ENVIRONMENT ENGINEERING

water demand :-

for an average indian town the requirement of water in various uses is ——

domestic purpose	135 lpcd
Industrial "	40 "
Public use "	25 "
fire demand	15
losses, wastage, Theft	55 lpcd
total water demand	270 lpcd

note:-

① IS code domestic water demand = 135 to 225 lpcd

As

② under ordinary condition

min. domestic water demand for a town having flushing system = 200 lpcd

But for EWS & LIG colony = 135 lpcd

③ IS code max. water demand = 335 lpcd

As per

v. imp

note:- coincident draft = max. daily demand + fire demand

fire demand formula's	Q
1- kuichling formula	$3182\sqrt{P}$ → (lt/min)
2- freeman "	$1136\left(\frac{P}{10}+10\right)$ (lt/min)
3- Buston "	$5663\sqrt{P}$ (lt/min)
4- National Board of fire under writer's formula	. for P < 2 lakh $4637\sqrt{P}\left[1-\frac{\sqrt{P}}{100}\right]$ (lt/min) • for P > 2 lakh. → 54600 lt/min for 1st fire → 9100 to 36400 lt/m for 2nd fire
5. Govt. of India "	$100\sqrt{P}$ (KL)
note: P → in thousands (Population	Ans → lt/min except Govt. formula

Units	Design parameter
water treatment unit	for 15 years, max. daily demand
Pipe mains, filter, other treatment unit	max. daily demand
Distribution system or distribution mains	max { ① max. hourly demand of max. day ② coincident draft
wells & tube wells	max. daily demand
demand reservoir	Average annual demand
Service reservoir	15 years
Pipe connection to several treatment units, distribution system	30 years

Ans

max. daily demand = 1.8 (Avg. daily demand)

max. hourly demand = 1.5 × Avg. hourly demand of max. day

$$= 1.5 \times \left(\frac{\text{max. daily demand}}{24} \right)$$

$$= 1.5 \times 1.8 \times \frac{(\text{Avg. daily demand})}{24}$$

= 2.7 Annual avg. hourly demand

Ans

$\frac{\text{max. daily demand}}{\text{Avg. daily demand}} = 1.8$	180 %
$\frac{\text{max. weekly demand}}{\text{Avg. weekly "}} = 1.48$	148 %
$\frac{\text{max. monthly demand}}{\text{avg. monthly demand}} = 1.28$	128 %

Goodrich formula :-

$$\frac{\text{Peak (max) demand}}{\text{Avg. demand}} = 180\, t^{-0.1}$$

P = Percentage of annual avg. demand for time 't' in days

Population	Peak factor
< 50000 (small town)	3
50000 – 2 लाख (medium town)	2.5
> 2 लाख (large town)	2

Population forecasting methods

① Arithmetical Increase method

- assumption → future population increases at constant rate $\left(\frac{dp}{dt} = k\right)$

$$P_n = P_0 + n\bar{x}$$

(n → no. of decades)

- suited → large & established cities where there is limited scope of expansion (old cities)

② Geometric Increase method (Uniform Increase method)

- assumption → per decade % growth rate is constant

$$P_n = P_0\left(1 + \frac{r}{100}\right)^n \qquad r = \sqrt[n]{\frac{P_2}{P_1}} - 1 \qquad r = (r_1 r_2 \cdots r_n)^{1/n}$$

suited → Applied to young & rapidly developing cities with a large scope of expansion

③ Incremental Increase method or method of varying Increament

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$$

$\bar{x}$ → avg. increase of population of known decade

$\bar{y}$ = avg. of increamental increase of known decades

suited → to any city (old or new)

④ decreasing rate of growth method

- when rate of growth shows downward trend. if population is reaching towards saturation and growth rate is decreasing

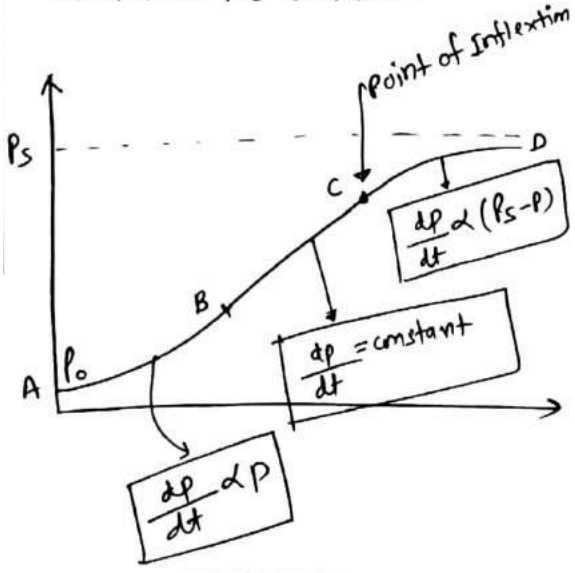
⑤ Comparative graphical method

- cities of smaller condition & characteristics are selected which have grown in similar fashion in the past, plot in graph & compares.

⑥ logistic curve method by (P.F verhulst)

↓

for community with limited land area for future.



Ex. 1931 P_0 $t_0 = 0$
1941 P_1 $t_1 = t$ (t = 10 yr)
1951 P_2 $t_2 = 2t$

Population at any time 't' from start

$$P = \frac{P_s}{1 + m\ln^{-1}(nt)} \qquad m = \frac{P_s - P_0}{P_0}$$

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

$$n = \frac{1}{t}\ln\left\{\frac{\frac{P_s - P_1}{P_1}}{\frac{P_s - P_0}{P_0}}\right\}$$

Physical parameter

① Suspended solid

SS > 30 mg/lt
As per EPA

- origin → from inorganic particles, only in surface water (not in ground water)
- measurement → By Gravimetric technique
- dissolve solids = total solids − suspended solids
  (chemical parameter)

filtration

- suspended solids (SS)
- dissolve solid + colloidal solid (notable to know individually)

∴ classify
- filtrable solids
- non filtrable solids

⑪ Turbidity

1 – 5 NTU

- Indirect measurement of suspended solid
- 1 standard Turbidity unit (1 STU)

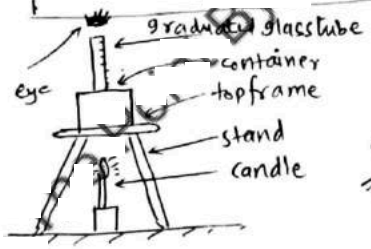
* 1 STU = 1 mg Silica (SiO_2) + 1 litre distill water
  (fuller earth)

measurement

absorption method

Turbidity rod
- field method
- Rod with Pt needle insert
- depth at which Pt needle just becomes invisible gives turbidity in ppm.
- longer light path low turbidity
- depth of insertion increase, turbidity decreases.

(lab method) Jackson's turbidimeter
- not used for drinking water
- Used when turbidity is 25–1000 PPM
- level of water kept in jar increased till the image of flame kept at bottom of jar ceases to be seen.



Baylis turbidimeter
- Used when turbidity (0–10) PPM
- light measure in the direction

Nephlometer
- Used (< 1 ppm)
- Based on Scattering Principle
- light measure perpendicular to diration.

** 1 NTU or 1 FTU = 1 mg formazine + 1 lt distill water

→ modern method to turbidity measurement ⇒ Photometer

③ color

5-15 Hazen

- origin → due to suspended [redacted] & disolve matter in water
- measurement — By tintometer (nessler tubes) → (color matching Technique)
  - using Burghese scale, cobalt scale

- 1 True color unit / 1 hazen unit = 1 mg Pt (chloroplatinate ion) + 1 litre water

note:- It is only for yellowish Brown color

note:- other than this like Industry effluent → spectrophotometric technique used

④ taste, odour

(TON ✱3)

origin → By disolve gases → H_2S, methane, mercaptons

measurement → By osmoscope

- Threshold odour number (TON) = $\frac{A+B}{A}$

take final volume of Bottle = 200 ml { if nothing given }

⑤ temperature (10-25°C)

✱25°C

- An increase in 10°C temp → doubles the Biological activity.

chemical water Quality Parametir	Description

(1) total disolve solids (TDS)

500–2000 ppm

major source → Na, mg, Ca, HCO_3^-, SO_4^{-2}, Cl⁻

measurement

- (Rough) → dionic Testir
- (Exact) → Gravimetric Technique

$TDS = 0.65 \times EC$ (μmho/cm) @ 25°C (mg/lt)

Dessactual fan

(11) Alkalinity

(200–600) mg/lt

Source

- HCO_3^- → Bicarbonate alkalinity
- CO_3^{--} → Carbonate Alk.
- OH^- → Caustic Alk.

- Definition → qnt of ions to neutralize (H^+) ions
- titrant = $\frac{N}{50}$ H_2SO_4
- indicator ⇒ ① phenophathaline ② methyl orange

∵ HCO_3^-, OH^- → never exist at a time ∵ HCO_3^-, OH^-, CO_3^- ✗ never at a time

(3) pH

6.5–8.5

PH < 5.6 acidrain

- measurement by → "Aquascope potentiometir with calomel rods"
- Indicator → Bromine-methyl" (∵ range – 6 to 7.6)

note:- PH ↑ Alkaline watir → Incrustation in pipe (deposits of minerals on interior of pipe from material being conveyed)

PH ↓ Acidic watir → Corrsion & Tuberculosis → deposition of ferrous oxide (tuberiles) from watir

name	Indicator type	pH range	Initial color	final color
(i) methyl orange	acidic indicator	(2.8 – 4.2)	Red	yellow
(ii) Phenophathaline	Basic Indicator	(8.6 – 10.3)	colorless	red
(iii) Bo-methyl	-	(6 – 7.6)		

④ Hardness (200–600) mg/lt

→ Produced by multivalent cation {Ca^{+2}/Mg^{+2}/Al^{+3}/Si^{+4} etc}

→ measurement by Spectrophotometric Technique

titrant ⇒ versenate soln
$\frac{N}{50}$ EDTA
ethylene diamine tetra acetate

Indicator – EBT
red → Blue
initial final

types

carbonate hardness (CH) or temporary hardness	HCO_3^- & CO_3^{--}	min (TH, Alk)
non carbonate hardness (NCH) or permanent hardness	SO_4^{--}/Cl^-/NO_3^- nitrate	TH – CH

Ind
noti:- Zero hardness by → ion exchange method / zeolite method / Base exchange treatment

noti:
$CaCO_3$ & $Mg(OH)_2$ ⇓ least soluble

→ British degree of hardness → 14.25 mg/lt as $CaCO_3$
→ French → 10 " " "

⑤ chloride content as ('Cl') (250–1000) mg/lt

mohr's method ($\frac{N}{35.5}$ $AgNO_3$, Potasium arsenate ($K_2Cr_2O_4$)) → Brown red ppt is formed at end of titration.

argentometric method

• sudden increase → Organic Pollution

Ind
noti → total concentration of chlorine → By (SNORT) method (Amperometric titration)

⑥ Nitrogen content

Ind
noti:-
free ammonia + organic ammonia ⇒ kjeldal nitrogen

if nitrate excess → Blue baby disease (methemoglobinemia) (affect health of infants)

nitrogen content And Presence of organic matter

free ammonia
0.15 mg/lt
• recent pollution
• Simple Boil & measure

organic ammonia
0.3 mg/lt
or Albumonoid
• quantity of nitrogen Before decomposition or organic complex nature
• Boiling + Kmno4 (Alk. soln)

NO_2^- Nitrite
(0)
• Partial decomposition condition
color match (SAN)
Sulphonic acid + naphthamine

NO_3^- Nitrate
(45) mg/lt
• old pollution / fully decomposed / fully oxidised
color match (PAPN)
phenol di-sulphonic acid + potasium hydroxide

⑦ floride

acceptable limit = 1 mg/lt → upto 1 mg/lt floride required → for growth of permanent teeth and to prevent dental cavity

rejection limit = 1.5 mg/lt → floride > 1.5 mg/lt

- case-1: floride 1.5 – 2 mg/lt → mottling of teeth (discoloration of teeth)
  - note → infants affects, not adult
- case-2: floride > 5 mg/lt → Bone fluorosis & skeleton deformation (Deformation of Bone)

⑧ Disolve oxygen (DO)

→ measurement by winkler method for (Pure water)

NaOH + KI

titrant = $\frac{N}{40}$ $Na_2S_2O_3$ Sodium thiosulphate

indicator → starch

- if Brown ppt. ($MnO_2\downarrow$) → (H added) → DO present
- if white ppt ($Mn(OH)_2\downarrow$) → " → DO absent.

note:- modified winkler method (if water has ferric ion, nitrite ion)

titrant:- $\frac{N}{40}$ $Na_2S_2O_3$ + (NaOH + KI + NaN_3 (azide) **)

Indicator - Starch

temp	Saturated DO (mg/lt)
0°c	14.62
20°c	9.17
30°c	7.63

increase: effect on DO

Temperature	Solubility of gas ↓ DO ↓
chloride ion	DO ↓
Pressure	DO ↑

Some other Topics :-

① COD :-

method → dichromate method

Indicator → ferroin

Use :- $K_2Cr_2O_7 + H_2SO_4$

- $K_2Cr_2O_7$ → good oxidising agent
- H_2SO_4 → to reduce PH so that it increases oxidising power of $K_2Cr_2O_7$.

- a sample of domestic sewage is digested with
  - $AgSO_4$ (silver sulphate)
  - H_2SO_4 (Sulphuric acid)
  - $K_2Cr_2O_7$
  - $HgSO_4$

The digested sample is then titrated with standard Ferrous amonium sulphate (FAS) to determine unreacted amount of $K_2Cr_2O_7$.

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② jar test → to know coagulant doses

Biological water quality Parameter :-

Pathogen Bacteria → difficult task to test in lab & count.

∴ we count → presence of coliform (E-coli)

⇓

(harmless aerobic lactose fermenters organism)

note: if coliform absent → then pathogen absent

Test of coliform

- membrane filtration Technique
  - Nutrient → M-Endo medium
  - Coliform colonies Counted.
- MPN Test (most probable no.)
  - By multiple tube fermentation test.
- coliform Index Test
  - Reciprocal of smallest quantity of sample giving (+)ve B coli Test

MPN, Test → 3 phase :-

(Based on Application of Poisson distribution)

1- Presumptive Test :- (+)ve result test indicate the likely presence of coliform.

2- Confirmed Test - sample from (+)ve tube of presumptive Test is used to confirm presence of coliform.

3- Completed Test - used for obtaining isolated colonies, cells from isolated colonies are gram stained & examined under microscope to confirm the coliform.

MPN calculation
- By MPN table
- By thorna's eqn
- By poisson's distribution formula

Thornas eqn :-

$$\frac{MPN}{100ml} = \frac{\text{no. of (+)ve tube} * 100}{\text{ml of sample in (-)ve tube} * \text{ml of sample of all tubes}}$$

Water Borne Diseases

Bacteria	virus	Protozoa
1- Typhoid (Salmonella typhi)	1- Jaundice (Hepatitis virus)	1- Amoebic dysentry (entamoeba histolitic Jerm)
2- Cholera (vibrio cholera)	2- Polio (Poliomylitis)	
3- Bacillary dysentry (sonne bacilus, shiga, flexner)		

Nuisance bacteria

- Iron (fe-bacteria) → Pitting and tuberculation in Pipe → unsuitable for Industrial purpose
- Sulpher-Bacteria → durability affected
  - acid produced during their metabolism is destructive to concrete & other structure hence durability affected.

V. Imp.

As per IS : 10500 latest version – 2012 for Drinking water :-

	water quality Parameter	Permissible limit	Cause for Rejection
Physical	Suspended solids	500	2000 mg/lt
	turbidity	1	5 NTU
	color	5	15 hazen (Zn)
	taste & odour	1	3 TON
	temp	10 – 25°C	10–25 otherwise reject
Chemical	total dissolve solids	500	2000 mg/lt
	Alkalinity	200	600 mg/lt
	hardness	200	600 mg/lt
	pH	(6.5 – 8.5)	(6.5 – 8.5) otherwise reject
	Chloride content (as 'Cl')	250	1000 mg/lt
	free amonia	0.15	0.15 mg/lt
	organic amonia	0.30	0.30 mg/lt
	nitrite	0	0
	Nitrate	45 mg/lt	45 mg/lt
	Sulphates (SO_4^{-2})	200	400 mg/lt
	floride	1	1.5 mg/lt
	free residual chlorine	0.2	1 mg/lt
metals	Iron (Fe)	0.3	no relaxation (0.3) mg/lt
	manganese (Mn)	0.1	0.3 mg/lt
	copper	0.05	1.5 mg/lt
	Calcium (Ca)	75	200 mg/lt
	Zn (Zinc)	5	15 mg/lt

(lung/respiratory problem)

dangerous metal order :- Hg (मरकरी) > Cd > lead (Pb) > Arsenic > Ni > Cr & CN

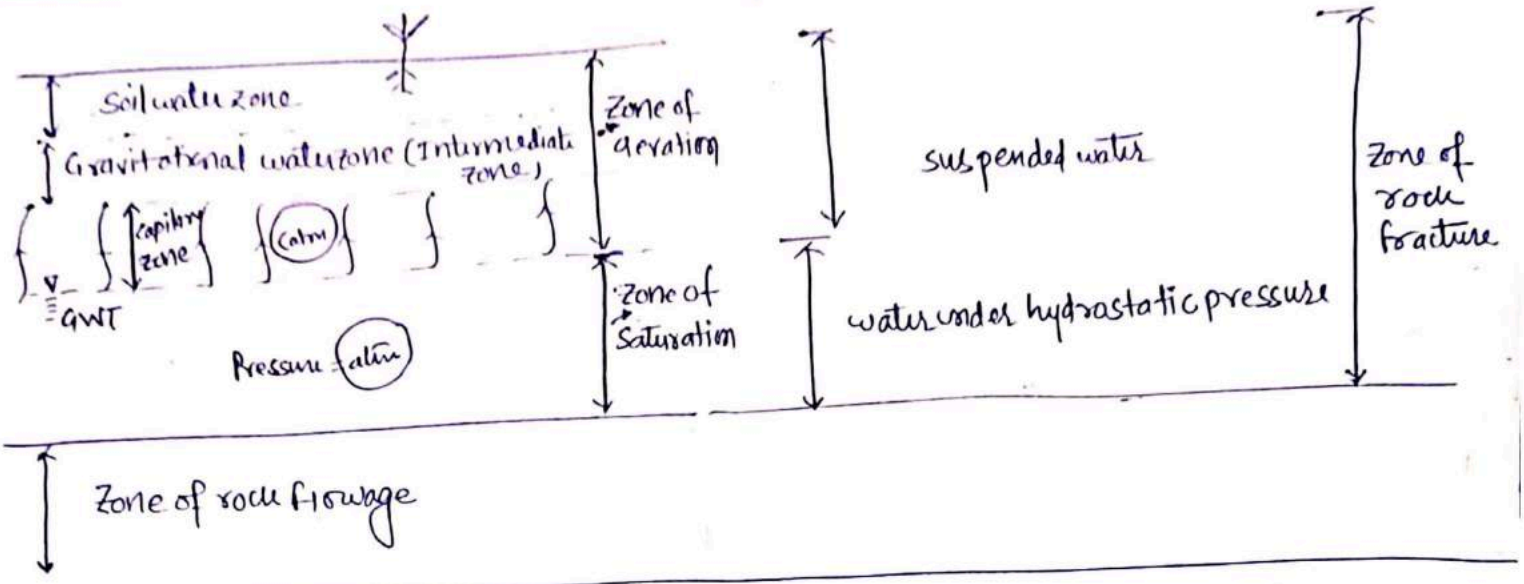
(खतरनाक)

metal
- toxic → Barium / Hg / Cd / lead / Arsenic / Ni / Cr / CN
- nontoxic → Ca, K, Na, Fe, Mn, Zn

Na → measured by Atomic absorption technique

Fe, Mn → cause color problem

Development of grd. water



(I) Soil water zone :- water drawn by vegetation, unsaturated except period of heavy infiltration.

Soil water zone / soil moisture zone

- Hygroscopic water
  - water on soil particles held by adsorption* force in form of thin Film layer with soil water tension = 31 atm.
- Capillary water
  - water held by surface tension* in capillary voids with thick film with soil water tension = $\frac{1}{3}$ atm.
- Gravitational water
  - water that can be moves freely by gravity* through pores & drain out from of soil

(II) Intermediate zone → above capillary zone, all infiltration water must pass through it.

(III) Capillary zone →
- above zone of saturation.
- Pressure < atm. pressure (101.3 KPa)
- unsaturated zone (partially zone)

$$h = \frac{4T\cos\theta}{\rho d g}$$

(IV) Zone of saturation →
- below Ground water table (GWT)
- pores completely filled by water
- Pressure = atm. pressure

from ground water utilization →

Saturated formation

- **Aquifer** → fn: to store water, transmit + store water
  - sand deposits, gravel forms good aquifer.
  - not only store water but yield sufficient water
  - Porous + Permeable.
- **Aquitard** → sand–clay unit
  - only seepage possible, yield Insignificant in comparison to aquifer
- **aquiclude** → formation like clay
  - high porous (∵ voids more) But not permeable (due to small size voids)
- **Aquifuge**
  - massive compact rock without any fracture
  - neither porous nither permeable.

Aquifer

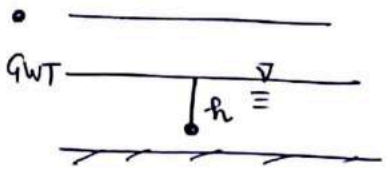
- (Gravity well)
  - unconfined aquifer
  - water table aquifer
  - Phreatic aquifer
- confined aquifer
- artesian-aquifer.

water level in dugwell is same as level of water in unconfined aquifer.

- special case of unconfined aquifer → perched aquifer

① **unconfined / water table / Phreatic aquifer** :

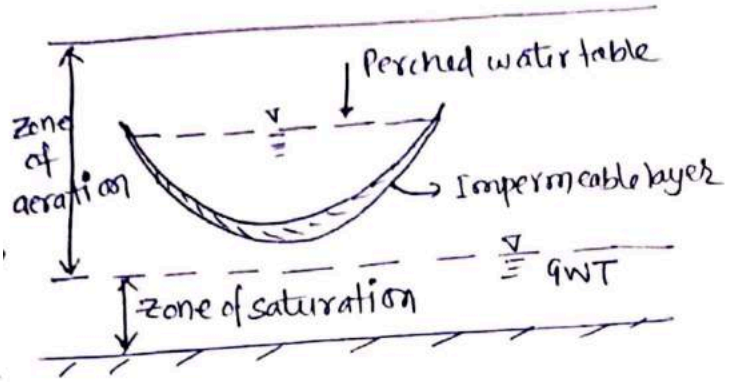
- In this gravity well exists
- absence of layer (above GWT) confining zone of saturation → ∴ unconfined aquifer.



hydraulic head at any point in unconfined aquifer = h = depth of point below GWT

- unconfined aq.
  - water withdrawn → GWT ↓
  - water recharge → GWT ↑

special case of unconfined aquifer
→ perched aquifer :-



- perched aquifer → above GWT exist
- Infiltrated rainwater intercepted by Impermeable layer & local zone of saturated formed. upper surface of zone is perched water table.

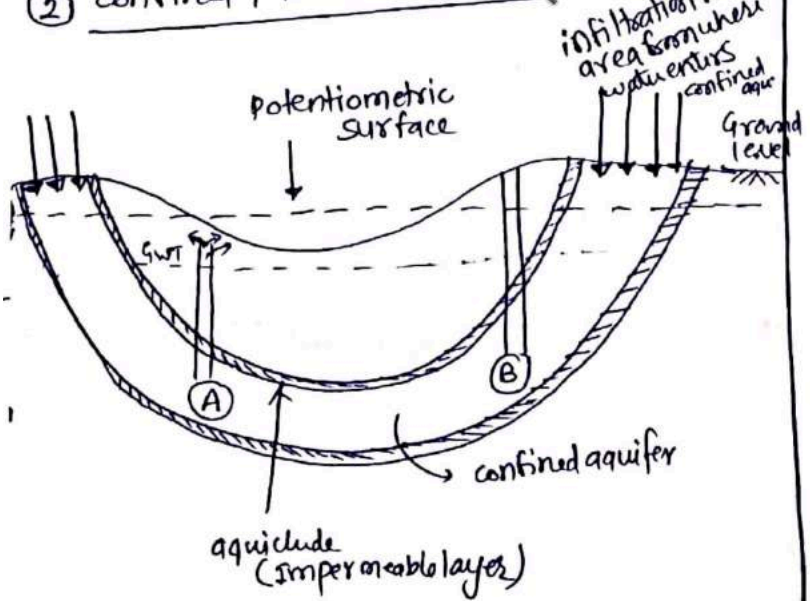
(A) → flowing well → when grd. level is below potentiometric surface

(B) → non flowing well → when grd. level is above of Potentiometric surface.

potentiometric surface :-
- level upto which water will rise in the well
- Indicates magnitude of pressure within confined area.

- confined aquifer overlain by aquicude (Impermeable layer)
- confined aquifer not directly contact with atmosphere.
- Ground water within confined aquifer
  pressure > atm. pressure
  ↓
  artesian pressure or confined pressure

(2) confined / artesian aquifer



- well dug in confined aquifer
  → water rises in well, due to release of pressure within confined aquifer.

Some Important Definitions :-

(1) $\text{Porosity } (n) = \frac{V_v}{V}$

V_v → volume of porous medium or aquifer material.

(2) specific yeild :- actual volume of water that can be extracted by gravity from unit volume of aquifer material (Porous medium)

$\left(\frac{V_{wy}}{V}\right)$ (S_y)

(3) specific retention S_R (field capacity) :- fraction of water held back in aquifer per unit volume of aquifer material.

$\frac{V_{wR}}{V}$

note :- for unconfined aquifer :-

$S_y + S_R = n$ → Porosity

$\frac{V_{wy}}{V} \quad \frac{V_{wR}}{V}$

(4) formation coefficient

- Storage coefficient (S)
- coefficient of transmissibility (T)

$T = KB$ or $T = KH$

(5) Storage coefficient (S) :-

- volume of water given by unit plan area of aquifer when piezometric surface falls by unity. Ans

S

- unconfined aquifer → $S = S_y$
- confined aquifer / artesian aquifer → $S = \gamma_w n B \left[\frac{1}{k_w} + \frac{1}{n k_s}\right]$

$n = \frac{V_v}{V}$ (porosity) — thickness of confined aquifer — B by expansion of water — by compression of soil grain

note :

Storage coefficient due to expansion of water (%)

$$= \frac{\gamma_w n B \left[\frac{1}{k_w}\right]}{\gamma_w n B \left[\frac{1}{k_w} + \frac{1}{n k_s}\right]} \times 100$$

(6)

Specific storage (S_s) = Storage coefficient (S) / Depth of confined aquifer (B)

- Solely due to compression of aquifer and expansion of water
-

Trial (UP) — equation of motion — Trial (CS)

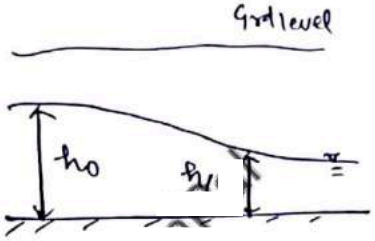
for unconfined aquifer

HGL (water surface) → parabola

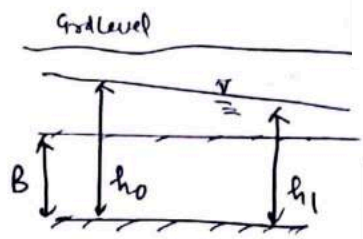
for confined aquifer

HGL → straight line

(7) Specific capacity = discharge / drawdown



$$q = \frac{k(h_0^2 - h_1^2)}{2L}$$



$$q = \frac{kB(h_0 - h_1)}{L}$$

(per unit width)

(8) Intrinsic / specific permeability :-

unit = m^2 or darcy

$\Rightarrow \frac{K\mu}{\gamma_w}$

Independent of fluid property

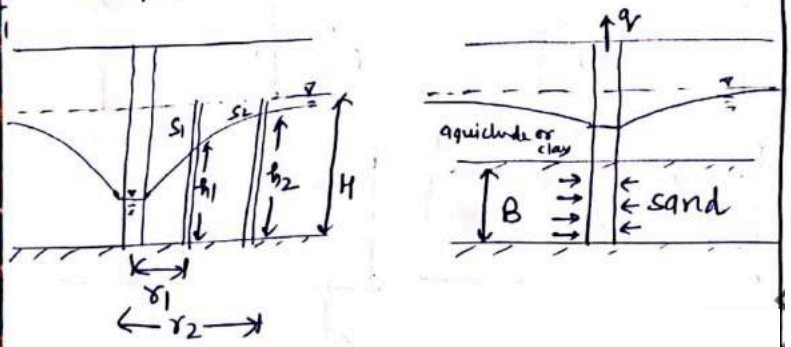
1 darcy = $10^{-15}\ m^2$

Pumping In Test → for smaller area

- Open end Test
- Packer Test

Pumping out Test → for large area

- For unconfined aquifer (Dupits theory)
- confined aquifer (Theim's theory)



$$R = 3000 S \sqrt{K}$$

(Radius of influence)

$$K = \frac{2.303 q \log\left(\frac{r_2}{r_1}\right)}{\pi (h_2^2 - h_1^2)}$$

→ dupit

$$K = \frac{2.303 q \log\left(\frac{r_2}{r_1}\right)}{2\pi B (h_2 - h_1)}$$

Note:- originally for unconfined flow, eqn is given by dupit, later modified by theims for confined flow.

Drawback in dupit's & Theim's theory

↳ to achieve equilibrium condition pumping done for long time so that steady flow can be maintained, which is not easy to do.

So adopt non equilibrium formula

⇓

for confined aquifer (or) unsteady radial flow in confined aquifer

$$\text{well function} = W(u) = \int_u^\infty \frac{e^{-u}}{u}\, dt$$

$$W(u) = \ln \frac{4Tt}{r^2 S} - 0.5772$$

$$W(u) = \ln \frac{2.25\, Tt}{r^2 S}$$

T → coff. of transmisibility

S → Storage coff.

r → radius of observation well from pumping well

drawdown in well after 't' time →

$$s = \frac{Q}{4\pi T} \times \text{wellfn}$$

$$s_2 - s_1 = \frac{Q}{4\pi T} \ln\left(\frac{t_2}{t_1}\right)$$

well loss in confined aquifer

↓

total drawdown in well S_w

↓

formation loss C_1Q + well loss C_2Q^2

↓

head loss required to cause laminar flow in porous media.

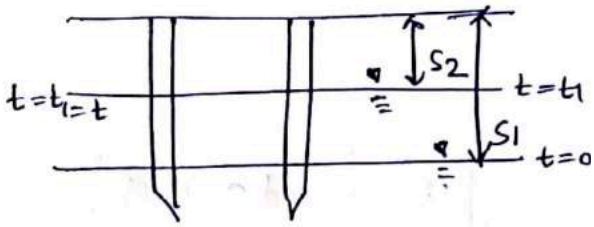
$S_{wt} \propto Q^2$ — drop of piezometric head required to sustain turbulent flow near well

$S_{wc} \propto Q^2$ — head loss in casing and screen.

$$\text{well efficiency} = \frac{\text{formation loss } (C_1Q)}{\text{total drawdown measured in well } (C_1Q + C_2Q^2)}$$

$$\text{Specific capacity} = \frac{\text{discharge } (Q)}{\text{drawdown } (S_w)} = \frac{Q}{C_1Q + C_2Q^2}$$

open well Recuperation Test :-



$$Q = S\,A\left(\frac{C}{A'}\right)$$

S → depression head

A → well area $\left(\frac{\pi}{4}d^2\right)$

$\frac{C}{A'}$ = specific capacity of open well or specific yield

$$\frac{C}{A'} = \frac{2.303}{T}\log\frac{S_1}{S_2}$$

S_1 → Initial drawdown at $t=0$

S_2 → final drawdown at $t=T$

Interference among wells → Q individual of well ↓ But Q total ↑

$Q = Q_1 + Q_2$

$Q = Q_1 + Q_2 + Q_3$

Unconfined aquifer

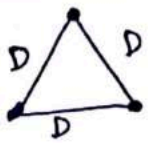
2 wells :-

$$Q_1 = Q_2 = \frac{\pi K (H^2 - h^2)}{2.303 \log\left(\frac{R}{r} * \left(\frac{R}{D}\right)\right)}$$

R → Radius of area of influence
D → distance between wells

3 wells identical → in form of equilateral triangle

$$Q_1 = Q_2 = Q_3 = \frac{\pi K (H^2 - h^2)}{2.303 \log\left(\frac{R}{r} * \left(\frac{R}{D}\right) * \left(\frac{R}{D}\right)\right)}$$



Confined aquifer

2 wells :-

$$Q_1 = Q_2 = \frac{2\pi KB (H - h)}{2.303 \log\left(\frac{R}{r} * \left(\frac{R}{D}\right)\right)}$$

3 wells identical → in form of equilateral triangle

$$Q_1 = Q_2 = Q_3 = \frac{2\pi KB (H - h)}{2.303 \log\left(\frac{R}{r} * \left(\frac{R}{D}\right) * \left(\frac{R}{D}\right)\right)}$$

* Water Treatment :-

treatment based on water → raw water quality
→ output we want (treated water)

water treatment process flowchart :-

Screening – Prechlorination – aeration
aeration → sedimentation
sedimentation → Sedimentation with coagulation aided
Sedimentation with coagulation aided → Flocculation
Flocculation → filtration → Disinfection – watersoftening → minortreatment

1- screening
- coarse screens
- fine screens

2- Prechlorination :- when extremly polluted clear water or there is bacteria, then only adopt.

3- aeration :- add O_2 for oxidation of unclesirable substance like oil, decomposing product of Algae.

- remove disolve gases → CO_2, H_2S
- remove → color → remove Fe, Mn; taste; odour

methods:
- Spray nozzle
- Cascade aerator
- diffused air aerator
- trickling Bed/tray tower

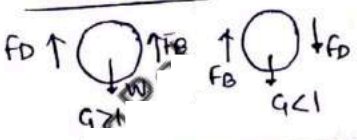
- noti:- Disolve oxygen ↑ ⇒ acidity ↑ = corrosion ↑

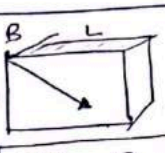
(4) Sedimentation :- ⁿ → remove suspended solids by gravity action

Sedimentation tank
- Quiescent type or Fill & draw type or Intermittent type
  - detention time t_d = 24 hr
  - min no = 3 (1 standby)
- continuous type
  - Horizontal type (Ex. Rectangular)
  - vertical type (Ex. circular)

noti:- min no. of tank → based on → detention time (t_d)
may → discharge Q

Stoke's law :





$SOR = \frac{Q}{BL}$

$V_s = \sqrt{\frac{4}{3}\frac{(G-1)gd}{C_D}}$, $C_D = \frac{24}{Re}$ $Re < 0.5$

$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$ $0.5 < Re < 10^4$

$C_D = 0.410$ $Re > 10^4$

V. Imp

$V_s = \frac{(G-1)\gamma_w d^2}{18\mu}$ { $T = 20^\circ C$, $d < 0.1$ mm }

$V_s = 418(G-1)d^2\frac{(3T+70)}{100}$ $T \neq 20^\circ$, $d < 0.1$ mm

(V_s in mm/sec, d in mm)

$V_s = 418(G-1)d\left(\frac{3T+70}{100}\right)$ $0.1 < d < 1$ mm

$V_s = 1.8\sqrt{gd(G-1)}$ $d > 1$ mm

$t_d = \frac{L}{V_f} = \frac{H}{V_s}$ (V_f → horizontal, V_s ↓)

circular tank $t_d = \frac{d^2(0.011d + 0.785H)}{Q}$

V.V.Imp

noti:-
- $V_s \propto d^2$, $d < 0.1$ mm
- $V_s \propto d$, d (0.1 – 1 mm)
- $V_s \propto \sqrt{d}$, $d > 1$ mm

- SOR ↑ η ↓

SOR decide efficiency of tank

$$\eta = \frac{V_s}{V_o\,(SOR)} \times 100$$

- Settle concentration = total − removed conc. $\left(\frac{V_s}{V_o} \times 100\right)$

- displacement efficiency = $\frac{\text{Flow through period } (F)}{\text{detention period } (D)}$

{ (due to current produced by coming fluid (short circuiting)
F < D)

detention time (td)

- Plain sedimentation — 4–8 hr
- Sedimentation with coagulation — 2–4 hr

SOR

(12–18000) (lt/m²/day) (18–24000)

⑤ coagulation aided sedimentation

- fn → to remove fine suspended solid
- coagulant dose → by Jar Test

Coagulation → process of adding chemicals in water to destablize the surface-charge of colloid particles so that free contact b/w them can take place.

mechanism of coagulation :-

1- Ionic layer compression
2- adsorption & charge neutralization
3- sweep coagulation
4- Inter particle Bridging.

coagulant	Description
Alum $Al_2(SO_4)_3 \cdot 18H_2O$ Aluminium Sulphate (6.5–8.3) range PH	• commonly used • dose (10–30 mg/lt) • Flocs formed are stable • reduce color, taste, odour. $Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(HCO_3)_2$ 666 — 486 (162×3) $3CaSO_4 + 2Al(OH)_3 + 6CO_2\uparrow + 18H_2O$ (Permanent hardness) (ppt. gelatine) — corrosion ↑ PH ↓ 2×78 = 156 ∵ $Ca(HCO_3)_2$ utilization → hence decrease Alkalinity. $CaO + CO_2 \rightarrow CaCO_3 \xrightarrow[H_2O]{CO_2} Ca(HCO_3)_2$ (56) quick lime (100) (162) If Alkalinity not sufficient add lime {gives no acidity} — add soda ash (Na_2CO_3) (gives acidity) Alum + $Ca(OH)_2$ → $3CaSO_4 + 2Al(OH)_3 + 18H_2O$ (Permanent hardness) Alum + $3Na_2CO_3$ → $3Na_2SO_4 + 2Al(OH)_3 + 3CO_2\uparrow + 5H_2O$ (acidity)
copperas ($FeSO_4 \cdot 7H_2O$)	• commonly used for treating sewage. • Heavy flocks • PH range > 8.5
chlorinated copperas $Fe_2SO_4 + FeCl_3$	• not for colored water • effective in color removal also • works in large PH range • for low PH water treatment. • They are effective in combination with lime.
Sodium Aluminate ($Na_2Al_2O_4$)	• costly coagulant • beside coagulation, reduce hardness (zero hardness water can be got) • Useful for water which don't require alkalinity.

mixing Basin :-

rapid mix T = 60 sec

GT → measure of coagulation opportunity

$G = \frac{V_2 - V_1}{x}$ (sec⁻¹) ⇒ measure of relative velocity of 2 particles of fluid & distance between them.

$G = \sqrt{\frac{P}{\mu V}}$ (P → W, μV → m3, G → sec⁻¹, μ → NS/m2)

G → temporal mean velocity gradient

⑤ Flocculation :- coagulation opportunity ↑↑

- Size of flock (t↑ size↑)
- density of flock (G↑ density↑)

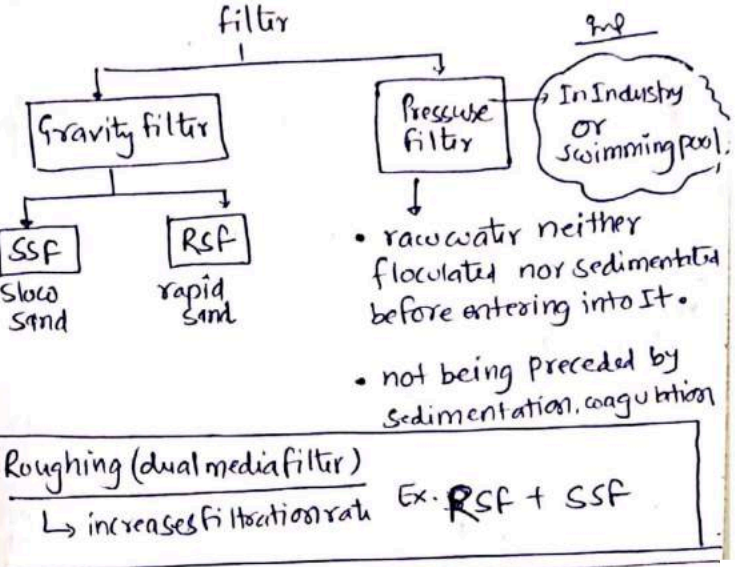
$\frac{G_{inlet}}{G_{outlet}} = 2$

Rate of Flocculation depend → turbidity, type of coagulant & its dose, G

Imp.

note :- clarriflocolators = flocculation (in Inner tank) + sedimentation (in outer tank)

⑦ filtration :- remove → floc particles, color, microorganism, fine suspended solids particles



Roughing (dual media filter) → increases filtration rate Ex. RSF + SSF

Theory of filtration

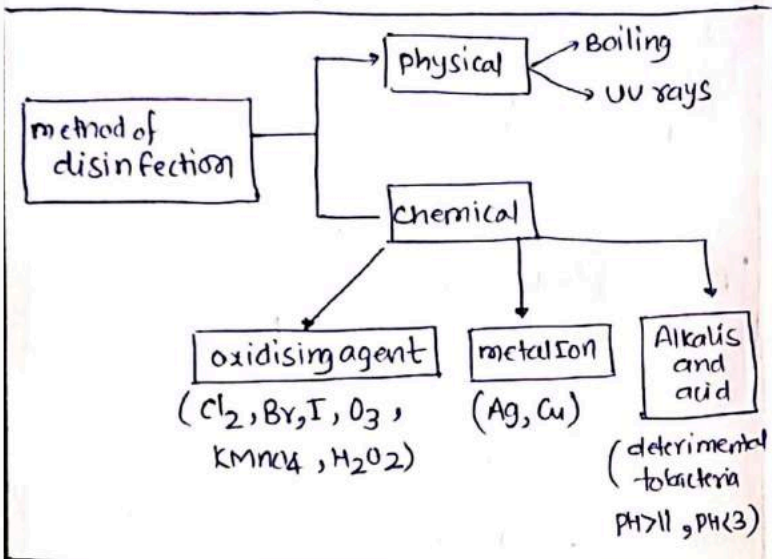
mechanical Straining (remove SS) ⇒ Sedimentation (remove SS) → Biological action (remove DOM, bacteria) → electrolytic changes (dissolve mineral removal)

Slow sand filter (SSF)	Rapid sand filter (RSF)
Operation cost low ∵ no other energy source required.	
Rate of filtration = 100–200 lt/hr/m²	30 times of SSF (3000–6000) lt/hr/m²
D_{10} 0.20 – 0.30, $2 < C_u < 3$	D_{10} 0.35 – 0.55, $1.3 < C_u < 1.7$
• not use after coagulation aided sedimentation otherwise floc will chock it.	• very efficient in color removal
	$N = 1.22\sqrt{Q_{m/D}}$ $N_{min} = 2$
frequency of cleaning = 1–3 month	$(1-n)D = (1-n_e)D_e$ if expansion = 50% ∴ $D_e = 1.5D$
Bacteria removal = 98–99%	
Can not use if turbidity > 50 ppm	$n_e = \left(\frac{V_b}{V_s}\right)^{0.22}$
remove → taste, color (due to om) → color removal (less efficiency)	$h_L = D(1-n)(G-1)$
area > 1200 m² min 6 unit (5+1)	Problems in RSF operation :- ① air binding ② Mud Ball formation ③ cracking of sand Bed ④ Bumping of filter Bed.

⑧ Disinfection :- process of removal of disease causing micro-organism (harmful) Bacteria

- Sterilization → process of removal of all types of microorganism.

{(doing disinfection does not mean sterlization is done)}



1- UV rays :- not for turbid water (10-15 PPM)

2- O_3 :- • removes color, taste, odour also
- gives highest quality water
- do esnot ensure safety against recontamination

3- $KMnO_4$:- used in rural area
- 100 % cholera causing bacteria removal.
- produce dark brown precipitate on utensils
- if pink color disappear means OM present

Recarbonation :- most common process to reduce pH. (6.5-8.5)

- $CaCO_3$ ppt soluble by pasing CO_2 for less load on filter.

Chick watson law :- $C^n t$ = constant { ∴ for a particular disinfectant

$\log \frac{N_0}{N} = 1$ one log disinfection

$\log \frac{N_0}{N} = 2$ 2 log disinfection

$\frac{N}{N_0}$ = const.

Chlorination :- By this pathogens killed

- process of adding chlorine (Cl_2) or hypochlorite ion to water
- used to prevent the spread of water borne disease → cholera, dysentry, typhoid

Types of chlorination :-

① Plainchlorination :- → only chlorination & no other treatment given to water.
- remove bacteria, OM, color
- dose ⇒ 0.5 mg/lt
- used when turbidity (20-30 mg/lt)

② Prechlorination :- in this chlorine is added before filtration or rather before sedimentation & coagulation.
- used when concentration of pathogenic bacteria is higher.

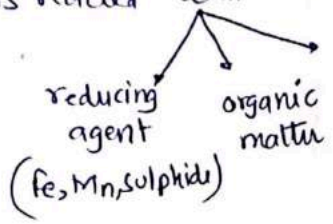
③ Superchlorination (Excesschlorination) :-
- whenever excess chlorine (5-15 mg/lt) is added in water during epidemic such that its residual chlorine >1 to 2 mg/lt above breakpoint chlorination)

④ Break point chlorination :- ***

close = demand + residual

- Break point is a point at which the chlorine demand has been totally satisfied.

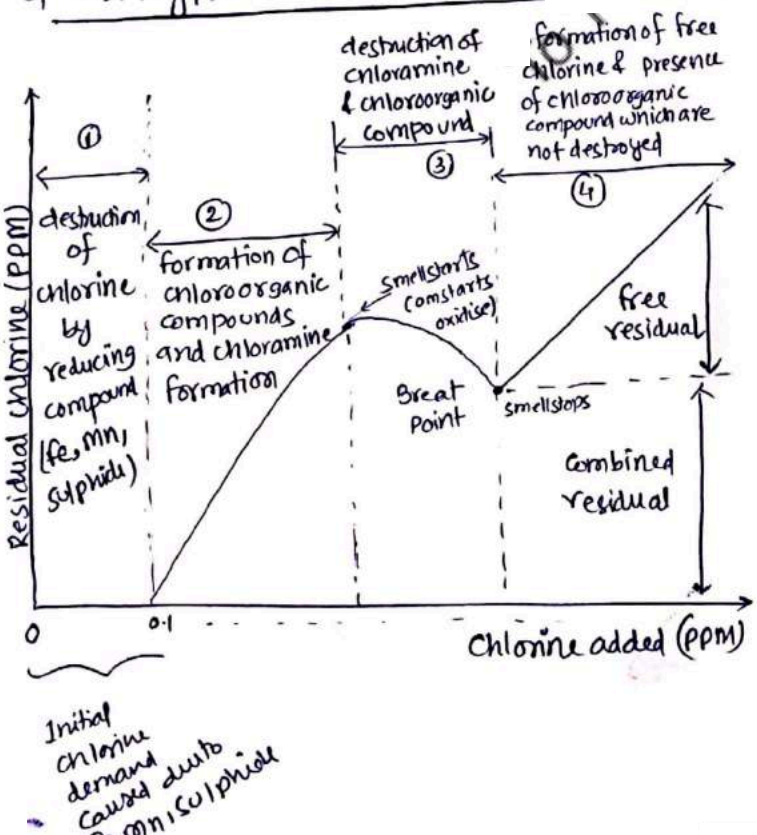
(chlorine has reacted with in water.



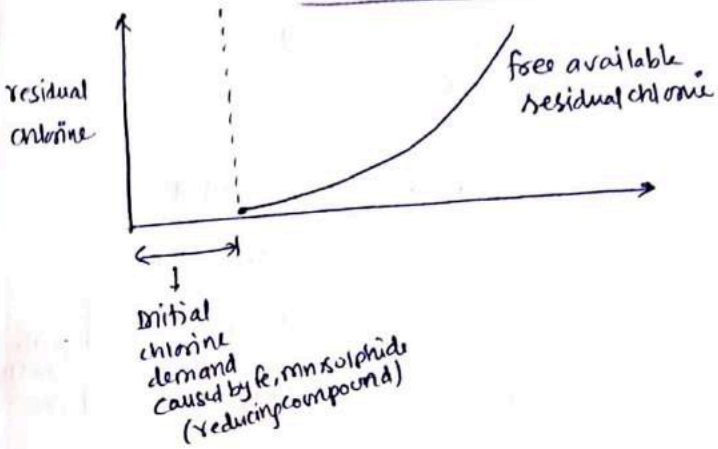
- After this point whatever chlorine is added breaks free from it and appears as a residual chlorine hence this point is referred as break point.

- The amount of Cl_2 required to reach upto this point is referred as break point dose.

- Theortically no chlorine is rep. to be added beyond breakpoint but practically it is added to ensure residual chlorine of 0.2 mg/lt at contact period of 10 min.



special case :- when no amonia or organics are present in water.



Reaction / Theory behind chlorination :-

Imp

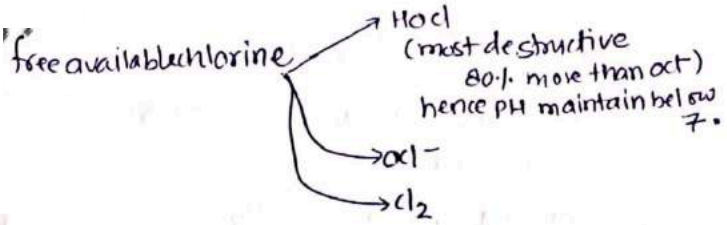
Chlorination | Best PH range → 5 to 7

$$Cl_2 + H_2O \xrightleftharpoons{PH<5} HOCl + HCl$$

(free chlorine)

$$HOCl \xrightleftharpoons[PH<7]{PH>8} H^+ + OCl^-$$

(unstable hence breakdown at high PH)



note:- moreover chlorine will immediately react with amonia present in water to form chloramines.

$$NH_3 + HOCl \xrightarrow{PH\,7\text{-}7.5} NH_2Cl + H_2O$$

(monochloramine) no disinfectant property

$$NH_2Cl + HOCl \xrightarrow[PH]{5\text{-}6.5} NHCl_2 + H_2O$$

dichloramine (predominant) Imp

$$NHCl_2 + HOCl \xrightarrow[PH]{<4.4} NCl_3 + H_2O$$

note: ∵ PH maintained 5 to 7 hence dichloramine ($NHCl_2$) Predominant.

Imp

Chloramine combined form of chlorine less effective than free chlorine (25 times less) But they are stable and remains in water for great duration.

forms in which chlorine is added :-

(i) as free chlorine (gas or liquid form)
(ii) as hypochlorite (Bleaching powder) → no sludge formed
(iii) chloramines (amonia + chlorine) → no sludge formed
(iv) chlorine dioxide ClO_2

residual chlorine Tests :-

(i) orthotolodine Test → measure combined & free chlorine
(ii) DPD Test
(iii) chlorotex Test
(iv) Starch Iodine Test

Imp

Dechlorinating agent / process :-

1- $Na_2S_2O_3$ (sodiumthio sulphate) cheapest
2- Activated carbon → costly
3- SO_2
4- UV (solar radiation)
5- Reverse osmosis
6- evaporation, freezing, electrodyalysis.

(3) water softening :- $Ca^{+2}/Mg^{+2}/Fe^{+2}/Sr^{+2}/Al^{+3}$

Hardness (due to multivalent cation)

- temporary hardness (carbonate hardness) → due to presence of CO_3^{-2}/HCO_3^- of Ca^{+2}, Mg^{+2} → Removal by: Boiling, Lime addition → ppt remove by sedimentation & filtration, rich Ref.
- Permanent hardness (non carbonate hardness) → due to $SO_4^{-2}/Cl^-/NO_3^-$ of Ca^{+2}, Mg^{+2} → Removal by: Lime-Soda Process; Zeolite or ion exchange method → Gives zero hardness water; De-mineralisation → remove mineral in water

(b) Minor Treatments :-

① Activated carbon
- Good adsorbent due to its high surface area to volume ratio
- Size 0.1-2mm

Activated carbon → removes taste, odour, color

- remove Phenol type impurity.
- dechlorinating agent
- add before or after coagulation But before [redacted] filtration.

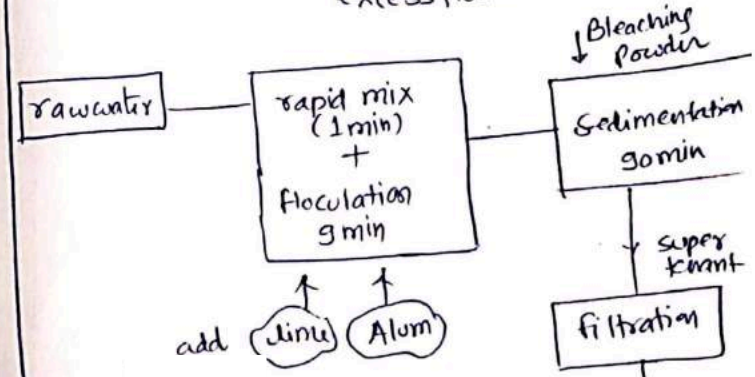
② $CuSO_4$ → kill algae.

③ Removal of Fe, Mn
- without organic matter → aeration → sedimentation → filtration
- combine with organic matter → oxidant
  - water [redacted] to Break bond with Lime / Cl_2 / $KMnO_4$

④ Floridation (addition of Florine)
- NaF (Sodium floride)
- Na_2SiF_6 Sodium Silico-fluoride
- H_2SiF_6 Hydrosilic acid

⑤ Defloridation (excess florine removal) :-
1 - Absorption by activated Alumina (Prashanti Technology)
2 - Nalgonda Technique
3 - ion exchange adsorption method
4 - reverse osmosis process.

Nalgonda Technique :- mainly used in rural area where grd. water contains excess floride.



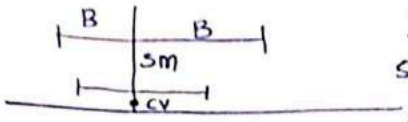
⑥ Desalination :-
- By Reverse osmosis
- By electrodialysis
- By freezing

⑦ removal of toxic metals :-
(By coagulation added sedimentation)

21/3/2020

layout of distribution system

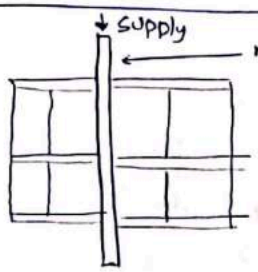
1) dead end system



B → Branch
sm – submain
CV → cut off valve

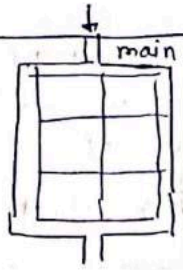
- followed for old town where houses are situated in unplanned way
- water reaches by only 1 route → disadvantage.

2) Grid Iron system



- main pipe run through centre.
- branch & latural run in grid pattern which are interconnected.
- since main, branch, latural are interconnected hence dead end eliminated and water reaching at different location by more than 1 route.

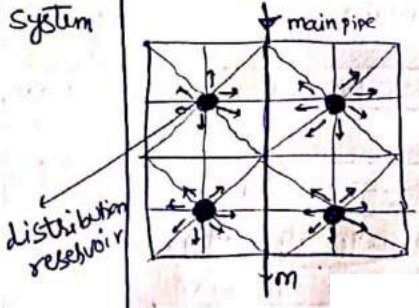
3) Ring System or circular system



- main pipe all around the area.

4) Radial system

- In this water flows towards the outer perifery.



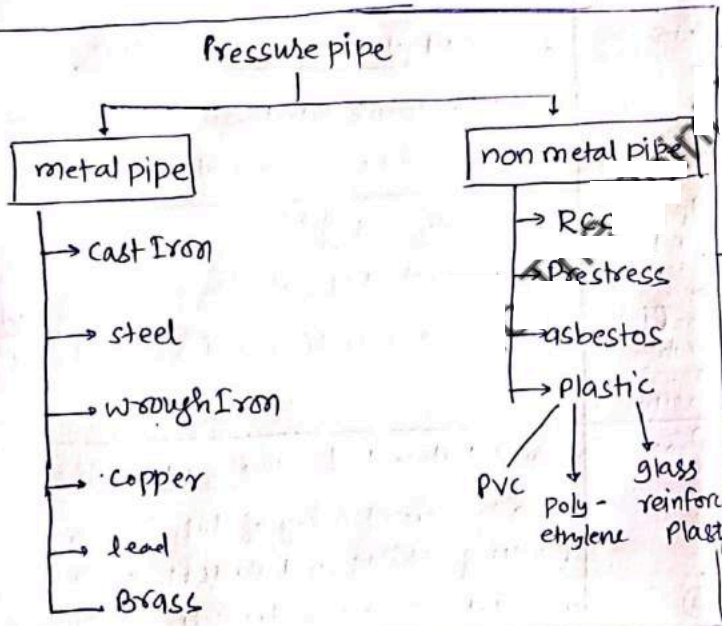
- A big area is divided in several zone and at the centre of each zone a distribution reservoir is kept
- This method gives higher service head and efficient water distribution.

Pipe Appurtenances

① sluice valve or Gate valve or shut off valve note:- stopcocks (small size sluice valve)	fⁿ → to regulate flow • essential to divide the mainline into sections • Provided at summit (∵ pressure → low) • made of Iron with Brass mounting solid wedge type, double disk type
② Air-relief valve or air valve	• provided at summit on d/s of sluice valve to release air pressure (otherwise due to accumulation of air, a backward pressure is generated which cause blockage of flow of water
③ check valve or reflux valve or non return valve ** [Automatic works]	• allows water only in one direction. • made by brass or gun metal • provided in pipeline which draws water from pump
④ scour valve or blow off valve or drain valve	• Provided at dead end of pipeline fⁿ → to remove sand, silt from pipeline (It is similar to sluice valve but fⁿ different)
⑤ Pressure relief valve or relief valve or safety valve	• Automatic works ** • used to control / limit the pressure in system (otherwise bursting or Instrument fails)
⑥ foot valve	• Provided at end of pump suction pipe fⁿ → to prevent entry of debris into pumping system and Back flow also
⑦ Butterfly Valve	• Provided in large diameter size pipe. • High head loss than sluice valve ∴ not suitable for continuous Throttling / regulation (कम-ज्यादा)
⑧ Ball Valve or Ball Float valve	fⁿ → maintain constant level in service reservoir.

(9) Globe Valve 	• change direction through 90 degree twice ⟶ ∴ high head loss
(10) needle cone valve	• for throattling flow (regulation purpose)
(11) Pilot valve	• human operated • used in critical Application (emergency + safety control) • (high pressure or high flow feed)
(12) Bibcocks	• Small size water tap < wash basin, bathroom • gun metal / plastic

Pipes	Description
Cast Iron pipe	• not for pressure > 700 kN/m² • Use :- water supply for trunk + distribution system
Steel pipe	• where water pressure ⟶ High & size ⟶ large • (not to withstand external load of backfill or traffic.)
Wrought Iron	• Inside Building ⟶ service connection • easy workability • for protection against corrosion ⟶ galvanizing (zinc coating) ∴ GI pipe ⟶ liable to affect by acidic or alkaline water
Copper Pipe	• Highly resistant to acidic & Alkaline water. • Used for hot water carrying inside factory / building
Lead Pipe	• more common in sanitary fitting • not for domestic water supply ∵ lead poisoning chances
Brass Pipe	• decorated plumbing, harder than copper pipe
Prestress pipe	• withstand High pressure, corrosion resistance
RCC pipe	mostly in water main
Vitrified clay pipe	• not for pressure pipe • for carrying sewage
Asbestos pipe	• made of (Silica + cement) • not suited in (sulphate soil). • Highly resistant to corrosion • due to expansion / contraction of Black soil use of these pipes avoided..



Corrosion control in metal pipes

- Quality of water
  - (i) pH ↑ (Alkalinity ↑)
  - (ii) CO_2 ↓
- Protective coating
  - (i) Paint
  - (ii) galvanizing (Zn-coating)
  - (iii) cement lining

Joints in water supply pipes :-

) Spigot & Socket Joint	Plain end → spigot end enlarge end → socket • mostly used for cast Iron, steel pipes this joint used.
collar Joint	• RCC pipe, asbestos cement pipe ∴
expansion Joint	• in metal pipe (to account change in pipe length) (thermal variation)
flange Joint	• for temporary work (where we dismantle pipeline / shifted) CI/steel • not used where deflection, vibration comes
flexible Joint	• where settlement of pipe may occure.
Threaded Joint	GI pipes
simplex Joint	in asbestos pipe • pipe sleeves + rubber gasket

laying of sewer :

from their out fall ends
(towards starting end)

Reason → utilization during initial period of construction
(not wait for completion of entire scheme)

Steps of laying of sewer :

(i) mark alignment (By theodolite + Invar tape)

- Referencing line method
  - ref. line
  - centre line
- sight rail method

(ii) Trench excavation

(iii) Bracing of trench

(iv) dewatering of trench

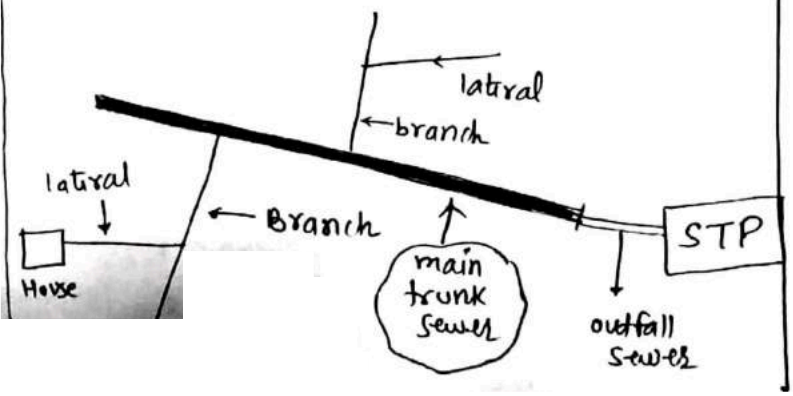
(v) lay & join pipes

(vi) Testing of Leakage in sewers

- By water Test
  - carried out b/w 2 manhole
- By air Test
  - for large dia. sewer
  - measure pressure, if drops then leakage

note:- apply soap solution to get exact location of leakage.

Design of Sewer system :



sewer design → not design for full flow
{ Reserve space for fluctuations in sewage flow }

sanitary sewage ⇒ domestic + Industrial sewage

storm sewers ⇒ for storm water + ground water
(not for domestic + Industrial)

Combined discharge = sanitary discharge (domestic + Industry) + Storm discharge

combined Sewerage System :-

- single sewer line of large diameter through which < sewage + storm > pass to treatment plant

advantage

(i) dilution → strength ↓

(ii) self cleansing velocity achieved (✓)

(iii) economical → ∵ single sewer line serve double function.

Velocity formula

manning's formula

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

Hazen william formula

good for close conduit / pressure flow

$$V = 0.854_H \, R^{0.63} \, S^{0.54}$$

chezy's formula

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

kutter's formula :-

$$C = \frac{\frac{1}{n} + \left(23 + \frac{0.00155}{S}\right)}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{n}{\sqrt{R}}}$$

Self cleansing velocity :-

minvelocity at which no solids gets deposited at the bottom of sewer.

Shield's formula :-

$$V = \sqrt{\frac{8\beta}{f}} \sqrt{gd(G-1)}$$

$$\beta = (1-n)\sin\theta$$

(n → Porosity)

note :-

when 2 sewer's → same degree of self cleansing

$$\therefore \quad r_w r_s = r_w R S$$

(i) $\frac{r}{R} = \frac{S}{s}$ (ii) $\frac{v}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{2/3}\left(\frac{s}{S}\right)^{1/2}$

Put $r/R = S/s$

(iii) $\frac{q}{Q} = \left(\frac{a}{A}\right)\cdot\left(\frac{v}{V}\right)$ ∴ $\frac{v}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{1/6}$ ***

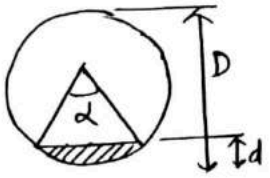
Hydraulically equivalent :-

if $Q_1 = Q_2$ (full flow), $n_1 = n_2$ roughness, $S_1 = S_2$ slope

Ex. circular & square

$D = 1.1B$

Hydraulic characteristic of circular sewer :-



Proportional depth	$\frac{d}{D} = \frac{1-\cos\alpha/2}{2}$
Proportional perimeter	$\frac{p}{P} = \frac{\alpha}{360}$
Proportional area	$\frac{a}{A} = \frac{\alpha}{360} - \frac{\sin\alpha}{2\pi}$
Proportional hydraulic radius	$\frac{r}{R} = \frac{a/A}{p/P}$
Proportional velocity	$\frac{v}{V} = \frac{N}{n}\frac{r^{2/3}}{R^{2/3}}$
Proportional discharge	$\frac{q}{Q} = \left(\frac{\alpha}{360} - \frac{\sin\alpha}{2\pi}\right)\left(1 - \frac{360\cdot\sin\alpha}{2\pi\cdot\alpha}\right)^{2/3}$

- if minvelocity condition not satisfied then
  - dia of sewer ↑
  - increase slope ↑

- In sanitary sewer
  Vmin = 0.8 m/s @ design peak flow
  & Vmin = 0.6 m/s @ current peak flow

max velocity in sewer (concrete) = 2.5–3 m/s

Asper manning's :-

Vmax	$\frac{d}{D} = 0.81$	14 % more velocity than full flow
Qmax	$\frac{d}{D} = 0.938$	7 % more discharge than full flow

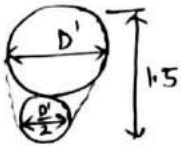
asper chezy's

Vmax	$\frac{d}{D} = 0.81$	+12.5 %
Qmax	$\frac{d}{D} = 0.95$	+5 %

egg shape sewer :-

$D' = 0.84D$

equivalent section



Circular
- advantage – when $\frac{d}{D} > 0.50$
- disadvantage – if $d/D < 0.50$ then velocity reduce

egg shape
- smaller section ($D'/2$) effective → dry weather flow
- upper large section effective → in monsoon season.

Time of concentration = overland flow time + channel flow time

Peak rate of runoff $Q = \frac{1}{36} KiA$ → ha
- Q → m³/sec
- i → cm/hr

$K_{eq} = K_1A_1 + K_2A_2 / A_1 + A_2$

Design Rainfall intensity or Critical rainfall intensity = Point rainfall intensity * areal dispersion factor

$P_c = P_o \left(\frac{2}{1+T_c}\right)$ → hr

P_o = Point rainfall intensity

'or' P_c (cm/hr) $= \frac{a}{t+b}$

t = min (time of concentration)

$t < 20$ min	$a = 75$, $b = 10$	$\frac{75}{30}$
$t \geq 20$ min	$a = 100$, $b = 20$	$\frac{100}{40}$

Sewer Appurtenances :

1- manhole : purpose
- for Inspection
- for Testing
- cleaning
- removal of obstruction from sewer line

depth < 1m → normal manhole

depth > 1.5m → deep manhole

- Built at every change of
  - alignment
  - gradient (slope)
  - diameter
  - head of all sewer and Branch
  - Junction of 2 sewer

dia of sewer (m)	Straight run dist b/w manhole
0.9 – 1.5	90 – 150 meter
1.5 – 2	150 – 200 meter
2 – 3	200 – 300 meter

note:- Before entering manhole, a candle is lowered to check oxygen in manhole

② Junction manhole :- at junction of 2 or more sewer
→ the bottom of small sewer should not lower than that of larger dia, otherwise reverse flow may happen.

③ Drop manhole :- to connect high level branch sewer to low level by vertical pipe. (>0.6m)

④ Flushing manhole :- where self cleansing-velocity not available then essential to provide some form of flushing device to generate minself cleansing velocity.

⑤ Lamphole :- an electric lamp is inserted into sewer for inspection purpose, if sewer is clear, the light will be visible from-adjacent manhole, then cleaning is done accordingly.

⑥ grease oil trap :- when sewage contain grease & oil, otherwise it will stick to interior surface of sewer then carrying-capacity of sewer will be decreased !!!.

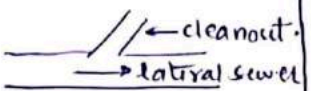
⑦ catch Basin : prevent/eliminate entry of silt, grit from storm water into sewer.

⑧ Storm water Inlet :- to admit surface runoff.

⑨ Cleanout :- Provided in lateral sewer in place of manhole.

↓

inclined pipe connect from sewer to cleaning of sewer



⑩ :- Inverted siphon :- when sewer pipe has to drop below HGL for passing it beneath a valley.

⑪ :- storm water regulator :- to prevent overloading of sewer pumping station, treatment plant by diverting the excess flow to relief sewers.

Imp.

Generally we design branch sewer only

Sewage Q_{max} = 3 × Avg. Flow of sewer

Q_{min} = $\frac{1}{3}$ × Avg flow of sewer.

Waste water pipe :- which carry only liquid waste from kitchen, wash basin

note :- It does not carry human excreta.

note

Vent pipe	Soil pipe
• provide for ventilation purpose to facilitate the exit of foul gases into atmosphere.	• carry human excreta from water closet to septic tank

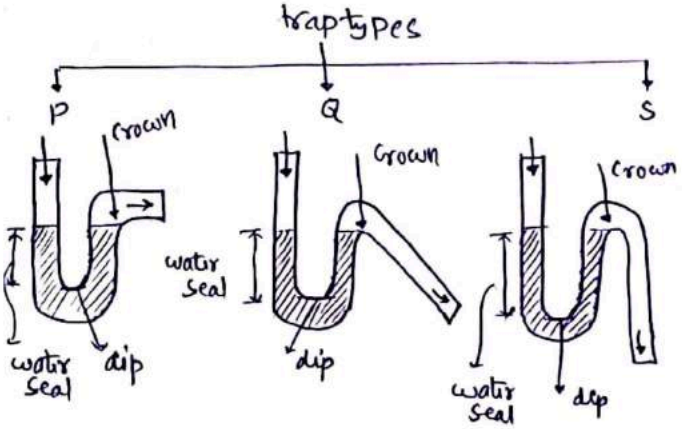
Antisiphonage pipe :- → separate smaller dia pipe installed in house drainage system

fn → to preserve the water seal of trap.

- helpful to seal the back flow of drainage
- It is connected to Top of 'P' trap W.C **

Trap :- used in household drainage system

fn → to prevent entry of foul gases in houses



note :- Intercepting trap :- fn :- disconnect house drain from street sewer so as to prevent the entry of foul gases of municipal sewer into house drainage system

note :- Nahani trap :- generally used to admit sludge from floor of rooms, bathroom, kitchen.

note :- Gully trap / Gully :- Provided at Junction of roof drain and other drain coming from kitchen or bathroom.

note :- 'S' trap / sink trap :- because it is installed under most sinks. of its shape, the trap retains some water after the fixture use.

Bacteria/virus	Description
Vibrio cholerae	• gram negative • comma shape bacteria • causes → "cholera" disease • can cause diarrhoea & vomitting in a host within several hours to 2-3 days of indigestion
Entamoeba histolytica	• anaerobic parasitic amoebozoa • infect humans causes amoebiasis
E-coli (Escherichia coli)	• Parasite living only in human or animal intestine • Detection of E-coli in drinking water is taken as evidence of recent pollution with human or animal face

Aerobic decomposition (Oxidation happens)	Anaerobic decomposition (reduction happens)
Carbonaceous om → (ox.) CO_2	(Red.) → CO_2
nitrogenous → (ox.) NO_3^- nitrate	→ NH_3
Sulphorus → SO_4^{-2} Sulphate	→ H_2S ↑
	organic acid → CH_4 ↑ (↓ methane forming anaerobic bacteria)

Nitrification ($NH_3 \rightarrow NO_3^-$ (nitrate))

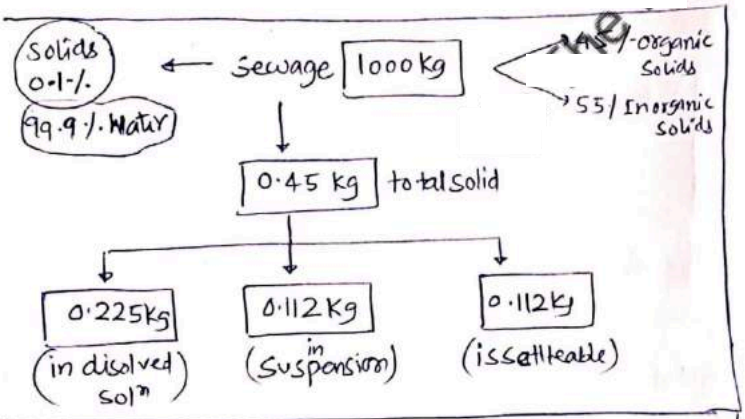
NH_3 —(nitrosomus)→ NO_2^- (Nitrite) —(nitrobacter)→ NO_3^- (nitrate)

aerobic microorganism

Denitrification: NO_3^- (nitrate) —(anaerobic microorganism (Bacaracsus))→ N_2 (nitrogen)

PH of fresh sewage >7 (Alkaline)

But as time passes, it becomes acidic because of the bacterial action in anaerobic or nitrification process.



Solids in sewage (0.1%): [water = 99.9%]

(i) Suspended solid → which remain floating in sewage

(ii) disolve solid → which remain disolve in sewage (just as salt in water)

(iii) colloidal solid → finely divided solids remaining either in solution or in suspension

(iv) Settleable solid → Portion of solid matter, which settles out
↳ measure by Imhoff cone

1 lit. { Sewage is allowed to remain undisturb for a period of 2hr in Imhoff cone }

Disolve oxygen (D.O): min 4 ppm for fish (aquatic)

• determine by → winkler method

(Oxidation reduction process carried out - chemically to liberate iodine is amount equivalent to the quantity of oxygen originally present.

Saturation D.O: max. quantity of D.O that can remain mix in water at particulate temp.

1 atm

temp.	D.O (saturated)
0°	14.6 mg/lt
20°c	9.2 mg/lt
30°c	7.6 mg/lt

Imp

note:- oxygen deficit = (DO)saturate at mix temp. − (DO) actual in Stream

Temp ↑ ⇒ DO ↓

Chloride content ↑ ⇒ DO ↓

Pressure ↑ ⇒ DO ↑

DO ↑ ⇒ Corrosion ↑

or chromate oxygen demand

Chemical oxygen demand (COD) :-

- to measure Biodegradable + non biodegradable om.
- Indicator → (ferroin) Test → (dichromate test)
- $K_2Cr_2O_7 + H_2SO_4 \xrightarrow{\text{add}} O_2$ measure.

  Strong oxidising agent
- for most cases COD ≈ ThOD

Theortical oxygen demand (ThOD) :-

- by stoichiometry if chemical formula and concentration of om is known then theostically calculating oxygen required to completely oxidize the organic matter using balanced chemical reaction.

TOC (total organic carbon) :- to express om in terms of carbon content.

Ex. $\underset{(180)}{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2 + 6H_2O$

ThOD = $\left[\frac{(32\times6)}{180}\right]$ × 200 gm glucose

TOC = $\left[\frac{(6\times12)}{180}\right]$ × 200 gm glucose

Imp.

note:- ThOD > COD > BOD_u > BOD_5 > TOC

Bio-chemical oxygen demand (BOD) :-

- used as a measure of quantity of oxygen required for oxidation of biodegradable organic matter in water sample. by aerobic chemical action.

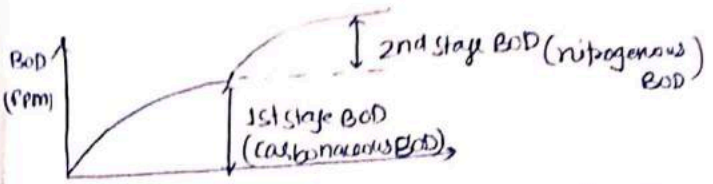
$$BOD_5 = (DO_i - DO_f) \times \text{Dilution factor (DF)}$$

DF = volume of diluted sample / sewage sample volume

if 4% dilution

then $DF = \frac{100}{4}(96+4) = 25$

$$DO_i = \frac{4\times DO_{waste} + 96\times DO_{aerated\ water}}{100}$$



BOD Test :- light excluded → to prevent algae growth otherwise they will produce oxygen.

Imp. **Special case :-** when seeded water mix.

20ml → waste sample 280ml — seeded water

Let initial DO of waste = x, final DO = x'] seeded water — y, " — y'

∴ Initial DO of diluted sample (waste + seeded water) $= \frac{x\times20 + Y\times280}{20+280}$

Final ——— $= \frac{x'\times20 + y'\times280}{20+280}$

$$(DO_i - DO_f)_{diluted} = \frac{(x-x')\times20 + (y-y')280}{300}$$ (↓ BOD_5)

∴ BOD_5 = $(DO_i - DO_f)$ diluted × (300/20) dilution factor

$= (y-y') \times \frac{280}{20}$

Population equivalent :- aim :- used to compare the pollution potential of domestic sewage generated in town & industry.

$$P.E = \frac{\text{Standard } BOD_5 \text{ of Industrial sewage}}{\text{Standard } BOD_5 \text{ of domestic sewage per person per day}}$$

if nothing given → (0.08 kg/capita/day) @ 20°c

Relative stability (S) :- aim → to check Test for treatment process

$$S = \frac{O_2 \text{ available in effluent}}{\text{total } O_2 \text{ required for 1st stage BOD } (BOD_u)}$$

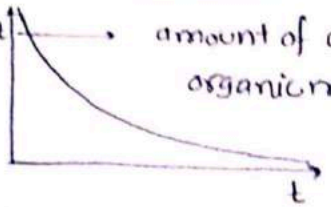
$S = 100\left(1 - (0.794)^{t_{20}}\right)$

$S = 100(1 - (0.630)^{t_{37}})$

t_{20} / 37 → time in (days) for sewage sample of to decolorise sample of methelene — blue solution when incubated at 20°c / 37°c

Sooner decoloration → earlier anaerobic condition which means lesser O_2 available

Reaction kinetics :



- amount of oxygen equivalent of organic matter present.

L_t = amount of om present at 't' time

L_o = at $t = 0$ (om)

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

$$L_t = L_o e^{-kt}$$ → exponentially decreases.

$$BOD(Y_t) = L_o - L_t = L_o(1 - e^{-kt})$$

at $t \to 0$ $(BOD)_t = L_o$

$$\therefore (BOD)_t = (BOD)_u [1 - e^{-kt}]$$

↓ not changed with temp.

Imp

Base 'e' 'k' × 0.434 = Base '10' k_D

	k_D (/day)
tap water	< 0.05
Surface water, treated sewage	0.05 – 0.10
municiple sewage	0.10 – 0.15

Hdeta
k_D range ≈ 0.10 /day

→ Vant hoff – arhenious eqn.

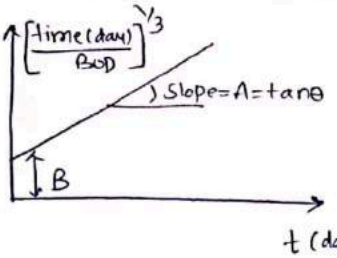
$$k_D \text{ (deoxygenation constant)}_T = k_{D_{20}}(1.047)^{T-20}$$

$$k_{R_T} \text{ (reoxygenation const)} = k_{R_{20}}(1.016)^{T-20}$$

↓ temp. coffiicent

$$k_{R_{20}} = \frac{3.9\sqrt{v}}{y^{1.5}}$$

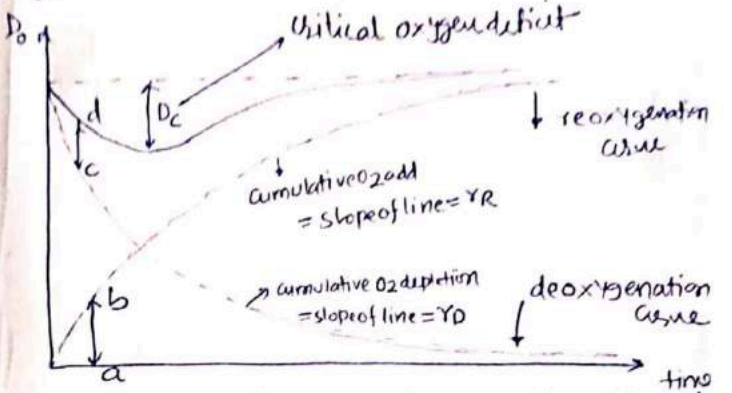
k_D experiment :- (Thoma's Graphical solution) :-



$$k_D = 2.61 \frac{A}{B} \text{ day}^{-1}$$

$Ob = cd$

Sag curve :



oxygen deficit at 't' time (Streeter Phelp's equation)

$$D_t = \frac{k_D \cdot L}{k_R - k_D}\left[10^{-k_D t} - 10^{-k_R t}\right] + D_o\, 10^{-k_R t}$$

L → ultimate BOD of mix at point of discharge

↓ initial oxygen deficit

$$t_c = \frac{1}{k_D(f-1)} \log\left[\left(1 - (f-1)\frac{D_o}{L}\right) f\right]$$

f → self purification constant

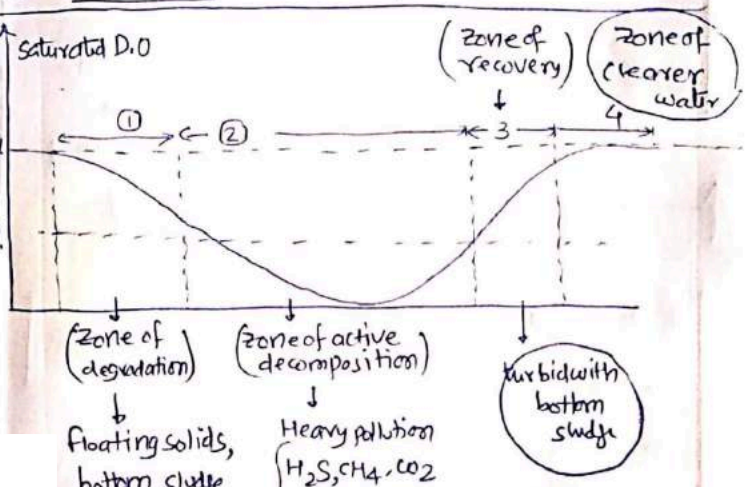
$$\left(\frac{L}{D_c f}\right)^{f-1} = \left(1 - (f-1)\frac{D_o}{L}\right) f$$

$$f = \frac{k_R}{k_D} \text{ at mix temp.}$$

Deficit max (D_c) where rate of reaeration = rate of oxygenation

mechanism of self purification :

(I) Dilution & dispersion
(II) Sedimentation → suspented solid settled.
(III) sunlight → photosynthesis, oxidation of OM
(IV) oxydation of organic matter
(V) reduction → Hydrolysis of organic matter.



(zone of degradation) → floating solids, bottom sludge present.

(zone of active decomposition) → Heavy pollution (H_2S, CH_4, CO_2 gas) → darker & greyish color

Self purification depends :-

(i) temp. (ii) turbulence (iii) Amount & type of organic matter
(iv) Hydrography of river stream
(v) Rate of reaeration.

Productivity of Lake :-

• ability to support food chain
'or' measure of Algae growth

order of Productivity :-

oligotropic < mesotropic < eutropic < senescent lake

↓

very old lake which almost becomes marshy.

lake pollutant :- major pollutant - phosphorus

• (max. killing during mixing) aquatic animal

lake layers :-

(i) upper layer → warm layer → epilimnion (**)
(mixed sufficient O_2)

(ii) middle layer → region of temp. gradient
→ Thermocline / metalimnion (**)

(iii) lower layer (unmixed) → Hypolimnion (less O_2) → cool layer

• late stratification → changes.

E
T/M
H

$$\text{Dilution factor} = \frac{Q_S + Q_R}{Q_S}$$

Dilution factor	treatment needed / given
>500	no treatment given, directly discharge
300 - 500	Plain sedimentation (Primary sedimentation)
150 - 300	Sedimentation + screening + chemicals ppt
<150	complete treatment

Biological zones in lake :-

(i) Euphotic zone	till where sunlight penetrates; if turbidity ↑ EZ ↓
(ii) Littoral zone	where rooted plant grow
(iii) Benthic zone	• Bottom sediments in lake which contain Bacteria • living organism → settled hence decompose by bacteria.

Eutrophication in lake :-

• Lake + excessive Algae — due to Excessive N, C, P

How to avoid → lake should not be used for disposal of even treated sewage

Unit operation (Physical process) → screening, mixing, sedimentation
* ERT contaminant removal

Unitprocess — By chemical or Biological process contaminant removal

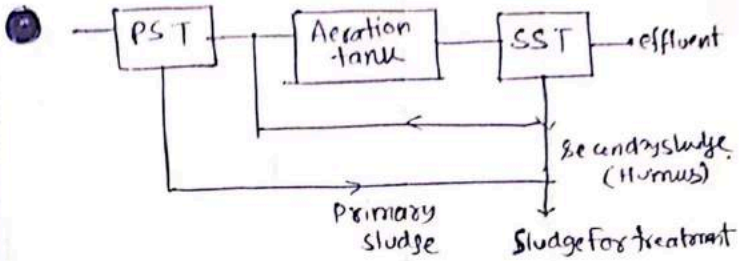
Based on Biological unit process

- Suspended growth system
  - (I) ASP (Activated sludge process)
  - (II) Aerated lagoons
  - (III) oxydation Pond
  - (IV) Aerobic & Anaerobic digestor
- attached growth system
  - (I) Trickling filter (TF)
  - (II) Rotating biological chamber (RBC)
  - (III) Biotowers

↓ both treated upto nitrate level

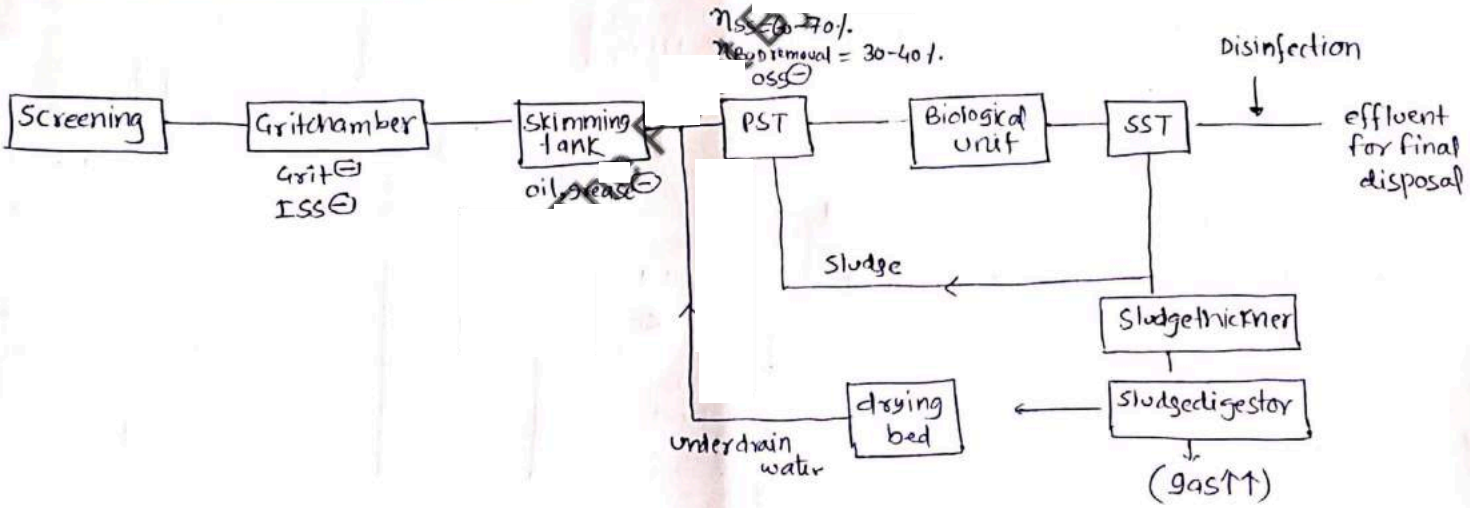
(2) Primary treatment → (Preliminary treatment + PST)
(remove suspended solids)

(3) Secondary treatment :- (remove colloidal & soluble organic matter)
[Biological conversion of dissolve & colloidal OM into Biomass]



(4) Tertiary Treatment :- to meet effluent standard

(river → if used as source of water supply then tertiary treatment is must before disposing treated waste into ft.



① Preliminary treatment system :-

fn → remove (floating material) + (large inorganic particulate content)

Screening → grit chamber → skimming tank → for further treatment

note:- Before skimming tank → Parshall flume or other velocity control device

unit	detention time (td)	unit	time
Grit chamber	40 – 60 sec.	sludge digestion	30 days
Skimming tank	3 – 5 min.		
vacuator	10 – 15 min		
SST	1.5 – 2 hr.		
Imhoff tank	2 hr		
PST	2 – 2.5 hr.		
septic tank	24 hr.		
oxidation pond	15 – 30 days		

Sludge process	Description	
Sludge thickening	water removal (for reduction of sludge volume) basically	① Gravity thickening → for primary sludge + ASP sludge (not for ASP sludge alone) ② Air floating → normally used for ASP sludge ③ centrifugation → where space restriction
Sludge conditioning (increase drainability of sludge)	water removal (Sludge volume ↓↓)	① heat treatment ② chemical treatment
Sludge stabilization	digestion	• generally by Anaerobic Process
Reduction of Sludge	volume decreases by chemical oxidation	

① Screening :- remove certain piece of wood, debris
→ protect pump & other mechanical equipment

② communution & maceration :-
↓ Cutting ↓ Grinding.

③ Grit chamber :- remove grit, sand (>2.4) (Inorganic suspended solid)
↓
advantage :- reduce frequency of cleaning of sedimentation tank, digestor

$V_h = 0.15 - 0.30$ m/s
$t_d = 40 - 60$ sec.

$V_t = K_c\sqrt{gd(G-1)}$ (horizontal) ↓ (3-4)

length of channel increase by 20% as an allowance.

note:- velocity controll device
- for Rectangular section → Proportional weir provided
- for Parabolic section → Parshall flume provided

④ Detritus tank :- same as grit chamber only difference It removes finer inorganic ss.

⑤ Removal of oil, grease, soap
- Skimming tank: t_d = 3 to 5 min
- vaccuator: t_d = 10-15 min

before sedimentation tank provided.

⑥ Sedimentation (under gravity) → organic suspended solid settled

Discreti Settling (1°)	Flocullent Settling (2°)	Hindered Settling or Zone Settling (3°)	Compression Settling (4°)
in Grit chamber	PST (OSS-)	SST in ASP	SST in TF
• Stokes law valid • no change in size & shape of particle V = constant	as Time ↑ V ↑	Particle concentration don't change during settling	Particle concentration increases during settling

Secondary treatment (Biological Treatment)

- Aerobic treatment
  - (i) Trickling filter
  - (ii) ASP
  - (iii) Aerated lagoon
  - (iv) oxidation pond
- Anaerobic Treatment
  - (i) septic tank
  - (ii) Imhoff tank
  - (iii) Upflow Anaerobic Sludge blanket (UASB) + Use for Industrial Sewage

- Attached growth system → TF, RBC, Biotower
  - Biomass attached to medium & sewage containing OM is passed through medium
- Suspended growth system
  - Biomass is in suspension in liquid containing OM

Trickling filter (attached growth system)

- Predominant organism → facultative bacteria
- each TF must be having SST (due to removal of Biomass) 'or' Slaughing

TF
- Standard Rate TF: R = 0, f = 1 (no recirculation)
- High rate TF: R ≠ 0, f > 1; R = 1 f = 1.65; R = 1.5 f = 1.89

F → recirculation factor

$$F = \frac{1+R}{(1+0.1R)^2}$$

recirculation ratio $R = \frac{Q_R}{Q_0}$

$0.1 = 1 - f$ → f → treatability factor which is 0.9 for sewage

conventional (Standard Rate TF): (no recirculation)

TF → SST → effluent; SST → sludge

High Rate TF

PST → TF → SST → Q_0

Q_0, S_0; Q_R; S

$$R = \frac{Q_R}{Q_0}$$

$$\eta = \frac{100}{1+0.0044\left[\frac{Y}{VF}\right]}$$

Applied BOD to TF (kg/day)

Y (sharm)

note: Organic loading, situ $= \frac{Y}{V}$ kg/sham/day

note: TF design → Avg. flow
distributory arm, under drainage pipeline → Peak flow (check for Avg. flow)

Rate of removal depends (TF)
- Hydraulic loading rate (HLR) or Hoco rate (m3/m2/day)
  - (HLR ↑ Slaughing ↑) → removal of Biomass film
- organic loading rate OLR (kg/sham/day)
  - OLR ↑ · rapid growth of Biomass ∴ plugging of Pores & flooding of tank
- temp
- Rate of diffusibility of food & O_2 into Biofilm

operational trouble in standard Rate TF (R=0)

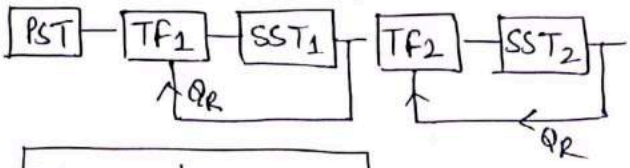
- filter media Ponding & Clogging → when OLR ↑
  - Solution:
    - wash filter
    - add $CuSO_4$ to prevent growth of Algae
    - chlorinated Sewage
- Excessive fly breeding
  - Soln: • reduce by flooding for 24 hrs.
  - Soln: • do chlorinating
- odour → due to H_2S ↑
  - Cl_2 being oxidising agent oxidise H_2S

High Rate Trickling filter :- Design :-

① Surface area of TF (include recirculation) $= \frac{Q_o + Q_R}{HLR}$ $\frac{m^3/d}{m^3/m^2/d}$

② Volume of TF (exclude recirculation) $= \frac{Q_o S_o}{OLR}$ $\frac{kg/d}{kg/ham/d}$ (excluding recirculation)

Two stage TF :- (adopted if BODin → more if BODout → less treatment.



$$\eta_1 = \frac{100}{1 + 0.0044\sqrt{\frac{Y_1}{VF_1}}}$$

$Y_2 = Y_1 (1 - \eta_1)$ → BOD removal efficiency

$$\eta_2 = \frac{100}{1 + \frac{0.0044}{(1-\eta_1)}\sqrt{\frac{Y_2}{V_2 f_2}}}$$

Advantage of High Rate TF :-

- BOD removal η ↑

But nitrogeneous matter may not get sufficient time for nitrification as rate of flow is fast, Biological film may get sloughed before nitrification has had time to take place.

So to avoid this 2 stage filtration →

- 1st stage: Carbonaceous matter removal
- 2nd stage: (nitrification)

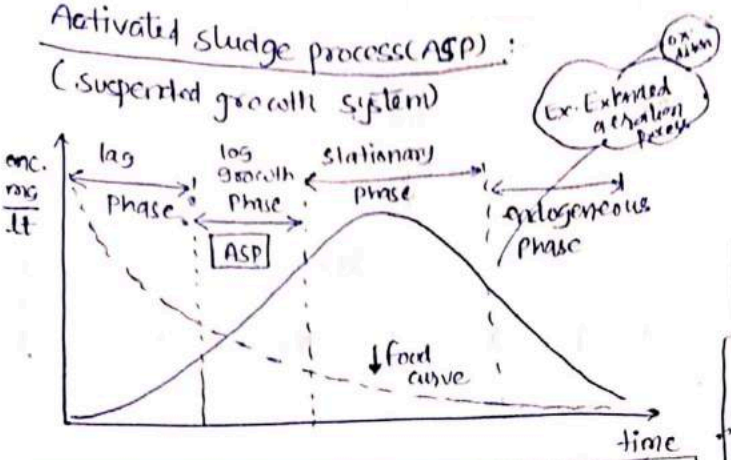
RBC (Rotating Biological crrarober)

↳ treatment upto nitrate level

- take advantage of both (suspended growth system, attached growth system.

Activated sludge process (ASP):

(Suspended growth system)



MLSS ⇒ Inorganic + dead ⇒ living + dead Bacteria

MLVSS ⇒ 80% of MLSS (only organic)

ASP → in this settled sludge in SST. [containing living organism] returned to aeration tank (reactor) to increase the available biomass (rich in microbial mass) & speed up the reaction.

Process

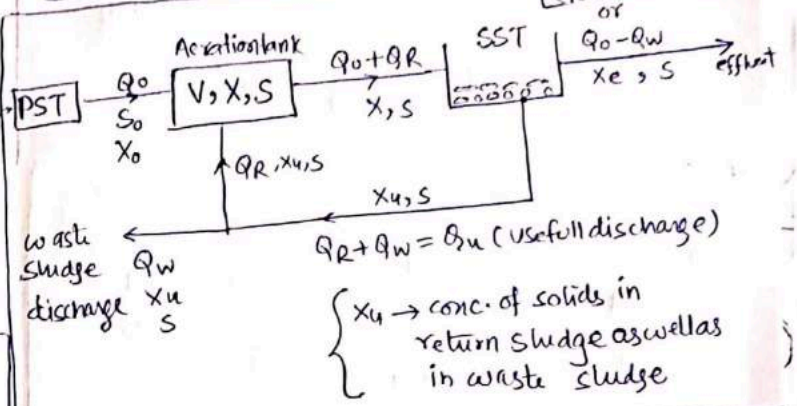
- Completely mix process (<25 MLD)
  - use where hourly variation → more
  - F/m, O_2 demand constant at all place.
- Plug flow process (upto 300 MLD)
  - along length F/m ↓ (∵ OM decompose)
  - O_2 demand ↓
- Extended aeration process (<4 MLD)
  - Imp Ex. Oxidation ditch
  - PST avoid
  - no digestion tank
  - sludge directly taken to sludge Bed
  - O_2 requirement is very high.

Complete mix process :-

Assumption (i) Influent (X_o), effluent (X_e) Biomass concentration negligible as compare to Biomass at other point.

(ii) all reaction occur in reactor (aeration tank)

(iii) BOD removal in SST → negligible (S → S)



$Q_R + Q_w = Q_u$ (useful discharge)

X_u → conc. of solids in return sludge as well as in waste sludge

Design parameter :-

(i) Aeration time / detention time / Hydraulic retention time $= \frac{V}{Q_o}$ (volume of tank / ratio of flow in tank) — excluded recirculation

(ii) Organic loading rate (OLR) / volumetric " $= \frac{Q_o S_o}{V}$ kg/ham/d

→ mass of BOD Applied / Volume of A. Tank

(iii) Specific substrate utilization $U = \frac{Q_o (S_o - S)}{VX}$

→ mass of BOD remove in tank / mass of Biomass in tank

(iv) Food Applied / Biomass $F/m = \frac{Q_o S_o}{VX}$ {when $S \to 0$ and $S_o >>>> S$}

$F/m \uparrow \Rightarrow$ BOD removal ↓ ($\eta \downarrow$)

$\eta \downarrow \Rightarrow Q_w \uparrow$ (Temp ↓ ⇒ $Q_w \uparrow$) bcz

$Q_w \uparrow$ F/m ↑ $\eta \downarrow$ T ↓

note:-

$\frac{1}{\theta_c} = Y_y - K$

$\frac{Q_o(S_o - S)}{VX}$

θ_c → sludge age

⑤ Sludge age (θ_c) → Avg. time for which biomass remain in system.
↳ indicate residence time of Biological solid in system.

$$\theta_c = \frac{VX}{(Q_o - Q_w)X_e + Q_w X_u}$$

VX → mass of MLSS in tank
$(Q_o - Q_w)X_e + Q_w X_u$ → mass of MLSS leaving system per day.

if X_e → neglect

$$\theta_c = \frac{VX}{Q_w X_u}$$

$Q_w \downarrow$ $\theta_c \uparrow$

⑥ Sludge volume Index (SVI) | range → 50–150 $\frac{mL}{gram}$

(i) SVI → volume occupied by 1 gram of solid in mixed liquor after settling for 30 min.

$$SVI = \frac{V_{ob}}{X_{ob}} \times 1000 \quad \frac{mL}{gram}$$

V_{ob} → Settled volume in 1000 mL sludge (Imp)
X_{ob} → concentration of SS in mixed liquor (mg/lt)

$$SVI = \frac{10^6}{X_u}$$

(ii) SVI → decide rate of recycle of sludge (Q_R) req. to maintained desired MLSS (X), F/m in tank to achieve required degree of purification.

(iii) Sludge recirculation & settleability determined by SVI.

⑦ Sludge density Index (SDI) $= \frac{100}{SVI \text{ (mL/gram)}}$

⑧ Recirculation ratio ⇒ $R = \frac{Q_R}{Q_o} = \frac{X}{X_u - X}$

noti:- work Balance eqn in AT

$$Q_o X_o + Q_R X_u = (Q_o + Q_R)X$$

$SVI = \frac{10^6}{X_u}$

Imp printing ASP :-

(i) most imp. aspect to maintain F/m ratio which is done by < MLSS ↑ / MLSS ↓
depend on influent BOD load.

(ii) $Q_w \uparrow$ F/m ↑ Temp ↓ BOD removal ↓

Sludge Bulking :- → (Poor settling characteristic)

- due to inadequate air supply resulting in — lower PH septicity → leads to (filamentous organism.)
- ** filamentous organism → form due to low nutrient concentration
- growth of filamentous organism supported by → $\theta_c \uparrow$ (High sludge Age), F/m ↓ (<0.3), T ↑

noti:- Sludge Bulking control :-

(i) $\theta_c \downarrow$ (<6 days)
(ii) Chlorination of returned activated sludge
(iii) addition of nutrient if less
(iv) add lime or soda
(v) Increase recycle ratio (R)
(vi) Increase rate of reaeration.

Imp noti:- rise of sludge → caused by denitrification (Imp)

conventional nitrification → By Autotropic

Biological nitrogen removal → By Nitrifiers & denitrifiers.

Imp noti:-

process	η of BOD removal
oxidation ditch (Extended aeration)	98 %
oxydation pond	90 % (symbiotic relation)
TF	80–90 %
ASP	80–95 %

Sludge digestion :

Sludge life

- **Raw sludge / Primary sludge**
  - moisture content = 95%
  - → AFTER (PST)
  - here excess OM
- **Secondry sludge or Biological sludge or 2° sludge**
  - moisture content = 96–98%
  - after (SST)
  - here excess Biomass

Anaerobically sludge digestion process

- **digested sludge**
  - = 1/3 rd of raw sludge
- **supernatant liquid**
  - High BOD 1500–3000 mg/lt
  - ∴ sent back to PST
- **gases**
  - CH_4 70%
  - CO_2 30%
  - other H_2S N_2

Sludge digestion

- **Aerobically** (only for secondry sludge)
  - (adopt if BOD in is less)
  - • Extension of extended aeration process.
  - (there is scarcity of food, endogenous respiration will start)
  - • digested sludge consist of cell walls, cell fragments
  - • energy consumption → more
  - • This sludge dewaters poorly.
- **Anaerobically** (only for primary sludge)
  - (adopt if BOD in is high)
  - Gases released: CH_4, CO_2

total solid (100)%

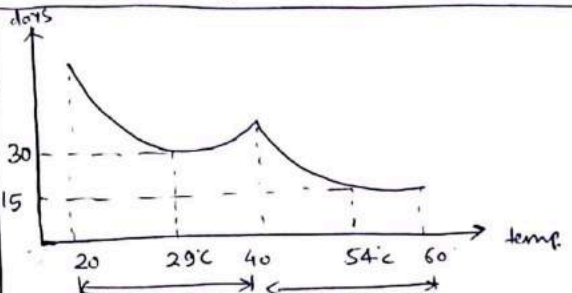
- (70)% (volatile solids) (organic solid) → measure by muffle furnace
- (30)% (nonvolatile solid) (Inorganic solid)

65% gases, 35% digested sludge → Sludge solids

- → gas produced = 0.6 m³/kg volatile solid present
- → methane heat content = 8600 Kcal/m³

factor's affecting sludge digestion

Temp.



PH

pH ↑ rate ↑

- if pH of sludge drops down to low value Bacterial action will get supressed resulting in reduced digestion rate.

Seeding with digested sludge —

mix & steering of raw sludge —

Nuisance organism —

Stages in sludge digestion :-

Acid fermentation — acid regression — Alkali formation — methane formers

Hydrolysis → fermentation (acidogenesis) → methane formation (methanogenesis)

- Hydrolysis
  - ↓
  - • form simple monomer
  - • process of solubilization of organic solid.
  - complex OM (protein, cellulose, lipid) → simple (soluble)
- Simple soluble OM → (acid former) → CH_3COOH, H_2, CO_2
- $CH_3COOH \rightarrow CH_4 + CO_2$
- $H_2 + CO_2 \rightarrow CH_4$

V.Imp

$$V_1 (100 - P_1) = V_2 (100 - P_2)$$

V_1 → Volume, P_1 → Moisture content.

digester capacity

$$V = \left(\frac{V_1 + 2V_2}{3}\right) t + V_2 T \quad \text{or} \quad \left[V_1 - \frac{2}{3}(V_1 - V_2)\right] t + V_2 T$$

(V_1 → undigested, V_2 → digested)

$$V = \left(\frac{V_1 + V_2}{2}\right) t + V_2 T$$

Parabolic variation

Straight line variation

t → digestion period (30 days)

$V_2 T$ → monsoon storage

SST (Secondary Sedimentation tank) :-

(I) must produce an effluent sufficient clarified.

(II) They must concentrate the biological solids to minimize the sludge to be handled.

(III) design basis

- Solid loading rate: area = $\frac{Q_0 + Q_R}{\text{Solid loading rate}}$
- Hydraulic loading rate: area = $\frac{Q_0}{\text{overflow rate}}$

(IV) detention time ⇒ 1.5 – 2 hr

(Otherwise denitrification will occur & N_2 will evolve)

Note:- All units of treatment are kept above HFL of river except sludge drying bed hence during flooding, only sludge drying bed is flooded, rest is operational.

Oxydation Pond :-

$$td = \frac{1}{KD} \log \frac{Lin}{Lout}$$

- open flow earthen Basin
- long detention period (15-30 days) during which waste get stablized by action of natural force.
- algae symbiosis occuse (oxygen demand is met by combined action of Algae & other micro-organism)

- Depth - (1-1.5m)
- td - 15-30 days
- $L/B = 3$ $L > 750$ m
- Area unit = 0.5-1 ha
- Pathogenic bacterial removal = 99.9%.
- BOD removal = 90% (80-90%)

Septic tank :-

→ ordinary settling tank with large detention time (24-36 hr) with extra provision for sludge digestion by anaerobic bacteria

- flow of sewage = 40-70 lpcd
- detention time = 24-36 hr
- Rate of accumulation of sludge = 30 lpc per year
- cleaning period = 6-12 month (0.5-1 yr)
- min width = 0.75m (min liquid capacity = 1000 litre)
- $L/B = 3$
- free Board = 0.30

Imhoff tank :-

use in case of small treatment plants require only primary treatment

upper sedimentation | lower portion (anambar) digestion

oxidation ditch :- (extended aeration system)

- no PST
- no digestor
- In this Biological solids produced are destroyed by endogeneous respiration and separate sludge handling not required.

Solid waste management

(i) Composting method

- Biological method of decomposing solid waste
- used when → high organic content & high moisture content
- final product → manure *

Process

- Indore process → Aerobic process
  - ∴ (turn mass either manually or mechanically)
- Banglore method → anaerobic process
  - turning not required ∴ more clean than Indore method

(ii) Sanitary land filling method

- used when → high density
- layer of 300–600mm
- Leachate formed
- non biodegradable matter + acid + water, carciogenic compound.

(iii) Autoclaving

- low heat Treatment process, for (biomedical waste) under controll. temp.

(iv) Incineration

- adopt when → MSW has (high calorific value).
- Burn of refuse in presence of O_2 (oxygen)

(v) pulverization

refuse pulverised (by grinding machine)

(vi) pyrolysis

- limited / Nil presence of O_2
- for plastic & rubber

(vii) deep well Injection method

- for disposal of (liquid hazardous waste)
- expensive
- It poses a danger of leakage hazardous waste and eventually polluting subsurface water supplies

10/3/20

Primary air pollutants :- directly emit from identified source.

1. Particulate matter
2. Sulpher compounds (SO_2)
3. Oxide of nitrogen (NO_x) → NO, NO_2
4. Carbon monooxide (CO)
5. Halogen compounds (methyl & ethyl mercaptans)
6. Volatile organic matter (hydrocarbon)
7. Radioactive compounds

others CH_4 / NH_3 | CFC | toxic metals.

Secondary pollutant :- produced in air by interaction among two or more primary pollutants, or by reaction with normal atmospheric constituent with or without photoactivation.

1. $H_2SO_4 \longrightarrow SO_2 + O_2(DO)$, when water vaps are present in atm.
2. ozone (ground level)
3. formaldehyde (HCHO)
4. PAN (peroxyacetyl nitrate)
5. photo chemical smog

NAQI (national air quality index)

8 pollutants ⇒ PM_{10} / $PM_{2.5}$ / NO_2 / O_3 / CO / SO_2 / NH_3 / Pb

6 category
- good (0-50)
- Satisfactory (51-100)
- moderately (101-200)
- Poor (201-300)
- very poor (301-400)
- severe (401-500)

V. V. Imp

Ambient Air quality standard Leq (dB)

Zone	day	night
Industrial	75	70
commercial	65	55
Residential	55	45
Silence	50	40

KRS

Trick

75 — 70

65 — 55

55 — 45

50 — 40

Sound pressure level $L_p(dB) = 20\log\left(\frac{P_{rms}}{20\mu Pa}\right)$

note: Man — min 20 μPa, 20 hz; max 200 Pa, 20000 hz

Sound Intensity level $dB = 10\log\left(\frac{I}{I_0}\right)$

$\because I \propto P_{rms}^2$

$I_0 = 10^{-12}$ W/m²

Sound power level $= 10\log\frac{W}{(10^{-12})}$ → $\frac{W}{m^2}$

Note

$L_p + L_p$	Pressure →	$\sqrt{2}L_p$ $\{\sqrt{L_{p1}^2 + L_{p2}^2}\}$
$I + I$	Intensity →	$2I$
$P + P$	sound power →	$2P$

Sound power (watt) $= 4\pi R^2 \times I$

Net $P_{rms} = \sqrt{P_{rms_1}^2 + P_{rms_2}^2}$

Difference in noise level	Increase in noise Pollution (बड़े वाले से)
0-1	3
2-5	2
6-8	1

Ex. 70dB, 70dB → 70+3 = 73 dB

70, 73dB → 73+2 = 75dB

Average sound :-

$$L_{avg} = 20\log\left(\frac{10^{L_n/20} + 10^{L_n/20} + \cdots}{N}\right)$$

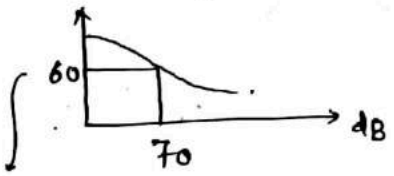
equivalent sound :-

$$L_{eq} = 10\log\left[10^{L_i/10} \times \text{fraction of time}\right]$$

noise rating system < Ln
Leq

① Ln concept (statistical concept) :-

Sound pressure level that will exceed for N./. of gauging time.



Ex. 70 dB of L_{60}

Sound level will exceed 70dB for 60/. of measuring time

/. of time ≥ standard value

② Leq concept :- constant noise level which over a given time expands the same amount of energy as is expanded by the fluctuating level over the same time.

Ex. $L_{eq}(8)$ → 8 hr. measurement

if nothing is given → then it is for 1 hr.

lapse rate :- In troposphere ,

temp of ambient air ↓ ⇒ if Altitude ↑ (height)

this rate of change of temp. is called lapse rate.

Environmental lapse rate (ELR) :- $\{T/H\}$

or Ambient lapse rate or
Prevailing lapse rate

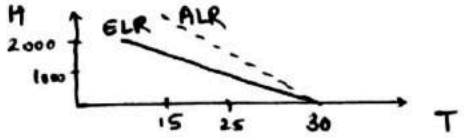
- send ballon (equipped with thermometer) ⟶ self recording mechanism

Adiabatic lapse rate (ALR) :-

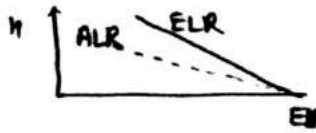
When parcel of air (which is hotter and higher than surrounding air) is released, then naturally it tends to rise up untill a level at which its own temp. and density becomes equal to that of surrounding air, this rate of decrease of temp. with height ⟶ adibatic lapse rate.

- dry ALR : 9.8 °C/km
- wet ALR : 6°C/km

① Superadiabatic lapse rate (ELR > ALR)
↳ unstable environment



② Subadiabatic lapse rate (ELR < ALR)
↳ Stable environment



③ neutral lapse rate (ELR = ALR)

Negative lapse rate / Inversion :-

temp ↑ if H ↑ (ठंडा / गर्म)

Inversion – state in which warm air lies below cold air

- inversion may be near earth surface and greater height.

inversion
- Radiation Inversion or ground surface inversion
  - arising from unequal cooling rate of earth & air above earth
- Subsidence Inversion or mechanical inversion
  - associated with high pressure system.

double inversion = Radiation Inversion + Subsidence Inversion.

Design of stack height

- if chimney → particulate matter pm (tonn/hr)
  - $h = 74\, Q_p^{0.27}$ (meter)
- if chimney → SO_2 (kg/hr)
  - $h = 14\, Q_s^{2/3}$ meter

But minstackheight

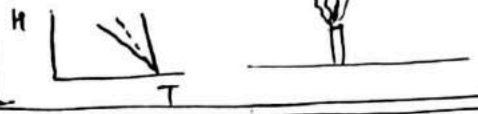
- Industry ⇒ 30 mtr
- Thermal powerplant
  - 200–500 MW : 220 meter
  - >500 MW : 275 meter

Plume :- Path taken by continuous discharge of gaseous effluent emitted from stack / chimney.

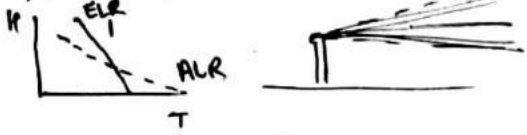
- The shape of path and concentration distribution of gaseous plumes depends upon localised air stability.

① looping plume :-
- most common type plume under superadiabatic lapse rate (ELR > ALR)
- condition → light to moderate wind speed on a hot summer afternoon when large scale thermal eddies are present
- High turbulence → rapid dispersion of plume but high concentration touch the grd.

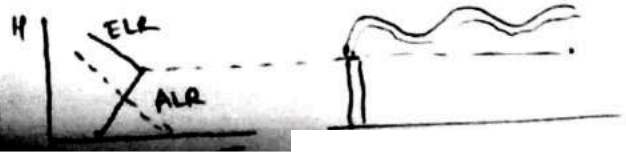
② Neutral plume :- (ELR = ALR)
- upward lifting of plume will continue till air density becomes similar to that of the plume itself.



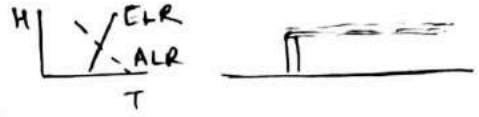
③ coning plume :- in cloudy day / night v / 32 kmph, when lapse rate is near neutral.
(ELR < ALR)
- Plume shape is vertically symmetrical about plume line



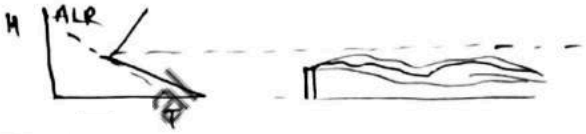
④ lofting plume :- in strong superadiabatic lapse rate above inversion.
(best / Ideal plume)
∵ downward motion & mixing is prevented by surface inversion but upward-mixing will be quite turbulent and rapid.



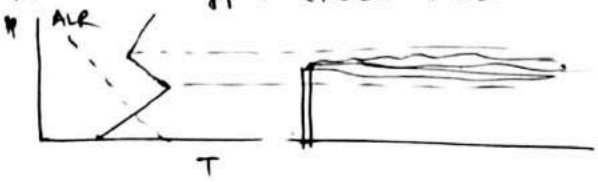
⑤ fanning plume :-
- in extreme inversion condition in the presence of light wind.
- most of the vertical dispersion is supressed by extremly stable condition, plume fans out in the horizontal direction



⑥ fumigation plume :- → worst plume
- just inversion of lofting plume.
- fumigation takes place when an inversion layers occures at a short distance above the top of stack and super adiabatic conditions prevails beloaw it.

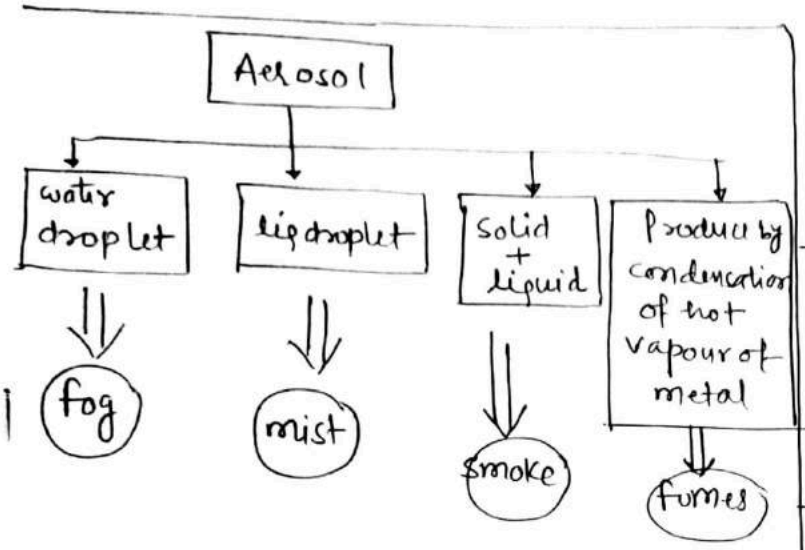


⑦ Trapping plume :- when plume caught between 2 inversion layers, hence the emitted plume can nither go up nor down and will be trapped between the 2 levels.



method of removing particulate matter :-

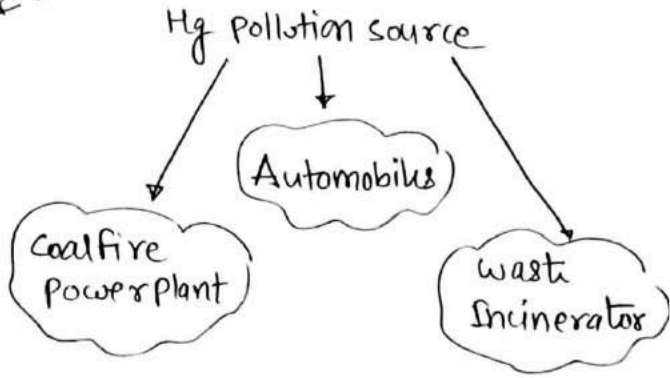
equipment	outsize removed	remarks
Gravitational ① settling chamber	large particles ($> 50\mu m$)	• simple design. • low efficiency require more space • Low pressure loss
cyclone collector ↓ or separator ② use of centrifugal force	($40-50\ \mu m$)	• simple to design & maintain • require less floor area • low to moderate Pressure loss
③ fabric filter	filter bag usually tubular ($< 1\mu m$) $\eta = 99\%$.	• high efficiency • The flue gas must be dry to avoid condensation & clogging. The fabric is liable to chemical attack.
④ electrostatic precipitator $\eta = 1 - e^{-\frac{WA}{\theta}}$ A → collector Plate area (m^2)	$\simeq 1\mu m$ $\eta = 95-99\%$ • very small particles also wet & dry can be easily trapped. more than 99% efficiency can be achieved in their functioning	• mostly used in Industry → thermal Power Plant, cement plant, paper mill • gas is flown in high voltage field
⑤ wet scrubber		
venturi scrubber	• can remove gaseous as well as particulate contaminant ($0.5-5\mu m$)	• suit for removal of submicron particulate associated with smoke & fumes.
spray tower	low cost handling of large volume of gases	
wet cyclone scrubber	higher efficiency than spray towers.	



Gas	Source & remarks
H_2S	• foul smelling type gas • rotten egg type • anaerobic biological decay process in land, marsh, ocean • from craft pulp industry
mercapton	• strong odour {∴ mix in LPG} • pulp mill, Refinery, chemical manufacturing plant
SO_2	• from combustion of coal • Refinery, chemical plant, incineration plant
HF	• Pottery • Brick Plant • Aluminium Industry • phosphate fertilizer

NO_x	• automobile exhaust • effluent in Industry where HNO_3 (nitric acid) Present
CO (asphyxiant)	• due to Incomplete combustion of carbonaceous material (especially due to automobile exhaust)
Aldehyde	• formed by combustion of gasolin, disel oil, fuel oil, natural gas. • formed in air due to photo-chemical reaction.

Imp.



Photochemical smog constituent → O_3, PAN, CO

$HC + NO_X \xrightarrow[\text{air}]{\text{sunlight}}$ ✓✓ (PCS)

major constituent (i) O_3 (ii) PAN (iii) HC

factors affecting (PCS)

(i) light intensity (ii) Hydrocarbon reactivity

(iii) HC, Nitric oxide (iv) Presence of light absorber

(v) metereological absorber

(vi) height and intensity of atm. inversion

effects :- (PCS)

(i) eye irritation due to aldehyde, PAN

(ii) vegetation damage due to O_3/NO_2 ~~LPAN~~

(iii) visibility reduction

(iv) cracking of rubber

(v) fading of dyes.

Photochemical oxidant effects

(i) cause coughing

(ii) shortness of Breathe

(iii) headache.

effect of air pollution on human :-

(i) SO_2	• affect mucous membrane • bronchial spasm → swelling • Asthma patient badly affected
(ii) CO	• affect central nerve system (CNS) • great affinity for combine with hemoglobin to form COHb hence it reduce ability of hemoglobin to carry O_2 to body tissue.
(iii) NOx → NO (nitric oxide), NO_2 (nitrogen dioxide)	• eye & nasal irritation • pulmonary discomfort.
(iv) H_2S	• rotten egg type smell • exposure for short period can result into fatigue of sense of smell
(v) Ozone	• harmfull respiratory system than SOx
(vi) fluride	• fluorine cumulative poison (H_2F → less harmfull)
(vii) Lead	Source → automobile • mental retardness • Abnormality in fertility & Pregnancy • liver & kidney damage • gastrointestinal damage

Exosphere Thermosphere Mesosphere Stratosphere troposphere	78% → N_2 21% → O_2 1% → Ar 0.03% → CO_2 Inert

acid rain (pH < 5.6) :-

Sox (2/3) [Burning of coal]
NOX (1/3) [Auto emission]

sunlight ⇓ water vapour

H_2SO_4 / HNO_3 (H_2CO_3)

acid rain effect :
- greenery vanish ↓
- earthworm population decreases ↓ ∵ they can not tolerate acidic environment.

Remedy :- neutralize the acid with (Lime)

Reverberation time — time required to reduce noise by 60dB
'or'
time rep. to reduce the intensity to one million of intensity.

TTS (temporary Threshold shift)
→ temporary loss of hearing

PTS → (Permanent Threshold shift)
→ Permanent loss of hearing

Global warming :-

major greenhouse gases {water vapour}

source	
CO_2	Burning of fossil fuel, solid waste
CH_4	Anaerobic decay of organic waste
N_2O nitrous oxide	agriculture and industrial activity.
CFC	Refrigerator, AC, Paint, spray
SF_6	Insulator, magnesium industry

Ozone layer Depletion :- group of cfc's

- Primary Reason → (cfc / freons)
- Ozone layer acts as filter for (UV) rays thus protect against { Burn, Skincancer }
- 90% ozone → Stratosphere (15-50 km)
- montreal convention → ozone depleting substance (ODS) ↓ (CFC, HFC)
- vienna convention → Protection of ozone layer.