Homework #3 - Solutions

Due: April 20, 2018 (Fri), 18:00

1. Read the following article discussing the ecology of *Vibrio cholerae* and briefly summarize the article. (in less than 0.5 page, strictly monitored for plagiarism).

   Cottingham, K.L.; Chiavelli, D.A.; Taylor R. K. Environmental microbe and human pathogen: the ecology and microbiology of *Vibrio cholerae*. *Frontiers in Ecology and the Environment*. Vol. 1, No. 2, 80-86, 2003.

   link:

   http://onlinelibrary.wiley.com/doi/10.1890/1540-9295(2003)001%5B0080:EMAHPT%5D2.0.CO;2/abstract

(15 points)

2. Select one from the types of pathogenic protozoa and helminthes in the box below. Attach a figure illustrating the life cycle of the pathogen you selected. Describe each stage of the life cycle (in Korean).

Pathogenic protozoa	**Pathogenic helminthes**
Giardia lamblia *Entamoeba histolytica* Malaria parasites (genus: *Plasmodium*)	*Hymenolepis nana* (a tapeworm species) *Diphyllobothrium latum* (a tapeworm species)

(15 points)

3. The following data are obtained in a laboratory completely-mixed batch reactor for a degradation reaction of compound A (CA: concentration of A). Answer the questions below.

Time (hr)	C_A (g/m^3)
0	30.0
0.5	12.0
1	7.5
2	4.3
4	2.3
8	1.2
16	0.6
32	0.3

C_A: concentration of A

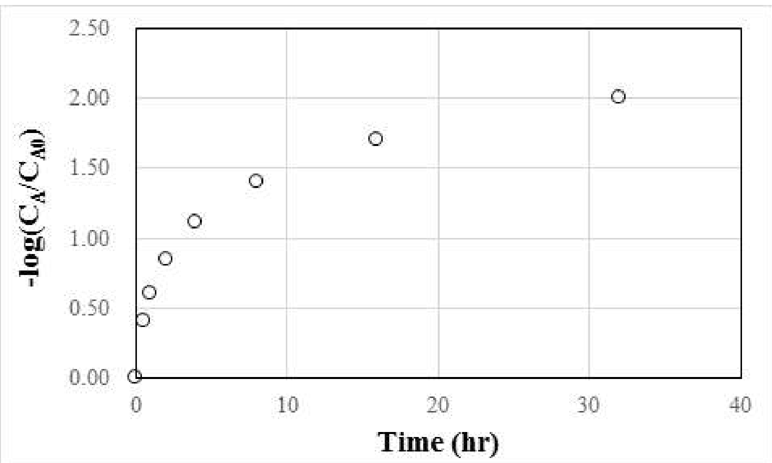
1) Determine the reaction order and the reaction rate constant. (10 points)

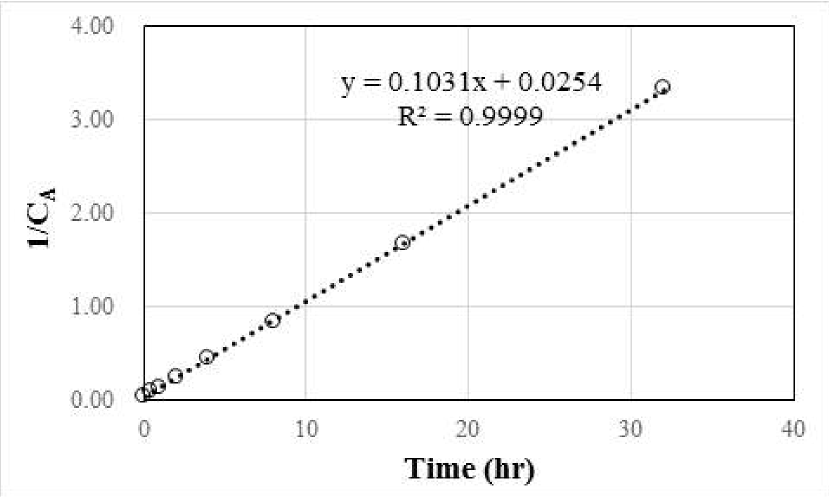
Answer)

Considering the concentration change pattern, the reaction is likely to be 1st or 2nd order. To obtain a linearized plot, reconstruct the data as follows:

Time (hr)	C_A (g/m^3)	$-\log(C_A/C_{A0})$	$1/C_A$
0	30	0.00	0.03
0.5	12	0.40	0.08
1	7.5	0.60	0.13
2	4.3	0.84	0.23
4	2.3	1.12	0.43
8	1.2	1.40	0.83
16	0.6	1.70	1.67
32	0.3	2.00	3.33

By plotting the data:





it is obvious that the reaction is at 2nd order with respect to A.

By taking the slope of the regression curve, the 2nd order reaction rate constant is 0.103 m^3/g-hr.

2) A CSTR is receiving an influent containing 20.0 g/m^3 of A at a flow rate of 10 m^3/hr. To achieve 90% removal efficiency of A, what is the volume required for the CSTR being operated at a steady state? (10 points)

Answer)

As we do not have a steady-state solution for 2nd order reaction in a CSTR, we need to derive the solution first.

Taking the whole reactor as CV:

mass balance equation: $V\frac{dC_A}{dt} = QC_{A0} - QC_A - kC_A^2 V = 0$ *(steady state)*

Dividing the equation by Q, we get

$(C_{A0} - C_A) = kC_A^2 \tau$ *(τ = hydraulic retention time)*

$$\tau = \frac{V}{Q} = \frac{C_{A0} - C_A}{kC_A^2}$$

$$V = Q \times \frac{C_{A0} - C_A}{kC_A^2} = 10\ m^3/hr \times \frac{0.9 \times 20\ g/m^3}{0.103\ m^3/g-hr \times (2\ g/m^3)^2} = 437\ m^3$$

4. 하수도 시설기준에 의하여 주거지역만으로 이루어진 국내 어떤 도시의 하수처리 시설을 설계하고자 한다(즉, 공장폐수, 영업오수 및 관광오수 제외). 이 지역에는 분류식 관거(separate sewer)가 설치되어 있다. 도시의 15년전 인구수는 78000명, 현재 인구수는 95000명이며, 상수도계획 상의 1인1일최대급수량은 400 L/인-일이다. 다음 물음에 답하시오.

i) 계획목표년도를 20년으로 할 때, 등비급수법을 이용하여 이 도시의 계획인구수를 계산하시오. (5 points)

Answer)

$$\gamma = (P_0/P_t)^{1/t} - 1 = (95000/78000)^{1/15} - 1 = 0.0132$$

$$P_N = P_0(1+\gamma)^N = 95000(1+0.0132)^{20} = 123500$$

123,500명

ii) 지하수량(I/I)을 1인1일최대오수량의 20%로 가정하여 계획1일최대오수량을 구하시오. (5 points)

Answer)

(계획1일최대오수량) = (1인1일최대오수량) × (계획인구수) + (지하수량)

= (400 L/인-일 × 141,000인) × 1.20

= 59280000 L/일 = 59280 m^3/일

iii) 계획1일평균오수량 및 계획시간최대오수량을 구하시오. 단, PF_{season} = 1.3, PF_{day} = 1.5. (5 points)

Answer)

(계획1일평균오수량) = (계획1일최대오수량) / PF_{season}

= 59280 m^3/일 / 1.3 = <u>45600 m^3/일</u>

(계획시간최대오수량) = (계획1일최대오수량) × PF_{day}

= 59280 m^3/일 × 1.5 = <u>88920 m^3/일</u>

iv) 이 도시의 생활오수 오염부하량 원단위는 BOD 100 g/인-일, SS 80 g/인-일이다. 이때, 하수처리시설의 계획오염부하량 및 계획유입수질을 계산하시오. (5 points)

Answer)

(계획오염부하량) = (오염부하량 원단위) × (계획인구수)

BOD: 100 g/인-일 × 123,500인 × 10^{-3} kg/g = <u>12350 kg/일</u>

SS: 80 g/인-일 × 123,500인 × 10^{-3} kg/g = <u>9880 kg/일</u>

(계획유입수질) = (계획오염부하량) / (계획1일평균오수량)

BOD: 12350 kg/일 / 45600 m^3/일 = 0.271 kg/m^3 = <u>271 mg/L</u>

SS: 9880 kg/일 / 45600 m^3/일 = 0.217 kg/m^3 = <u>217 mg/L</u>

5. Determine the settling velocity (in m/s) of a spherical particle with a density of 2.00×10^3 kg/m^3 and a particle diameter of i) 0.5 mm and ii) 1.0 mm. Use the water density of 1.00×10^3 kg/m^3 and the dynamic viscosity of 1.00×10^{-3} N-s/m^2. Assume the settling of both particles are in <u>transient region</u> of flow regime. You can choose any methods you would like, including manual calculation with trial-and-error and computer software such as Microsoft Excel or MATLAB. If you used computer software, attach the screenshot of the program. (30 points)

Answer)

In case Microsoft Excel is used with a "find solution(해찾기)" function, the spreadsheet *may be constructed as follows:*

	A	B	C	D
1	**Calculating settling velocities at transient region**			
2				
3		**d_p = 0.5 mm**	**d_p = 1 mm**	
4	**Input parameters**			
5	**gravity acceration, g (m/s^2)**	9.81	9.81	
6	**particle density, ρ_p (kg/m^3)**	2000	2000	
7	**water density, ρ_w (kg/m^3)**	1000	1000	
8	**particle diameter, d_p (m)**	0.0005	0.001	
9	**dynamic viscosity, μ (N-s/m^2)**	0.001	0.001	
10				
11				
12	**Assumed settling velocity, v_p (m/s)**	6.3E-02	1.3E-01	
13				
14	**N_R with assumed v_p**	31.7	128.6	
15	**C_D with assumed v_p**	1.63	0.79	
16				
17	**Calculated settling velocity, v_p (m/s)**	6.3E-02	1.3E-01	
18	**Square error**	4.13E-25	4.78E-28	
19				
20				
21				
22				
23				

Here, equations are embedded in each cell such that:

$$N_R = \frac{v_p d_p \rho_w}{\mu}$$ *(here "assumed v_p" is used as v_p)*

$$C_D = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$$

calculated setting velocity, $$v_p = \sqrt{\frac{4g}{3C_D}\left(\frac{\rho_p - \rho_w}{\rho_w}\right) d_p}$$

square error $= \{(assumed\ v_p) - (calculated\ v_p)\}^2$

Then, the "find solution" function is used to minimize the square error by adjusting the assumed setting velocity.

As seen in the spreadsheet, the settling velocities for the two particle sizes are:

0.5 mm: <u>0.063 m/s</u>

1.0 mm: <u>0.13 m/s</u>