_t L}{V_h}$, only partial ~~suspension~~ seperation

Terminal settling velocity using stokes law $= V_t = \frac{(\rho_p - \rho_a) d^2}{18\mu} \cdot g$

$$H = \frac{V_t L}{V_h} \Rightarrow V_t = \frac{H \cdot V_h}{L} = \frac{\rho_p d^2 g}{18\mu} \quad (\rho_a = 0)$$

$$d^2 = \frac{H \cdot V_h \cdot 18\mu}{L \rho_p \cdot g}$$

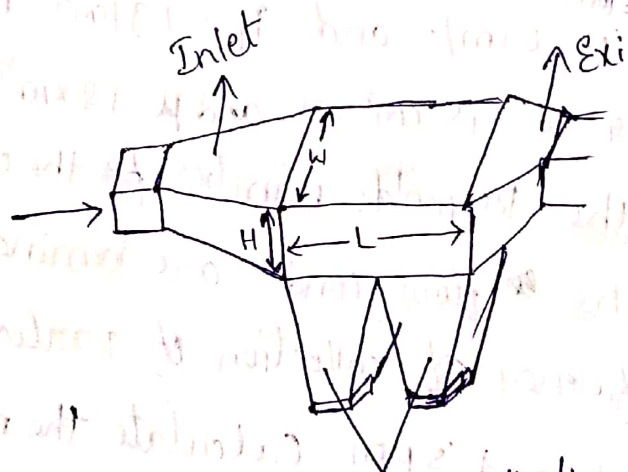


Fig: Gravitational Chamber (for > 30μm size)

Eg: Calculate the minimum size of the particle that will be removed with 100% efficiency from a settling chamber under the following condⁿ:

$V_h = 0.3\,m/s$, $T = 77°C$, $\rho = 2.0$, $L = 7.5\,m$, $H = 1.5\,m$

$$d^2 = \frac{18\,\mu \cdot H \cdot V_h}{L\,\rho_p\, g} = \frac{18 \times \mu \times 1.5 \times 0.3}{7.5 \times 2 \times 9.8}$$

$\mu = 2.09 \times 10^{-5}$ kg/ms

$$d^2 = \frac{18 \times 2.09 \times 10^{-5} \times 1.5 \times 0.3}{7.5 \times 2 \times 9.8 \times 10^{3}}$$

$= 0.115 \times 10^{-8}$

$d^2 = 0.0115 \times 10^{-8}$

$d = \cancel{0.107 \times 10^{-2}}$ $\Rightarrow d = 0.340 \times 10^{-4}$

$= \cancel{1.07 \times 10^{-3}}$ $= 34\,\mu m$

$= \cancel{1.1\ mm}$

(Source: Flagan 1998 pg 398)

Eg 7.1: Efficiency of a laminar flow settling chamber in the stokes Law regime. Consider a settling chamber for which $H = 0.1m$, $L = 10m$, $\bar{u} = 0.1 m/s$ and $\rho_p = 1 g/cm^3$. At 298 K, ν for air is $15\ cm^2 s^{-1}$ and $\mu = 1.8 \times 10^{-4}\ g cm^{-1} s^{-1}$. Under these condn, the Reynolds number for the channel flow is 667. ⇒ the flow condn are laminar. Calculate the efficiency of collection of particles of the sizes 1, 2, 3, 4 and 5 μm. Calculate the minimum size that can be seperated with 100% efficiency

$$V_t = \frac{\rho_p \cdot g \cdot D_p^2}{18\mu}$$

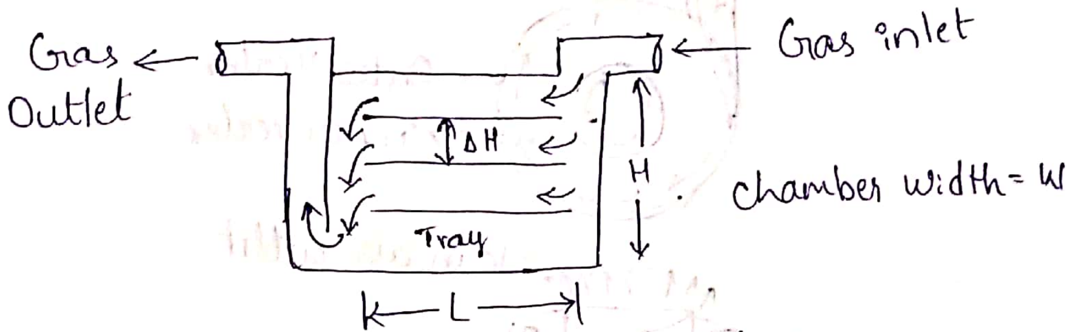
$$\eta(D_p) = \frac{V_t \cdot L}{\bar{u} \cdot H}$$

* To determine the expression for the collection efficiency, we need to compute the fraction of particles of a size D_p that is collected over a length L. The flow of particles into the chamber, in number of particles per unit time, for a chamber of width W is:

$$\eta(D_p) = \frac{V_t L}{\bar{v} H}$$

$\bar{v}$ = mean velocity
V_t = Terminal settling velocity

→ Howard settling chamber:-



Eg:- Four no. of trays (at uniform interval) are inserted vertically in the sedimentation chamber of the previous problem. Calculate the efficiency of collection of particles of the sizes 1, 2, 3, 4 and 5 μm. Calculate the minimum size that will be seperated with 100% efficiency.

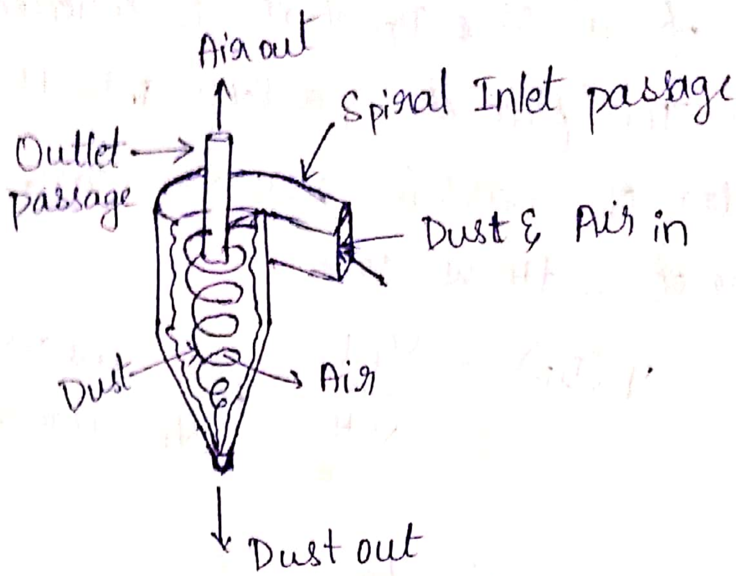
$$V_t = \frac{\rho_p \cdot g \cdot D_p^2}{18\mu}$$

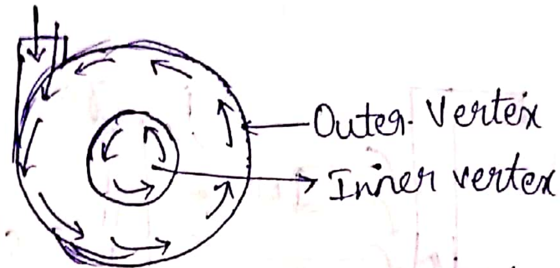
$$\eta(D_p) = \frac{V_t \cdot L\, N_c}{\bar{u} \cdot H}$$

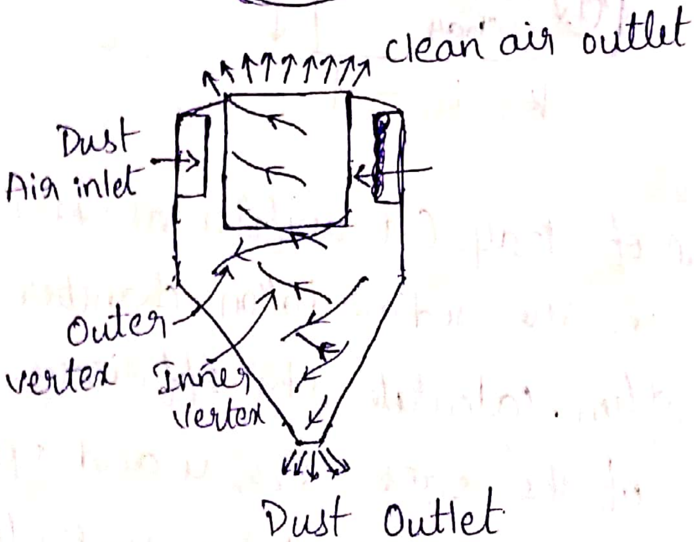
(N_c = No. of trays + 1)

09/08/19

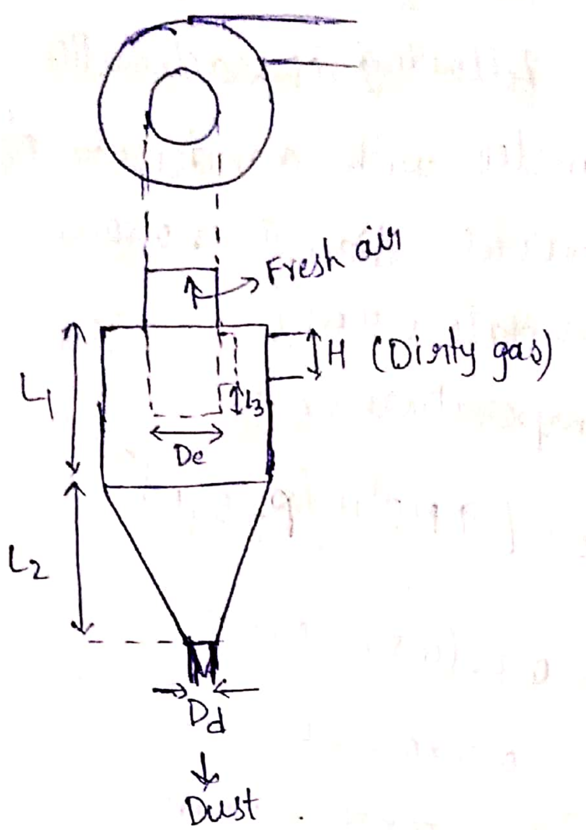
→ Centrifugal Collectors :- (Cyclones) (for 15 to 20μm







$$F_c = M_p \times \frac{V_i^2}{R}$$



$L_1 = 2D_2$

$L_2 = 2D_2$

$D_e = 0.5\,D_2$

$H = 0.5\,D_2$

$B = 0.25\,D_2$

$D_d = 0.25\,D_2$

$L_3 = 0.125\,D_2$

Collection efficiency $\eta_i = \dfrac{1}{[1 + (D_{50}/D_i)^{\beta}]}$

D_{50} : Diameter of particle with 50% collection efficiency

β = exponent dependent on cut diameter D_{50}

$D_{50} = \left[9\mu B^2 H / \rho_p Q_g \theta\right]^{0.5}$ → Laple Equation.

B = width of entry (cyclone entrance)

H = Height of entry

Q = Flow rate

θ = No. of turns the air is undergoing

μ = dynamic viscosity (kg/m.s)

$\theta = \pi\,(2L_1 + L_2)/H$

Eg1:- Determine the efficiency of a standard cyclone having the following characteristics for particles $10\mu m$ diameter with a density of $800 kg/m^3$

cyclone barrel diameter : 0.50m

Gas Flow rate : $4 m^3/s$

Gas Temperature : 25°C

$$d_{50} = [9\mu B^2 H / \rho_p Q_g \theta]^{0.5}$$

$B = 0.25(0.5) = 0.13 m$

$H = 0.5 \times 0.5 = 0.25 m$

$L_1 = L_2 = 2 \times 50 = 1.0 m$

$\rho_p = 800 kg/m^3$

$Q_g = 4 m^3/s$

No. of turns, $\theta = \pi(2 \times 1 + 1) = 3\pi$

16/08/19

→ Fabric Filter (Baghouse Filters):- For better efficiency ($<5\mu m$)

Particulate-laden gas is allowed to pass through filters (mostly Baghouse) which filters out the particulate matter and allow gas to pass through.

Mechanisms :- i) Direct Interception

ii) Inertial Impaction

iii) Electrostatic attraction

Three processes of cleaning the bags: Shaking, Reverse flow, pulse jet flow.

Homework :- Give the information of Filter cost & its life time.

Filtering rates range from 0.5 to 5 m/min.

Eg: A fabric filter is to be constructed using bags that are 0.3m in diameter and 6.0 m long. The bag house is to receive 10 m^3/s of air, and the filtering velocity is 2.0 m/min. Determine the no. of bags needed for a continously cleaned operation

$$\frac{\text{Air Quantity}}{\text{Filtering rate}} = \text{Surface Area}$$

$$\frac{10 \times 60}{2} = \text{Surface Area} = 300 m^2$$

$$\pi (0.3) \times 6 \times n = 300$$

$$n = \frac{50}{0.3\pi} = \frac{50}{0.94} = 53.19$$

$\approx$ 54 filters

Limitations :- 1) Explosion, Energy Expenditure, requires inspection & maintenance, higher cost, requires proper handling of dust.

Advantages :- Efficient

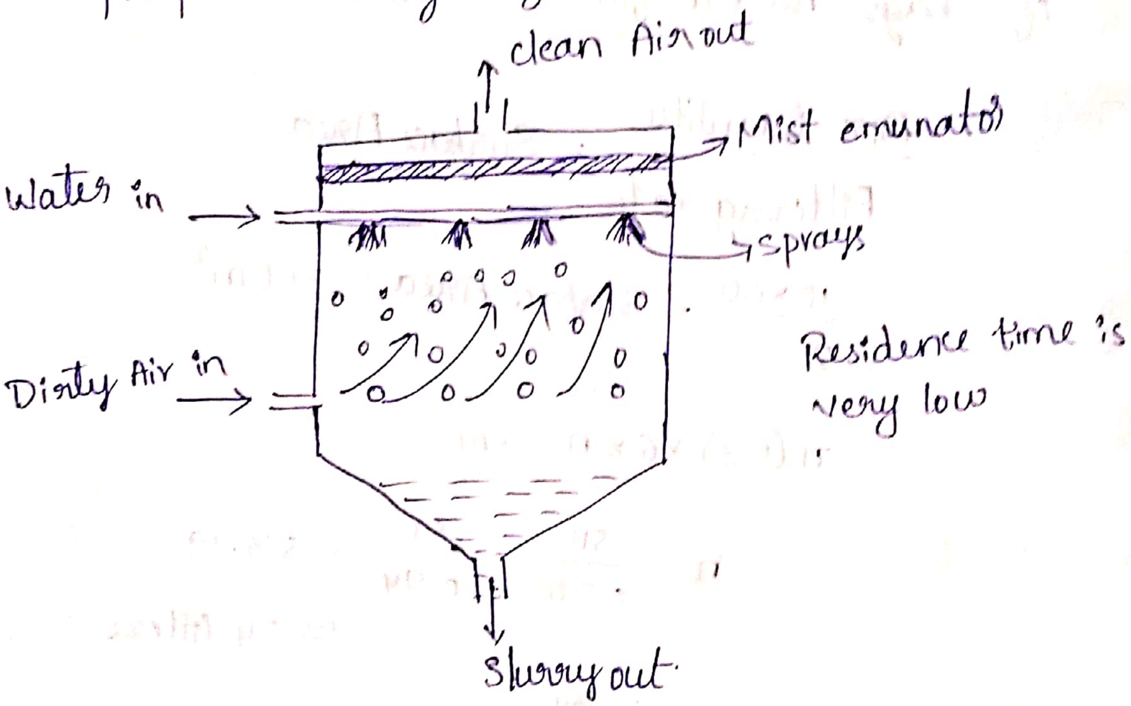
22/08/19

→ Wet Collectors or Scrubbers :-

Assignment :- Discuss the different mechanisms of particle retention in a scrubber.

Advantages :

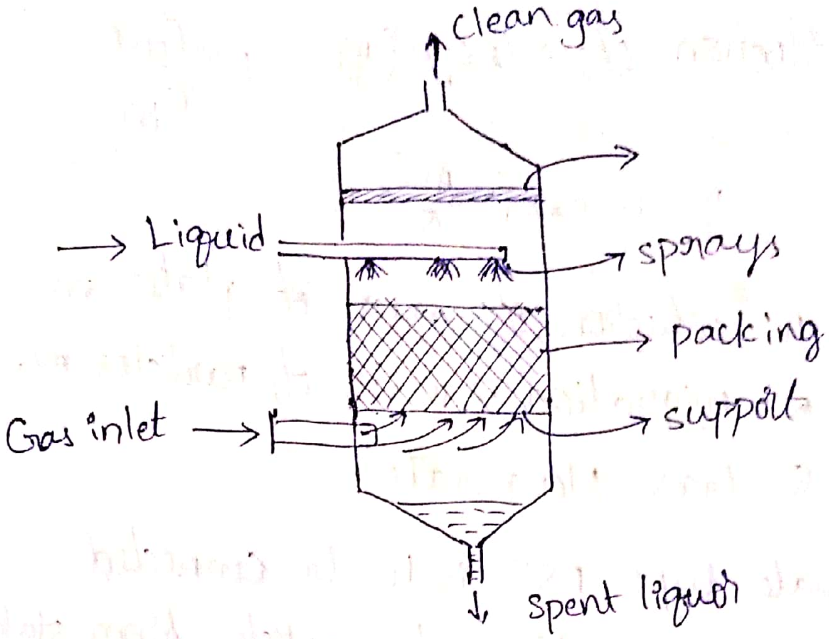
1) Simultaneous removal of Gases & particulates
2) Less space requirement
3) Hazards of explosive dust - air mixtures are reduced.
4) Indifference to the Temperature and moisture content of gas.
5) Corrosive gases can be neutralised by selecting proper wetting agent.



Scrubber (Counter-current spray tower scrubber)

Maximum efficiency of dust capture occurs when the liquid droplet size is about 800 μm.

Efficiency depends upon i) Droplet size ii) Flow velocity of the gas iii) Liquid : Gas Ratio iv) ~~To~~ Droplet trajectory



Packed bed tower scrubber

Residence time increases because of packing which increases efficiency. The pressure drop through a spray tower is between 0.25 and 0.5kpa and for a packed tower, it is b/w 0.25 and 2.0kpa. The liquid to Gas ratio in a spray tower is between 1.3 to 2.7 L/m³ and in a packed tower, it is between 0.1 to 0.5 L/m³

self study from Fragan book

* Venturi scrubbers, Centrifugal scrubber (Homework)

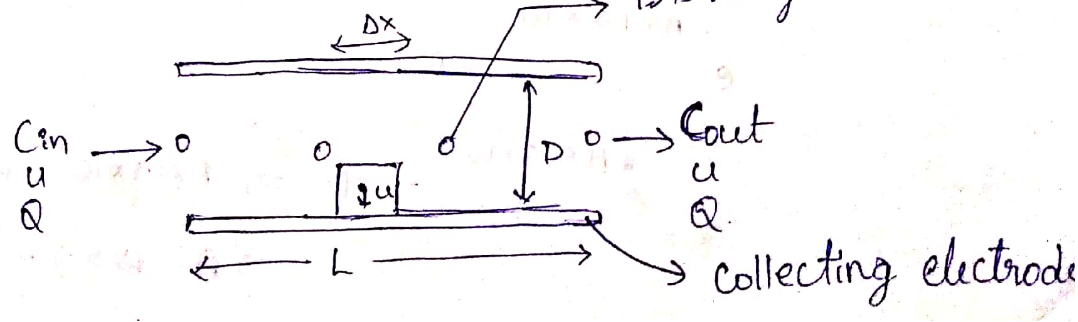
→ Electrostatic precipitators :-

23/08/19

$W = qE / 6\pi\mu a$

W = Migration velocity / drift velocity

$W = Ka$ (K is



particle collection efficiency $(\eta) = 1 - \frac{C_{out}}{C_{in}}$

$$\eta = 1 - \exp\left(-\frac{Aw}{Q}\right);$$

A = collection of area of plates, m^2

w = migration velocity of particles, m/s

Q = Gas Flow rate.

<u>Example</u>: A plate type ESP is to be ~~connected~~ constructed to remove fly-ash particles from stack gases flowing at rate of $10 m^3/s$. The drift velocity can be taken as $w = 3.0 \times 10^5 d_p$ m/s. Determine the plate area required to collect a 0.5 µm particle with a) 90% efficiency and b) 99% efficiency. Calculate the number of plates, if the plate dimensions are 4m length and 4m height.

$Q = 10 m^3/s$

$w = 3 \times 10^5 d_B = 3 \times 10^5 \times 0.5 \times 10^{-6} = 0.15 m/s$

$a = 0.5 \mu m$

$\eta = 0.9$

$$0.9 = 1 - e^{-\left(\frac{A \times 3 \times 10^5 d_p}{10}\right)}$$

$$e^{-\frac{A \times 3 \times 10^5 \times 0.5 \times 10^{-6}}{10}} = 0.1$$

$$e^{-A \times 1.5 \times 10^{-2}} = 0.1$$

$$e^{A \times 1.5 \times 10^{-2}} = 10 \Rightarrow A \times 1.5 \times 10^{-2} = 2.3$$

$$\Rightarrow A = 153.5 m^2$$

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No. of plates $= \frac{153.5}{4\times4} = 9.59 \approx 10$

b) $0.99 = 1 - e^{-\frac{A\times3\times10^5\times0.5\times10^{-6}}{10}}$

$e^{-A\times1.5\times10^{-2}} = 0.01$

$e^{A\times1.5\times10^{-2}} = 100$

$A\times1.5\times10^{-2} = 4.605$

$A = 307\ m^2$

$n = \frac{307}{16} = 20$

Example :- Electrostatic precipitators are normally divided into fields (portions of ESP controlled by seperate power supplies) which are arranged in series. A four field ESP is used for control of particulate matter of a coal fired boiler. The gas flow rate is $120 m^3/s$. Each field contains 11 collection plates measuring 12m high by 18m length. The inlet particulate concentration is $4000 mg/m^3$. Assuming a migration velocity of 0.05m/s. Calculate the efficiency of the ESP? What would be the outlet particulate concentration?

$Q = 120 m^3/s$, $n = 11$, $h = 12m$, $l = 18m$

$A = 12\times18 = 216 m^2$

$C_{in} = 4000\ mg/m^3$, $w = 0.05 m/s$

$\eta = 1 - \exp\left(-\frac{AW}{Q}\right) = 1 - \exp\left(-\frac{216\times11\times0.05}{120}\right)$

$= 1 - 0.878 \quad = 0.122$

$$\eta = 1 - \frac{C_{out}}{C_{in}}$$

$$= 1 - \frac{C_{out}}{4000} \Rightarrow C_{out} = 0.878 \times 4000$$

$$\Rightarrow C_{out} = 3512 \ mg/m^3$$

$$0.122 \ \cancel{0.878} = 1 - \frac{C_{out}}{3512}$$

$$\Rightarrow C_{out} = 0.878 \times 3512 = 3083.536 \ mg/m^3$$

$$\Rightarrow C_{out} = 0.878 \times 3083.536 = 2707.34$$

$$\Rightarrow C_{out} = 2707.34 \times 0.878$$

$$= 2376.746 \ mg/m^3$$

Assignment :- Define Migration velocity and derive the expression for Migration velocity

→ Water Pollution:-

The depth in the ocean to which light can reach is called Photic zone.

Aerobic degradation:-

$$\text{Organic matter} + O_2 \xrightarrow[\text{bacteria}]{\text{Aerobic}} CO_2 + H_2O + \text{New cells} + \text{stable products} \ (SO_4, PO_4, NO_3)$$

Anaerobic degradation:-

$$\text{Organic matter} \longrightarrow CO_2 + H_2O + \text{new cells} + \text{Unstable Product} \ (H_2S, NH_3, CH_4)$$

(by anaerobic microorganisms)

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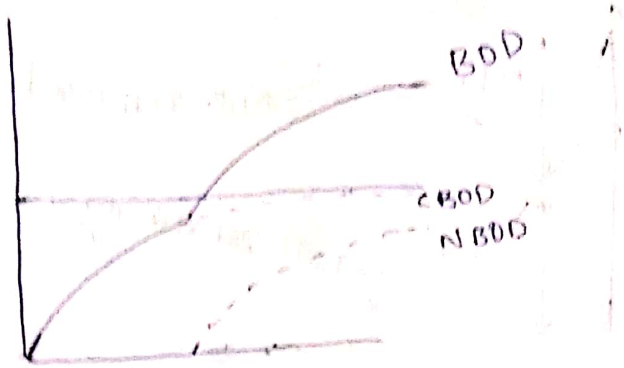


29/08/19

12th Sep (Thursday) - Quiz-1

* Maximum 'DO' is 15 mg/L

Homework: Name atleast 5 groups of bacteria which degrades the organic waste in presence of Oxygen.

List 5 different classes of Anaerobic bacteria

Self Study: Discuss the process of Anaerobic degradation

Discuss the process of Methane extraction from the landfills.

Eg: Compute the ThOD of 108.75 mg/L of glucose

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

$6 \times 12 + 12 \times 1 + 6 \times 16$

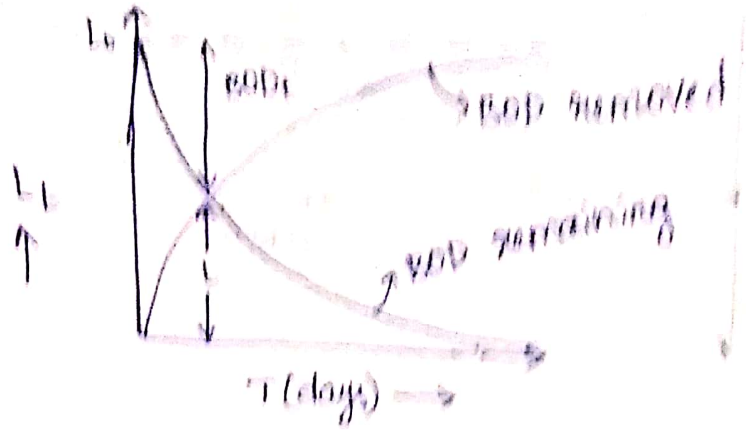
180 g $\quad$ 6×32

$= 192$

For 180 g $\rightarrow$ 192 g of O_2

108.75 g $\rightarrow$?

$= \dfrac{192 \times 108.75}{180} = 116$ mg/L



$L_t = L_0 e^{-kt}$ (L_0: ultimate BOD)

K: degradation Rate Constant (t^{-1})(day^{-1})

$BOD_t = L_0 - L_t = L_0(1 - e^{-kt})$

$K_t = K_{20}\,\theta^{(T-20)}$ (variation of 'K' with T)

T: Temperature (°C)

θ: Temperature coefficient (1.047)

Eg: If the BOD_3 of a water is 75 mg/l and $k = 0.15\ d^{-1}$. Calculate ultimate BOD and BOD_5

$BOD_3 = L_0(1 - e^{-kt}) \Rightarrow 75 = L_0(1 - e^{-0.15\times 3})$

$\Rightarrow L_0 = \frac{75}{0.36} = 206.9$ mg/l

$BOD_5 = 206.9(1 - e^{-0.15\times 5}) = 109.16$ mg/l

→ N-BOD:-

Plants cannot take Nitrogen gas directly, it needs to be converted to NH_3 or NO_2. So the process of conversion of N_2 to NH_3 or NO_3 by Blue-green algae & bacteria is called Nitrogen fixa

Reverse process of Nitrogen fixation is Nitrification
It is a 2 stage reaction

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$$
(Nitrosomonas)

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \text{ (Nitrobacter)}$$

The above two process together are called Nitrification

The Oxygen required to convert NH_3 to NO_3^- by chemical and biological means is called NBOD.

Eg:- page No: ~~...~~ 196 (Masters. Ela).
A domestic waste has 30mg/L of nitrogen in the form of organic nitrogen/Ammonia. Assuming that very few new cells of bacteria are formed during the nitrification of the waste (that is, the oxygen demand can be found formed. A simple stiochiometric analysis of the nitrification reactions given above). Find
a. The ultimate nitrogenous oxygen demand
b. The ratio of the ultimate NBOD to the concentration of Nitrogen in the waste.

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O \quad -(1)$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad -(2)$$

$$① + ② \Rightarrow NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O$$

14g of N requires 64g of Oxygen
30mg/L of N " ? " "

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$\Rightarrow NBOD = \frac{30 \times 64}{14} = 137 \text{ mg/L}$

$\frac{NBOD}{\text{Conc. of waste } (N_2)} = \frac{137}{30} = 4.57 \text{mg } O_2/\text{mg N}$

* Total Kjeldal Nitrogen:

30/08/19

→ Chemical Oxygen Demand:

$COD\left(\frac{mg}{L}\right) = \frac{8000(B-A)(\text{Normality of FAS})}{V}$

FAS = Ferrous ammonium sulphate titrant
$Fe(NH_4^+)$

B =

A =

V =

Reference: Introduction to Environmental Engineering by Mackenzie Davis (Mc Graw Hill publication)
Chapter: Water Chemistry (Numericals Imp.)

Alkalinity: Measure of waters capability to absorb hydrogen ions without significant change in pH. Major alkalinity in water is produced by carbonates, bicarbonates and hydroxides. Other alkalinity may be HPO_4^{2-}, NH_3^{0}.

$\text{Alkalinity} = [HCO_3^-] + [CO_3^{2-}] + [OH^-] - [H^+]$

Eg:- A water contains 100 mg/l of CO_3^{2-} and 75 mg/l of HCO_3^- at a pH of 10. Calculate the alkalinity exactly at 25°C. Approximate the alkalinity by Ignoring $[OH^-]$ and $[H^+]$

$$pH = 10 \Rightarrow -\log[H^+] = 10$$

$$\Rightarrow [H^+] = 10^{-10} = 10^{-7} \text{ mg/L}$$

$[K_w = [OH^-][H^+]$, $K_w = 10^{-14}$ at 25°C$]$

$$\Rightarrow [OH^-] = 10^{-4} \frac{mol}{L} = 17 \times 10^{-4} \times 10^{3} \text{ mg/L} = 1.7$$

$$\text{Alkalinity} = [CO_3^{2-}] + [HCO_3^-] + [OH^-] - [H^+]$$

Eq.wt of $[CO_3^{2-}] = \frac{60}{2} = 30$ ~~100 + 75/+1.7~~

" " $[HCO_3^-] = \frac{61}{1} = 61$ ~~175 mg/L + 1.7~~ ~~176.7 mg/L~~

$$[CO_3^{2-}] \text{ eq. to } CaCO_3 = 100 \times \frac{50}{30} = 167$$

$$[HCO_3^-] \text{ eq. to } CaCO_3 = 75 \times \frac{50}{61} = 61$$

$$[H^+] \text{ eq. to } CaCO_3 = 10^{-7} \times \frac{50}{1} = 5 \times 10^{-6}$$

$$[OH^-] \text{ eq. to } CaCO_3 = 1.7 \times \frac{50}{17} = 5.0$$

Exact alkalinity $= 61 + 167 + 5 - (5 \times 10^{-6})$

$= 233$ mg/L as $CaCO_3$

Approximated by $61 + 167 = 228$ mg/L as $CaCO_3$

→ Hardness :-

Hardness refers to the presence of multivalent metallic cations like Ca^{+2}, Mg^{+2}, Sr^{+2}, Mn^{+2}, Fe^{+2}

Reactions in removing Temporarily hardness (heating)

Total Hardness = $[Ca^{+2}] + [Mg^{+2}]$
(TH)

Temporary hardness = carbonate Hardness (CH)

$= [CO_3^{2-}] + [HCO_3^{-}]$

Non Carbonate hardness NCH = $[Cl^-] + [SO_4^{2-}] + \ldots$

$= TH - CH$

If $6 < pH < 8.5$, $CH = [HCO_3^{-}]$

Eg: 6.6 (Masters Ela. P.307)

Find the total hardness (TH), the carbonate hardness (CH) the noncarbonated hardness (NCH), and the alkalinity all expressed as $CaCO_3$, Find the dissolved solids (TDS) in mg/l.

Ion	mg/l	Eq.wt.	Eq. $CaCO_3$
Ca^{+2}	80	20	$\frac{80 \times 50}{20} = 200$
Mg^{+2}	30	12	$\frac{30 \times 50}{12} = 125$
Na^{+}	72	23	$\frac{72 \times 50}{23} = 156.5$
K^{+}	6	39	$\frac{6 \times 50}{39} = 7.69$
Cl^{-}	100	35.5	$\frac{100 \times 50}{35.5} = 140.85$
SO_4^{2-}	201	48	$\frac{201 \times 50}{48} = 209.375$
HCO_3^{-}	165	61	$\frac{165 \times 50}{61} = 135.25$

TDS = 974.66 eq of $CaCO_3$ (or) 654 mg/L

Total Hardness = 200 + 125

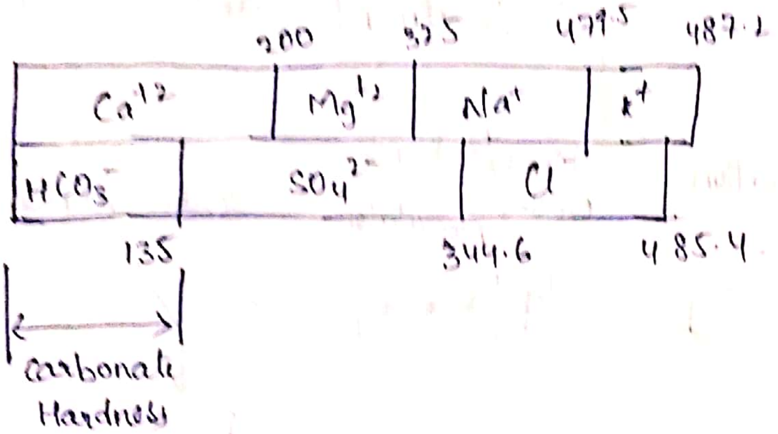
= 325

CH = 135.25

NCH = 140.85 + 209.37 = 350

TH − CH = 325 − 135

= ~~##~~ 190 eq. of $CaCO_3$



05/09/19

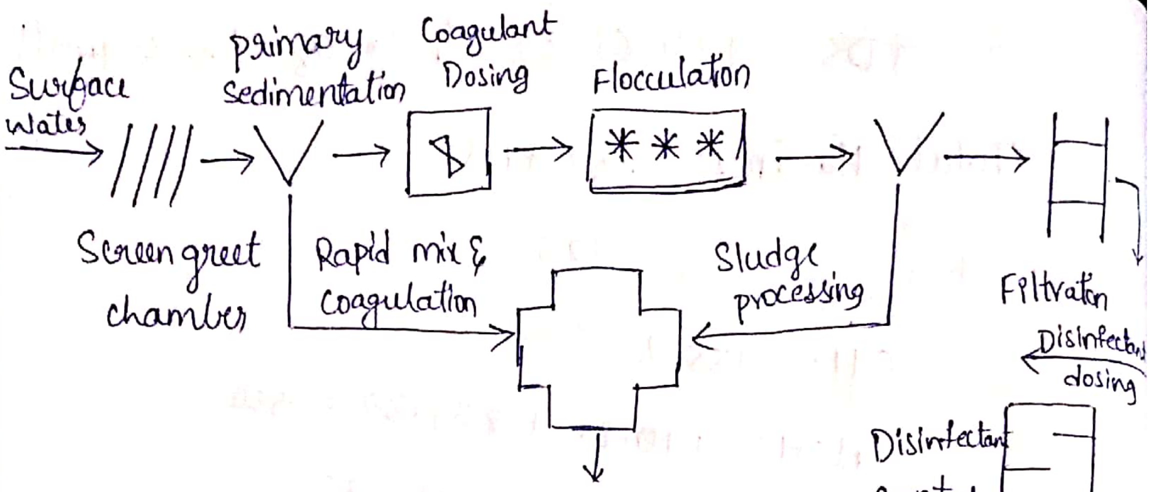
Actinomyces
Clostridium
Bacteriodes
pre votella
Fusobacterium

} 5 Anaerobic bacteria

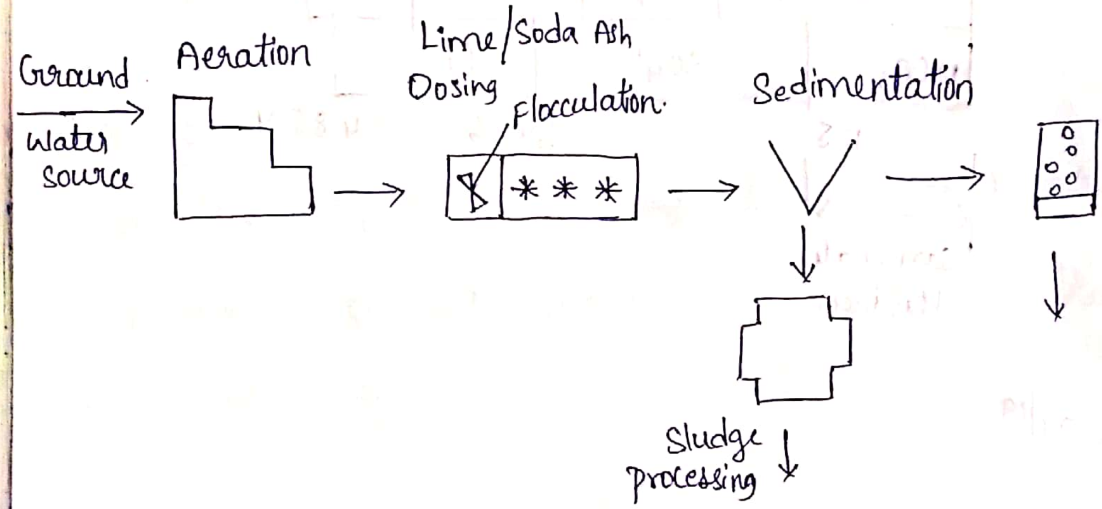
→ Water Treatment system :

- Drinking water quality standard (IS 10500 - 9001)
- Industrial Waste effluent standard

Ground water contains more minerals than Surface water, has ~~more~~ Less DO than Surface water



Schematic of typical Surface water treatment plant



$$4Fe^{+2} + O_2 + 10H_2O \longrightarrow 4\underset{(+3)}{Fe}(OH)_3 \downarrow + 8H^+$$

$$2Mn^{+2} + O_2 + 2H_2O \longrightarrow 2\underset{(+4)}{Mn}O_2 \downarrow + 4H^+$$

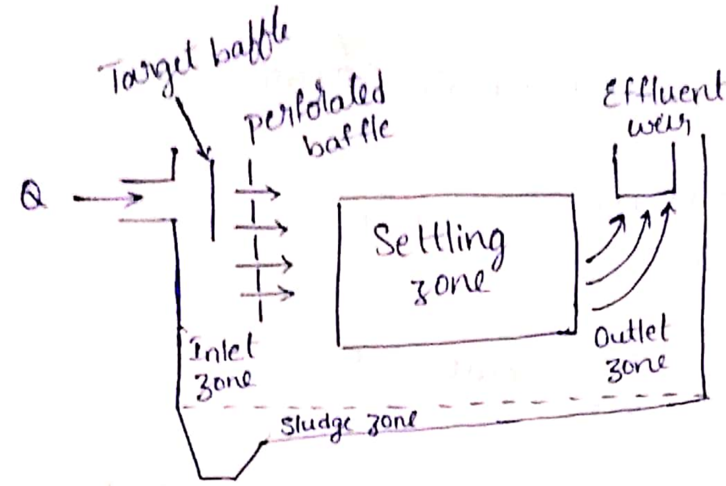
Aeration Rxn's

pH is lowered by the production of Hydrogen ions

06/09/19

Terminal settling velocity $V_t = g(\rho_p - \rho_w) d^2 / 18\mu$
(vertical velocity)
↓
Stokes equation

Detention time = $\frac{\text{Volume of time}}{\text{Flow rate}}$



Eg: A drinking water treatment plant uses a circular sediment basin to treat 3.0MGD of river water (1MGD = 0.0438 m^3/s). After a storm, the river carries 0.010 mm slit particles with an average density of 2.2 g/cc and the slit must be removed before the water can be used. The plants clarifier is 3.5m deep and 21m in diameter. Temperature of the water is 15°c ($\mu = 1.14 \times 10^{-3}$ kg $m^{-1} s^{-1}$)

a) What is the hydraulic detention time of clarifier

b) Will the clarifier remove the slit particles from the river water?

$v = \frac{s}{t}$

Sol:

$A_{clarifier} = \frac{\pi d^2}{4} = \frac{\pi \times 21^2}{4} = 346.36 \, m^2$

$\frac{m^3/s}{m^2}$

Detention time = $\left(\frac{3 \times 0.0438}{346.36}\right)^{-1} \times 3.5 = 7.6 \, hrs/3$

$= 2.56$ hrs

(b) $V_{t1} = 9.8(2.2 \times 10^3 - 10^3) \times (0.01 \times 10^{-3})^2 / 18 \times 1.14 \times 10^{-3}$

$$= \frac{9.8 \times 1.2 \times 10^3 \times 10^{-10}}{18 \times 1.14 \times 10^{-3}} = 0.57 \times 10^{-4}\ m/s$$

$$t = \frac{7.68 \times 60 \times 60}{3}\ sec$$

$$d = 0.57 \times 10^{-4} \times \frac{7.68 \times 60 \times 60}{3}$$

$$= \frac{1.575\ m}{3} = 0.525\ m$$

$$\eta = \frac{0.525}{3.5} \times 100 = 15\%$$

Typical Alum dosage range from 5mg/L to 50mg/L

Alum ($Al_2(SO_4)_3 \cdot 14H_2O$)

Homework: Discuss the process of coagulation by $FeCl_3$ and $FeSO_4$. Mention the pH range for rxns. Write the equations and Typical dosages.

Eg: A surface water containing 50 mg/L of natural alkalinity as $CaCO_3$ is coagulated with an alum dose of 125 mg/L; Determine if there is sufficient alkalinity present in the source water to prevent inhibition of alum coagulation. If there is insufficient alkalinity present, calculate the amount of lime necessary to react with alum

$$Al_2(SO_4)_3 \cdot 14H_2O + 3Ca(HCO_3)_2 \rightleftharpoons 2Al(OH)_3 \downarrow + 6CO_2 + 14H_2O + 3CaSO_4$$

Mwt of $Ca(HCO_3)_2 = 40 + (1+12+48)\times 2$

$= 122 + 40 = 162$

Eq. wt $= \frac{162}{2} = 81$

Eq. wt of $CaCO_3 = 50$

$50 \rightarrow 50$

$81 \rightarrow 7.81$

Mwt. of $Al_2(SO_4)_3 \cdot 14H_2O = 54 + (32+64)\times 3 + 14\times 18$

$= 288 + 54 + 252$

$= 594$

For 594 g Alum 486 g $Ca(HCO_3)_2$ required

125 mg/L $\rightarrow$?

$\frac{125 \times 486}{594} = 102.27$ mg/L

Amount of lime required $= 102.27 - 81$

$= 21$ mg/L.

* CO_2 adds acidity to water.

→ Softening reactions :-

Step 1:- Neutralize free acid

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

Step 2:- Precipitate carbonate hardness due to Ca

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

Step 3:- Precipitate carbonate hardness due to Mg

$$Mg^{+2} + 2(HCO_3^-) + Ca(OH)_2 \rightleftharpoons MgCO_3 + CaCO_3 \downarrow s + 2H_2O$$

$$Mg^{+2} + CO_3^{2-} + Ca(OH)_2 \rightleftharpoons CaCO_3 \downarrow s + Mg(OH)_2 \downarrow s$$

Step 4:- Precipitate non-carbonate hardness due to Ca

$$Ca^{+2} + Na_2CO_3 \rightleftharpoons CaCO_3 \downarrow s + 2Na^+$$

Step 5:- Precipitate non-carbonate hardness due to Mg

$$Mg^{+2} + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow s + Ca^{+2}$$

$$Ca^{+2} + Na_2CO_3 \longrightarrow Ca(CO_3) \downarrow s + 2Na^+$$

at a pH > 10.

$Ca(OH)_2$ - Lime

Na_2CO_3 - Soda

Lime is added to remove carbonate Hardness

Soda is added to remove non-carbonate hardness

Eg:- From the water analysis presented below, determine the amount of lime and soda (in mg/L as $CaCO_3$) necessary to soften the water to 80.0 mg/L hardness as $CaCO_3$. Water composition (mg/L) is

Ca^{+2}: 95.20, CO_2: 19.36, HCO_3^-: 241.46, Mg^{+2}: 13.44,

SO_4^{2-}: 53.77, Na^+: 25.76, Cl^-: 67.81