Homework #4

Released: 11/10/2014 (Mon) - Due: 11/19/2014 (Wed), in class

The homework will NOT be graded, but we will check for MISSING ANSWERS and CHEATING. Note that a cheated homework will get 80% of the lowest score in the class. You can give the answers **either** in English **or** Korean.

1. [Water treatment] Look up the drinking water quality standard[1] for your own country. Summarize the standards for following disinfection byproducts: trihalomethanes (THMs), haloacetic acids (HAAs), and bromate (BrO_3^-).

[1]한글명: 먹는물의 수질기준

Answer)

** The following is for the Korean standard. Each country may have different standards.*

The Korean drinking water quality standard (or any environmental laws, regulations, and standards) can be found in: http://www.law.go.kr.

The standards for the disinfection byproducts are as follows:

i) THMs: regulated both as total THMs and as individual compounds (not allowed to exceed any of the standards)

0.1 mg/L total THMs

0.08 mg/L chloroform

0.03 mg/L bromodichloromethane

0.1 mg/L dibromochloromethane

ii) HAAs: regulated as the sum of three representative HAAs (dichloroacetic acid, trichloroacetic acid, dibromoacetic acid): 0.1 mg/L

iii) Bromate: 0.01 mg/L

2. [Water treatment] A groundwater sample with pH=7.2 is analyzed to have the following ion concentrations. Determine the total and carbonate hardness (in mg/L as $CaCO_3$).

Ion	Concentration (mg/L)	Ion	Concentration (mg/L)
F^-	1.1	HCO_3^-	318.0
Cl^-	4.0	SO_4^{2-}	52.0
NO_3^-	0.0	Fe^{2+}	0.5
Na^+	14.0	Mn^{2+}	0.07
K^+	1.6	Zn^{2+}	0.27
Ca^{2+}	96.8	Ba^{2+}	0.2
Mg^{2+}	30.4		

Answer)

The hardness (or alkalinity for HCO_3^-) contributed by each species is summarized as below:

Ion	Concentration (mg/L)	Molecular weight	Concentration (mM)	Hardness (or alkalinity)	
				in meq/L	in mg/L as $CaCO_3$
Ca^{2+}	96.8	40.1	2.41	4.82	241
Mg^{2+}	30.4	24.3	1.25	2.50	125
Fe^{2+}	0.5	55.8	8.96×10^{-3}	1.79×10^{-2}	0.896
Mn^{2+}	0.07	54.9	1.28×10^{-3}	2.56×10^{-3}	0.128
Zn^{2+}	0.27	65.4	4.13×10^{-3}	8.26×10^{-3}	0.413
Ba^{2+}	0.2	137.3	1.46×10^{-3}	1.92×10^{-3}	0.146
HCO_3^-	318.0	61.0	5.21	5.21	261

Total hardness = hardness contributed by all polyvalent cations

The table verifies that the almost all of the hardness is from Ca^{2+} and Mg^{2+}.

Therefore,

Total hardness $\fallingdotseq (Ca^{2+}) + (Mg^{2+}) = 241 + 125 = 366$ *mg/L as $CaCO_3$*

As total hardness > HCO_3^- concentration,

Carbonate hardness $= (HCO_3^-) = 261$ *mg/L as $CaCO_3$*

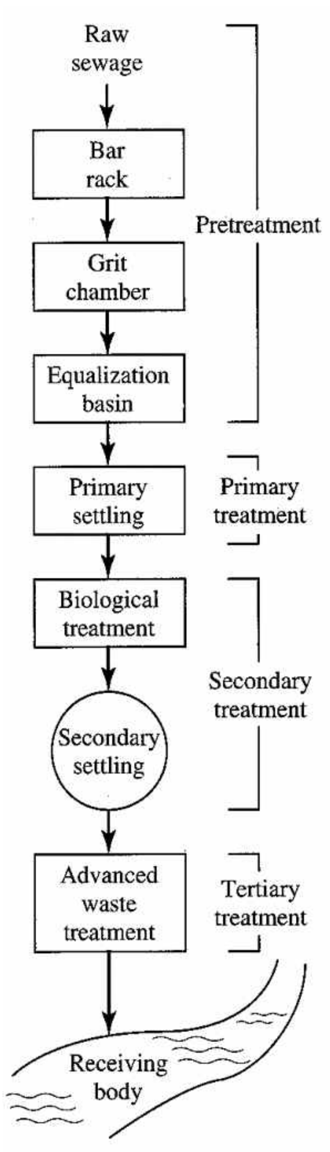
Note that HCO_3^- concentration at neutral pH (6~8.5) is very close to total alkalinity.

3. [Water treatment] Explain why the dual media filter using anthracite coal and sand is used to improve the performance of the drinking water filtration system.

Answer) The disadvantage of using a single media filter (sand only) is that the particle removal occurs only at the top layer of the filter bed. As particles accumulate at the top, the head loss occurs relatively fast and thus, the filter bed needs to be backwashed frequently. If larger-grain media are laid at the top and smaller-grain media are laid at the bottom, then some particles are trapped at the top and some particles pass through the top layer and are trapped at the bottom, smaller-grain media. So the full depth of the filter bed can be used, in other words, we can use the filter bed more efficiently (improved performance). One problem is that if we use the media with the same density for the larger and smaller grains, then after backwashing, the larger grains will settle at the bottom and the smaller-grain settle on top of it because the larger grains have faster settling velocity. A solution for this problem is to use lighter material for the larger grains and heavier material for the smaller grains. This is the reason why the dual media filter is used with anthracite coal at the top, which has relatively small density and larger grain size, and sand at the bottom, which has relatively high density and smaller grain size.

4. [Wastewater treatment] Draw a diagram of the general municipal wastewater treatment system. Briefly (not more than a sentence for each) explain the function of each step.

Answer)



· *Bar rack: remove large objects that would damage or foul mechanical equipment*

· *Grit chamber: remove settleable, inert dense materials that cause abrasion of pumps and other mechanical devices by gravity*

· *Equalization basin: even out the variation of the wastewater flow rate and strength*

· *Primary treatment: remove SS and some particulate BOD by gravity*

· *Secondary treatment: give additional removal of BOD and SS by activity of microorganisms followed by a settling tank*

· *Tertiary treatment: further improve the effluent quality by removal of nutrients, remaining BOD, or refractory organic compounds*

5. [Wastewater treatment] A 1000 m^3-sized activated sludge aeration tank is going to receive primary treatment effluent having a soluble BOD_5 of 150 mg/L at a flow rate of 8000 m^3/d. Using these data, you are trying to adjust the return sludge flow rate (Q_r) and sludge wasting flow rate (Q_w) to achieve the target effluent soluble BOD_5 of 10 mg/L. From experiment, it was observed that an MLSS concentration 10000 mg/L can be obtained at the bottom of the secondary settling basin (this equals to the return sludge MLSS concentration). Eighty percent of the MLSS was MLVSS. For the microorganism in the activated sludge process, following parameters were obtained:

yield coefficient = 0.50 maximum specific growth rate = 2.5 day^{-1}

decay rate = 0.05 day^{-1} half saturation constant = 100 mg/L

Assuming that the MLSS and MLVSS in the primary treatment effluent and the secondary settling basin effluent are negligible, determine the following:

i) The mean cell residence time to achieve the target effluent soluble BOD_5 concentration

Answer)

$$S = \frac{K_s(1+k_d\theta_c)}{\theta_c(\mu_m - k_d) - 1} = \frac{100\ mg/L \cdot (1 + 0.05\ day^{-1} \cdot \theta_c)}{\theta_c(2.5\ day^{-1} - 0.05\ day^{-1}) - 1} = \frac{100 + 5\theta_c}{2.45\theta_c - 1}\ mg/L \qquad (\theta_c\ in\ days)$$

$$10 = \frac{100 + 5\theta_c}{2.45\theta_c - 1}$$

$$19.5\theta_c = 110$$

$$\theta_c = 5.64\ days$$

ii) The MLVSS concentration in the aeration tank when the target effluent soluble BOD_5 concentration is achieved

Answer)

The hydraulic detention time, t_0

$$t_0 = \frac{V}{Q} = \frac{1000\ m^3}{8000\ m^3/d} = 0.125\ day = 3\ hr$$

The MLVSS concentration in the aeration tank, X

$$X = \frac{\theta_c(Y)(S_0 - S)}{t_0(1 + k_d\theta_c)} = \frac{5.64\ days \cdot 0.50 \cdot (150 - 10)\ mg/L}{0.125\ day \cdot (1 + 0.05\ day^{-1} \cdot 5.64\ days)} = 2460\ mg/L$$

iii) The sludge wasting flow rate (Q_w) and the return sludge flow rate (Q_r)

Answer)

Since the effluent MLVSS is neglected, the mean cell-residence time can be expressed as follows:

$$\theta_c = \frac{VX}{Q_w X_r}$$

As MLVSS = 0.8 × MLSS, $X_r = 8000\ mg/L$.

$$Q_w = \frac{VX}{\theta_c X_r} = \frac{1000\ m^3 \cdot 2460\ mg/L}{5.64\ day \cdot 8000\ mg/L} = 54.5\ m^3/d$$

Since the effluent MLVSS is neglected, the return sludge flow rate is:

$$Q_r = \frac{QX' - Q_w X_r'}{X_r' - X'}$$

$X_r' = 10000\ mg/L$ *and* $X' = \frac{1}{0.8}X = 3080\ mg/L$.

$$Q_r = \frac{8000\ m^3/d \cdot 3080\ mg/L - 54.5\ m^3/d \cdot 10000\ mg/L}{(10000 - 3080)\ mg/L} = 3480\ m^3/d$$