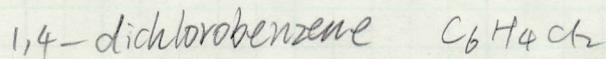
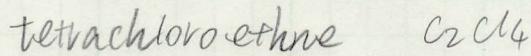


19-7



The average depth $h = 0.4\text{m}$ mean flowing velocity $\bar{u}_f = 0.67\text{m/s}$

According to equation 19-2

$$\frac{1}{V_{ia}} = \frac{1}{V_{iw}} + \frac{1}{V_{H2Oa}}$$

$$D_{ia} = 1.52 \times \bar{V_i}^{-0.67} \quad (17-21)$$

$$= 1.52 \times (116.5)^{-0.67} = 0.06 \text{ cm/s}$$

$$V_{ia} = \left(\frac{D_{ia}}{D_{H2Oa}} \right)^{\frac{1}{3}} \cdot V_{H2Oa} \quad (D_{H2Oa} = 0.26 \text{ cm}^2/\text{s}, V_{H2Oa} = 0.15 \text{ cm/s})$$

From textbook.

$$= \left(\frac{0.06}{0.26} \right)^{\frac{1}{3}} \times 0.15 = 0.06 \text{ cm/s}$$

Using Small-Eddy and Small Roughness Model

$$V_{iw} = 0.17 (Sc_{iw})^{-1/2} \cdot \left(\frac{V_w \times (\bar{u}_f / \alpha)^3}{h} \right)^{1/4}$$

where h is total water depth $h = 4\text{m}$

α is a nondimensional factor then $\alpha = 1.5 \cdot \bar{u}_f = 0.67 \text{ m/s}$

$$V_w = 1.004 \times 10^{-6} \text{ m}^2/\text{s} \quad (T = 293\text{K})$$

$$\therefore V_{iw} = 6.57 \times 10^{-4} \cdot Sc_{iw}^{-1/2}$$

Given the table of C_2Cl_4 .

0 m	0 s	690 $\mu\text{g/L}$
600 m	900 s	585 $\mu\text{g/L}$
1200 m	1800 s	505 $\mu\text{g/L}$
2400 m	3600 s	565 $\mu\text{g/L}$

$\therefore D_{iw}$

$$6.3 \times 10^{-6} \text{ cm}^2/\text{s} \quad \frac{dc}{dt} = D_w \frac{dc}{dx^2}$$

* detailed calculation by Python.

$$\therefore \bar{D}_{iw} = 6.3 \times 10^{-6} \text{ cm}^2/\text{s} \quad \bar{S}_{ciw} = \frac{V_w}{\bar{D}_{iw}} = 1593.7$$

According to the Appendix C $K_{ciw} = 10^{0.08}$

$$\therefore \frac{1}{V_{ciw}} = \frac{1}{V_{iw}} + \frac{1}{V_{ia} K_{ciw}}$$

the V_{iw} equation mentioned before.

$$\bar{V}_{iw} = 6.57 \times 10^{-4} \times (\bar{S}_{ciw})^{-\frac{1}{2}} = 1.65 \times 10^{-5} \text{ cm/s}$$

$$\frac{1}{V_{ciw}} = \frac{1}{V_{iw}} + \frac{1}{V_{ia} K_{ciw}} \Rightarrow V_{ciw} = 0.072 \text{ cm/s}$$

(2) In the same way for 1,4-dichlorobenzene.

$$\bar{V}_i = 174.8 \frac{\text{cm}^3}{\text{mol}}$$

$$D_{ia} = 1.52 \times \bar{V}_i^{-0.67} = 0.05 \text{ cm}^2/\text{s}$$

$$V_{ia} = \left(\frac{D_{ia}}{D_{H2Oa}} \right)^{\frac{1}{2}} \cdot V_{H2Oa} = 0.05 \text{ cm/s}$$

And use small-Zoddy and small Roughness model

$$V_{iw} = 0.17 \cdot (S_{ciw})^{\frac{1}{2}} \cdot \left(\frac{V_w \cdot (U_{T12})^3}{n} \right)^{\frac{1}{4}}$$

$$= 3.6970 \times 10^{-4} \times (S_{ciw})^{-\frac{1}{2}}$$

Given the table of $C_6H_4Cl_2$ \bar{D}_{iw}

0m	0s	234	m^3/L	
600m	900s	201	m^3/L	$4.8 \times 10^{-6} \text{ cm}^2/\text{s}$
1200m	1800s	180	m^3/L	
2400m	3600s	130	m^3/L	

$$\bar{D}_{iw} = 4.8 \times 10^{-6} \text{ cm}^2/\text{s}$$

$$\bar{S}_{ciw} = \frac{\bar{V}_{iw}}{\bar{D}_{iw}} = 2100$$

$$\text{Then } \bar{V}_{iw} = 3.6970 \times 10^{-4} \times (\bar{S}_{ciw})^{1/2} = 1.43 \times 10^{-5} \text{ cm/s}$$

$$\text{Therefore } \frac{1}{V_{iaw}} = \frac{1}{V_{iw}} + \frac{1}{V_{iakaw}}$$

According to the Appendix-C $K_{iaw} = 10^{-1.04}$

$$\frac{1}{V_{iaw}} = \frac{1}{1.43 \times 10^{-5}} + \frac{1}{0.05 \times 10^{-1.04}}$$

$$V_{iaw} = 0.0046 \text{ cm/s}$$

2

According to the Van equation

$$\frac{1}{V_{IAW}} = \frac{1}{V_{IW}} + \frac{1}{V_{IA} K_{IAW}}$$

when value of K_{IAW} increase the term of $\frac{1}{V_{IA} K_{IAW}}$ decline.

Therefore, $\frac{1}{V_{IAW}}$ close to 0 with a larger K_{IAW} value.

Then $V_{IAW} \approx V_{IW}$ (At constant). As we can see from the figure. V_{IAW} nearly doesn't change when K_{IAW} is relatively large. On the other hand, when K_{IAW} is relatively small, the term of $\frac{1}{V_{IA} K_{IAW}}$ cannot be ignored. Therefore. V_{IAW} increase with the increase in K_{IAW} .

For different value of U_{IO} . According to the equation.

$$V_{IW} = (9 \times 10^{-4} + 7.2 \times 10^6 U_{IO}) \times \left(\frac{S_{CIO}}{600} \right)^{-1/2}$$

when U_{IO} increase, V_{IW} will increase too. In addition K_{IAW} is relatively large. $\frac{1}{V_{IAW}} \approx \frac{1}{V_{IW}}$. Therefore. $\frac{1}{V_{IAW}} (U_{IO}=20m/s)$ is larger than $\frac{1}{V_{IAW}} (U_{IO}=10m/s)$ due to $\frac{1}{V_{IW}} (U_{IO}=20m/s)$ is higher than $\frac{1}{V_{IW}} (U_{IO}=10m/s)$. And this figure can valid this assumption.

3. (a) trichloroethane (TCE) CHCl_3

$$\bar{V_f} = 0.27 \text{ m/s} \quad h = 2 \text{ m}$$

I assume it's water-controlled in this situation.

$$\text{Then } \frac{1}{V_{\text{airw}}} = \frac{1}{V_{\text{airw}}}$$

$$\text{Then } \bar{V_i} = 104.3 \frac{\text{cm}^3}{\text{mol}} \quad (\text{box 7.2 from textbook})$$

$$D_{\text{airw}} = \frac{13.26 \times 10^{-5}}{\eta^{1/4} \bar{V_i}^{-0.59}} = 539 \text{ cm}^2/\text{s} \quad (T = 293 \text{ K} \quad \eta = 1002 \times 10^{-3} \frac{\text{kg}}{\text{m.s}})$$

$$V_{\text{airw}} = 1.004 \times 10^{-6} \text{ m}^2/\text{s}$$

Then

$$S_{\text{airw}} = \frac{V_{\text{airw}}}{D_{\text{airw}}} = 186.3$$

$$\therefore V_{\text{airw}} = 0.17 \times \left(\frac{V_{\text{airw}} (\bar{V_f}/\alpha)^3}{h} \right)^{1/4} \times (S_{\text{airw}})^{-1/2} \quad 19-23$$

where $h = 2 \text{ m}$ $\alpha = 15$ in this situation.

$$\therefore V_{\text{airw}} = 1.64 \times 10^{-5} \text{ m/s}$$

$$\text{Then } \frac{1}{V_{\text{airw}}} = \frac{1}{V_{\text{airw}}} \Rightarrow V_{\text{airw}} = 1.64 \times 10^{-5} \text{ m/s}$$

$$K_v = \frac{1}{h} \times V_{\text{airw}} = 0.5 \text{ m}^{-1} \times 1.64 \times 10^{-5} \text{ m/s} = 8.2 \times 10^{-6} \text{ s}^{-1}$$

(b) According to $K_{\text{airw}} = 10^{-0.4} \gg 10^{-3} = K_{\text{airw}}^{\text{critical}}$

Then it's water controlled.

$$\frac{1}{V_{\text{airw}}} = \frac{1}{V_{\text{airw}}} + \frac{1}{V_{\text{airw}} \times K_{\text{airw}}} \quad \text{Then the term of } \frac{1}{V_{\text{airw}} \times K_{\text{airw}}} \text{ can be ignored due to large of } K_{\text{airw}}$$

$$\text{Then } R_{\text{airw}} = \frac{1}{V_{\text{airw}}} = 6.1 \times 10^4$$

$$V_{\text{air}} = \left(\frac{D_{\text{air}}}{D_{\text{H}_2\text{O}, \alpha}} \right)^{2/3} \times V_{\text{H}_2\text{O}, \alpha}, \quad D_{\text{air}} = 1.52 \times \bar{V}^{-0.67} \quad (17-21)$$

then

$$D_{\text{air}} = 0.07 \text{ cm}^2/\text{s}$$

$$V_{\text{air}} = \left(\frac{D_{\text{air}}}{D_{\text{H}_2\text{O},a}} \right)^{1/3} \times V_{\text{H}_2\text{O},a} \quad \text{where } \begin{cases} V_{\text{H}_2\text{O},a} = 0.15 \text{ cm}^3/\text{s} \\ D_{\text{H}_2\text{O},a} = 0.26 \text{ cm}^2/\text{s} \end{cases}$$
$$= 0.06 \text{ cm/s}$$

$$\therefore R_{\text{ia}} = \frac{1}{V_{\text{ia}}} = \frac{1}{0.06} = 16.67 \frac{\text{s}}{\text{cm}}$$

$$\therefore f = \frac{R_{\text{ia}}}{R_{\text{ia}} + R_{\text{iw}}} = \frac{(6.67)}{(6.67 + 6.1 \times 10^4)} = 2.73 \times 10^{-4}$$

Then air phase can be ignored safely

∴ After revised.

$$\frac{1}{V_{\text{airw}}} = \frac{1}{R_{\text{ia}} \cdot V_{\text{ia}}} + \frac{1}{V_{\text{iw}}} = 0.02 \text{ cm/s}$$

(c) For chlorophenol C_6H_5ClO $K_{\text{ia}} = 10^{-3.24}$.

$$\bar{V}_i = 175.03 \frac{\text{cm}^3}{\text{mol}}$$

$$D_{\text{ia}} = 1.52 \times \bar{V}_i^{-0.67} = 0.05 \text{ cm/s.}$$

$$V_{\text{ia}} = \left(\frac{D_{\text{ia}}}{D_{\text{H}_2\text{O},a}} \right)^{1/3} \times V_{\text{H}_2\text{O},a} = 0.05 \text{ cm/s.}$$

$$D_{\text{iw}} = 1.52 \times 10^{-4} \times \bar{V}_i^{-0.64} = 5.58 \times 10^{-6} \text{ cm}^2/\text{s.}$$

$$S_{\text{ciw}} = \frac{V_{\text{iw}}}{D_{\text{iw}}} = 180.0$$

$$\therefore V_{\text{iw}} = 0.17 \times \left(\frac{V_{\text{iw}} \times (\bar{V}_f \times \alpha)^{1/3}}{h} \right)^{1/4} \times (S_{\text{ciw}})^{1/2}$$

$$\approx 1.66 \times 10^{-5} \text{ cm/s}$$

$$\frac{1}{V_{iaw}} = \frac{1}{V_{iw}} + \frac{1}{V_{iaw} \cdot k_{iaw}} \Rightarrow V_{iaw} = 2.88 \times 10^{-5} \text{ cm/s}$$

Then $k_{iaw} = 10^{-3.24} \approx 10^{-3} = k_{iaw}^{\text{critical}}$

then liquid-phase resistance cannot be ignored safely.

(d) the river bottom is fine-grained sand

then $\alpha = 20$ due to this situation.

$$\therefore V_{iw} = 0.17 \times \left(\frac{V_w \times (C_p / \alpha)^3}{n} \right)^{1/4} \times (S_{iaw})^{-1/2}$$

$$= 1.34 \times 10^{-5} \text{ cm/s}$$

$$\therefore \frac{1}{V_{iaw}} = \frac{1}{V_{iw}} + \frac{1}{V_{iaw} \cdot k_{iaw}}$$

$$V_{iaw} = 0.024 \text{ cm/s}$$

the V_{iaw} nearly change because of k_{iaw} is very large.
then still a air-control.

4. PAH fluorine C₁₃H₁₀

$$K_{aw} = 10^{-2.39}$$

$$K_{iow} = 10^{4.32}$$

$$V_{sw} = \rho_s \frac{1-\phi}{\phi} = 1.52 \frac{\text{kg}}{\text{L}} \times \frac{1-0.37}{0.37} = 2.59 \frac{\text{kg}}{\text{L}}$$

$$D_{eff} = \frac{1}{P^2} D_{iw} \left(\frac{1}{1 + V_{sw} \cdot K_{id}} \right) \quad \text{where } K_{id} = 31.7 \frac{\text{L}}{\text{kg}}$$

I assume temperature is 20°C and there is non-sorbing

$$\bar{V} = 300.0 \frac{\text{cm}^3}{\text{mol}} \quad (\text{From table box 7.2})$$

$$D_{iw} = 1.52 \times 10^{-4} \times \bar{V} (1-0.64) = 3.95 \times 10^{-6} \text{ cm}^2/\text{s} \quad 17-24a.$$

$$\therefore D_{eff} = \frac{1}{14^2} \times 3.95 \times 10^{-6} \times \left(\frac{1}{1+2.59 \times 31.7} \right)$$
$$= 2.43 \times 10^{-8} \text{ cm}^2/\text{s}$$

(2) According to equation 17-9

$$C_2 = C_1 \operatorname{erfc} \left(\frac{x}{2(Dt)^{1/2}} \right)^{1/2} \Rightarrow \operatorname{erfc} \left(\frac{x}{2(Dt)^{1/2}} \right) = 0.1 = \frac{C_1}{C_2}$$

And use result of Append A.2

$$\operatorname{erfc} \left(\frac{x}{2(Dt)^{1/2}} \right) = 0.1 \Rightarrow \frac{x}{2(Dt)^{1/2}} = 1.2$$

$$\therefore t = \frac{x^2}{2.4^2 \times D_{eff}} = \frac{0.01 \text{ cm}^2}{2.4^2 \times 2.43 \times 10^{-8} \text{ cm}^2/\text{s}} \approx 20.0 \text{ h}$$

(3) the constant is not constant.

When the fluorine concentration in sediment is decreasing, it will take longer time to reach 10% Co

in $x = 10 \text{ cm}$.

(d) Sodimare cap containing 0.3% organic carbon.

$$\therefore k_{dl} = K_{locw} \times fac = 0.03 \times 10^{4.32} = 62.68 \frac{L}{kg}$$

$$D_{eff} = \frac{1}{T^2} \times D_{lw} \times \frac{1}{1 + r_{sw} \times k_{dl}} = 7.23 \times 10^{-8} \text{ cm}^2/\text{s}$$

In the same way

$$\operatorname{erfc}\left(\frac{x}{2(D_{eff}t)^{1/2}}\right) = 0.1 \Rightarrow \frac{x}{2(D_{eff}t)^{1/2}} = 1.2 \quad (\text{Appendix A})$$

$$t = \frac{x^2}{2 \cdot 4^2 \times 7.23 \times 10^{-8} \text{ cm}^2/\text{s}} = 14815 \text{ s} \approx 40 \text{ h}$$

(e) 0.3% organic carbon + 5% activated carbon

from a article.

$$K_{dl} = fac \times k_{locw} + fac \times k_{iacw}$$

$$= 62.68 + 0.05 \times 1.5 \times 10^3 = 137.7 \frac{L}{kg}$$

$$\therefore D_{eff} = \frac{1}{T^2} D_{lw} \times \frac{1}{1 + r_{sw} \times k_{dl}} = 5.64 \times 10^{-9} \text{ cm}^2/\text{s}$$

In the same way

$$\operatorname{erfc}\left(\frac{x}{2(D_{eff}t)^{1/2}}\right) = 0.1 \Rightarrow \frac{x}{2(D_{eff}t)^{1/2}} = 1.2$$

$$\therefore t = \frac{x^2}{2 \cdot 4 \times 5.64 \times 10^{-9} \text{ cm}^2/\text{s}} \approx 85 \text{ h}$$

(f) As the result, I think organic rich sands with activated can be an effective strategy. On the other hand the life-span of activated carbon and turbulence should be considered.