2-3 Estimated emission of a new dry cleaning fluid

Given: Problem 2-2, Volatility = 1/6 of former fluid, Density = 1.622 g/mL

Solution:

a. Mass balance diagram same as problem 2-2

b. Mass of dry cleaning fluid into tank

\[
\frac{0.160 \text{ m}^3}{\text{mo}} \times \frac{1.662 \text{ g/mL}}{1000 \text{mL/L}} \times \frac{1000 \text{L}/\text{m}^3}{1000 \text{g/kg}} = 265.92 \text{ kg/mo}
\]

c. Mass emission rate at 1/6 volatility

\[
\frac{1}{6}(0.90)(265.92 \text{ kg/mo}) = 39.89 \text{ kg/mo}
\]

d. Savings in volume (note: 1.0 g/mL = 1000 kg/m³)

Old dry cleaning fluid (from problem 2-2)

\[
\text{Mass}_{\text{out}} = (0.90)(255.04 \text{ kg/mo}) = 229.54 \text{ kg/mo}
\]

\[
V_{\text{out}} = \frac{229.54 \text{ kg/mo}}{1594 \text{ kg/m}^3} = 0.1440 \text{ m}^3/\text{mo}
\]

New dry cleaning volume

\[
V_{\text{out}} = \frac{39.89 \text{ kg/mo}}{1622 \text{ kg/m}^3} = 0.0240 \text{ m}^3/\text{mo}
\]

Savings = \[(0.1440 \text{ m}^3/\text{mo} - 0.0240 \text{ m}^3/\text{mo})(12 \text{ mo/y}) = 1.44 \text{ m}^3/\text{y}\]
NaOCl pumping rate

Given: NaOCl at 52,000 mg/L
Piping scheme in figure P-2-6
Main service line flow rate = 0.50 m³/s
Slip stream flow rate 4.0 L/s

Solution:

a. Mass balance at return of slip stream to main service line

\[ Q_{\text{SS}} = 4.0 \text{ L/s} \quad C_{\text{SS}} = ? \]

\[ \text{Slip Stream} \quad \begin{array}{c} \downarrow \\ Q_{\text{IN}} = 0.50 \text{ m}^3/\text{s} \\ C_{\text{IN}} = 0.0 \text{ mg/L} \end{array} \quad \text{Main service line} \quad \begin{array}{c} \downarrow \\ Q_{\text{OUT}} \approx 0.50 \text{ m}^3/\text{s} \\ C_{\text{OUT}} = 2.0 \text{ mg/L} \end{array} \]

b. Calculate \( C_{\text{SS}} \)

Mass out = Mass in

\[
(0.50 \text{ m}^3/\text{s})(2.0 \text{ mg/L})(1000 \text{ L/m}^3) = (4.0 \text{ L/s})(C_{\text{SS}})
\]

\[ 1000 \text{ mg/s} = (4.0 \text{ L/s})(C_{\text{SS}}) \]

\[ C_{\text{SS}} = \frac{1000 \text{ mg/s}}{4.0 \text{ L/s}} = 250 \text{ mg/L} \]

c. Mass balance at the junction of pump discharge and slip stream line

\[ Q_{\text{PUMP}} = ? \quad C_{\text{inlet}} = 52,000 \text{ mg/L} \]

\[ \text{Pump Discharge} \quad \begin{array}{c} \downarrow \\ Q_{\text{IN}} = 4.0 \text{ L/s} \\ C_{\text{IN}} = 0.0 \text{ mg/L} \end{array} \quad \text{Slip stream line} \quad \begin{array}{c} \downarrow \\ Q_{\text{OUT}} \approx 4.0 \text{ L/s} \\ C_{\text{OUT}} = 250.0 \text{ mg/L} \quad \text{from “b” above} \end{array} \]
d. Calculate $Q_{\text{PUMP}}$

$$\text{Mass in} = \text{Mass out}$$

$$(Q_{\text{PUMP}})(52,000 \text{ mg/L}) = (4.0 \text{ L/s})(250 \text{ mg/L})$$

$$Q_{\text{PUMP}} = \frac{(4.0 \text{ L/s})(250 \text{ mg/L})}{52,000 \text{ mg/L}} = 0.0192 \text{ L/s}$$

2-11 Concentration of nickel in wastewater stream

Given: Figure P - 2-11, concentration of plating solution = 85 g/L, drag-out rate = 0.05 L/min, flow into rinse tank = 150 L/min, assume no accumulation in tank.

Solution:

a. Mass balance diagram

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<table>
<thead>
<tr>
<th>Q_in = 0.05 L/min</th>
<th>C_in = 85 g/L</th>
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<td>C_nickel = ?</td>
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<tr>
<td></td>
<td>Q_dragout = 0.05 L/min</td>
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<td>C_rinse = 0</td>
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<td>Q_rinse = 150 L/min</td>
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<td>C_rinse = ?</td>
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<tr>
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<td>Q_out = 150 L/min</td>
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<tr>
<td></td>
<td>C_nickel = ?</td>
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</tbody>
</table>
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b. Mass balance equation

$$Q_{\text{in}}C_{\text{in}} + Q_{\text{rinse}}C_{\text{rinse}} - Q_{\text{dragout}}C_{\text{nicker}} - Q_{\text{rinse}}C_{\text{nicker}} = 0$$

c. Because $C_{\text{rinse}} = 0$, this reduces to

$$Q_{\text{in}}C_{\text{in}} = Q_{\text{dragout}}C_{\text{nicker}} + Q_{\text{rinse}}C_{\text{nicker}}$$

d. Solving for $C_{\text{nicker}}$

$$C_{\text{nicker}} = \frac{Q_{\text{in}}C_{\text{in}}}{Q_{\text{dragout}} + Q_{\text{rinse}}}$$

e. Substituting values

$$C_{\text{nicker}} = \frac{(0.05 \text{ L/min})(85 \text{ g/L})}{0.05 \text{ L/min} + 150 \text{ L/min}} = 28 \text{ mg/L}$$
4. An air pollution control device is to remove a particulate, which is being emitted at a concentration of 125,000 µg/m$^3$ at an airflow rate of 180 m$^3$/sec. The device removes 5.5 g/sec. Draw a mass balance diagram. Calculate the concentration of the emission in µg/m$^3$ and the % recovery of collection.

\[
\text{Inflow mass/time} = \frac{125,000 \text{ µg/m}^3 \times 180 \text{ m}^3/\text{sec}}{10^6 \text{ µg/g}} = 22.5 \text{ g/m}^3
\]

Therefore Emission is 22.5-5.5 g/m$^3 = 17/ \text{ g m}^3$

Recovery = 5.5/22.5 = 24.4%

5. A radionuclide decays at the rate of 9.5x10$^{-5}$ day$^{-1}$. What is the half life in years?

\[t_{1/2} = \frac{0.693}{k} = \frac{0.693}{9.5 \times 10^{-5} \text{ day}^{-1}} = 7295 \text{ days/365 days/yr} = 19.9 \text{ years}\]

6. What is the reaction rate for a first order reaction if 90% of a pollutant is removed in 10 minutes?

If 90% removed \(C_t = 0.1 \ Co\) For 1st order \(\ln Ct/Co = -kt\)

Therefore \(\ln 0.1Co/Co = -k.10\) or \(k = 0.23 \text{ min}^{-1}\)

7. A Gook manufacturing facility obtained the following plots for determining the reaction rate for gook removal in their wastewater.

(a) What is the order of the reaction? _first_____

(b) What is the value of the reaction rate? __.0481____ Units __min$^{-1}$___
(c) What was the initial gook concentration in mg/L at the start of the reaction?

(d) If the reaction rate for gook was 0.057 day\(^{-1}\), what is the value of its half-life in days?

\[ \ln(C_0) = 5.1597 \quad \text{or} \quad C_0 = 174 \text{ mg/L} \]