1.(d) A water sample was analysed in the laboratory and the following were reported:
HCO_3^- = 300 mg/l; Na^+ = 115 mg/l; SO_4^{-2} = 240 mg/l; Mg^{+2} = 36.6 mg/l; Cl^- = 71 mg/l; Ca^{+2} = 100 mg/l.
Find the % error in cation-anion balance. Also draw a bar diagram to indicate cation-anion balance. Comment on the Result of cation-anion balance error %. 12

Ans: **Calculate equivalent weights of ions.**

Equivalent weight of HCO_3^- is $\frac{61}{1} = 61$.

Equivalent weight of Na^+ is $\frac{23}{1} = 23$.

Equivalent weight of SO_4^{2-} is $\frac{96}{2} = 48$.

Equivalent weight of Mg^{2+} is $\frac{24.3}{2} = 12.15$.

Equivalent weight of Cl^- is $\frac{35.5}{1} = 35.5$.

Equivalent weight of Ca^{2+} is $\frac{40}{2} = 20$.

Convert concentrations to meq/L

$$HCO_3^- = \frac{300}{61} \approx 4.92 \text{ meq/L}.$$

$$Na^+ = \frac{115}{23} = 5.00 \text{ meq/L}.$$

$$SO_4^{2-} = \frac{240}{48} = 5.00 \text{ meq/L}.$$

$$Mg^{2+} = \frac{36.6}{12.15} \approx 3.01 \text{ meq/L}.$$

$$Cl^- = \frac{71}{35.5} = 2.00 \text{ meq/L}.$$

$$Ca^{2+} = \frac{100}{20} = 5.00 \text{ meq/L}.$$

Sum total cations and anions in meq/L

Total cations $= 5.00(Na^+) + 3.01(Mg^{2+}) + 5.00(Ca^{2+}) = 13.01$ meq/L.

Total anions $= 4.92(HCO_3^-) + 5.00(SO_4^{2-}) + 2.00(Cl^-) = 11.92$ meq/L.

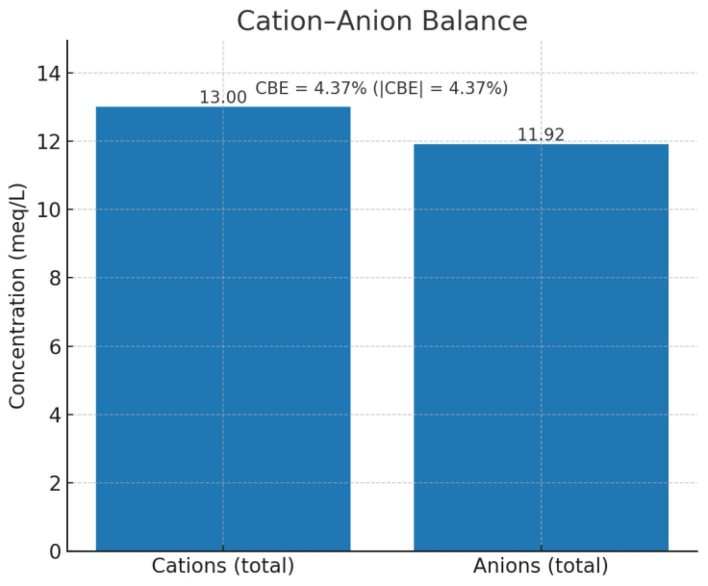
Calculate % of Error :

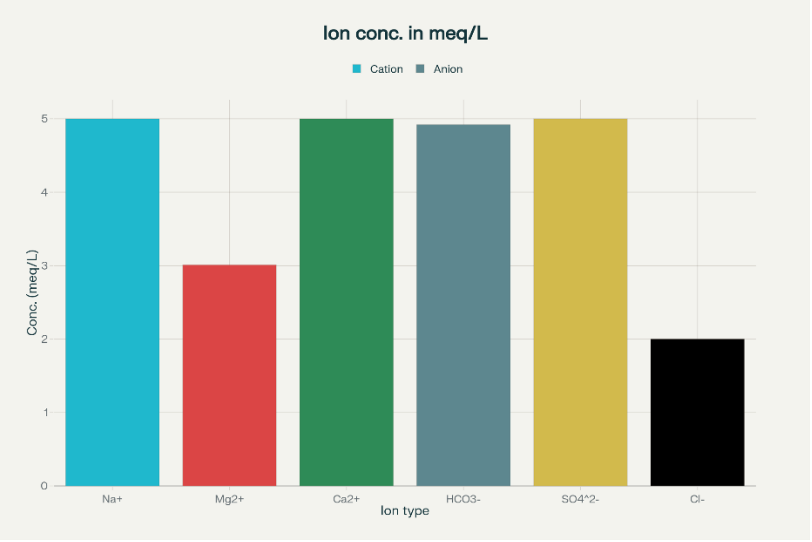
$$\frac{\Sigma cations - \Sigma anions}{\Sigma cations + \Sigma anions}$$

$$\text{Percent error} = \frac{|13.01 - 11.92|}{13.01 + 11.92} \times 100\% = \frac{1.09}{24.93} \times 100\% \approx 4.37\%.$$

Comment on acceptability

- Typical acceptance criteria: |% of Cation Anion Balance Error| ≤ 5 %
- The sample's error (4.37 %) is within the common 5 % limit, so the analysis is generally acceptable, though it's a little high—worth a quick look at Na^+/HCO_3^- entries and dilutions





1.(e) Data pertaining to a conventional ASP is given below:

Population of town	= 10 lakhs
Wastewater contribution	= 100 lpcd
BOD in settled sludge	= 180 mg/l
Effluent BOD required	= 30 mg/l
F/M ratio	= 0.2
MLSS concentration	= 2800 mg/l
SVI	= 100

Find the volume of aerator, Hydraulic Retention time (HRT), Volumetric loading and Return Ratio. Also comment if the parameters match with design conditions.

Ans:

1) BOD load to aerator

$$L = QS_0 = 100{,}000 \times 0.18 = \mathbf{18{,}000}\ \mathrm{kg\ BOD/d}$$

2) Aeration tank volume, V

Using $\mathrm{F/M} = \dfrac{QS_0}{VX} \Rightarrow V = \dfrac{QS_0}{(\mathrm{F/M})\,X}$

$$V = \frac{18{,}000}{0.2 \times 2.8} \approx \mathbf{32{,}143}\ \mathrm{m^3}$$

3) Hydraulic retention time (HRT)

$$\mathrm{HRT} = \frac{V}{Q} = \frac{32{,}143}{100{,}000} = 0.3214\ \mathrm{d} \approx \mathbf{7.71}\ \mathrm{h}$$

4) Volumetric loading (kg BOD/m³·d)

$$\lambda_v = \frac{QS_0}{V} = \frac{18{,}000}{32{,}143} \approx \mathbf{0.56}\ \mathrm{kg/m^3 \cdot d}$$

(Also equals $X \times \mathrm{F/M} = 2.8 \times 0.2 = 0.56$.)

5) Return sludge ratio, $R = Q_r/Q$

Estimate return sludge concentration from SVI:

$$X_r\ (\mathrm{mg/L}) \approx \frac{10^6}{\mathrm{SVI}} = \frac{10^6}{100} = \mathbf{10{,}000}\ \mathrm{mg/L}$$

$$R = \frac{X}{X_r - X} = \frac{2800}{10{,}000 - 2800} \approx \mathbf{0.39} \quad \text{(about 39\%)}$$

- HRT ≈ 7.7 h → within the typical 6–8 h range for conventional ASPs.
- MLSS = 2,800 mg/L → within the usual 2,000–3,000 mg/L range.
- F/M = 0.2 d^{-1} and Volumetric loading ≈ 0.56 kg/m^3·d → both consistent with conventional ASP operation.
- Return ratio ≈ 0.39 → lies well within the common 25–50% return flow band.
- Effluent BOD target 30 mg/L with these settings is typical of a conventional ASP.

Conclusion: All computed parameters are compatible with conventional ASP design practice.

2) a) In a water treatment plant which treats 10 MLD of water, it is proposed to design a circular PST and RSF. Using the data given below, find:

(A) Surface area, DT (Detention Time) of the PST and diameter

(B) Horizontal velocity **(C) Surface area of RSF**

(D) No. of filter units

PST surface loading = 50 m³/m²/day **Depth of PST = 2.5 m**

Rate of filtration = 5000 l/m²/hr **Quantity of backwash water = 15%**

Time for backwashing = 1 hr **12M**

Ans:

(A) PST surface area, detention time and diameter

Surface area

$$A_{\mathrm{PST}} = \frac{Q}{\text{surface loading}} = \frac{10{,}000}{50} = \boxed{200\ \mathrm{m}^2}$$

Detention time (DT)

$$V = A_{\mathrm{PST}} \times \text{depth} = 200 \times 2.5 = 500\ \mathrm{m}^3$$

$$\mathrm{DT} = \frac{V}{Q} = \frac{500}{10{,}000}\ \mathrm{d} = 0.05\ \mathrm{d} = \boxed{1.2\ \mathrm{h}}$$

Diameter (circular tank)

$$A = \frac{\pi D^2}{4} \Rightarrow D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{800}{\pi}} \approx \boxed{15.95\ \mathrm{m}}\ (\text{say } 16\ \mathrm{m})$$

(B) Horizontal velocity in PST

$$v_h = \frac{\text{overflow rate}}{\text{depth}} = \frac{50}{2.5} = 20\ \mathrm{m/d}$$

(C) RSF total surface area

Account for wash-water use and downtime.

- Net required production $= Q_{\mathrm{net}} = 10{,}000\ \mathrm{m}^3/\mathrm{d}$
- Wash-water allowance $W = 15\% \Rightarrow Q_{\mathrm{filtered}} = \frac{Q_{\mathrm{net}}}{1-W} = \frac{10{,}000}{0.85} = 11{,}764.7\ \mathrm{m}^3/\mathrm{d}$
- Filtration hours per day $= 24 - 1 = 23\ \mathrm{h}$
- Required filtration rate (plant-wide):

$$q_h = \frac{11{,}764.7}{23} = 511.5\ \mathrm{m}^3/\mathrm{h}$$

- Filter area:

$$A_{\mathrm{RSF}} = \frac{q_h}{5} = \boxed{102.3\ \mathrm{m}^2}$$

(D) Number of filter units

Pick a practical unit area ~25–26 m² (common for RSF).

$$\frac{102.3}{\sim 25.5} \approx 4\ \text{units}$$

2.(a)(ii) Explain the mechanisms responsible for removal of colloidal solids by coagulation 8M

1. Charge Neutralization

- **Colloids in water** (e.g., clay, organic matter) usually have a **negative surface charge**.
- This charge creates an **electrical double layer**, causing particles to repel one another and remain stable in suspension.
- **Coagulants** like alum $(Al_2(SO_4)_3)$, ferric salts, or polyaluminium chloride release multivalent cations (Al^{3+}, Fe^{3+}) that **neutralize these surface charges**.
- Once the repulsive forces are reduced or eliminated, particles can come closer and stick together.

2. Adsorption and Interparticle Bridging

- When **polyelectrolyte coagulants** (long-chain polymers) are used, they can **adsorb onto particle surfaces**.
- These polymer chains extend into the water and attach to other particles, forming **bridges** between them.
- This creates larger, stronger flocs that are easier to settle or filter.

3. Sweep Flocculation (Enmeshment in Precipitate)

- At higher coagulant doses and appropriate pH, coagulants form **voluminous metal hydroxide precipitates**:

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 \downarrow$$

- As these gelatinous precipitates settle, they **physically trap and enmesh** colloidal particles, dragging them down with the settling floc ("sweeping" them from the water).

4. Compression of the Electrical Double Layer

- The addition of electrolytes from coagulants increases **ionic strength** in the water.
- This compresses the thickness of the electrical double layer around particles, reducing repulsion and allowing particles to collide and stick.

2.(b) Determine the area required for a proposed landfill for a town with population of 5 lakhs. The per capita waste generation is about 0.5 kg. It is proposed that the landfill life to be 30 years with maximum height of 20 m. Density of compacted waste is 450 kg/m ^{3}. Assume ratio of solid waste to soil cover as 4:1.
20

1. Daily waste mass

$$\text{Daily mass} = 5 \times 10^5 \times 0.5 = \mathbf{250{,}000\ kg/day}$$

2. Annual waste mass

$$\text{Annual mass} = 250{,}000 \times 365 = \mathbf{91{,}250{,}000\ kg/year}$$

3. Total mass for 30 years

$$\text{Total mass}_{30\text{yr}} = 91{,}250{,}000 \times 30 = \mathbf{2{,}737{,}500{,}000\ kg}$$

4. Compacted volume of waste

$$V_{\text{waste}} = \frac{\text{Total mass}}{\text{density}} = \frac{2{,}737{,}500{,}000}{450} = \mathbf{6{,}083{,}333.33\ m^3}$$

5. Volume of soil cover (ratio 4:1 → soil = waste/4)

$$V_{\text{soil}} = \frac{V_{\text{waste}}}{4} = \mathbf{1{,}520{,}833.33\ m^3}$$

6. Total required volume (waste + soil)

$$V_{\text{total}} = V_{\text{waste}} + V_{\text{soil}} = 6{,}083{,}333.33 + 1{,}520{,}833.33 = \mathbf{7{,}604{,}166.67\ m^3}$$

7. Plan area at max height 20 m

$$\text{Area} = \frac{V_{\text{total}}}{H} = \frac{7{,}604{,}166.67}{20} = \mathbf{380{,}208.33\ m^2}$$

3.(c)(i) An industry consumes 10,000 lit. of fuel per day for generation of steam. Based on quality of the fuel, the emission data indicates the following average emissions for 1 ML of fuel consumed per year.
SPM = 3 t/yr; SO_2 = 75 t/yr; NO_x = 12 t/yr; HC = 0.6 t/yr; CO = 0.75 t/yr.
Determine the height of the chimney required for the industry. 10M

4.(a) Using the data given below, estimate
(i) Volume of fresh sludge produced
(ii) Unit weight of raw sludge
(iii) Volume of digested sludge

Wastewater discharge = 2 MLD
Influent suspended solids = 200 mg/l
Suspended solids removal in PST = 60%
Moisture content of fresh sludge = 96%
% conversion of fresh sludge to liquid and gas = 50%
Moisture content of digested sludge = 90%
Specific gravity of solids = 1.2 20M

Ans:

1. Mass of suspended solids captured in PST (dry solids/day)

Influent suspended solids mass per day:

$$\mathrm{SS}_{in} = Q \times \mathrm{SS\ conc.} = 2000\ \mathrm{m^3/d} \times 0.2\ \mathrm{kg/m^3} = 400\ \mathrm{kg/d}$$

PST removes 60% → dry solids in fresh sludge:

$$M_{ds,fresh} = 0.60 \times 400 = \mathbf{240\ kg/day}$$

2. (i) Volume of fresh sludge produced (m^3/day)

Fresh sludge solids fraction $= 1 - 0.96 = 0.04$ (mass basis). Wet mass of fresh sludge:

$$\text{Wet mass}_{fresh} = \frac{M_{ds,fresh}}{0.04} = \frac{240}{0.04} = 6000\ \mathrm{kg/day}$$

Bulk density (unit weight) of fresh sludge:

$$\rho_{fresh} = f_s\rho_s + f_w\rho_w = 0.04(1200) + 0.96(1000) = 48 + 960 = 1008\ \mathrm{kg/m^3}$$

So volume:

$$V_{fresh} = \frac{6000\ \mathrm{kg}}{1008\ \mathrm{kg/m^3}} = \mathbf{5.95\ m^3/day}\ \text{(rounded)}$$

3. (ii) Unit weight of raw (fresh) sludge

As computed above:

$$\boxed{\rho_{fresh} = 1008\ \text{kg/m}^3\ (\approx 1.008\ \text{t/m}^3)}$$

(Alternatively you can express unit weight as 1008 kg/m^3 ≈ 9.88 kN/m^3 if needed.)

4. (iii) Volume of digested sludge (m^3/day)

Given 50% conversion of fresh sludge dry solids to gas/liquid:

$$M_{ds,digested} = 0.50 \times M_{ds,fresh} = 0.50 \times 240 = 120\ \text{kg/day}$$

Digested sludge solids fraction = 10% (mass basis), so wet mass of digested sludge:

$$\text{Wet mass}_{digested} = \frac{120}{0.10} = 1200\ \text{kg/day}$$

Bulk density of digested sludge:

$$\rho_{digested} = 0.10(1200) + 0.90(1000) = 120 + 900 = 1020\ \text{kg/m}^3$$

Volume:

$$V_{digested} = \frac{1200}{1020} = \mathbf{1.18\ m^3/day}\ \text{(rounded)}$$