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S1 17/18 EN 3003 ENVIRONMENTAL TRANSPORT PROCESS. Date YEO PEI QI No.

Q1 a)(i) $x = 0.1\ mm/s \times 10\ hr \times 3600\ s/hr$

$= 3600\ mm$

$= 3.6\ m.$

(ii) $4\sigma = 4\sqrt{2D_m t}$

$= 4\sqrt{2(5.21\times10^{-4})(10\times3600)}$

$= 24.499\ cm.$

(iii) $C\ (3.5m, 10hr) = \left(\frac{M}{\sqrt{4\pi D_{eff} t}}\right) e^{-\frac{(x-ut)^2}{4D_{eff}t}}$

$= \left[\frac{\frac{10^{-5}}{\frac{\pi}{4}(2\times10^{-3}m)^2}}{\sqrt{4\pi(5.21\times10^{-8}m^2/s)(36000s)}}\right] e^{-\frac{[3.5-(1\times10^{-4}m/s)(36000)]^2}{4(5.21\times10^{-8})(36000)}}$

$= \frac{3.1831}{0.1535} e^{-1.3329}$

$= 5.4677\ g/m^3.$

b) (i) time $= 10\ hr - 0.5\ hr = 9.5\ hr = 34200\ s.$

2nd injection : $C = \left(\frac{3.1831}{\sqrt{4\pi(5.21\times10^{-8})(34200)}}\right) e^{-\frac{[3.5-(1\times10^{-4})(34200)]^2}{4(5.21\times10^{-8})(34200)}}$

$= \frac{3.1831}{0.1496} e^{-0.898}$

$= 8.6684\ g/m^3.$

salt concentration = 1st injection + 2nd injection.

$= 5.4677 + 8.6684$

$= 14.1361\ g/m^3.$

(ii) Advection flux $J = uC$

$= (1\times10^{-4}m/s)(14.1361\ g/m^3)$

$= 1.4136\times10^{-3}\ g/m^2\cdot s$

(iii) Diffusive flux $J_m = -D_m \frac{dc}{dx}$

Differentiate equation $C = \frac{M}{\sqrt{4\pi D_{eff} t}} e^{-\frac{(x-ut)^2}{4D_{eff}t}}$ with respect to x, to find $\frac{dc}{dx}$.

Diffusive flux due to the two injections will be in same direction. Substance diffuse from high conc. to lower conc. Both injection started from $x=0$, which are transported in same direction.

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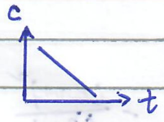
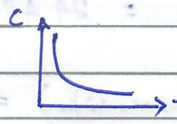
Q2 a) (i)

	Zeroth order	Second order
Equation	$[A] = [A]_0 - kt$	$\frac{1}{[A]} = \frac{1}{[A_0]} + kt$
unit of k	$\frac{mol}{L \cdot s}$	$\frac{L}{mol \cdot s}$
half time	$\frac{[A_0]}{2k}$	$\frac{1}{k[A_0]}$





zero order reaction has constant rate that is independent of reactant's concentration. rate = k.

Second order reaction has a rate proportional to the product of 2 reactants or square of the concentration of a single reactant.

rate = $k[A]^2$ or rate = $k[A][B]$.

(ii) zero order $[A] = [A]_0 - kt$.

$$0.1C_0 = C_0 - kt.$$

$$t = \frac{0.9C_0}{k}$$

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

$$\frac{1}{0.1C_0} = \frac{1}{C_0} + kt.$$

$$\frac{1}{C_0}(10-1) = kt.$$

$$t = \frac{9}{kC_0}$$

b) (i) $DO = DO_{sat} - (DO_{sat} - DO_0)e^{-\frac{k_2}{u}x} - \frac{k_1 L_0}{k_2 - k_1}\left(e^{-\frac{k_1}{u}x} - e^{-\frac{k_2}{u}x}\right)$

$$= 8.4\ \frac{g}{m^3} - [8.4 - (6-1)]e^{-\frac{1.736\times10^{-6}}{0.1}(10\times1000)} - \frac{1.736\times10^{-6}(20.909)}{2.014\times10^{-6} - 1.736\times10^{-6}}\left(e^{-0.1736} - e^{-0.2014}\right)$$

$k_1 = 0.15/d$

$= 1.736\times10^{-6}/s.$

$$= 8.4 - 2.8582 - 130.568\,(0.023)$$

$$= 2.5387\ g/m^3.$$

$k_2 = 0.174/d$

$= 2.014\times10^{-6}/s.$

(ii) $x_c = \frac{u}{k_2 - k_1}\ln\left\{\frac{k_2}{k_1}\left[1 - \left(\frac{k_2}{k_1} - 1\right)\left(\frac{D_0}{L_0}\right)\right]\right\}$

$L_0 = \frac{Q_1L_1 + Q_2L_2}{Q_1 + Q_2}$

$= \frac{0.5(20) + 0.05(30)}{0.55}$

$= 20.909\ g/m^3.$

$$= \frac{0.1}{2.014\times10^{-6} - 1.736\times10^{-6}}\ln\left\{\frac{2.014\times10^{-6}}{1.736\times10^{-6}}\left[1 - \left(\frac{2.014\times10^{-6}}{1.736\times10^{-6}} - 1\right)\left(\frac{5}{20.909}\right)\right]\right\}$$

$$= 359712.23\ \ln\{1.1601\,(0.9617)\}$$

$$= 39377\ m.$$

$$= 39.377\ km.$$

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(iii)

$$DO = DO_{sat} - (DO_{sat} - DO_0) e^{-\frac{k_2}{u}x} - \frac{k_1 L_0}{k_2 - k_1}\left(e^{-\frac{k_1}{u}x} - e^{-\frac{k_2}{u}x}\right)$$

$$3 = 8.4 - [8.4 - 5] e^{-\frac{1.736\times10^{-6}}{0.1}(39377)} - \frac{1.736\times10^{-6}(L_0)}{(2.014 - 1.736)\times10^{-6}}\left[e^{-\frac{1.736\times10^{-6}}{0.1}(39377)} - e^{-\frac{2.014\times10^{-6}}{0.1}(39377)}\right]$$

$$-5.4 = -3.4(0.5048) - 6.2446 L_0 (0.5048 - 0.4525)$$

$$-3.68368 = -0.3266 L_0.$$

$$L_0 = 11.279 \ g/m^3.$$

If able to bring wastewater stream BOD to zero.

$$L_0 = \frac{Q_1 L_1 + Q_2 L_2}{Q_1 + Q_2}$$

$$= \frac{0.5(20) + 0}{0.5 + 0.05}$$

$$= 18.18 \ g/m^3 > 11.279 \ g/m^3.$$

∴ Cannot achieve. BOD conc. in open channel flow alone is higher than requirement.

(iv) Instead of calculating L_0 using weighted average of both streams, can use channel BOD for L_0.

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Q3. a) $t = \frac{x}{u}$

$= \frac{540\ m}{0.2\ m/s}$

$= 2700\ s$

$= 45\ mins.$

b) $c = \frac{3m^3 \times 1000\ kg/m^3}{1200\ m^3}$

$= 2.5\ kg/m^3$

c) (i) case 1

$c = C_0 e^{-\frac{Q}{V}t}$

$0.05(\cancel{2.5}) = \cancel{2.5}\ e^{-\frac{0.25\ m^3/min}{1200\ m^3}t}$

$\ln 0.05 = -2.083 \times 10^{-4}\ t$

$t = 14381.816\ min$

$= 9.987\ days.$

(ii) case 2.

$c = C_0 e^{-\frac{t}{\bar{t}} - kt}$

$\bar{t} = \frac{V}{Q} = \frac{1200}{0.25} = 4800\ mins. = 80\ hr$

$0.05(\cancel{2.5}) = \cancel{2.5}\ e^{-\frac{t}{80} - 0.1t}$

$\ln 0.05 = -\frac{t}{80} - 0.1t$

$\ln 0.05 = -0.1125\ t$

$t = 26.63\ hrs.$

$= 1.1\ days.$

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Q 4a) (i) $K_{oc} = 0.63\ K_{ow} = 0.63\ (10^{1.2})\ L/kg$

$= 9.985\ L/kg$

$= 9.985 \times 1\times10^{-6}\ m^3/g$

$= 9.985 \times 10^{-6}\ m^3/g$

$K_d = f_{oc} K_{oc}$

$= 0.05\ (9.985 \times 10^{-6})$

$= 4.9925 \times 10^{-7}\ m^3/g$

(ii) $K_p = K_d \cdot \rho_s$

$= 4.9925 \times 10^{-7}\ (1500 \times 10^3\ g/m^3)$

$= 0.7489$

(iii) $\frac{1}{F_s} = 1 + \frac{V_w}{V_s}\frac{1}{K_p} + \frac{V_g}{V_s}\frac{H_{cc}}{K_p}$

$= 1 + \frac{20}{1}\frac{1}{0.7489} + \frac{5}{1}\frac{0.02}{0.7489}$

$= 27.839$

$F_s = 0.0359$ //

$\frac{1}{F_w} = \frac{V_s K_p}{V_w} + 1 + \frac{V_g H_{cc}}{V_w}$

$= \frac{1(0.7489)}{20} + 1 + \frac{5(0.02)}{20}$

$= 1.0424$

$F_w = 0.9593$ //

$\frac{1}{F_g} = \frac{V_s}{V_g}\frac{K_p}{H_{cc}} + \frac{V_w}{V_g}\frac{1}{H_{cc}} + 1$

$= \frac{1}{5}\frac{0.7489}{0.02} + \frac{20}{5}\frac{1}{0.02} + 1$

$= 7.489 + 200 + 1$

$F_g = 4.796 \times 10^{-3}$ //

(iv) F_s will be twice as calculated above. F_w and F_g will reduce but it is insignificant. Because the differences between the ratio are still very big.

b) ① Remove containment from sediment from river bed.
② Treating sludge containing organic contaminants.
③ Treating solid wastes such as synthetic rubber, to remove harmful compound.

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Q5 a) Accumulation = In − out ± reaction.

$$A \Delta x \frac{dc}{dt} = A_q (C_x - C_{x+\Delta x}) - k \Delta S (C - C_s)$$

$$\frac{dc}{dt} = -q \frac{dc}{dx} - ka, (C - C_s)$$

steady state, $0 = -q \frac{dc}{dx} - ka (C - C_s)$

$$q \frac{dc}{dx} = -ka (C - C_s)$$

$$v \frac{dc}{dx} = -k \left(\frac{2}{R}\right) (C - C_s)$$

$$v \frac{dc}{dx} = \frac{2k}{R} (C_s - C)$$

b) $$v \frac{dc}{dx} = \frac{2k}{R} (C_s - C)$$

$$\frac{1}{C_s - C} \frac{dc}{dx} = \frac{2k}{Rv}$$

$$\int \frac{1}{C_s - C} dc = \int \frac{2k}{Rv} dx$$

$$-\ln \frac{C_s - C}{C_s - C_0} = \frac{2k}{Rv} x$$

$$\frac{C_s - C}{C_s - C_0} = e^{-\frac{2k}{Rv} x}$$

$$C_s - C = (C_s - C_0) e^{-\frac{2k}{Rv} x}$$

$$C = C_s - (C_s - C_0) e^{-\frac{2k}{Rv} x}.$$

c) $$\frac{kd}{D} = 0.023 \, Re^{0.83} \, Sc^{0.33}.$$

$$\frac{k(2.5)}{1 \times 10^{-5}} = 0.023 \left[\frac{(20)(2.5)(1)}{0.01}\right]^{0.83} \left[\frac{0.01}{1(1 \times 10^{-5})}\right]^{0.33}$$

$$2.5 \times 10^{5} \, k = 0.023 (1175.29)(9.7724)$$

$$k = 1.0567 \times 10^{-3}.$$

d) $$C = C_s - (C_s - C_0) e^{-\frac{2k}{Rv} x}.$$

$$= 10 \, mg/L - (10 - 0) e^{-\frac{2(1.0567 \times 10^{-3})}{1.25 \, cm \cdot 20 \, cm/s}(5 cm)}.$$

$$= 10 - 10 e^{-4.2268 \times 10^{-4}}$$

$$= 4.226 \times 10^{-3} \, mg/L.$$

Assume C_0, the concentration of pb in the bulk water at upstream is zero.

Assume Pb at the soldered surface is uniformly distributed and dissolves at same k.