Homework #4

1. Dry Cleaning

Each month the Speedy Dry Cleaning Company buys one barrell (0.160 m^3) of dry cleaning fluid per month. Ninety percent of the fluid is lost to the atmosphere and 10% remains as residue to be disposed of. The density of the cleaning fluid is 1.5940 g/mL.

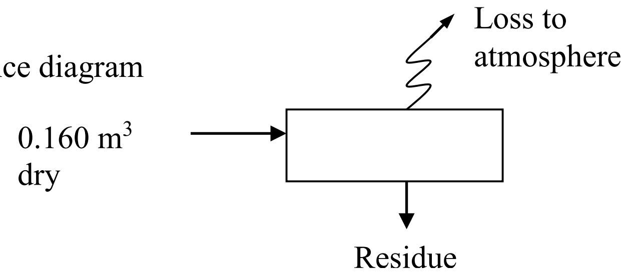
1 point

a. Draw a mass balance diagram
b. Estimate monthly mass emission rate to the atmosphere in kilograms per month

Given: 1 barrel (0.160 m^3) of dry cleaning fluid per month, density = 1.5940 g/mL, 90% lost to atmosphere.

Solution:

a. Mass balance diagram



b. Mass of dry cleaning fluid into tank

$$= \frac{(0.160\ m^3)}{(month)} * \frac{(1.5940\ g)}{(mL)} * \frac{(1000\ mL)}{(L)} * \frac{(1000\ L)}{(m^3)} * \frac{(1\ kg)}{(1000\ g)}$$

= 260 kg/month

c. Mass emission rate at 90% loss

(0.90)(260 kg/month) = 230 kg/month

2. Corrosion Control

Near the end of a drinking water treatment plant we often add a chemical to inhibit corrosion of pipes in the water distribution system. Suppose a plant treats a flow of 4 million gallons per day (MGD) (or 175 L/s) and wants to achieve a dose (or concentration) of 2 mg/L of orthophosphate (PO_4^{3-}) for corrosion control. A dosing pump is used to inject a

1 point

high concentration feed stock of the orthophosphate. If the dosing pump flow rate is 0.20 L/s what is the required concentration of orthophosphate in the feed solution? Assume steady state, complete mixing and a conservative substance.

In general:
Dose (mass loading) = Concentration(C) * Flow(Q)

Also only source of phosphate is from the dosing pump, so that the flux from this chemical feed must also equal the flux in the main water flow leaving the plant.

PO_4 Loading from plant = 2 mg/L * 175 L/s
= 350 mg/s

PO_4 Loading from dosing pump = x mg/L * 0.2L/s

And setting them equal:

x mg/L * 0.2 L/s = 350 mg/s
x = 350 mg/s ÷ 0.2 L/s
= 1750 mg/L
=1.75 g/L

3. Sludge

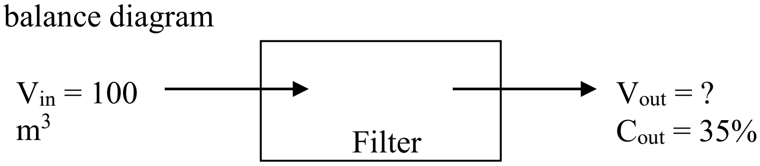
1 point

In water and wastewater treatment processes a filtration device may be used to removal water from the sludge formed by a precipitation reaction. The initial concentration of sludge from a softening reaction is 2% (20,000 mg/L) and the volume of sludge is 100 m^3. After filtration the sludge solids concentration is 35%. Assume that the sludge does not change density during filtration and that liquid removed from the sludge contains no sludge. Using the mass-balance method, determine the volume of sludge after filtration.

Volume of sludge after filtration

Given: Sludge concentration of 2%, sludge volume = 100 m^3, sludge concentration after filtration = 35%
Solution:

a. Mass balance diagram



b. Mass balance equation

$$C_{in}\forall_{in} = C_{out}\forall_{out}$$

c. Solve for $\forall_{out}$

$$\forall_{out} = \frac{C_{in}\forall_{in}}{C_{out}}$$

d. Substituting values

$$\forall_{out} = \frac{(0.02)(100\ m^3)}{(0.35)} = 5.71 \text{ or } 5.7\ m^3$$

4. Radon

A 90 m^3 basement in a residence is found to be contaminated with radon coming from the ground through the floor drains. The concentration of radon in the room is 1.5 Bq/L (becquerels per liter) under steady state conditions. The room behaves as a CMFR, and the decay of radon is a first-order reaction with a decay rate constant of $2.09 \times 10^{-6}\ s^{-1}$. If the source of radon is closed off and the room is vented with radon-free air at a rate of 0.14 m^3/s, how long will it take to lower the radon concentration to an acceptable level of 0.15 Bq/L?

1 point

Given: $\forall = 90\ m^3$, radon = 1.5 Bq/L, radon deacy rate constant = $2.09 \times 10^{-6}\ s^{-1}$, vent at 0.14 m^3/s, allowable radon = 0.15 Bq/L, assume CMFR.

Solution:

a. recognizing that this is a batch reactor once the input is closed off

$$C_{out} = C_o \exp\left[-\left(\frac{1}{\theta} + k\right)t\right]$$

$$\frac{C_{out}}{C_o} = \exp\left[-\left(\frac{1}{\theta} + k\right)t\right]$$

$$\theta = \frac{\forall}{Q} = \frac{90\ m^3}{0.14\ m^3/s} = 642.857\ s$$

$$\frac{0.15}{} = \exp\left[\left(\frac{-1}{} + 2.09 \times 10^{-6}\right)t\right]$$

1.5 642.857 s

$0.10 = \exp[-(1.558 \times 10^{-3})t]$

Take the natural log of both sides

$-2.303 = (-1.558 \times 10^{-3})t$

$t = 1.478 \times 10^{3}$ s or 24.64 min or 25 min

5. Reactor Kinetics

Compare the reactor volume required to achieve 95% efficiency for a CMFR and a PFR for the following conditions; steady-state, first-order reaction, flow rate = 14 m^3/d, and reaction rate coefficient = 0.05 day^{-1}.

1 point

Given: $Q = 14\ m^3/d$, $k = 0.05$.
Solution:

a. Solve for fraction of C_o

$$\eta = 0.95 = \left(\frac{C_o - (X)C_o}{C_o}\right)$$

$1 - X = 0.95$

$X = 0.05$

Therefore

$$\frac{C_t}{C_o} = 0.05$$

b. CMFR

$$C_t = \frac{C_o}{1 + k\theta}$$

Solve for θ

C_t 1

$$\frac{C_t}{C_o} = \frac{1}{1 + k\theta}$$

$$\frac{C_o}{C_t} = 1 + k\theta$$

$$k\theta = \frac{C_o}{C_t} - 1$$

$$\theta = \frac{\frac{C_o}{C_t} - 1}{k}$$

Substituting values,

$$\theta = \frac{20 - 1}{0.05} = 380 \text{ d}$$

Solve for the volume

$$\theta = \frac{\forall}{Q}$$

$\forall = (\theta)(Q) = (380 \text{ d})(14 \text{ m}^3/\text{d}) = 5{,}320 \text{ m}^3$

c. PFR

$$\frac{C_t}{C_o} = \exp[-k\theta]$$

As in (a.) above

$0.05 = \exp(-0.05\theta)$

Take the natural log of both sides

$-2.9957 = -0.05\theta$

$\theta = 59.9147 \text{ d}$

Solve for volume

$$\theta = \frac{\forall}{Q}$$

$$\forall = (\theta)(Q) = (59.9147\ d)(14\ m^3/d) = 838.8\ m^3$$