Seoul National University
457.210A.002
Environmental Engineering

FINAL EXAMINATION

TIME ALLOWED: 75 MINUTES

December 10, 2014

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1. Students may use two double-sided, A4 notes prepared in their own handwriting. Mechanical or electronic reproduction of any notes are not allowed.
   (앞뒷면 모두를 사용하여 A4 용지 두 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. Be aware that the cheated student will get 80% of the lowest score in class! There is no tolerance at all.
   (주지한 바와 같이, 부정행위를 할 경우 학급 최저점수의 80%를 부여합니다. 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 8 questions. Each full question is worth 15 to 25 points. Total points = 155.
   (본 시험은 8 문항으로 구성되어 있으며, 각 문항의 배점은 15점에서 25점입니다. 총점은 155점입니다.)

Use following values for physical constants and properties, if needed:

Atomic weights: C, 12; Cl, 35.5; H, 1; N, 14; O, 16; P, 31; S, 32.1; Ca, 40; Mg 24.3

Density of water at 4°C: 1 g/cm^3

1. Describe the two possible approaches to improve pathogen removal for a chlorine disinfection process based on the Chick-Watson law. Briefly discuss the possible disadvantages associated with each approach. (15 points)

Answer)

Chick-Watson law: $\ln\left(\frac{N}{N_0}\right) = k' C^n t$

Therefore, the solutions for improving pathogen removal efficiency would be to i) increase the disinfectant concentration (i.e., dose) and ii) increase the contact time.

The disadvantages would be:

i) increasing the disinfectant concentration: greater production of disinfection byproducts and higher chemical cost

ii) increasing the contact time: larger reactor is needed (more land use, higher capital cost)

2. A water sample having a pH of 7.3 is analyzed to have the following ion concentrations. With those data, calculate the alkalinity, total hardness, and carbonate hardness of the water sample in mg/L as $CaCO_3$.

Ion	Concentration (mg/L)	Ion	Concentration (mg/L)
Na^+	28.1	Cl^-	8.5
K^+	5.6	HCO_3^-	153.1
Ca^{2+}	38.2	SO_4^{2-}	28.3
Mg^{2+}	6.5		

(25 points)

Answer)

We need to consider Ca^{2+}, Mg^{2+}, and HCO_3^- only. The calculations are shown in the following table:

Ion	*Conc. (mg/L)*	*Ionic weight*	*Conc. (mM)*	*Conc. (meq/L)*
Ca^{2+}	*38.2*	*40*	*0.955*	*1.91*
Mg^{2+}	*6.5*	*24.3*	*0.267*	*0.535*
HCO_3^-	*153.1*	*61*	*2.510*	*2.51*

$Alkalinity \approx (HCO_3^-) = 2.51\ meq/L = 126\ mg/L\ as\ CaCO_3$

$Total\ hardness \approx (Ca^{2+}) + (Mg^{2+}) = 1.91\ meq/L + 0.535\ meq/L = 2.45\ meq/L = 122\ mg/L\ as\ CaCO_3$

Since Total hardness < Alkalinity, Carbonate hardness = Total hardness

$Carbonate\ hardness = 122\ mg/L\ as\ CaCO_3$

3. An aeration tank having an effective volume of 20000 m^3 is receiving a primary effluent of 10^5 m^3/d with a BOD_5 of 400 mg/L. Following parameters are determined for the microbial degradation of BOD_5 in the aeration tank:

$K_s = 100\ mg/L\ BOD_5$ $k_d = 0.15\ d^{-1}$

$\mu_m = 3\ d^{-1}$ $Y = 0.5 mg\ VSS/mg\ BOD_5$

i) Calculate the mean cell residence time required to achieve the effluent BOD_5 of 15 mg/L. (10 points)

Answer)

$$S = \frac{K_s(1+k_d\theta_c)}{\theta_c(\mu_m - k_d) - 1} = \frac{100\ mg/L \cdot (1 + 0.15\ day^{-1} \cdot \theta_c)}{\theta_c(3\ day^{-1} - 0.15\ day^{-1}) - 1} = \frac{100 + 15\theta_c}{2.85\theta_c - 1}\ mg/L \qquad (\theta_c\ \text{in days})$$

$$15\ mg/L = \frac{100 + 15\theta_c}{2.85\theta_c - 1}\ mg/L$$

$$42.75\theta_c - 15 = 100 + 15\theta_c$$

$$27.75\theta_c = 115$$

$$\theta_c = 4.14\ d$$

ii) Calculate the amount of solids produced from secondary treatment every day in kg MLSS/d. Assume that following relationship applies for MLSS and MLVSS: (MLSS) = 1.43×(MLVSS). (15 points)

Answer)

$$Solids\ produced = Q_w X_r{}' = Q_w(1.43 X_r) = 1.43 Q_w X_r$$

As $\theta_c = \dfrac{VX}{Q_w X_r}$,

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

And

$$X = \frac{\theta_c Y(S_0 - S)}{t_0(1 + k_d \theta_c)}$$

Summarizing,

$$Solids\ produced = 1.43 \frac{VY(S_0 - S)}{t_o(1 + k_d\theta_c)} = 1.43 \frac{QY(S_0 - S)}{1 + k_d\theta_c}$$

$$= \frac{1.43 \cdot (10^5\ m^3/d) \cdot (0.5\ mg\ VSS/mg\ BOD_5) \cdot (400 - 15)\ mg\ BOD_5/L}{1 + (0.15\ d^{-1}) \cdot (4.14\ d)} \times 10^3\ L/m^3 \times 10^{-6}\ kg/mg$$

$$= 1.70 \times 10^4\ kg/d$$

4. The Korean air quality standard for ozone (O_3) is 0.1 ppm as an average over an hour. Convert this value to μg/m^3 at 1 atm and at temperatures of 30°C and 0°C. (15 points)

Answer)

$$\mu g/m^3 = ppm \times MW \times \frac{P}{RT}$$

i) at 30°C

$$\mu g/m^3 = (0.1\ ppm) \times (48\ g/mole) \times \frac{1\ atm}{(8.21 \times 10^{-5}\ m^3 - atm/K - mole) \times (303\ K)}$$

$$= 193\ \mu g/m^3$$

ii) at 0°C

$$= (0.1\ ppm) \times (48\ g/mole) \times \frac{1\ atm}{(8.21 \times 10^{-5}\ m^3 - atm/K - mole) \times (273\ K)}$$

$$= 214\ \mu g/m^3$$

5. Describe how substituting chloroflurocarbons (CFCs) with hydrochlorofluorocarbons (HCFCs) or hydrofluorocarbons (HFCs) slower or stop ozone depletion. (15 points)

Answer)

HCFCs: more reactive than CFCs in the troposphere → less amount reaches the stratosphere to induce ozone depletion

HFCs: no chlorine atoms present → no ozone depletion potential

6. Suggest at least three possible approaches to treat food wastes generated from residential areas. Briefly discuss the advantages and disadvantages of each approach. (20 points)

Answer)

Composting

advantages: environmentally friendly, recover carbon and nutrients from food wastes

disadvantages: can cause odor problems, not easy to find consumers

Incineration

advantages: food waste has high organic matter content (high heating value), can minimize amount of solid waste for disposal

disadvantages: production of air pollutants, high moisture content

Landfilling

advantages: easy and simple solution

disadvantages: takes landfill space, high CH_4 *and leachate production*

7. An underground storage tank (UST) located 2 meters below the ground level developed a leak. Gasoline was released from the tank into the surrounding soil having relativity high hydraulic conductivity. As a result, the soil in the unsaturated zone and the groundwater underneath the tank was contaminated with benzene, which is one of the constituents of gasoline. A groundwater pumping well near the contaminated area provides drinking water to the residents living nearby. With those as backgrounds, answer the following.

i) List potential pathway(s) for the exposure of benzene to humans. Assume that benzene was not transported up to the ground surface. (10 points)

Answer)

Ingestion of groundwater (major), dermal contact with groundwater, inhalation of benzene vapor from groundwater

(You should not include pathways of ingestion/dermal contact/inhalation of contaminated soil as the assumption is that benzene does not exist on the ground surface. Groundwater may eventually flow into rivers and oceans, but the amount of benzene humans will get exposed by contacting to river and ocean waters would be too little. The major pathway should be drinking the contaminated groundwater.)

ii) List at least four possible remediation technologies to treat the benzene-contaminated soil and groundwater. Note that benzene is a volatile compound that can be biodegraded in the presence of oxygen. (15 points)

Answer)

Soil vapor extraction, air sparging, bioventing, biosparging, in situ bioremediation (biostimulation, bioaugmentation, monitored natural attenuation)

** Instructor note: My intention was to select the remediation technologies based on the fact that the contaminated soil and groundwater is quite below the ground surface that excavating the soil would be too expensive (so try in-situ technologies) and the fact that benzene is volatile and aerobically biodegradable. PRBs are not often applied for petroleum-derived contaminants. The technologies listed above are selected according to those backgrounds. However, I find that it is not impossible to apply other technologies as well (ex: soil washing, thermal desorption, PRBs, and landfarming), so any of these technologies are also deemed as correct answers. One exception is phytoremediation as benzene should reach the ground surface to be available to plants. Those who listed phytoremediation would lose 2 points.*

8. You are curious that if people at Bldg 35 can hear you shouting at the top of Gwanak Mt. One day, you climbed up the mountain to the top and shouted out “Ya-ho” with a sound meter placed 1 m away from you. The sound meter record was 80 dB as sound pressure level. Assuming no sound reflection or interference, would the people at Bldg 35 be able to hear your voice? Assume that people can hear the sound down to the reference sound pressure value (20 μPa) and Bldg 35 is 5 km away from the top of the mountain. (20 points)

Answer)

The minimum sound pressure level people can hear:

$$L_p = 20\log\frac{(p_{rms})^2}{(p_{rms})_o^2} = 20\log(1) = 0\ dB$$

For a point source,

$$L_{p2} = L_{p1} - 10\log_{10}\left(\frac{r_2}{r_1}\right)^2$$

$$L_{p2} = 80 - 10\log_{10}\left(\frac{5000\ m}{1\ m}\right)^2 = 6.0\ dB$$

Yes, people can hear your voice.