Homework #8

0.5 pts each

Drinking Water Problems

1. Drinking Water Quality

The following mineral analysis was reported for Michigan State Well water. Determine the following in units of mg/L as $CaCO_3$

a. total hardness,
b. carbonate hardness and
c. noncarbonate hardness

Mineral	Conc (mg/L)	Mineral	Conc (mg/L)
Fluoride	1.1	Silica (as SiO_2)	13.4
Chloride	4.0	Bicarbonate	318.0
Nitrate	0.0	Sulfate	0.5
Sodium	14.0	Iron	0.5
Potassium	1.6	Manganese	0.07
Calcium	96.8	Zinc	0.27
Magnesium	30.4	Barium	0.2

Solution:

a. Begin by converting to units of mg/L as $CaCO_3$

recall that the equivalent weight of $CaCO_3$ is 100 g, so that there are 50 mg-$CaCO_3$ per meq.

Substance	mg/L as ion	GFW	mMoles/L	meq/L	mg/L as $CaCO_3$
Ca^{+2}	96.8	40.08	2.415	4.83	242.0
Mg^{+2}	30.4	24.3	1.253	2.506	125.3
HCO_3^-	318.0	61	5.213	5.213	260.9

b. Calculate TH, CH and NCH

TH = 242.0 + 125.3 = 367.3 mg/L as $CaCO_3$

CH = 260.9 mg/L as $CaCO_3$

NCH = TH - CH = 367.3 - 260.9 = 106.4 mg/L as $CaCO_3$

2. Flocculation.

Two parallel flocculation basins are to be used to treat a water flow of 0.150 m^3/s. If the design detention time is 20 min, what is the volume of each tank?

Solution:

$$V = Qt_0 = (0.150\ m^3/s)(20\ min)(60\ s) = 180\ m^3$$

$$\text{Volume for each tank} = \frac{180}{2} = 90\ m^3$$

3. Gravity Settling.

Assuming a conservative value for an overflow rate, determine the surface area (in m^2) of each of two sedimentation tanks that together must handle a flow of 0.05162 m^3/s of lime softening floc. Use an overflow rate of 57 $m^3/day/m^2$.

Solution:

a. With 57 $m^3/d\text{-}m^2$ as a conservative overflow rate, i.e. one that will yield the larger and, hence, more conservative surface area.

b. Since two tanks (assume in parallel):

$$Q = \frac{0.05162\ m^3/s}{2} = 0.02581\ m^3/s$$

c. And surface area of each tank

$$A_s = \frac{(0.02581\ m^3/s)(\ 86{,}400\ s/d)}{57\ m^3/d\text{-}m^2} = 39.123 \text{ or } \mathbf{39\ m^2}$$

4. Filtration.

The water flow meter at the Westwood water plant is malfunctioning. The plant superintendent tells you the four dual-media filters (each 5.00 m x 10.0 m) are loaded at a velocity of 280 m/day. What is the flow rate through the filters (in m^3/s)?

Solution:

a. Note that 280 m/d = 280 $m^3/d\text{-}m^2$

b. Compute flow in m^3/d

$$Q = (280\ m^3/d\text{-}m^2)(4)(5.00\ m)(10.00\ m)$$

$Q = 56{,}000\ m^3/d$

c. Convert to m^3/s

$$Q = \frac{56{,}000\ m^3/d}{86{,}400\ s/d} = \underline{\mathbf{0.648\ m^3/s}}$$

Wastewater Treatment Problems

5. Gravity Settling.

If the terminal settling velocity of a particle falling in acquiescent water having a temperature of 15°C is 0.0950 cm/s, what is its diameter? Assume a particle density of 2.05 g/cm^3 and a density of water equal to 1000 kg/m^3. Assume Stokes' law applies.

$$v_p = \frac{(\rho_p - \rho_w) d^2 g}{18\mu}$$

$$d = \sqrt{\frac{v_p 18\mu}{g(\rho_p - \rho_w)}}$$

$$d = \sqrt{\frac{0.095\frac{cm}{s} 18\left(0.01139\frac{g}{cm-s}\right)}{980.6\frac{cm}{s^2}(2.05-1)\frac{g}{cm^2}}}$$

d = 0.004349 cm = 0.04343 mm

6. Microbial Growth

You're operating a batch reactor. At the start (time =0) you have 0.85 mg/L of biomass. After two full weeks of operation you find that the biomass concentration is 286 mg/L.

a. What is the specific growth rate assuming simple exponential growth throughout?

b. Is the value you calculated in part "a" equal to the μ_{max} ? Why or why not? Explain.

From equation on Slide #4 of Lecture #17:

$$X_t = X_0 e^{\mu t}$$
$$286 = 0.85 e^{\mu(14d)}$$
$$\mu = \frac{1}{14d} \ln\left(\frac{286}{0.85}\right)$$
$$= 0.42 d^{-1}$$
$$= 0.017 hr^{-1}$$

a. Is the value you calculated in part "a" equal to the μ_{max} ? Why or why not? Explain.

It is not necessarily equal to the μ_{max} because the growth rate may or may not be restricted due to limited substrate concentration or other environmental factors. Information on growth limitation is not provided, so we cannot assume that such limitation does not exist. In other words, the growth is exponential, but not necessarily "unlimited". With better conditions it might be able to grow at a faster exponential rate.

7. Activated Sludge I.

The 500- bed Amherst General Hospital has a small activated sludge plant to treat its wastewater. The average daily hospital discharge is 1200 L/day per bed, and the average soluble BOD_5 after primary settling is 500 mg/L. The aeration tank has effective liquid dimensions of 10.0 m wide x 10.0 m long x 4.5 m deep. The plant operating parameters are as follows: MLVSS = 2000 mg/L, MLSS = 1.2 x MLVSS, and return sludge concentration = 12,000 mg/L (VSS). Determine:

a. Aeration Period in hrs

$$Q = 500\ people\ x\ 1200\ \frac{L/person}{d} = 600{,}000 \frac{L}{d} = 600\ \frac{m^3}{d}$$
$$V = 10m\ x\ 10m x\ 4.5m = 450\ m^3$$

$$\theta = \frac{V}{Q} = \frac{450m^3}{600\ {m^3}/{d}} = \mathbf{0.75\ d = 18\ hrs}$$

b. F/M ratio

$$\frac{F}{M} = \frac{Q\ BOD}{V\ X} = \frac{\left(600\ {m^3}/{d}\right)\left(500\ {mg}/{L}\right)}{450m^3\left(2000\ {mg}/{L}\right)} = \mathbf{0.33\ d^{-1}}$$

If you use MLSS for X instead of MLVSS (which is more common), you would have gotten 0.278

8. Activated Sludge II

Using the following assumptions, determine:

a. the solids retention time (days), and the

b. cell wastage flow rate

for the Amherst General Hospital problem above.

Assumptions:

Suspended solids in effluent = 30 mg/L

Wastage is from the return sludge line

Yield coefficient = 0.60

Bacterial decay rate = 0.060 day^{-1}

Inert fraction of suspended solids = 66.67%

Allowable BOD in effluent = 30.0 mg/L

a., the SRT

In Lecture #32, slide #21, we have the combined model:

$$\frac{1}{\theta_c} = \frac{1}{\theta}\frac{Y(S_o - S)}{X} - k_d$$

This can be rearranged, solving for X:

$$X = \frac{\theta_c Y(S_o - S)}{\theta(1 + k_d\theta_c)}$$

And you can also rearrange

$$\theta X + \theta_c k_d \theta X = \theta_c Y(S_o - S)$$

Solving for the SRT, which is more to the point:

$$\theta_c = \frac{-\theta X}{k_d\theta X - Y(S_o - S)}$$

If you used the 30 mg/L effluent BOD value as given

$$\theta_c = \frac{-0.75d\left(2000\frac{mg}{L}\right)}{0.060d^{-1}(0.75d)2000\frac{mg}{L} - 0.60(500 - 30)\frac{mg}{L}} = \mathbf{7.81d}$$

Some converted this to 10 mg/L, and then would have gotten.

$$\theta_c = \frac{-0.75d\left(2000\frac{mg}{L}\right)}{0.060d^{-1}(0.75d)2000\frac{mg}{L} - 0.60(500 - 10)\frac{mg}{L}} = \mathbf{7.35d}$$

If you use MLSS for X instead of MLVSS (which is more common), you would have gotten 10.3 days

b. the waste sludge flow

see equation 9.9 in the textbook (M&Z) page 461:

$$\frac{Q_w X_w}{VX} = \frac{Q_o Y}{VX}(S_o - S) - k_d$$

This can be rearranged to solve for the waste sludge flow:

$$Q_w = \frac{Q_o Y}{X_w}(S_o - S) - k_d \frac{VX}{X_w}$$

And plugging in the values:

$$Q_w = \frac{600\frac{m^3}{d}0.6}{12{,}000\frac{mg}{L}}\left(500\frac{mg}{L} - 30\frac{mg}{L}\right) - 0.06d^{-1}\frac{450m^3 2000\frac{mg}{L}}{12{,}000\frac{mg}{L}}$$

$$Q_w = 14{,}100\frac{L}{d} - 4{,}500\frac{L}{d}$$

Q_w = 9,600 L/d

Or if you used the 10 mg/L effluent BOD, you would have gotten:

$$Q_w = \frac{600\frac{m^3}{d}0.6}{12{,}000\frac{mg}{L}}\left(500\frac{mg}{L} - 10\frac{mg}{L}\right) - 0.06d^{-1}\frac{450m^3 2000\frac{mg}{L}}{12{,}000\frac{mg}{L}}$$

$$Q_w = 14{,}700\frac{L}{d} - 4{,}500\frac{L}{d}$$

Q_w = 10,200 L/d