Homework #4 - Solutions

Due: May 21, 2018 (Mon), in class

1. Determine the removal efficiency for a sedimentation basin with an overflow rate of 2 m/h in treating a wastewater containing particles whose settling velocities are distributed as given in the table below. Plot the particle histogram for the influent and effluent wastewater. (10점)

settling velocity, m/h	No. of particles
0.0-0.5	10
0.5-1.0	29
1.0-1.5	47
1.5-2.0	65
2.0-2.5	74
2.5-3.0	60
3.0-3.5	28
3.5-4.0	13
4.0-4.5	5

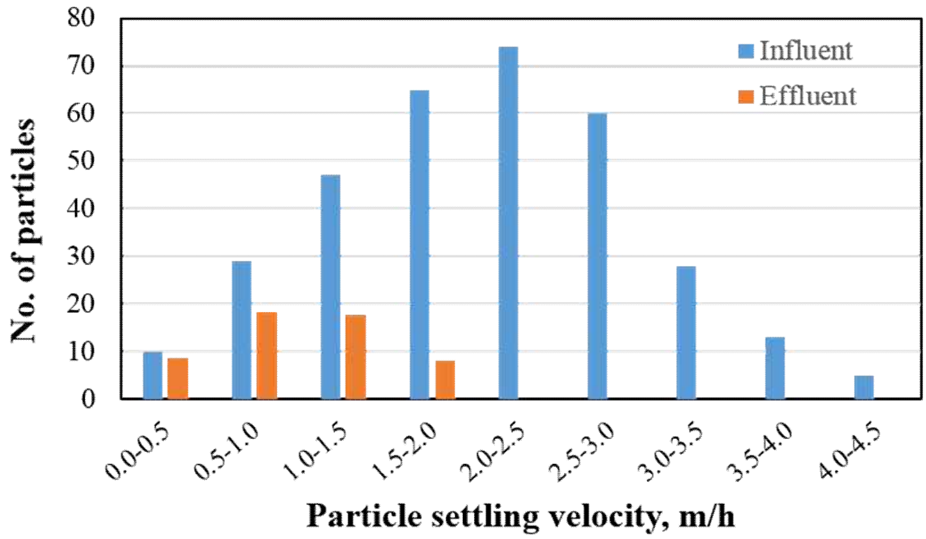
Answer)

Construct a table using the data above:

Avg. settling vel., m/h	No. of particles	Fraction removed	No. of particles removed	No. of particles in effluent
0.25	10	0.125	1.25	8.75
0.75	29	0.375	10.875	18.125
1.25	47	0.625	29.375	17.625
1.75	65	0.875	56.875	8.125
2.25	74	1.000	74	0
2.75	60	1.000	60	0
3.25	28	1.000	28	0
3.75	13	1.000	13	0
4.25	5	1.000	5	0
Total	**331**		**278.4**	**52.6**

removal efficiency $= 278.4/331 \times 100(\%) = 84.1\%$

Particle histogram:



2. The following data were obtained from a test program in a batch reactor designed to evaluate a new aeration system. Using these data, determine the K_La and the equilibrium dissolved oxygen concentration in the test tank. (10점)

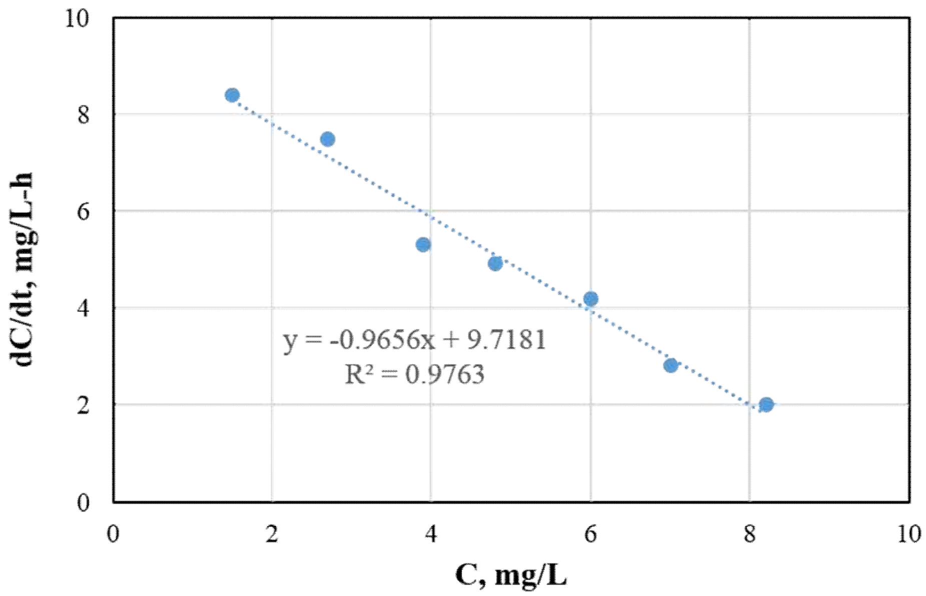
DO concentration, C, mg/L	dC/dt, mg/L-h
1.5	8.4
2.7	7.5
3.9	5.3
4.8	4.9
6.0	4.2
7.0	2.8
8.2	2.0

Answer)

Absorption of gas in a batch reactor:

$$\frac{dC}{dt} = K_L a(C_s - C_t) = K_L a C_s - K_L a C_t$$

Plotting C vs. dC/dt, we get the following regression:



Therefore,

$$K_L a = 0.966\ h^{-1}$$

$$C_s = \frac{9.718\ mg/L-h}{0.966\ hr^{-1}} = 10.1\ mg/L$$

3. 우리나라에서는 2013년 수질 및 수생태계 보호에 관한 법률 개정에 따라 공공하수처리시설의 총 인(total phosphorus; T-P) 배출허용기준이 2014년부터 2016년까지 단계적으로 대폭 강화되었다. 이에 따라 국내에 하수처리시설에 인 제거를 위한 고도처리가 본격적으로 도입되고 있다. 현재 화학적 총인처리시설을 가동 중이거나 설치 또는 기획 중인 하수처리장 사례 하나를 조사하여 적용된 처리공정의 원리를 간략하게 설명하시오. (15점)

4. Briefly (in one or two paragraphs for each) describe the following two biological treatment processes for wastewater treatment: i) rotating biological contactor (RBC) and ii) upflow anaerobic sludge blanket (UASB). (10점)

5. A CSTR without solids recycle is used to treat a wastewater containing 100 mg/L phenol at 20℃. Using the following kinetic coefficients at 20℃, determine i) the minimal hydraulic retention time (HRT) in days at which the biomass can be washed out faster than they can grow, ii) the minimum HRT at 10℃, assuming the temperature coefficient θ is 1.07 for k and 1.04 for b, iii) the effluent phenol and biomass concentration at an HRT of 7.0 d at 20℃.

$$k = 0.80\ g\ phenol/g\ VSS/d$$

$$K_s = 0.15\ mg\ phenol/L$$

$$Y = 0.45\ g\ VSS/g\ phenol$$

$$b = 0.08\ /d$$

Hint 1: When there's no solids recycle, SRT should be the same as HRT.

Hint 2: The modified van't Hoff-Arrhenius relationship, $k_2/k_1 = \theta^{(T_2 - T_1)}$, applies to both k and b. Assume Y and K_s are not functions of temperature.

(25점)

Answer)

i)

Since $K_s \ll S^0$,

$$SRT_{\min} = \frac{1}{Yk-b} = \frac{1}{0.45\ g\ VSS/g\ phenol \cdot 0.80\ g\ phenol/g\ VSS/d - 0.08/d}$$

$$= 3.57\ d$$

ii)

$$k_{10} = k_{20} \cdot \theta^{(10-20)} = 0.8 \cdot 1.07^{-10} = 0.41\ g\ phenol/g\ VSS/d$$

$$b_{10} = b_{20} \cdot \theta^{(10-20)} = 0.08 \cdot 1.04^{-10} = 0.054/d$$

$$SRT_{\min} = \frac{1}{Yk-b} = \frac{1}{0.45\ g\ VSS/g\ phenol \cdot 0.41\ g\ phenol/g\ VSS/d - 0.054/d}$$

$$= 7.66\ d$$

iii)

$$S = \frac{K_s(1 + b \cdot SRT)}{SRT(Yk-b)-1}$$

$$= \frac{0.15\ mg\ phenol/L \cdot (1 + 0.08/d \cdot 7.0\ d)}{7.0\ d \cdot (0.45\ g\ VSS/g\ phenol \cdot 0.80\ g\ phenol/g\ VSS/d - 0.08/d) - 1}$$

$$= 0.24\ mg\ phenol/L$$

$$X_a = \left(\frac{SRT}{\tau}\right)\left[\frac{Y(S^0 - S)}{1 + b \cdot SRT}\right] = \frac{Y(S^0 - S)}{1 + b \cdot SRT}$$

$$= \frac{0.45\ g\ VSS/g\ phenol \cdot (100 - 0.24)\ mg\ phenol/L}{1 + 0.08/d \cdot 7.0\ d} \times 10^{-3}\ g\ phenol/mg\ phenol \times 10^{3}\ mg\ VSS/g\ VSS$$

$$= 28.8\ mg\ VSS/L$$

6. A complete-mix activated sludge process with secondary clarification and sludge recycle is used to treat a wastewater at a flowrate of 1,000 m^3/d with a bsCOD of 2,000 mg/L. The MLSS concentration is 3,300 mg/L, MLVSS/MLSS ratio is 0.80, effluent TSS concentration is 20 mg/L, HRT is 24 h, recycle MLSS concentration is 10,000 mg/L,

and waste sludge flowrate is 85.5 m^3/d. Using the given information, determine i) the system SRT, ii) the F/M ratio in g bsCOD/g VSS/d, iii) the observed yield in g TSS/g bsCOD, and iv) the true yield in g VSS/g bsCOD. Assume that the effluent bsCOD concentration is negligible compared to the influent concentration, and influent nbVSS is negligible. Use the following parameters.

$$b = 0.10\ g\ VSS/g\ VSS/d$$

$$f_d = 0.15\ g\ VSS/g\ VSS$$

(30점)

Answer)

i)

Applying the same logic as we used in class to get SRT of active biomass for TSS:

$$SRT = \frac{VX_{TSS}}{(Q - Q^w)X^e_{TSS} + Q^w X^r_{TSS}}$$

$$V = Q\tau = 1000\ m^3/d \cdot 1\ d = 1000\ m^3$$

$$= \frac{1000\ m^3 \cdot 3300\ mg/L}{(1000 - 85.5)\ m^3/d \cdot 20\ mg/L + 85.5\ m^3/d \cdot 10000\ mg/L} = 3.8\ d$$

ii)

$$F/M = \frac{QS^0}{VX_{VSS}} = \frac{1000\ m^3/d \cdot 2000\ g\ bsCOD/m^3}{1000\ m^3 \cdot 3300\ g\ TSS/m^3 \cdot 0.80\ g\ VSS/g\ TSS} = 0.76\ g\ bsCOD/g\ VSS/d$$

iii)

$$Y_{obs} = \frac{P_{X,TSS}}{Q(S^0 - S)} = \frac{X_{TSS} \cdot V}{Q(S^0 - S) \cdot SRT} = \left(\frac{\tau}{SRT}\right)\frac{X_{TSS}}{S^0}$$

$$= \frac{1\ d}{3.8\ d} \cdot \frac{3300\ mg\ TSS/L}{2000\ mg\ bsCOD/L} = 0.43\ g\ TSS/g\ bsCOD$$

iv)

$$Y_{obs} = 0.80\ g\ VSS/g\ TSS \cdot 0.43\ g\ TSS/g\ bsCOD = 0.35\ g\ VSS/g\ bsCOD$$

$$Y_{obs} = \frac{Y}{1+b \cdot SRT} + \frac{f_d \cdot b \cdot Y \cdot SRT}{1+b \cdot SRT} = Y \cdot \frac{1+f_d \cdot b \cdot SRT}{1+b \cdot SRT}$$

$$Y = Y_{obs} \cdot \frac{1+b \cdot SRT}{1+f_d \cdot b \cdot SRT} = 0.35\ g\ VSS/g\ bsCOD \cdot \frac{1+0.10/d \cdot 3.8\ d}{1+0.15 \cdot 0.10/d \cdot 3.8\ d}$$

$$= 0.46\ g\ VSS/g\ bsCOD$$