

Water & Wastewater Engineering Semester project

14:180:429 Water and Waste

Group member:

Group number 10

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1.Introduction:

The goal of this project is targeted at designing a new treatment system to protect groundwater resources at a site in Belmont to solve the improper chemical waste handling issues that damages the environment. To accomplish the goal of reducing excessive chemical compounds at the site, the project team decided to approach the problem through designing a stripping tower that transfers excessive and harmful chemical components in liquid to air stream to purify groundwater resources. The major steps the project team took to accomplish the project include determining dimensions of the air stripping column, designing the air stripping column through determining liquid loading rate, stripping factor, HTU(height of a transfer unit), NTU(number of transfer unit) and height of packing in column.

2. Site Conditions:

The site is located at Woodlawn Avenue, in North Belmont. According to the previous site investigation records provided by EPA Environmental Response Team/Response Engineering and Analytical Center (ERT/REAC) indicated there were volatile organic compounds contained in the groundwater resources. The investigation team discovered high levels of pesticide chlordane in collected soil samples and trichlorofluoromethane near the site which could lead to serious health concerns to individuals living around the region.

3. Design Specifications:

In the project, some of the known constants for calculation include: Henry's constant is 0.7 under 18 degrees temperature; Liquid diffusion coefficient is 9.1×10^{-10} Pa-s; 1 inch Raschig Rings for Type of Packing.

Location: 201/601 Woodlawn

PCE = 12 average Mg/L

PCE standard = 0.7 Mg/L

Designing air stripping tower:

with below conditions & designing factors

$Q = 250 \text{ gph}$

diameter = 2.5 m

Air to water ratio = 8

Henry's constant = 0.7 at 18°C

Cross-section Area = $\pi(r)^2 = \pi\left(\frac{2.5}{2}\right)^2 = 4.909 \text{ m}^2$

$$R = H' \frac{Q_A}{Q_W}$$

$$R = 0.7 * \frac{Q_A}{Q_W}$$

suppose a stripping factor of 8

$$8 = 0.7 * \frac{Q_A}{Q_W} \quad Q_W = 250 \text{ gph} = 250 * 6.3 * 10^{-5} \text{ m}^3/\text{min}$$

$$8 = 0.7 * \frac{Q_A}{0.01575} \quad = 0.01575 \text{ m}^3/\text{min}$$

$$\therefore Q_A = 0.157 \text{ m}^3/\text{min}$$

Then, determining L & $K_L a$

$$L = \frac{0.01575 \text{ m}^3/\text{min} * 998.2 \text{ kg/m}^3 * 60}{4.909 \text{ m}^2} = 0.466 \text{ kg/m}^2/\text{s}$$

$$\text{then } K_L a = \alpha D_L (0.305 \text{ L/m})^{1-n} \left(\frac{M}{P D_L} \right)^{0.5}$$

Assume 1 inch Raschig rings of packing

$$\alpha = 100 \quad n = 0.22$$

$$M = 1.002 * 10^{-3} \text{ Pa-s}$$

$$P = 998.2 \text{ kg/m}^3$$

$$D_L = 9.1 * 10^{-10} \text{ m}^2/\text{s}$$

$$\therefore K_L a = 100 * (9.1 * 10^{-10})^{1-0.22} (0.305 * \frac{0.466}{1.002 * 10^{-3}})^{0.5} \left(\frac{1.002 * 10^{-3}}{998.2 * 9.1 * 10^{-10}} \right)^{0.5}$$

$$= 1.11 * 10^{-4} \text{ s}^{-1} = 0.000111 \text{ s}^{-1}$$

$$\therefore \text{HTU} = \left(\frac{Q_W}{K_L a B} \right) = \left(\frac{0.01575 * 60}{0.000111 * 4.909} \right) = 0.421 \text{ m}$$

$$\text{NTU} = \frac{R}{R-1} \ln \left(\frac{C_{in}/C_{out}}{R} (R-1) + 1 \right) = \frac{8}{7} * \ln \left(\frac{(12/0.7) * (8-1) + 1}{8} \right) = 3.104$$

Explanation: By the calculation, $\text{HTU} = 0.421 \text{ m}$ and $\text{NTU} = 3.104$. Therefore, the height of the packing is 1.307 m . With the safety factor, $Z = 1.4377$. We choose the height of the column for 2 meter.

For the 96.01/2309ACME, $L = 0.0466 \text{ kg/m}^2/\text{s}$. $K_L a = 0.000111 \text{ s}^{-1}$. For PCE reduction, Z with safety factor $10\% = 3.386 \text{ m}$. For TCE, Z with safety factor $10\% = 1 \text{ meter}$. Hence, we decided to use 2 columns, one with height 4 meter for reducing PCE and another with height 1.5 meter for reducing TCE.

For the 108/1050Daniel, $\text{NTU} = 0.4$, $\text{HTU} = 0.421 \text{ m}$. $Z = 0.194 \text{ meter}$. $Z * 1.1 = 0.21 \text{ m}$.

$$Z = NTU \times HTU = 3.104 \text{ m} \times 0.421 \text{ m} = 1.307 \text{ m}$$

Consider 10% safety factor,

$$Z' = 1.1 \times 1.307 \text{ m} = 1.4377 \text{ m}$$

∴ the stripping tower height: 2 m

diameter: 2.5 m

Q_A/Q_W or $R = 8$

Packing: 1.4377 m

Packing material: 1 inch Raschig rings of Packings

Location: 96.01/2309 ACME

$$PCE = 480 \text{ Mg/L} \times TCE = 22 \text{ Mg/L}$$

$$PCE = 0.7 \text{ Mg/L}$$

$$TCE = 3 \text{ Mg/L}$$

Designing air stripping tower:

$$Q = 250 \text{ gph}$$

$$\text{diameter} = 2.5 \text{ m}$$

$$\text{stripping factor} = 8$$

$$T = 18^\circ$$

$$\text{Henry's constant} = 0.7$$

$$R = 0.7 \times \frac{Q_A}{Q_W} = 8$$

$$\therefore Q_W = 0.01375 \text{ m}^3/\text{min}$$

$$\therefore Q_A = 0.157 \text{ m}^3/\text{min}$$

$$\text{Then determine } L, L = \frac{0.01375 \times 998.2 \times 1\%}{(4.909)} = 0.0466 \text{ kg/m}^2/\text{s}$$

$$KLa = 0.000111 \text{ s}^{-1} \text{ base on the table (using 1 inch Raschig rings)}$$

$$\therefore HTU = \left(\frac{Q_W}{KLa B} \right) = \left(\frac{0.01375 \times 1\%}{0.000111 \times 4.909} \right) = 0.421 \text{ m}$$

For PCE

$$\therefore NTU = \frac{8}{7} \ln \left(\frac{e^{4.8\%} - 1}{8} \right) (7 + 1) = 7.311$$

$$\therefore Z = 7.311 \times 0.421 = 3.077931 \text{ m}$$

$$\therefore Z' = 1.1 \times Z = 3.386 \text{ m}$$

For TCE

$$NTU = \frac{8}{7} \ln \left(\frac{e^{2.2\%} - 1}{8} \right) (7 + 1) = 2.1465$$

$$Z = 2.1465 \times 0.421 = 0.9 \text{ m}$$

$$Z' = 0.9 \times 1.1 = 0.99 \text{ m} \approx 1 \text{ m}$$

then using 2 air stripping column for ACME

$$\text{For TCE: } \begin{cases} D = 2.5 \text{ m} \\ \text{Packing} = 1 \text{ m} \\ H = 1.5 \text{ m} \\ \text{Packing material: 1 inch Raschig ring} \end{cases}$$

$$\text{For PCE: } \begin{cases} D = 2.5 \text{ m} \\ \text{Packing} = 3.386 \text{ m} \\ H = 4 \text{ m} \\ \text{Packing material: 1 inch Raschig ring} \end{cases}$$

Location: 108/105 ODaniel

$$1-1 \text{ DCE} = 9.4 \text{ Mg/L}$$

$$1-1 \text{ DCE} = 6 \text{ Mg/L}$$

Designing air stripping column:

with below conditions & design factors

$$Q = 250 \text{ gph} = 0.01375 \text{ m}^3/\text{min}$$

$$\text{diameter} = 2.5 \text{ m}$$

$$\text{stripping factor} = 8$$

$$\text{Henry's constant} = 0.7$$

$$T = 18^\circ \text{C}$$

$$8 = 0.7 \times \frac{Q_A}{Q_W} \therefore Q_A = 0.157 \text{ m}^3/\text{min}$$

$$\text{then, determine } L \text{ \& } KLa \quad L = \frac{0.01375 \times 998.2 \times 1\%}{4.909} = 0.466 \text{ kg/m}^2/\text{s}$$

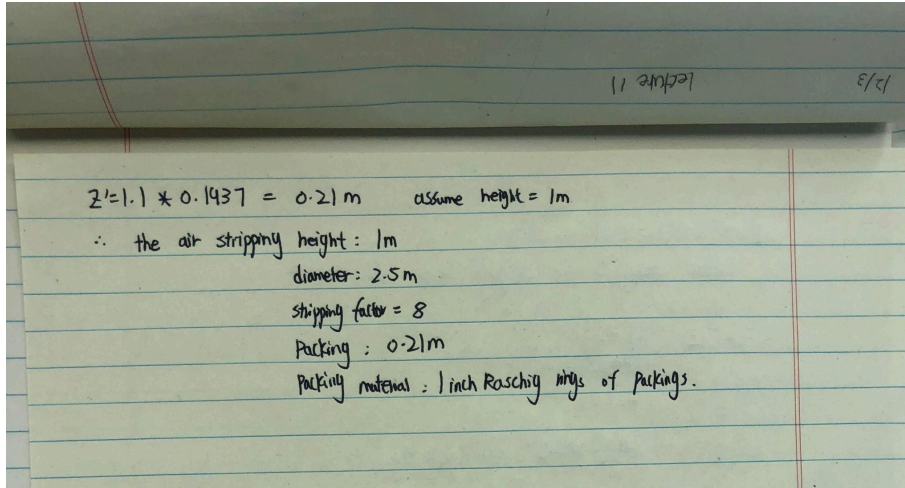
$$\text{then, } KLa = 100 \times (9.1 \times 10^{-10}) \times (0.305 \times 0.466 / 1000 \times 10^{-3}) \left(\frac{1.002 \times 10^{-2}}{998.2 \times 9.1 \times 10^{-10}} \right)^{1/4}$$

$$KLa = 0.000111 \text{ s}^{-1}$$

$$\therefore HTU = \left(\frac{Q_W}{KLa B} \right) = 0.421 \text{ m}$$

$$NTU = \frac{8}{7} \ln \left(\frac{e^{4.8\%} - 1}{8} \right) (7 + 1) = 7.311$$

$$\therefore Z = 0.46 \times 0.421 = 0.194 \text{ m}$$



3. Cost Estimations

Design Flow Rate: 250 GPM

Tower Dimensions:

Tower 1: Heights: 2m, Diameter: 2.5m

Tower 2(For TCE): Heights: 1.5m, Diameter: 2m

Tower 3(For PCE): Heights: 4m, Diameter: 2.5m

Tower 1: Heights: 1m, Diameter: 2.5m

Items	Price
Towers	230000 USD
Packing Materials	100000 USD
	Total

Operations	Price
Cost per 1000 gallons treated	6 USD/1000gallons
Human workforce	351 USD/day

