Seoul National University
M1586.000300
Water Quality and Water Pollution Control

FINAL EXAMINATION

TIME ALLOWED: 75 MINUTES

June 07, 2016

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1. Students may use one double-sided, A4 notes prepared in their own handwriting. Mechanical or electronic reproduction of any notes is not allowed.
   (앞뒷면 모두를 사용하여 A4 용지 한 장에 필요한 내용을 적어 시험에 사용할 수 있습니다. 다만, 컴퓨터로 출력하거나 복사한 것은 불가합니다.)
2. Students should bring their own calculator which is not pre-programmed with formulae from the class.
   (계산기를 사용하되, 수업과 관련된 공식이 프로그램되어 있으면 안됩니다.)
3. Cheating is NOT allowed. There is no tolerance for cheating.
   (부정행위는 절대 용납하지 않습니다.)
4. Make sure your answers includes units if appropriate. Watch your units! Prepare your answers in a logical, easy-to-follow format.
   (해당사항이 있을 경우, 꼭 단위를 기입하고, 정확한 단위를 사용하십시오. 답은 논리적이고 이해하기 쉽게 기재하십시오.)
5. This exam contains 6 questions with a total score of 110.
   (본 시험은 6 문항으로 구성되어 있으며, 총점은 110점입니다.)

Use the following values for atomic weights if needed:

C: 12; H: 1; N: 14; O: 16

1. Mark O or X for the following statements.

(+2 points for correct answers; -1 points for incorrect answers)

1) The gas-liquid mass transfer of a compound having an extremely high Henry's law constant will likely be controlled by the liquid film.

Answer) O

2) When the hydroxyl radical (HO·) concentration is maintained as constant in an advanced oxidation process, the degradation kinetics of trace organic compounds follows 1^{st} order.

Answer) O

3) Solubility of metal hydroxides is generally smaller at low pH.

Answer) X

4) The net biomass yield is smaller than the true biomass yield.

Answer) O

5) The active fraction of biomass in MLVSS decreases with an increase in SRT.

Answer) O

6) In an enhanced biological phosphorous removal process, phosphorus is removed as waste sludge from the mixed liquor.

Answer) O

7) Enzymes involved in the oxidation of trichloroethylene (TCE) by cometabolism is induced by the presence of TCE.

Answer) X

8) Filamentous bulking can be prevented by maintaining high SRT in an activated sludge system.

Answer) X

9) Straining is the principal mechanism for the removal of particulate and dissolved matter by reverse osmosis.

Answer) X

10) When the external pressure applied at saline water is smaller than the osmotic pressure, the water moves from the fresh water to the saline water through a reverse osmosis membrane.

(고염수에 가해지는 외부 압력이 삼투압보다 작으면 물은 역삼투막을 통과하여 저염수에서 고염수 방향으로 이동한다.)

Answer) O

2. Answer the following questions.

1) List at least three mechanisms for the precipitation of phosphate using aluminium or ferric salts. (5 points)

Answer)

Adsorption of phosphate onto the hydrous oxide or hydroxide precipitates

Incorporation of phosphate into the hydrous oxide or hydroxide structure

Formation of mixed cation phosphate precipitates

Formation of ferric or aluminum phosphate precipitates

2) List at least two potential mechanisms for nitrogen removal in a conventional activated sludge process. Assume that the process is operated at a sufficient SRT and with sufficient DO such that nitrification can occur. (5 points)

Answer)

Assimilatory nitrate reduction; Simultaneous nitrification and denitrification

3) Describe the syntrophic relationship between methanogens and acidogens (or acetogens) during anaerobic oxidation of organic matter. (6 points)

Answer)

Acidogens or acetogens produce H_2 and VFAs, which are essential nutrients for methanogens. Acidogens or acetogens are inhibited by the presence of H_2 gas, and methanogens comsumes H_2 to lower its partial pressure.

4) Among the following biological nutrient removal (BNR) processes, list those that are effective for both nitrogen and phosphorus removal.

Modified Ludzak-Ettinger (MLE)	Phoredox (A/O)
University of Capetown (UCT)	Anaerobic/Anoxic/Aerobic (A^2O)

(4 points)

Answer)

UCT & A^2O

3. A water sample contains 26 g/L of casein ($C_8H_{12}O_3N_2$). If 36 g of bacterial cell tissue ($C_5H_7NO_2$) is synthesized per 100 g of casein consumed, determine the amount of oxygen required to completely oxidize the casein to end products and cell tissue (in g O_2/L). Use the following reaction stoichiometry for the oxidation of casein and bacterial cells using O_2 as an electron acceptor.

casein: $C_8H_{12}O_3N_2 + 8O_2 \rightarrow 8CO_2 + 2NH_3 + 3H_2O$

bacterial cells: $C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + NH_3 + 2H_2O$

(15 points)

Answer)

MW of casein = $12\times 8 + 12\times 1 + 16\times 3 + 14\times 2 = 184\ g/mole$

COD of casein = $\dfrac{8\ mole\ O_2/mole\ casein \times 32\ g\ O_2/mole\ O_2}{184\ g\ casein/mole\ casein} = 1.39\ g\ COD/g\ casein$

COD of cells = 1.42 g COD/g cells

Biomass yield = $0.36\ g\ cells/g\ casein\ used \times \frac{1.42\ g\ COD/g\ cells}{1.39\ g\ COD/g\ casein} = 0.37\ g\ cell\ COD/g\ COD\ used$

Oxygen consumed = COD utilized – *COD cells*

$= 26\ g\ casein/L \times 1.39\ g\ COD/g\ casein \times (1-0.37)\ g\ COD/g\ COD\ used$

$= 22.8\ g\ O_2/L$

4. Calculate the alkalinity requirement (in mg as $CaCO_3$/L) for the following processes.

i) Removal of particulate matter using alum precipitation at an alum dose of 250 mg/L. Alum precipitation reaction is as follows (alum molecular weight = 666.5 g/mole).

$$3Ca(HCO_3)_2\ +\ Al_2(SO_4)_3 \cdot 18H_2O\ \leftrightarrow\ 2Al(OH)_3\ +\ 3CaSO_4\ +\ 6CO_2\ +\ 18H_2O$$

(5 points)

Answer)

Alkalinity consumed per alum mass:

$$\frac{6\ eq\ Alk/mole\ alum \times 50\ g\ as\ CaCO_3/eq\ Alk}{666.5\ g\ alum/mole\ alum} = 0.45\ mg\ as\ CaCO_3/mg\ alum$$

Alkalinity requirement: $250\ mg\ alum/L \times 0.45\ mg\ as\ CaCO_3/mg\ alum = 110\ mg\ as\ CaCO_3/L$

ii) Nitrification of wastewater containing 50 mg NH_4-N/L.

(5 points)

Answer)

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

Alkalinity consumed per mass of NH4+-N oxidized:

$$\frac{2\ eq\ Alk/mole\ NH_4^+ \times 50\ g\ as CaCO_3/eq\ Alk}{14\ g\ NH_4-N/mole\ NH_4^+} = 7.14\ mg\ as\ CaCO_3/mg\ NH_4-N$$

Alkalinity requirement: $50\ mg\ NH_4-N/L \times 7.14\ mg\ as\ CaCO_3/mg\ NH_4-N = 360\ mg\ as\ CaCO_3/L$

5. A complete-mix activated sludge process with sludge recycle is receiving a wastewater with a bsCOD of 300 g/m^3. Using the following growth parameters determined at 20℃, determine the design SRT of the process to achieve the process safety factor of 5.0 at 15℃.

$k = 6.0\ g\ bsCOD/g\ VSS/d$

$K_s = 15\ g\ bsCOD/m^3$

$Y = 0.5\ g\ VSS/g\ COD$

$b = 0.10/d$

$\theta = 1.07$ for k; $\theta = 1.04$ for b

(15 points)

Answer)

$k_{15} = k_{20} \cdot \theta^{15-20} = 6.0\ g\ bsCOD/g\ VSS/d \cdot 1.07^{-5} = 4.3\ g\ bsCOD/g\ VSS/d$

$b_{15} = b_{20} \cdot \theta^{15-20} = 0.10/d \cdot 1.04^{-5} = 0.082/d$

$$SRT_{\min} = \left(\frac{YkS^0}{K_s + S^0} - b \right)^{-1}$$

$$= \left(\frac{0.5\ g\ VSS/g\ COD \cdot 4.3\ g\ bsCOD/g\ VSS/d \cdot 300\ g\ bsCOD/m^3}{(15+300)\ g\ bsCOD/m^3} - 0.082/d \right)^{-1}$$

$= 0.51\ d$

$SRT_{des} = SF \times SRT_{\min} = 5.0 \times 0.51\ d = 2.5\ d$

6. Following data are obtained for an effluent from a primary clarifier.

Item	Value	Item	Value
Flowrate	4000 m^3/d	bsCOD	400 g/m^3
nbVSS	20 g/m^3	iTSS	5 g/m^3

The kinetic constants and operating conditions are given as follows.

$\mu_m = 2.5/d$

$SRT = 10\ d$

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

Aeration tank MLVSS = 2500 g/m^3

$b = 0.10/d$

Biomass VSS/TSS ratio = 0.85

$K_s = 20\ g\ bsCOD/m^3$

$f_d = 0.10$

Determine the followings for the design of an activated sludge process with sludge recycle.

i) the effluent bsCOD concentration (5 points)

Answer)

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

$$= \frac{20\ g\ bsCOD/m^3 \cdot (1 + 0.10/d \cdot 10\ d)}{10\ d \cdot (2.5/d - 0.10/d) - 1} = 1.74\ g\ bsCOD/m^3$$

ii) the aeration tank volume required (17 points)

Answer)

$$X_{VSS} = X_a + f_d \cdot b \cdot X_a \cdot SRT + \frac{X_i^0 \cdot SRT}{\tau}$$

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

$$= \left(\frac{10\ d}{\tau}\right)\left[\frac{0.45\ g\ VSS/g\ COD \cdot (400 - 1.74)\ g\ bsCOD/m^3}{1 + 0.10/d \cdot 10\ d}\right] = \frac{896}{\tau}\ g\ VSS - d/m^3$$

$$X_{VSS} = \frac{896\ g\ VSS - d/m^3}{\tau} + 0.10 \cdot 0.10/d \cdot \frac{896}{\tau}\ g\ VSS - d/m^3 \cdot 10\ d + \frac{20\ g\ VSS/m^3 \cdot 10\ d}{\tau}$$

$$= \frac{1185.6\ g\ TSS - d/m^3}{\tau}$$

$$\tau = \frac{1185.6\ g\ TSS - d/m^3}{2500\ g\ TSS/m^3} = 0.47\ d$$

$$V = \tau \times Q = 0.47\ d \times 4000\ m^3/d = 1900\ m^3$$

iii) the MLVSS/MLSS ratio (8 points)

Answer)

$$X_{TSS} = \frac{X_{bio}}{0.85} + X_{nb\,VSS} + X_{i\,TSS} \quad , \quad X_{VSS} = X_{bio} + X_{nb\,VSS}$$

From ii),

$$X_a = \frac{896\ g\ VSS - d/m^3}{0.47\ d} = 1910\ g/m^3$$

$$X_{bio} = X_a \times (1 + f_d \cdot b \cdot SRT) = 1910\ g\ VSS/m^3 \times (1 + 0.10 \cdot 0.10/d \cdot 10\ d) = 2100\ g\ VSS/m^3$$

$$X_{nb\,VSS} = \frac{20\ g\ VSS/m^3 \cdot 10\ d}{0.47\ d} = 426\ g\ VSS/m^3$$

$$X_{i\,TSS} = \frac{5\ g\ TSS/m^3 \cdot 10\ d}{0.47\ d} = 106\ g\ TSS/m^3$$

$$X_{TSS} = \frac{2100\ g\ VSS/m^3}{0.85} + 426\ g\ VSS/m^3 + 106\ g\ TSS/m^3 = 3000\ g\ TSS/m^3$$

$$X_{VSS} = 2100\ g\ VSS/m^3 + 426\ g\ VSS/m^3 = 2530\ g\ VSS/m^3$$

$$\frac{X_{VSS}}{X_{TSS}} = \frac{2530}{3000} = 0.84$$