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Environment

BOD & DO ; DF :

BOD Reaction Rate/ Rate of Constant,

$K = K_{20} = 0.1$ /day (at 20°C)

- যখন $K \geq 0.18$, [K=0.18 to 0.23]

$$BOD_t = L_o \left(1 - e^{-Kt}\right)$$

$$BOD_5 = L_o \left(1 - e^{-5K}\right)$$

- যখন $K < 0.18$, [K = 0.1 to 0.179]

$$BOD_t = L_o \left(1 - 10^{-Kt}\right)$$

- BOD reaction rate,

$$K_T = K_{20} \times \theta^{(T-20)}$$

$$\Rightarrow K_T = 0.1 \times 1.047^{(T-20)}$$

Hints:

$\theta = 1.047$	when	T= 20°~ 30°C
$\theta = 1.135$	when	T= 4°~ 20°C
K_{20} = 0.1/day	when	T= 20°C

- $$BOD_5 = \frac{DO_i - DO_f}{DF}$$

> DF এর মান 1 হতে ছোট হলে তা ভাগ হবে।
> DF এর মান 1 হতে বড় হলে তা গুন হবে।

- Dilution Factor,

$$DF = \frac{V_{(sample)}}{V_{(bottle)}} = \frac{V_{(undiluted)}}{V_{(Diluted)}}$$

- BOD consumption = $DO_i - DO_f$

- For diluted water and waste water mixing:

$$BOD_m V_m = BOD_w V_w + BOD_d V_d$$

$$V_m = V_w + V_d$$

- For River flow and waste water mixing:

$$BOD_m Q_m = BOD_w Q_w + BOD_F Q_F$$

- Dissolved Oxygen Depletion = $DO_i - DO_f$

- BOD Remaining , $BOD_t = L_o \times e^{-Kt}$

BOD Maths :

① Determine the ultimate BOD for a sewage having 5 day BOD at 20°C is 150 mg/L. Assume, reaction rate constant is 0.22/day.

[BIFPCL-2015, BCIC-2016, JOCL-2018, RPGCL-2017, BWDB-2018, Combined Bank-2020]

Soln:

$L_o = ?$

$BOD_5 = 150$ mg/L

$K = 0.22$/day

$$BOD_t = L_o(1 - e^{-Kt})$$

$$\Rightarrow BOD_5 = L_o(1 - e^{-5 \times K})$$

$$\Rightarrow 150 = L_o(1 - e^{-5 \times 0.22})$$

∴ Ultimate BOD, $L_o = 224.84$ mg/L (Ans.)

Hints: mg/L = ppm

② The amount of BOD_5 in a sewage found 200 mg/L at temperature 20°C. If K = 0.22/day, then determine the BOD_{10} at the same temperature. [MPL-2017, BPDB-2018, SGFCL-2018]

Soln:

$BOD_5 = 200$ mg/L

$K = 0.22$/day

$BOD_{10} = ?$

$$BOD_5 = L_o(1 - e^{-5 \times K})$$

$$\Rightarrow 200 = L_o(1 - e^{-5 \times 0.22})$$

$$\therefore L_o = 299.79 \text{ mg/L}$$

Now,

$$BOD_t = L_o(1 - e^{-Kt})$$

$$\Rightarrow BOD_{10} = L_o(1 - e^{-10 \times K})$$

$$\Rightarrow BOD_{10} = 299.79(1 - e^{-10 \times 0.22})$$

∴ $BOD_{10} = 266.57$ mg/L (Ans.)

✓ $\theta = 1.047$ when $T = 21^\circ \sim 30^\circ C$

✓ $\theta = 1.135$ when $T = 4^\circ \sim 19^\circ C$

✓ When $T = 20^\circ C$, $K = 0.1/day$

⑦ If a wastes had an ultimate BOD equal to 300 mg/L. At 20°C, the five day BOD was 200 mg/L and the reaction rate constant was 0.22/day. What would the five day BOD of the waste be at 25°C ?

Solⁿ: BOD reaction rate,

$L_o = 300$ mg/L

BOD_5 @ 20°C $= 200$ mg/L

BOD_5 @ 25°C = ?

$K_{20} = 0.22$/day

$$K_T = K_{20} \times \theta^{(T-20)}$$

$\Rightarrow K_{25} = K_{20} \times 1.047^{(25-20)}$

$\Rightarrow K_{25} = 0.22 \times 1.047^{(25-20)}$

$\therefore K_{25} = 0.277$ /day

Now, At 25°C,

$$BOD_5 = L_o \left(1 - e^{-5 \times K_{25}}\right)$$

$= 300 \times \left(1 - e^{-5 \times 0.277}\right)$

$= 224.9$ mg/L (Ans)

⑧ If the BOD_5 at 20°C of a sewage sample is 320 mg/L, calculate its 10 day BOD at 30°C if $K = 0.23$/day. [DSCC - 2016]

Solⁿ: At 20°C,

BOD_5 @ 20°C $= 320$ mg/L

$K_{20} = 0.23$/day

BOD_{10} @ 30°C = ?

$$BOD_5 = L_o \left(1 - e^{-5 \times K_{20}}\right)$$

$\Rightarrow 320 = L_o \left(1 - e^{-5 \times 0.23}\right)$

$\therefore L_o = 468.27$ mg/L

At 30°C,

$$K_T = K_{20} \times \theta^{(T-20)}$$

$\Rightarrow K_{30} = 0.23 \times 1.047^{(30-20)}$

$\therefore K_{30} = 0.364$ / day

Now,

$$BOD_{10} = L_o \left(1 - e^{-10 \times K_{30}}\right)$$

$= 468.27 \left(1 - e^{-10 \times 0.364}\right)$

$= 455.98$ mg/L (Ans)

৫) Waste water এ BOD_5 ২০ ডিগ্রি সেলসিয়াস তাপমাত্রায় পাওয়া যায় 150 mg/L, K এর মান 0.23/day হলে ১৫ ডিগ্রি সেলসিয়াস তাপমাত্রায় BOD_8 এর মান কত হবে? [HED-2020]

Soln:

BOD_5 @ 20°C = 150 mg/L

$K_{20} = 0.23/d$

BOD_8 @ 15°C = ?

At 20°C,

$$BOD_5 = L_o\left(1 - e^{-5 \times K_{20}}\right)$$

$$\Rightarrow 150 = L_o\left(1 - e^{-5 \times 0.23}\right)$$

$$\therefore L_o = 219.50 \text{ mg/L}$$

At 15°C,

$$K_T = K_{20} \times \theta^{(T-20)}$$

$$\Rightarrow K_{15} = K_{20} \times 1.135^{(15-20)}$$

$$= 0.23 \times 1.135^{(15-20)}$$

$$= 0.122$$

$$\therefore BOD_8 = L_o\left(1 - e^{-8 \times K_{15}}\right)$$

$$= 219.50 \times \left(1 - e^{-8 \times 0.122}\right)$$

$$= 136.79 \text{ mg/L} \quad \text{(Ans.)}$$

৬) If a 2% solution of sewage is incubated for 5 days at 20°C and dissolved oxygen depletion was 5 ppm, determine BOD_5. [PGCB-2017]

Soln: For 2% solution,

Dilution Fraction, $DF = 2\% = \frac{2}{100} = 0.02$

Oxygen depletion, $DO_i - DO_f = 5$ ppm

Now,
$$BOD_5 = \frac{DO_i - DO_f}{DF}$$

$$= \frac{5}{0.02} = 250 \text{ ppm} \quad \text{(Ans.)}$$

৭) Waste water 40 ml is mixed with diluted water of 360 ml in a bottle. $DO_i = 8.5$ mg/L, $DO_f = 3.5$ mg/L, then $BOD_5 = ?$ [WARPO-2015]

Soln:
$$DF = \frac{\text{Volume of waste water}}{\text{Volume of waste water plus dilution water}}$$

$$\Rightarrow DF = \frac{40}{360 + 40} = 0.1$$

$$BOD_5 = \frac{DO_i - DO_f}{DF}$$

$$= \frac{8.5 - 3.5}{0.1} = 50 \text{ mg/L} \quad \text{(Ans.)}$$

(b) A standard 5 day BOD test is run using a mix consisting of four parts distilled water and one part waste water (no seed). The initial DO of the mix is 9 mg/L and the DO after 5 days is determined to be 1 mg/L. What is BOD_5? [BB-2021]

Solⁿ: Distilled water = 4 parts

Waste water = 1 part

$$\therefore DF = \frac{V_{(waste\ water)}}{V_{(waste\ +\ dilution\ water)}}$$

$$\Rightarrow DF = \frac{1}{1+4} = 0.2$$

Now,

$$BOD_5 = \frac{DO_i - DO_f}{DF}$$

$$= \frac{9-1}{0.2}$$

$$= 40\ mg/L \quad \text{(Ans.)}$$

(Seeded condition)

(2) A sample having 25 mL sewage water to dilute is 300 mL. $D_i = 8.7$, $D_f = 3.7$ and dilute water seed sample $D_i = 3.7$, $D_f = 2.6$, Determine BOD_5.

[WASA-2014, BCIC-2017]

Solⁿ: Here, $DO_i = 8.7$

$DO_f = 3.7$

For Seed Sample, $B_i = 3.7$

$B_f = 2.6$

Now,

$$DF = \frac{V_{(waste)}}{V_{(waste\ +\ dilution\ water)}}$$

$$\Rightarrow DF = \frac{25}{300} = 0.083$$

Now,

$$BOD_5 = \frac{(DO_i - DO_f) - (B_i - B_f)(1 - DF)}{DF}$$

$$= \frac{(8.7 - 3.7) - (3.7 - 2.6)(1 - 0.083)}{0.083}$$

$$= 48.09\ mg/L \quad \text{(Ans.)}$$

[DF এখানে 1 হতে বড়, তাই শূন্য করা হয়েছে।]

(১০) The dilution factor is 50 for a 5 days BOD test having initial dissolve oxygen 7.4 mg/L and final dissolved oxygen of 4.3 mg/L. The rate of constant (e base) is 0.2/day. Determine the ultimate BOD of the sample.

[BCIC-2019, BADC-2020, PGCB-21]

Soln:

DF = 50

DO_i = 7.4 mg/L

DO_f = 4.3 mg/L

K = 0.2 / day

Ultimate BOD, L_o = ?

Here, $BOD_5 = (DO_i - DO_f) \times DF$

$= (7.4 - 4.3) \times 50$

$= 155$ mg/L

And, $BOD_5 = L_o (1 - e^{-5 \times K})$

$\Rightarrow 155 = L_o \times (1 - e^{-5 \times 0.2})$

$\therefore L_o = 245.21$ mg/L (Ans.)

(১১) Ten 5mL samples of waste water are placed in 300mL BOD bottles and diluted to full volume. Half of the bottles are tested immediately and the average initial concentration of dissolved oxygen = 7.9 mg/L. The remaining bottles are incubated for 5 days after which the average dissolved oxygen is determined to be 4.5 mg/L. ($K = 0.13\ day^{-1}$), Find (i) Standard BOD and (ii) Ultimate Carbonaceous BOD. [BB AD-2018]

Soln:

$V_{(waste)} = 10 \times 5$ mL

$V_{(bottle)} = 300$ mL

$DO_i = 7.9$ mg/L

$DO_f = 4.5$ mg/L

K = 0.13 / day

BOD_5 = ?

L_o = ?

$DF = \frac{V_{(waste)}}{V_{(Bottle)}} = \frac{10 \times 5}{300}$

$= 0.167$

$BOD_5 = \frac{DO_i - DO_f}{DF}$

$= \frac{7.9 - 4.5}{0.167} = 20.36$ mg/L

$BOD_5 = L_o (1 - e^{-5 \times K})$

$\Rightarrow 20.36 = L_o (1 - e^{-5 \times 0.13})$

$\therefore L_o = 42.6$ mg/L (Ans.)

(32) The dissolved oxygen in an unseeded sample of diluted waste having an initial DO of 8 mg/L, and final dissolved oxygen after 5 days is 4 mg/L. If the sample is diluted in 1:50, find the BOD_5 of the sample. If this BOD_5 water discharge in an open source at a rate of 10 ft³/sec, what will be BOD load per year (ton/year)?

[NHA-2019]

Solⁿ:

$DO_i = 8\ mg/L$ BOD Load = ?

$DO_f = 4\ mg/L$

$DF = \frac{1}{50} = 0.02$

$Q = 10\ ft^3/sec$ through 24 hours

Now, $BOD_5 = \frac{DO_i - DO_f}{DF}$

$= \frac{8-4}{0.02} = 200\ mg/L$

Total BOD_5 Load discharge (/Year)

$= BOD_5$ Concentration (Dose) × Yearly discharge, Q

$= 200\ (mg/L) \times \left[10\ (ft^3/sec) \times 365\ (day/yr)\right]$

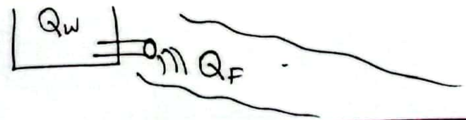
$= \frac{200}{10^6}\ (kg/L) \times \frac{10}{(3.28)^3}\ (m^3/s) \times (3600 \times 24 \times 365)\ \frac{sec}{yr}$

$= \frac{200}{10^6 \times 10^3} \left(\frac{ton}{L}\right) \times \frac{10 \times 10^3}{(3.28)^3} \left(\frac{L}{s}\right) \times (3600 \times 24 \times 365)\ \frac{sec}{yr}$

$= 1787.37\ (ton/year)$

(Ans)

Hints: বছরের 365 দিনই 10 ft³/sec flow 24 ঘন্টা ধরে discharge হতে থাকে।



(27) A municipal waste water treatment plant discharge 1.2 m³/sec of effluent having BOD of 60 mg/L that has a flow of 9.3 m³/sec and BOD 6 mg/L. ~~Assume complete mixing,~~ Estimate the mixing BOD of the river just downstream of the flow.

[BPDB-2015, ERL-2017]

Soln: Waste discharge, $Q_w = 1.2\ m^3/s$

Effluent BOD, $BOD_w = 60\ mg/L$

Flow, $Q_F = 9.3\ m^3/s$

Flow BOD, $BOD_F = 6\ mg/L$

Mixing discharge, $Q_m = Q_w + Q_F = 10.5\ m^3/s$

mixing BOD, $BOD_m = ?$

$$BOD_m \times Q_m = BOD_w Q_w + BOD_F Q_F$$

$\Rightarrow BOD_m \times 10.5 = 60 \times 1.2 + 6 \times 9.3$

$\therefore BOD_m = 12.17\ mg/L$ (Ans)

(28) A canal exerts wastewater in a river at 8000 m³/day. BOD of the waste water is given in 18 mg/L. What is the total amount of BOD exerted in the river? [DMTCL-2019]

Soln: Total amount of BOD = BOD concentration × Flow

$= 18\ (mg/L) \times 8000\ (m^3/day)$

$= \frac{18}{10^6}\ (kg/L) \times 8000 \times 10^3\ (L/day)$

$= 144\ kg/day$ (Ans)

(29) A canal exerts wastewater in a river at 55000 m³/day. BOD is 110 mg/L, what is the total amount of BOD exerted in river? If a treatment plant is treating the water to remove 70%. BOD, what is the BOD exerted now?

GTCL-2016

Soln: Total amount of BOD $= 55000\ (m^3/day) \times 110\ (mg/L)$

$= 55000 \times 10^3\ (L/day) \times \frac{110}{10^6}\ (kg/L)$

$= 6050\ kg/day$

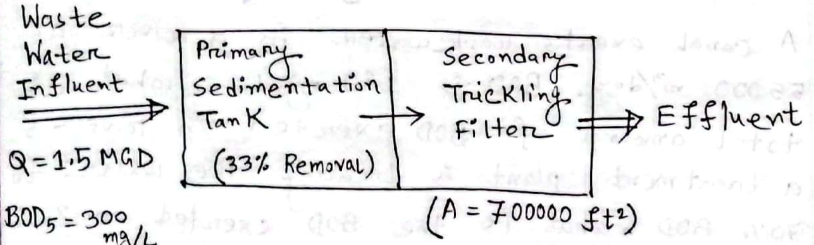
Amount of BOD exerted $= 6050 - 70\%$ of 6050

$= 1815\ kg/day$ (Ans)

(24) Waste water flowing from a city at a rate of 1.5 MGD is treated by primary sedimentation and secondary trickling filters with total surface area 700000 ft^2. The influent BOD_5 concentration is 300 mg/L and suspended solids concentration is 220 mg/L. The primary treatment process removes 33% of the BOD_5. Calculate the required loading rate (in $kg/ft^2/day$).

[DPDC-2020, JGTDSL-2021]

Sol^n:



Q = 1.5 MGD

$BOD_5 = 300$ mg/L

SS = 220 mg/L

1 Gallon = 3.785 L (US)

$\therefore$ 1 MG = 3.785×10^6 L

$\therefore$ 1.5 MG = $1.5 \times 3.785 \times 10^6$ L

1.5 MGD = $1.5 \times 3.785 \times 10^6$ L/day

At Primary Sedimentation Tank:

Total removal = 33% of Influent BOD

= 33% of 300 mg/L

= 99 mg/L

Remaining BOD = 300 − 99 = 201 mg/L

Secondary Trickling Filter:

To be treated = 201 mg/L + 220 mg/L SS

= 421 mg/L

= 421×10^{-6} kg/L

Total Loading = Concentration × Flow

= 421×10^{-6} (kg/L) × $1.5 \times 3.785 \times 10^6$ (L/day)

= 2390.23 kg/day

$\therefore$ Load rate = $\frac{2390.23}{700000}$ ~~×400~~ $\frac{kg/day}{ft^2}$

= 3.41×10^{-3} ($kg/ft^2/day$)

(Ans.)

(29) Just below the point where a continuous discharge of pollution mixes with river, the BOD is 10.9 mg/L and DO is 7.6 mg/L. The river and waste mixture has a temperature of 20°C, a deoxygenation constant of 0.20/day, an average flow speed 0.3 m/s, and an average depth of 3m. The saturation value of DO at 20°C is 9.1 mg/L and reaeration constant is 0.41/day.

(a) Find the time and distance downstream at which the oxygen deficit is at a maximum.

(b) Find the minimum value of DO.

[DMTCL-2019]

Soln: Ultimate BOD, L_o = 10.9 mg/L

K_d = 0.20/day , K_r = 0.41/day

V = Flow speed = 0.3 m/s = 0.3 × 24 × 3600 (m/day)

Initial deficit, D_o = 9.1 − 7.6 = 1.5 mg/L

Average depth = 3m

t_c = ? S_c = ? DO_{min} = ?

(a) Time at which the deficit is a maximum,

$$t_c = \frac{1}{K_r - K_d} \ln \left\{ \frac{K_r}{K_d} \left[1 - \frac{D_o (K_r - K_d)}{K_d L_o} \right] \right\}$$

$$= \frac{1}{0.41 - 0.20} \ln \left[\frac{0.41}{0.20} \left\{ 1 - \frac{1.5 \times (0.41 - 0.20)}{0.20 \times 10.9} \right\} \right]$$

= 2.68 days

The critical distance downstream would be,

$$S_c = v \times t_c$$

$= (0.3 \times 24 \times 3600)$ m/day $\times$ 2.68 day

= 69465.6 m (Ans)

= 69.46 Km

(b) Oxygen deficit, $D = \frac{K_d L_o}{K_r - K_d} \left(e^{-K_d \times t} - e^{-K_r \times t} \right) + D_o e^{-K_r \times t}$

$DO_{max} \doteq D = \frac{0.20 \times 10.9}{0.41 - 0.20} \left(e^{-0.20 \times 2.68} - e^{-0.41 \times 2.68} \right) + 1.5 e^{-0.41 \times 2.68}$

= 3.1 mg/L

$\therefore DO_{min} = DO_{sat} - DO_{max}$ = 9.1 − 3.1 = 6 mg/L (Ans)

Chlorine demand & Bleaching Powder :

(২৮) 500 m^3/d water is to be supplied from a water treatment plant with chlorine concentration of 0.5 mg/L, if bleaching powder that is used for chlorine has contains 30% available Cl_2 (by weight), find out the amount of bleacing poweder in Kg/day. [ERL-2017, DESCO-2019, 34th BCS]

Soln: Total Cl_2 amount = Cl_2 Dose X Total Water demand

$$= 0.5\ (mg/L) \times 500\ (m^3/day)$$

$$= \frac{0.5}{10^6}\ (Kg/L) \times 500\times10^3\ (L/day)$$

$$= 0.25\ Kg/day$$

Now, For 30% available Cl_2,

30 Kg Cl_2 in bleacing Powder of 100 Kg

$\therefore$ 0.25 (Kg/day) " " " $\frac{100\times0.25}{30}$ Kg/day

$$= 0.833\ Kg/day$$

(Ans.)

1 ppm = 1 mg/L

1 MLD = 1 Million Litre/Day

(২৯) 100 MLD water is to be supplied from a water treatment plant which containing 0.4 ppm Cl_2, if bleaching powder contains 25% available chlorine by weight, find out the amount of bleacing powder in Kg/day.
[DPDC-2014, RPGCL-2017, BWDB-2018, DTCA-2018, BCIC-2019, HED-2020, 30th BCS]

Soln: Total Cl_2 amount = Cl_2 Dose X Total Water Demand

$$= 0.4\ (mg/L) \times 100\ (MLD)$$

$$= \frac{0.4}{10^6}\left(\frac{Kg}{L}\right) \times 100\times10^6\left(\frac{L}{day}\right)$$

$$= 40\ Kg/day$$

For 25% available chlorine,

25 Kg Cl_2 in Bleacing Powder of 100 Kg

$\therefore$ 40 (Kg/day) " " " $\frac{100\times40}{25}$ Kg/day

$$= 160\ Kg/day$$

(Ans)

1 gallon = 3.785 Litre

1 gpd = 1 gallon/day

(20) It is required to disinfectant 500000 gpd of water with 0.3 mg/L of Chlorine. If bleaching powder that contains 33.33% of available chlorine is used, how much bleaching powder is needed to treat the daily flow of water?

[38th BCS, WRGCL-2014]

Soln: Total Cl_2 Amount = Cl_2 Dose × Total Water demand

$$= 0.3\,(mg/L) \times 500000\,(gpd)$$

$$= \frac{0.3}{10^6}\left(\frac{Kg}{L}\right) \times 500000 \times 3.785 \left(\frac{L}{day}\right)$$

$$= 0.567 \text{ Kg/day}$$

For 33.33% available Cl_2,

33.33 Kg Cl_2 in Bleaching powder of 100 Kg

∴ 0.567 (Kg/day) " " " $\frac{100 \times 0.567}{33.33}$ Kg/d

$$= 1.70 \text{ Kg/day}$$

(Ans)

(22) A water treatment plant produces 1 ML waste water per day. Bleaching powder (40% Cl_2) is used to disinfect the water in the plant. You must maintain 0.5 mg/L Cl_2 residual in the finished water with a Cl_2 demand of 3.5 mg/L. Calculate the amount of bleaching powder required per day.

[EGCB-2020]

Soln: Cl_2 Dose = Cl_2 demand + Residual Cl_2

$$= 3.5 + 0.5$$

$$= 4 \text{ mg/L}$$

Total Cl_2 amount = Cl_2 Dose × Total Water demand

$$= 4\,(mg/L) \times 1\,(ML/day)$$

$$= 4 \times 10^{-6}\,(Kg/L) \times 1 \times 10^6 \left(\frac{L}{day}\right)$$

$$= 4 \text{ Kg/day}$$

For 40% available Cl_2,

40 Kg Cl_2 in Bleaching powder of 100 Kg

∴ 4 (Kg/day) " " " $\frac{100 \times 4}{40}$ Kg/day

$$= 10 \text{ Kg/day}$$

(Ans)

1 lpcd = 1 Litre per Capita per day

(22) The population of 2005 is 10000 and 2015 is 19500. What is the water demand of 2025? Given water demand is 90 lpcd. Chlorine content of 0.5 mg/L is to be added in water. How much bleaching powder is needed if bleaching powder contains 25% of Chlorine? [PGCB-2020], [GTCL-2016, DESCO-2015, DPDC-2019]

Solⁿ:

$P_P = P_{2005} = 10000$

$P_F = P_{2015} = 19500$

$n = 2015 - 2005$
$= 10$ years

From 2005 to 2015:

$P_F = P_P (1+r)^n$

$\Rightarrow 19500 = 10000 (1+r)^{10}$

$\therefore r = 0.069$

From 2015 to 2025:

$P_F = P_P (1+r)^n$

$= 19500 \times (1 + 0.069)^{10}$

$= 38002$

~~Total Cl_2~~ Total Water demand = Population X Per Capita Demand

$= 38002 \times 90$ (L/day)

$= 3420180$ L/day

Total Cl_2 amount = Cl_2 Dose X Total Water Demand

$= 0.5$ (mg/L) $\times$ 3420180 (L/day)

$= 0.5 \times 10^{-6}$ (Kg/L) $\times$ 3420180 (L/day)

$= 1.71$ Kg/day

For 25% available Cl_2,

25 Kg Cl_2 in Bleaching Powder of 100 Kg

$\therefore$ 1.71 (Kg/day) " " " $\frac{100 \times 1.71}{25}$ Kg/day

$= 6.84$ Kg/day (Ans.)

pH and pOH

(26) If the $pH = 9.5$, what is the $[OH^-]$ concentration? [PGCB-2019]

Soln:

$$pH + pOH = 14$$

$\Rightarrow 9.5 + pOH = 14$

$\therefore pOH = 4.5$

And, $$pOH = -\log[OH^-]$$

$\Rightarrow 4.5 = -\log[OH^-]$

$\Rightarrow [OH^-] = 10^{-4.5}$

$\therefore [OH^-] = 3.16 \times 10^{-5}$ mol/L (Ans.)

(28) Find the hydrogen ion concentration and hydroxide ion concentration in tomato juice having pH of 4.1. [GTCL-2018]

Soln:

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

$\Rightarrow 4.1 = -\log[H^+]$

$\Rightarrow [H^+] = 10^{-4.1}$

$\therefore [H^+] = 7.94 \times 10^{-5}$ mol/L

And, $$pH + pOH = 14$$

$\Rightarrow 4.1 + pOH = 14$

$\therefore pOH = 9.9$

$\therefore$ $$pOH = -\log[OH^-]$$

$\Rightarrow 9.9 = -\log[OH^-]$

$\Rightarrow [OH^-] = 10^{-9.9}$

$\therefore [OH^-] = 1.26 \times 10^{-10}$ mol/L (Ans.)

$1\ M = 1\ mole/L$

(22) 100 mg H_2SO_4 (MW=98) added to 1L of water. Determine the value of pH. Equation is $H_2SO_4 = 2[H^+] + SO_4^{2-}$. [NPBCL-2019]

Solⁿ:

$H_2SO_4 = 2[H^+] + SO_4^{2-}$

1 mole — 2mole — 1 mole

$= 98\ g$

100 mg H_2SO_4

$= \frac{100}{1000}\ g\ H_2SO_4$

$= 0.1\ g\ H_2SO_4$

Here,

$98\ g\ H_2SO_4 = 1\ M\ H_2SO_4$

$\therefore 0.1\ g\ H_2SO_4 = \frac{1 \times 0.1}{98}\ M\ H_2SO_4$

$= 0.00102\ M\ H_2SO_4$

For,

$2\ mole\ [H^+] = 2 \times 0.00102\ M$

$= 0.00204\ M\ [H^+]$

Now, $pH = -\log[H^+]$

$\Rightarrow pH = -\log[0.00204]$

$\therefore pH = 2.69$ (Ans.)

$1\ M = 1\ mole/L$

(23) Calculate pH of 1 g/L of $Ca(OH)_2$.

Solⁿ: MW of $Ca(OH)_2 = 40 + (16+1) \times 2 = 74$

$Ca(OH)_2 = Ca^{2+} + 2[OH^-]$

1 mole — 1 mole — 2 mole

$= 74\ g$

Now, $74\ g\ Ca(OH)_2 = 2\ mole\ [OH^-]$

$\Rightarrow 74\ g/L\ Ca(OH)_2 = 2\ mole/L\ [OH^-]$

$\therefore 1\ g/L\ Ca(OH)_2 = \frac{2}{74}\ mole/L\ [OH^-]$

$= 0.027\ M\ [OH^-]$

$\therefore pOH = -\log[OH^-]$

$= -\log[0.027]$

$= 1.57$

$\therefore pH = 14 - pOH = 12.43$ [∵ Alkaline]

(Ans.)

Cl_2 Demand ; Future population :

✓ Future Population,

$$P_F = P_P (1+r)^n$$

$n \rightarrow$ year
r = Population increasing rate

✓ Cl_2 Dose = Required Cl_2 + Residual Cl_2

✓ Total Water Demand = Population × Per Capita demand

✓ Cl_2 Amount = Cl_2 Dose × Total water demand

✓ For $x\%$ available Cl_2,

$$\text{Bleacing Powder Amount} = \frac{Cl_2 \text{ Amount} \times 100}{x}$$

pH & pOH :

- $pH = -\log [H^+]$
- $pOH = -\log [OH^-]$
- $pH + pOH = 14$
- $[H^+] \times [OH^-] = 10^{-14} = K_w$

$pH < 7 \Rightarrow$ Acidic
$pH > 7 \Rightarrow$ Alkaline

$[H^+]$, $[OH^-] \rightarrow M$
$\rightarrow$ mole/L

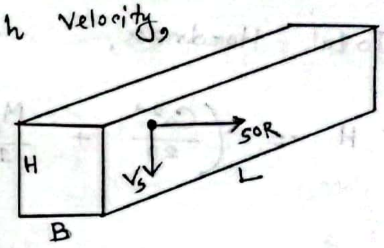
1 M = 1 mole/L

Sedimentation Tank : Settling velocity

✓ Settling velocity / Approach velocity,

$$V_s = \frac{Q}{A}$$

$$\Rightarrow V_s = \frac{Q}{BH}$$



✓ Surface Overflow Rate,

$$SOR_{(m/s)} = \frac{Q}{BL}$$

✓ % of Particle removed = $\frac{V_s}{SOR} \times 100$

✓ Detention time = $\frac{\text{Volume}}{\text{Discharge}}$

$$\Rightarrow T = \frac{BHL}{Q}$$

$$T = \frac{V}{Q}$$

In Grit Chamber,

$L = 15 \times B$

Settling velocity ; Sedimentation Tank:

(29) Waste water is flowing through a horizontal grit chamber at a maximum flow rate 30 ft^3/s. The depth of grit chamber is 6 ft and length is 15 times of its width. If the approach velocity is 1 ft/sec, determine the length of grit chamber.
[EGCB-2020, CPGCBL-2021

Soln: Approach velocity or Settling velocity,

$Q = 30\ ft^3/s$
$H = 6\ ft$
$L = 15 \times B$
$V_s = 1\ ft/sec$
$L = ?$

$$V_s = \frac{Q}{BH}$$

$$\Rightarrow 1 = \frac{30}{B \times 6}$$

$\therefore B = 5\ ft$

So, Length, $L = 15 \times B$
$= 15 \times 5$
$= 75\ ft$ (Ans.)

1 gallon = 3.785 L
1 million gallon = 3.785×10^6 L

(28) In 300 m^3 sedimentation tank, water is flowing in a rate of 1000 m^3/day. What is the detention time in hours?
[DPDC-2017] [NPCBL-2017, GTCL-2018]

Soln: Detention time,

Volume = 300 m^3
$Q = 1000\ m^3/day$
$= \frac{1000}{24}\ m^3/hr$
$= 41.67\ m^3/hr$

$$T = \frac{\text{Volume}}{\text{Discharge flow}}$$

$$\Rightarrow T = \frac{BHL}{Q}$$

$$\therefore T = \frac{300}{41.67} = 7.2\ hr$$ (Ans.)

(20) One million gallon liters of water (1 mgd) flows through a sedimentation tank. If the size of tank is 20′ X 50′ X 10′, find the detension time.
[BPDB-2016, CPGCBL-2018]

Soln:

Volume = $20 \times 50 \times 10\ ft^3$
$= \frac{20 \times 50 \times 10}{(3.28)^3}\ m^3$
$= \frac{20 \times 50 \times 10}{(3.28)^3} \times 1000\ L$
$= 2.83 \times 10^5\ L$
$Q = (1 \times 10^6 \times 3.785)\ L/day$

$$T = \frac{\text{Volume}}{Q} = \frac{BHL}{Q}$$

$$= \frac{2.83 \times 10^5}{3.785 \times 10^6} \frac{L}{L/day}$$

$= 0.0748$ day

$= 1.79$ hours (Ans.)

(60) A water treatment plant has a flow rate of 0.6 m^3/sec. The settling basin at the plant has an effective settling volume that is 20 m long, 3 m tall and 6 m wide. Will particles that have a settling velocity of 0.004 m/sec be completely removed?

(a) Determine Surface Overflow Rate, SOR.

(b) What percent of the particles will be removed (if not completely removed)?

[SGFL-2021]

Sol.n:

$Q = 0.6 \ m^3/sec$

Volume $= B \times H \times L$

$= 6m \times 2m \times 20m$

$= 240 \ m^3$

Settling velocity, $V_s = 0.004$ m/s

(a) Surface Overflow Rate,

$$SOR = \frac{Q}{BL} \quad \left(\frac{m^3/sec}{m^2}\right)$$

$$= \frac{0.6}{6 \times 20}$$

$$= 0.005 \ m/s$$

Here, $SOR > V_s$, so the particles will not be completely removed.

(b) $$\% \text{ of particle removed} = \frac{V_s}{SOR} \times 100$$

$$= \frac{0.004}{0.005} \times 100$$

$$= 80\%$$

(Ans.)

Ground water Discharge:

- Confined Aquifer or Artesian Aquifer,

$$Q = \frac{2\pi Km (D-d)}{\ln\left(\frac{R}{r}\right)}$$

- Unconfined Aquifer or Water Table Aquifer,

$$Q = \frac{\pi K (D^2 - d^2)}{\ln\left(\frac{R}{r}\right)}$$

K = Coefficient of Permeability
= Hydraulic Conductivity ($m^3/s / m^2$)

m = Thickness of Aquifer
= Difference betn confined and impervious layer (confined aquifer)

D-d = Draw down

D = Depth of Aquifer

d = depth of Tubewell

R = Radius of Drawdown
= Radius of "Circle of influence."

r = radius of well.

Ground water discharge:

(01) An artesian aquifer 10m thick with piezometric surface 40m above the bottom confining layer is being pumped by a fully penetrating well. The aquifer is medium sand (hydraulic conductivity 1.5×10^{-4} m/s). Steady state drawdowns of 5m and 1m are observed at two non-pumping wells located 20m and 200m respectively from the pumped well. Determine the discharge at the pumped well in m^3/s.

[SGFL-2017, BIWTA-2019]

Soln: For artesian aquifer,

$$Q = \frac{2\pi K.m(D-d)}{\ln\left(\frac{R}{r}\right)}$$

$$= \frac{2\pi \times 1.5 \times 10^{-4} \times (5-1) \times 10}{\ln\left(\frac{200}{20}\right)}$$

$$= 0.01637 \ m^3/sec$$

(Ans.)

$m = 10$ m
$D = 5$m
$d = 1$m
$r = 20$m
$R = 200$m
$K = 1.5 \times 10^{-4}$ m/s
$Q = ?$

$K \rightarrow m^3/s/m^2$
$K \rightarrow L/s/m^2$

(02) A 100 mm diameter tube well is sunk from a 10 m thick confined aquifer having a co-efficient of permeability equal to 0.75 lps/m². The depth of water below the piezometric level is 30m and it falls 2m in tube well while pumping. Calculate the discharge of the tubewell when radius of circle of influence is 30m.

[BCIC-2017, BUET MSc-2019]

Soln: Discharge,

$$Q = \frac{2\pi Km(D-d)}{\ln\left(\frac{R}{r}\right)}$$

$$= \frac{2\pi \times 0.75 \times 10 \times 2}{\ln\left(\frac{30}{0.05}\right)} \quad \left(\frac{l.m.m}{s.m^2}\right)$$

$$= 14.73 \ lps$$

(Ans.)

dia = 100m
$\therefore r = \frac{100}{2} = 50$mm $= 0.05$m
$m = 10$m
$K = 0.75$ lps/m² ~~7.5×10^{-4} m/s~~
$D-d = 2$m
$R = 30$m
$Q = ?$

(66) A 100 mm diameter tube well is sunk to 35m below in an unconfined aquifer. The depth of water in the tube well while pumping is 33 m and the radius of circle of influence is 30m. If the discharge is 33.4 lps, calculate the co-efficient of permeability. [WARPO-2017, 50 BMA]

Soln: For unconfined aquifer,

$$Q = \frac{\pi K (D^2 - d^2)}{\ln\left(\frac{R}{r}\right)}$$

$$\Rightarrow 33.4 = \frac{\pi \times K \times (35^2 - 33^2)}{\ln\left(\frac{30}{0.05}\right)}$$

$\therefore K = 0.5$ lps $/m^2$ (Ans.)

dia = 100 mm

$r = \frac{100}{2}$ mm $= 50$ mm $= 0.05$ m

$D = 35$ m

$d = 33$ m

$R = 30$ m

$Q = 33.4$ lps

$K = ?$

(P.T.O.)

Sulfur emission:

(68) The Boropukuria coal is burned at a rate 1 kg/sec. Analysis of BUET Lab shows the coal revels a sulfur content of 3%. What is the annual rate of SO_2 emission? Assume that 5% of the sulfur in the coal ends up in the ash.

[PGCB-2019, DESCO-2015]

Soln:

Coal Burn Rate $= 1$ kg/sec

$= 1 \times 3600 \times 24 \times 365$ kg/year

$= 31.536 \times 10^6$ kg/yr

Sulfur available $= 95\%$ of (3% of Burned Coal)

$= \frac{95}{100} \times \frac{3}{100} \times 31.536 \times 10^6$

$= 898776$ kg/yr

$$\underset{(32\,g)}{S} + O_2 \rightarrow \underset{(64\,g)}{SO_2}$$

From 32 g Sulfur, SO_2 formed 64 g

$\therefore$ " 898776 (kg/yr) " " " $\frac{64 \times 898776}{32}$ (kg/yr)

$= 1797552$ kg/yr (Ans.)

Hints:

Coal —burn→ 3% Sulfur → 5% Ash, 95% Sulfur

Coal —burn→ 97% other

Hardness & Alkalinity :

✓ Total Hardness,

$$TH = \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12}\right) \times 50$$

(mg/L as $CaCO_3$)

✓ Carbonate Hardness,

$$CH = \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30}\right) \times 50$$

(mg/L as $CaCO_3$)

✓ Non Carbonate Hardness,

NCH = TH − CH

✓ Total Alkalinity

$$\text{Total Alkalinity} = \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30} + \frac{OH^-}{17} - \frac{H^+}{1}\right) \times 50$$

(mg/L as $CaCO_3$)

⇒ Alkalinity

$$\text{Alkalinity} = \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30}\right) \times 50$$

(mg/L as $CaCO_3$)

CH = Alkalinity , when Alkalinity < TH

CH = TH , when TH < Alkalinity

✓ CH छोटा होगी,

✓ Total Dissolved Solid,

TDS = Σ Cations + Σ Anions

✓ Σ Cations = Σ Anions

$$\Rightarrow Ca^{2+} + Mg^{2+} + Na^+ + K^+ = HCO_3^- + CO_3^{2-} + Cl^- + SO_4^{2-}$$

$$\Rightarrow \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12} + \frac{Na^+}{23} + \frac{K^+}{39}\right) \times 50$$

$$= \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30} + \frac{Cl^-}{35.5} + \frac{SO_4^{2-}}{48}\right) \times 50$$

(mg/L as $CaCO_3$)

Hardness & Alkalinity:

(6a) An analysis of a sample of water with pH 7.5 has produced the following concentrations-

Cations	mg/L	Anions	mg/L
Ca^{2+}	80	Cl^-	100
Mg^{2+}	30	SO_4^{2-}	201
Na^+	72	HCO_3^-	165
K^+	6		

Find the total hardness, the carbonated hardness, the non-carbonated hardness and the alkalinity all expressed as $CaCO_3$. Find the total dissolved solids in mg/L.

Soln: Total Hardness, $TH = \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12}\right) \times 50$

$$= \left(\frac{80}{20} + \frac{30}{12}\right) \times 50$$

$$= 325 \text{ mg/L as } CaCO_3$$

Carbonated Hardness,

$$CH = \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30}\right) \times 50$$

$$= \left(\frac{165}{61} + \frac{0}{30}\right) \times 50$$

$$= 135.25 \text{ mg/L as } CaCO_3$$

Non-carbonated Hardness, $NCH = TH - CH$

$$= 325 - 135.25$$

$$= 189.75 \text{ mg/L as } CaCO_3$$

$$\text{Alkalinity} = \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30} + \frac{OH^-}{17} - \frac{H^+}{1}\right) \times 50$$

$$= \left(\frac{165}{61} + \frac{0}{30} + 0 - 0\right) \times 50$$

$$= 135.25 \text{ mg/L as } CaCO_3$$

$$TDS = \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12} + \frac{Na^+}{23} + \frac{K^+}{39} + \frac{Cl^-}{35.5} + \frac{SO_4^{2-}}{48} + \frac{HCO_3^-}{61}\right) \times 50$$

$$= \left(\frac{80}{20} + \frac{30}{12} + \frac{72}{23} + \frac{6}{39} + \frac{100}{35.5} + \frac{201}{48} + \frac{165}{61}\right) \times 50$$

$$= 974.68 \text{ mg/L as } CaCO_3$$

(Ans.)

(Q.4) The analysis of water from the bore shows the following results in mg/L as the ion.

$Ca^{2+} = 60$, $Mg^{2+} = 48$, $Na^{+} = 103.5$, $K^{+} = 19.5$, $HCO_3^- = 244$, $SO_4^{2-} = 220.8$, $Cl^- = 78.1$.

Find out total hardness, Carbonate hardness, and non-carbonate hardness in mg/L as $CaCO_3$. [WARPO-2017, DMTCL-2019]

Soln:

$$TH = \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12}\right) \times 50$$

$$= \left(\frac{60}{20} + \frac{48}{12}\right) \times 50$$

$$= 350 \text{ mg/L as } CaCO_3$$

$$Alkalinity = \left(\frac{HCO_3^-}{61} + \frac{CO_3^{2-}}{30} + \frac{OH^-}{17} - \frac{H^+}{1}\right) \times 50$$

$$= \left(\frac{244}{61} + 0 + 0 - 0\right) \times 50$$

$$= 200 \text{ mg/L as } CaCO_3$$

Here, TH > Alkalinity

So, CH = Alkalinity = 200 mg/L as $CaCO_3$

$$\therefore NCH = TH - CH$$

$$= 350 - 200$$

$$= 150 \text{ mg/L as } CaCO_3$$

(Ans.)

(09) A water has an alkalinity of 200 mg/L as $CaCO_3$. The Ca^{2+} concentration of 160 mg/L as the ion and Mg^{2+} concentration is 40 mg/L as the ion. The pH is 8.1. Find the total, carbonate and non-carbonate hardness. [PGCB-2019]

Soln:

$$TH = \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12}\right) \times 50$$

$$= \left(\frac{160}{20} + \frac{40}{12}\right) \times 50$$

$$= 567 \text{ mg/L as } CaCO_3$$

Given, Alkalinity = 200 mg/L as $CaCO_3$.

As, TH > Alkalinity,

So, CH = Alkalinity = 200 mg/L as $CaCO_3$

$\therefore$ NCH = TH − CH = 567 − 200

= 367 mg/L as $CaCO_3$

(Ans.)

(10) Hardness = 200 mg/L as $CaCO_3$, Ca^{2+} = 40 mg/L, K^+ = 39.1 mg/L, HCO_3^- = 300 mg/L, Cl^- = 10 mg/L, SO_4^{2-} = 109 mg/L. Find Na^+ = ? Mg^{2+} = ?

Soln:

$$TH = \left(\frac{Ca^{2+}}{20} + \frac{Mg^{2+}}{12}\right) \times 50$$

$$\Rightarrow 200 = \left(\frac{40}{20} + \frac{Mg^{2+}}{12}\right) \times 50$$

$\therefore Mg^{2+}$ = 24 mg/L

$$= \left(\frac{24}{12} \times 50\right) \text{ mg/L as } CaCO_3$$

$$= 100 \text{ mg/L as } CaCO_3$$

Now, Σ Cations = Σ Anions

$$\Rightarrow \left(\frac{Ca^{2+}}{20} + \frac{K^+}{39} + \frac{Na^+}{23} + \frac{Mg^{2+}}{12}\right) \times 50 = \left(\frac{HCO_3^-}{61} + \frac{Cl^-}{35.5} + \frac{SO_4^{2-}}{48}\right) \times 50$$

$$\Rightarrow \left(\frac{40}{20} + \frac{39.1}{39} + \frac{Na^+}{23} + \frac{24}{12}\right) \times 50 = \left(\frac{300}{61} + \frac{10}{35.5} + \frac{109}{48}\right) \times 50$$

$\therefore Na^+$ = 56.82 mg/L

(P.T.O.)

So, $Na^+ = 56.82$ mg/L

$= \frac{56.82}{23} \times 50$ mg/L as $CaCO_3$

$= 123.52$ mg/L as $CaCO_3$

(Ans.)

Hints: উল্লেখ না থাকলে —

- TH, CH, NCH ও Alkalinity বের করা হয় mg/L as $CaCO_3$ হিসেবে।
- Na^+, Mg^{2+} ইত্যাদি ion বের করা হয় শুধুমাত্র mg/L হিসেবে।
- তবে প্রশ্নে উল্লেখ থাকলে এসব ion গুলোকে $CaCO_3$ হিসেবে বের করতে হবে।