1. Show that $x_{tol} = 0.11$ in the gasoline.

Suppose we consider 1 L of gasoline.

Mass of gasoline = $(1\ L)(950\ g/L) = 950\ g$.

Moles of gasoline = $950\ g\ gasoline * \frac{1\ mol\ gasoline}{51\ g\ gasoline} = 18.63\ mol$

Mass of toluene = $(950\ g\ gasoline)(0.20) = 190\ g\ toluene$

Moles of toluene = $190\ g\ toluene * \frac{1\ mol\ toluene}{92.14\ g\ toluene} = 2.062\ mol$

$$X = \frac{2.062\ mol\ Toluene}{18.63\ mol\ gasoline} = 0.11 \checkmark$$

2. Estimate x^{SL} from C^{SL}

Given $C^{SL} = \frac{530\ mg\ toluene}{1\ L\ water}$

$$x^{SL} = \frac{530\ mg\ toluene}{1\ L\ water} * \frac{1\ g\ toluene}{1000\ mg\ tol} * \frac{1\ mol\ tol}{92.14\ g\ tol}$$

$$* \frac{1\ L\ water}{998\ g\ water} * \frac{18.01\ g\ water}{1\ mol\ water} = \boxed{1.0 \times 10^{-4}}$$

3. Estimate/calculate x_{tol}^{aq}

Equilibrium between phases: $\hat{f}_{tol}^{gas} = \hat{f}_{tol}^{aq}$

Gasoline is ideal liquid, water is not.

$$x_{tol}^{gas} \cancel{P^{sat}} = x_{tol}^{aq}\, \alpha\, \cancel{P^{sat}}$$

Notice P^{sat} drops out of equation.

Also notice $x^{SL} < 10^{-3}$ so $\alpha = \alpha^{\infty} = \frac{1}{x^{SL}}$!

$$x_{tol}^{gas} = x_{tol}^{aq} \cdot \frac{1}{x^{SL}} \Rightarrow x_{tol}^{aq} = (x_{tol}^{gas})(x^{SL})$$

$$x_{tol}^{aq} = (0.11)(1.0 \times 10^{-4}) = \boxed{1.1 \times 10^{-5}}$$

4. Estimate/calculate C_{tol}^{aq}

We just derived $\chi_{tol}^{aq} = (\chi_{tol}^{gas})(\chi^{SL})$ in problem 3

But this is the same as $C_{tol}^{aq} = (\chi_{tol}^{gas})(C^{SL})$

Thus $\frac{C_{tol}^{aq}}{C^{SL}} = \chi_{tol}^{gas} = 0.11$!!

$C_{tol}^{aq} = (0.11)(530 \text{ mg/L}) = \boxed{58 \text{ mg/L}}$ ... OK if you said $58.3 \frac{mg}{L}$

5. Estimate/calculate conc. of toluene in the sediment

$q = K_d C_{tol}^{aq}$

$K_d = f_{oc} K_{oc}$ ... so we need K_{oc}

Assume $\log_{10}(K_{oc}) \approx \log_{10}(K_{ow}) - 0.21$ from Karickhoff

$\Rightarrow \log_{10}(K_{oc}) = 2.73 - 0.21 = 2.52$

$K_{oc} = 331 \text{ L/kg} = 331 \frac{\text{L water}}{\text{kg organic matter}}$

$K_d = f_{oc} K_{oc} = \left(0.10 \frac{\text{kg organic matter}}{\text{kg sediment}}\right)\left(331 \frac{\text{L water}}{\text{kg organic matter}}\right)$

$= 33.1 \text{ L water / kg sediment}$

$q = \left(33.1 \frac{\text{L water}}{\text{kg sediment}}\right)\left(58.3 \frac{\text{mg toluene}}{\text{L water}}\right) = \boxed{1930 \frac{\text{mg Toluene}}{\text{kg sediment}}}$

6. Express conc. of toluene in the sediment as mg/L.

$$q_{tol}^{sed} = 1930 \frac{\text{mg toluene}}{\text{kg sediment}} \times \frac{1500 \text{ kg sediment}}{\text{m}^3 \text{ sediment}} \times \frac{1 \text{ m}^3}{1000 \text{ L}}$$

$$= 2900 \text{ mg/L}$$

$$q_{tol}^{sed} = 2900 \frac{\text{mg}}{\text{L}}, \qquad C_{tol}^{aq} = 58 \frac{\text{mg}}{\text{L}}$$

Much higher concentration in the sediment.

$$\text{Mass in water} = V^{water} C_{tol}^{aq} = (5\times10^5 \text{ m}^3)\left(1000 \frac{\text{L}}{\text{m}^3}\right)\left(58.3 \frac{\text{mg}}{\text{L}}\right)\left(\frac{1 \text{ kg}}{10^6 \text{ mg}}\right)$$

$$= 29{,}150 \text{ kg in the water}$$

$$\text{Mass in sediment} = V^{sed} q_{tol}^{sed} = (1.5\times10^3 \text{ m}^3)\left(1000 \frac{\text{L}}{\text{m}^3}\right)\left(2900 \frac{\text{mg}}{\text{L}}\right)\left(\frac{1 \text{ kg}}{10^6 \text{ mg}}\right)$$

$$= 4{,}350 \text{ kg in the sediment}$$

Higher mass of toluene in the water.

How do these make sense?
Toluene is moderately hydrophobic ... $\log(K_{ow}) = 2.73$
So it's concentration in organic phases will be much higher than its concentration in water.
But the volume of water is much higher than the volume of sediment. -- thus the mass of toluene in the water is about 6 or 7 times higher than the mass of toluene in the sediment.

7. Flux from water into sediment

Because $q_{tol}^{sed} < K_d C_{tol}^{aq}$, we know the mass must be moving from the water to the sediment.
Thus the flux is positive based on the problem statement.

$$N = K_L \left[C_{tol}^{aq} - C^* \right]$$

N = toluene mass flux, $\frac{\text{mass toluene}}{\text{area - time}}$

K_L = overall mass-transfer coefficient

C_{tol}^{aq} = concentration of toluene in the water

C^* = hypothetical aqueous concentration that would be in equilibrium with the sediment
$= q_{tol}^{sed} / K_d$

$$N = K_L \left[C_{tol}^{aq} - \frac{q_{tol}^{sed}}{K_d} \right]$$

From the values given,

$$A * N = (15{,}000\ m^2)\left(1.0 \times 10^{-6}\ \frac{m}{s}\right)\left[58.4\ \frac{mg}{L} - \frac{579\ mg/kg}{33.1\ L/kg}\right]\left(\frac{1000\ L}{1\ m^3}\right)$$

$$= 613.6\ \frac{mg\ \text{toluene}}{s} * \frac{86400\ s}{1\ d} * \frac{1\ kg}{10^6\ mg}$$

$$= 53\ kg/d$$ moving from water to sediment.

8. Partial pressure and concentration in the air

$$\hat{f}_{tol}^{air} = \hat{f}_{tol}^{gas}$$

$$y_i P = x_{tol} P^{sat} = (0.11)(37.6 \times 10^{-3} \text{ atm})$$

$$P_{tol} = \boxed{4.1 \times 10^{-3} \text{ atm} = 420 \text{ Pa}}$$

$$\frac{n}{V} = \frac{P}{RT} = \frac{419 \text{ Pa}}{(8.314 \text{ Pa} \cdot m^3/\text{mol} \cdot K)(298.15 \text{ K})} = 0.169 \frac{\text{mol}}{m^3}$$

$$C_{tol}^{air} = \left(0.169 \frac{\text{mol}}{m^3}\right)\left(92.14 \frac{g}{\text{mol}}\right)\left(\frac{1000 \text{ mg}}{1 \text{ g}}\right) = \boxed{15{,}600 \text{ mg}/m^3}$$

9. Estimate H_{cc}

From questions 4 and 8:

$$H_{cc} = \frac{15{,}578 \text{ mg}/m^3}{58.3 \text{ mg}/L} * \frac{1 \text{ m}^3}{1000 \text{ L}} = 0.2672 \approx \boxed{0.27}$$

From given value of H_{pc}

$$H_{cc} = \frac{6.6 \times 10^{-3} \text{ atm} \cdot m^3/\text{mol}}{\left(8.206 \times 10^{-5} \frac{\text{atm} \cdot m^3}{\text{mol} \cdot K}\right)(298.15 \text{ K})} = 0.2698 \approx \boxed{0.27}$$

They agree to two significant digits! Good news.
This probably means I did everything correctly.