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ENE/4

FINISH STRONG!

EN4104 17/18

1/ $Q_r = 4\times10^4\ m^3/yr$ $c_r = 30\ \mu g/L$ - Tributaries

Depth = 2m, Surface Area $A = 10^4 m^2$, $c = 15\ \mu g/L$ - Bay

$c_0 = 0\ \mu g/L$ - sea

$k_d = 1\ yr^{-1}$, $k_s = 0$

~~(a) The pesticide concentration from tributaries is higher than its in the bay → mixing, will dilute the concentration. Together with its decay~~

(a) Pesticide from tributaries ⇒ bay, mixing & dilute, exchange with coastal area, decay → steady state concentration

~~Conc~~ Pesticide in the bay is mixed with water from coastal area, concentration lower

(b) $\cancel{E' = \frac{Q(c_r - c)}{c - c_0} = \frac{4\times10^3(30-15)}{15-0} = 4\times}$

$$V\frac{dc}{dt} = W + Q(c_r - c) - kVc - E'(c - c_0)$$

Steady state: $V\frac{dc}{dt} = 0 \Rightarrow E' = \frac{W + Q(c_r - c) - kVc}{c - c_0}$

$$= \frac{0 + 4\times10^4(30-15) - 1\times(2\times10^4)\times15}{15-0}$$

$$= 2\times10^4\ m^3/yr$$

(c) $c' = 1.5\ mg/L = 1500\ \mu g/L$ $\frac{m^3}{yr}\times\frac{\mu g}{L} = 10^{-6}\frac{kg}{yr}$

Steady state: $0 = W + Q(c_r - c') - kVc' - E'(c' - c_0)$

$\Rightarrow W = kVc' + E'(c' - c_0) - Q(c_r - c')$

$= 1\times(2\times10^4)\times1500 + 2\times10^4(1500 - 0) - 4\times10^4(30 - 1500)$

$= 118.8\ kg/yr$

(d) $T_c = \frac{1}{1/T_w + k_d} = \frac{1}{4\times10^4/2\times10^4 + 1} = \frac{1}{3}\ yr$

Assume instant mixing, $c_{spill} = \frac{m}{V} = \frac{100}{2\times10^4} = 5\times10^{-3}\ kg/m^3 = 5\ mg/L$

Concentration in the bay after the spill:

$$c = c_{initial} + c_{spill}\, e^{-t/T_c}$$
$$= 15\times10^{-3} + 5e^{-3t} \quad (mg/L)$$

$c = 1.5\ mg/L \Leftrightarrow 1.5 = 15\times10^{-3} + 5e^{-3t}$

$\Leftrightarrow t = 0.405\ yrs$

2/ (a) Estuary number η: imposed characteristic time $1/k$

Distance L_d for diffusion/dispersion $\sim (E/k)^{1/2}$

Distance L_a for advection $\sim U/k$

ratio square given $\eta = kE/U^2 = \frac{L_d^2}{L_a^2} = \frac{\text{diffusive/dispersive distance}}{\text{advection distance}}$

η: measures transport by dispersion relative to advection for non-conservative substance ($k>0$) over a time scale $1/k$

$\eta \gg 1$: diffusion dominate $\quad \eta \cong 1$: both $\quad \eta \ll 1$: advection predominate

For conservative substance, Peclet number (Pe) should be used.

(b). At any time t, + the distribution is symmetric & bell-shaped in space

+ maximum concentration is located at Ut unit of distance downstream of the spill

. At any location x, + the concentration as function of time is skewed

+ spreading increases during time period which the concentration is observed

+ σ is not well-defined

+ maximum concentration happens at $t = \frac{x}{U}$

At time $t = 0$, the concentration is maximum at the point of spillage and it hasn't been spreaded

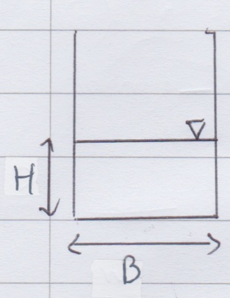
(c) (i) 95% encompassed $\Rightarrow 3.9\sigma = 300$

$$\Leftrightarrow 3.9\sqrt{2E_L t} = 300$$

$$\Leftrightarrow 3.9\sqrt{2E_t 8} = 300$$

$$\Leftrightarrow E_L = 369.8\ m^2/h \doteq 0.103\ m^2/s$$

(iii) Longitudinal dispersion coeff, $E_L = 0.011\dfrac{U^2B^2}{Hu_*}$



$$R = \frac{A}{P} = \frac{BH}{B+2H} = \frac{45\times 2}{45+2\times 2} \approx 1.837\ m$$

$$u_* = \sqrt{gRS} = \sqrt{9.81\times 1.837\times 10^{-3}} = 0.134\ m/s$$

$$\Rightarrow U = \sqrt{\frac{E_L H u_*}{0.011 B^2}} = \sqrt{\frac{0.103\times 2\times 0.134}{0.011\times 45^2}} = 0.035\ m/s$$

Distance needs to observe lateral concentration profile const to within ~1%:

$$L_m = 0.4\frac{UB^2}{E_t}$$

For natural rivers, $E_t = 0.6Hu_* = 0.6\times 2\times 0.134 = 0.161\ m^2/s$

$$\Rightarrow L_m = 0.4\times\frac{0.023\times 45^2}{0.161} \simeq 115.71\ m$$

Location of measurement, $x = Ut = 0.035\times 8\times 60\times 60 \simeq 1\ km$

$\Rightarrow$ No significant variation

(ii) $\dfrac{m}{2\sqrt{\pi E_L t}} = 50\ mg/L = 50\ g/m^3$

$m = \dfrac{mass}{Area} = \dfrac{mass}{90}$

$$\Rightarrow \frac{mass}{90\times 2\times\sqrt{\pi\times 369.8\times 8}} = 50$$

$\Rightarrow mass \doteq 867.65\ kg$

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3/(a) $c_c\,[ML^{-3}]$ $c_0\,[ML^{-3}]$ $Q_0\,[L^3T^{-1}]$

$M_0\,[L^4T^{-2}]$ $x\,[L]$

$n = 5,\ m = 3 \Rightarrow 2\ \pi$ groups

Use c_0, x, Q_0 as repeating variables

$\pi_1 = c_c\, c_0^{\,a} x^b Q_0^{\,d}$

$= (ML^{-3})(ML^{-3})^a (L)^b (L^3T^{-1})^d$

$$\left.\begin{aligned} M&: 1 + a = 0 \\ L&: -3 - 3a + b + 3d = 0 \\ T&: d = 0 \end{aligned}\right\} \Rightarrow \begin{aligned} a &= -1 \\ b &= 0 \\ d &= 0 \end{aligned}$$

$\Rightarrow \pi_1 = \dfrac{c_c}{c_0}$

$\pi_2 = M_0\, c_0^{\,a} x^b Q_0^{\,d}$

$= (L^4T^{-2})(ML^{-3})^a (L)^b (L^3T^{-1})^d$

$$\left.\begin{aligned} M&: a = 0 \\ L&: 4 - 3a + b + 3d = 0 \\ T&: -2 - d = 0 \end{aligned}\right\} \Rightarrow \begin{aligned} a &= 0 \\ b &= 2 \\ d &= -2 \end{aligned}$$

$\Rightarrow \pi_2 = \dfrac{M_0 x^2}{Q_0^{\,2}}$

$\Rightarrow \dfrac{c_c}{c_0} = f\left(\dfrac{M_0 x^2}{Q_0^{\,2}}\right)$

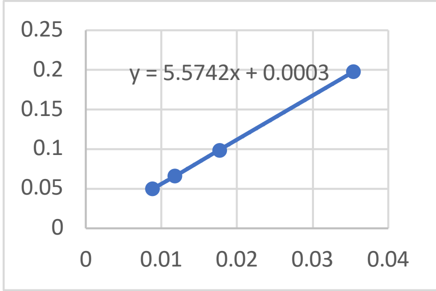
(b) $d = 0.1\,m$ $\quad Q_0 = w_0 A = w_0 \pi \dfrac{d^2}{4} = 0.0157\ m^3/s$

$w_0 = 2\,m/s$ $\quad M_0 = w_0 Q_0 = 0.0314\ m^4/s^2$

$c_0 = 1000\ mg/L$

(b)

x [m]	C_c [mg/L]	C_c/C_o	$M_o x^2/Q_o^2$	$Q_o^2/M_o x^2$	$Q_o/M_o^{1/2}x$
2.5	198	0.198	795.7747	0.001257	0.035449
5	99	0.099	3183.099	0.000314	0.017725
7.5	66	0.066	7161.972	0.00014	0.011816
10	50	0.05	12732.4	7.85E-05	0.008862



Qo = 0.015708 m3/s   Mo = 0.031416 m4/s2   Co = 1000 mg/L

⇨ Coefficient = 5.5742

(c) CMC: protect against acute or lethal effects (in a brief period of time) – immediate effect

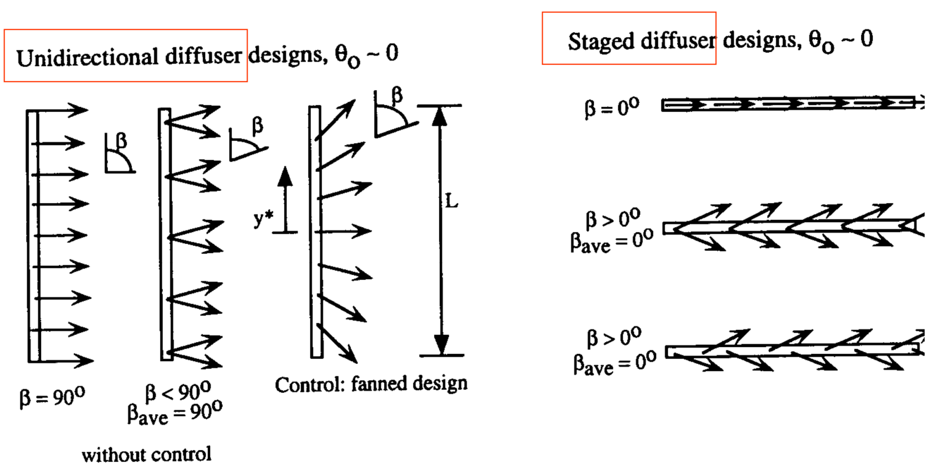
CCC: protect against chronic effects (in contact for a long period of time) – long-term effect

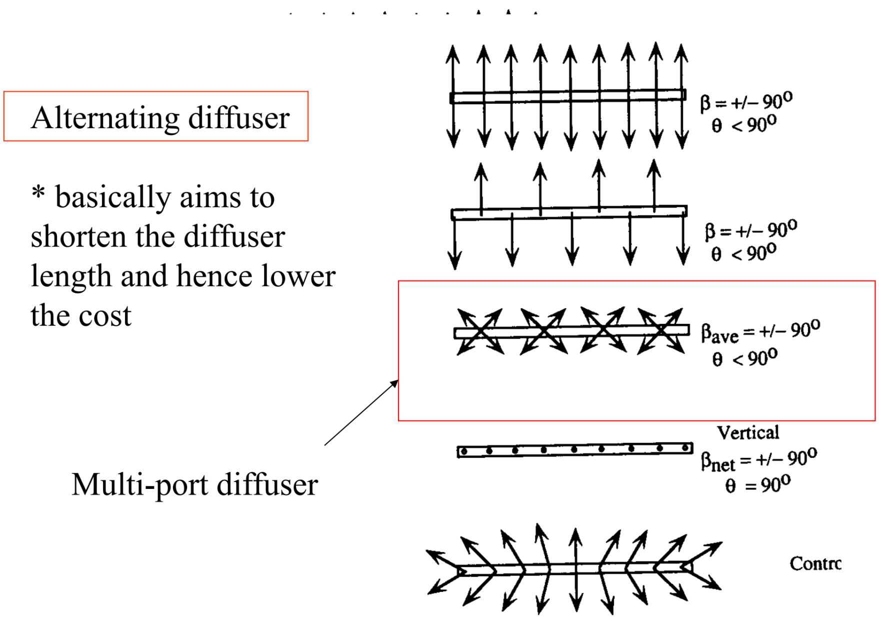
CMC >= CCC, and is more restrictive

CCC "must" be at the edge of the regulatory mixing zone

(d) The analysis is inappropriate. The relationship in (b) only applies to the zone of established flow, not near the discharge location.

4. (a)





Alternating diffuser designs, $\theta_o \sim 0$

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4| (b) $w_0 = \frac{Q_0}{A} = \frac{10}{10 \times 0.1} = 10\ m/s$

2Djet: $q_0 = w_0 b = 10 \times 0.1 = 1\ m^2/s$

$M_0 = q_0 w_0 = 10 m^3/s^2$

$\frac{c_c}{c_0} = 2.4 q_0 M_0^{-1/2} z^{-1/2} = 2.4 \times 1 \times 10^{-1/2} \times 20^{-1/2} \approx 0.1697$

$\Rightarrow c_c = 0.1697 c_0 \approx 0.1697 \times 600 = 101.82$ ppm $\Rightarrow$ doesn't meet requirement

(c) No of ports = 2 $\Rightarrow Q_0 = \frac{10}{2} = 5 m^3/s$

$w_0 = 10 m/s$

$\Rightarrow A = \frac{Q_0}{w_0} = \frac{5}{10} = 0.5 m^2$

$M_0 = w_0^2 A = 10^2 \times 0.5 = 50\ m^4/s^2$

$\frac{c_c}{c_0} = 5.6 Q_0 M_0^{-1/2} z^{-1} = 5.6 \times 5 \times 50^{-1/2} \times 20^{-1}$

$= 0.198$

$\Rightarrow c_c = 118.8$ ppm $\Rightarrow$ doesn't meet

(d) ~~Ex~~ No interference: $S_N > b_e = 0.127 z = 0.127 \times 20 = 2.54 m$

* (need to check with Prof) !!!

$\Rightarrow$ No of ports $< \frac{L}{S_N} + 1 = \frac{10}{2.54} + 1 \approx 4.9$

$\Rightarrow N = 4 \Rightarrow S_N = \frac{L}{N-1} = \frac{10}{4-1} = 3.33\ m$

$Q_0 = \frac{10}{4} = 2.5 m^3/s$; $w_0 = 10 m/s \Rightarrow A = \frac{Q_0}{w_0} = 0.25 m^2$

$M_0 = w_0^2 A = 10^2 \times 0.25 = 25 m^4/s^2$

$\frac{c_c}{c_0} = 5.6 Q_0 M_0^{-1/2} z^{-1} = 5.6 \times 2.5 \times 25^{-1/2} \times 20^{-1}$

$= 0.14$

$\Rightarrow c_c = 84$ ppm < 100 ppm (Meet standards !!)