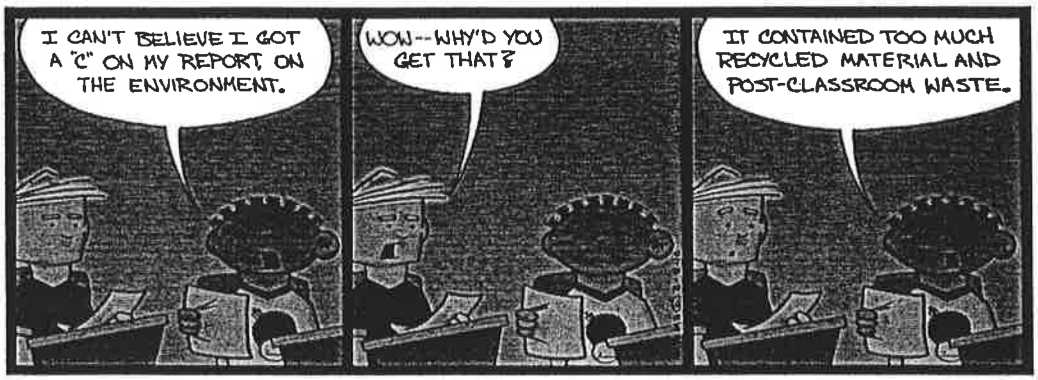
Midterm 2

CENG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills
November 20, 2013



Name: KEY

1. ________ (35 Points)
2. ________ (20 Points)
3. ________ (20 Points)
4. ________ (20 Points)
5. ________ (5 Points)

TOTAL ________ (100 Points)

Instructions: You may use calculators to solve numerical problems, as well as one double-sided equation sheet, which you should submit with your exam. **Please show all work; clearly label your solutions; and indicate units as appropriate.** SHOW All OF YOUR WORK!!!

1. *(35 pts)* The mean results of analyses for a water sample from the upper formation of the Brooklyn-Queens Aquifer in New York, are presented in Table 1 (results are from a set of measurements taken circa 2009).

Table 1: Mean values of water quality parameters from the upper formation of the Brooklyn–Queens Aquifer(2009).

Chemical Species	**mg/L (unless otherwise noted)**
Hydrogen ion (H^+)	pH = 6.3
Carbon dioxide (CO_2)	40 mg/L as $CaCO_3$
Ammonium (NH_4^+)	0.1
Sodium (Na^+)	40
Potassium (K^+)	4
Calcium (Ca^{2+})	45
Magnesium (Mg^{2+})	13
Manganese (present as Mn^{2+})	0.07
Barium (Ba^{2+})	0.004
Chloride (Cl^-)	60
Nitrate (NO_3^-)	17
Sulphate (SO_4^{2-})	74
Bicarbonate (HCO_3^-)	90 mg/L as $CaCO_3$
Silica (SiO_2)	21
Organic carbon	1.5
Turbidity	3.5 NTU
Total dissolved solids	353
Tetrachloroethylene (PCE)	100 µg/L
Vinyl chloride	0.5 µg/L
Methyl Tertiary Butyl Ether (MTBE)	2 to 350 µg/L

Don't count, b/c. small

(a) *(2 pts)* Name one compound or water quality parameter from the analyses presented in Table 1 that poses a risk to human health and is regulated by EPA's primary drinking water standards? If you can't identify one, list a pollutant regulated by EPA's primary drinking water standards that *is not* presented in Table 1. *(2 pts extra credit if the compound or water quality parameter that you list is from the table.)*

Vinyl Chloride   MTBE
NO_3^-, nitrate   PCE
turbidity

(b) *(2 pts)* What human health risk does the item in (a) pose?

Vinyl chloride – cancer
NO_3^- – blue baby syndrome
turbidity → pathogens → gastrointestinal disease → death

(c) *(3 pts)* What is the concentration of OH^- in moles/L?

$$pOH = 14 - pH = 14 - 6.3 = 7.7 \; ; \; [OH^-] = 10^{-pOH}$$

$$\boxed{[OH^-] = 10^{-7.7} \text{ mole/L}}$$

(d) *(3 pts)* What is the alkalinity in eq/L?

$$Alk \cong HCO_3^- = 90 \text{ mg/L as } CaCO_3 \times \frac{1\text{ eq}}{50\text{ g}} \times \frac{1\text{ g}}{1000\text{ mg}}$$

$$\boxed{Alk = 1.8 \times 10^{-3} \text{ eq/L}}$$

(e) *(10 pts)* What is the total hardness of the water in mg/L as $CaCO_3$?

Total Hardness

$$[Ca^{2+}] = 45 \text{ mg/L} \times \frac{1 \text{ mole}}{40\text{ g}} \times \frac{2\text{ eq}}{\text{mol}} \times \frac{50\text{ g } CaCO_3}{\text{eq}} = 112.5 \text{ mg/L as } CaC$$

$$[Mg^{2+}] = 13 \text{ mg/L} \times \frac{1 \text{ mole}}{24\text{ g}} \times \frac{2\text{ eq}}{\text{mole}} \times \frac{50\text{ g } CaCO_3}{\text{eq}} = 54.16 \text{ mg/L as } CaC$$

$$\boxed{\text{Total Hardness} = 167 \text{ mg/L as } CaCO_3}$$

(f) *(5 pts)* What is the carbonate hardness of the water in mg/L as $CaCO_3$?

Carbonate Hardness = 90 mg/L as $CaCO_3$

(g) *(10 pts)* How much lime in mg/L as $CaCO_3$ would be required to remove hardness due to calcium?

Ca only remove calcium due to carbonate hardness:

$$\text{Lime} = [CO_2] + \underbrace{[HCO_3^-]}_{\text{represents } Ca^{2+} \text{ as carbonate hardness}} = 40 + 90 = 130 \text{ mg/L as } CaCO_3$$

2. *(20 pts)* A suspension contains two sizes of particles of equal concentrations. One size settles at a velocity of 0.15 m/min, and the other size settles at a velocity of 0.1 m/min. The volumetric flow rate of the suspension is 400 m^3/h (6.66 m^3/min).

   (a) *(8 pts)* Determine the removal efficiency for this suspension (i.e., percent of particles removed from the water) in four sedimentation tanks, each with a surface area of 10 m^2 and a depth of 4 m.

$$OFR = \frac{Q}{A_{Tot}} = \frac{Q}{4A} = \frac{6.66\ m^3/min}{4 \times 10\ m^2} = 0.1665$$

$$OFR = \vartheta_{critical}$$

$$\text{Removal Eff} = \text{\% removal from water} = \frac{\vartheta_s}{\vartheta_{critical}}$$

$$\vartheta_{s(avg)} = \frac{0.15 + 0.1}{2} = 0.125\ m/min$$

$$\text{Removal Eff} = \frac{0.12}{0.167} = 0.72 = 72\%$$

   (b) *(8 pts)* What is the removal efficiency when one sedimentation tank is taken out of service?

When one tank is out of service:

$$A_{tot} = 3 \times A = 30\ m^2$$

$$\vartheta_c = OFR = \frac{Q}{A_{tot}} = \frac{6.66\ m^3/min}{30\ m^2} = 0.22\ m/min$$

$$\text{Rem. Eff} = \frac{0.125}{0.22} = 0.56 = 56\%$$

(c) *(4 pts)* What is the removal efficiency for four sedimentation tanks, each with a surface area of 10 m^2 and a depth of 2 m.

Removal Efficiency not a function of depth.

Answer, same as part (a)

72%

3. *(20 pts)* Suppose you add 150 milligrams of the artificial sweetner aspartame ($C_{14}H_{18}O_5N_2$, molecular weight=294 g/mole)to your coffee (volume = 150 mL):

(a) *(10 pts)* What is the theoretical oxygen demand of your coffee (assume that all of the oxygen demand comes from the sweetner)?

$$\underset{294\,g}{C_{14}H_{18}O_5N_2} + \underset{464\,g}{14.5\,O_2} \rightarrow 14\,CO_2 + 6\,H_2O + \underset{28\,g\ NH_3-N}{2NH_3}$$

$$\underset{28\,g}{2NH_3} + \underset{128\,g}{4O_2} \rightarrow 2NO_3^- + 2H_2O + 2H$$

Calculate carbonaceous ThOD:

$$\frac{150\ mg}{150\ mL} = 1\ \frac{g}{L} = 1000\ mg/L$$

$$1000\ mg/L\ asp. \times \frac{464\ g\ O_2}{294\ g\ asp} = 1578\ mg/L$$

Calculate nitrogenous ThOD:

$$1000\ mg/L\ asp \times \frac{28\ g\ NH_3-N}{294\ g\ asp} \times \frac{128\ g\ O_2}{28\ g\ NH_3-N} = 453\ mg/L$$

$$\boxed{\text{Total ThOD} = 2014\ mg/L}$$

(b) *(10 pts)* If the aspartame is 85% biodegradable, and 1.5 mL of the coffee with a dissolved oxygen (DO) of 5 mg/L is diluted to 300 mL with dilution water containing 10 mg/L of DO (and zero BOD), what will the DO level be in a stoppered BOD test bottle after 5 days (assume that k = 0.25 day^{-1} at 20 ^{0}C)?

$$BOD_5 = DO_{in} - D_{fin} \qquad DO_{fin} = ?$$

$$L_0 = 85\% \times \text{Carbonaceous ThOD}$$

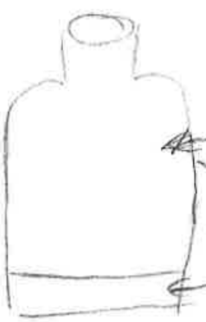
$$= 0.85 \times 1578 = 1341 \text{ mg/L}$$

$$BOD_5 = y(5) = L_0 (1 - e^{-kt}) = 1341 \text{ mg/L} (1 - e^{-0.25 \times 5})$$

$$BOD_5 = 957 \text{ mg/L}$$

In the Bottle

$$BOD_5 = \frac{1.5 \text{ mL} \times 957 \text{ mg/L}}{300 \text{ mL}} = 4.78 \text{ mg/L}$$



$V_D = 300 - 1.5 = 298.5$

$BOD_5 = 0$; $DO = 10$ mg/L

$V_W = 1.5$ mL

$BOD_5 = 957$ mg/L

$DO = 5$ mg/L

$$DO_{in} = \frac{5 \times 1.5 + 10 \times 298.5}{300} = 9.95 \text{ mg/L}$$

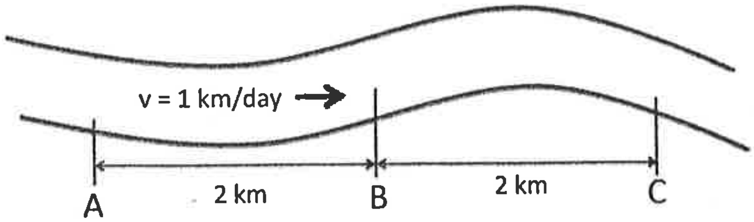
$$BOD_5 = DO_{in} - DO_{fin}$$

$$DO_{fin} = DO_{in} - BOD_5$$

$$DO_{fin} = 9.95 - 4.78$$

$$\boxed{DO_{fin} = 5.2 \text{ mg/L}}$$

4. *(20 pts)* Consider the following stream, which can be modeled as a plug-flow reactor (stream flows from Point A to Point B to Point C).



At time=0, assume that the stream has a uniform BOD_u concentration of 2 mg/L at all points. Also, at time=0, a continuous wastewater discharge begins at point A, immediately resulting in a steady-state, mixed concentration of 20 mg/L BOD_u. The first-order decay rate for BOD in the stream is 0.25 day^{-1}, and the stream's velocity is 1 km/day.

(a) *(10 pts)* At time=3 days, what is the BOD_u concentration at point C? Assume plug-flow behavior.

At $t = 3$ days, the waste won't have reached C.

$l = 4$ km

$v = 1$ km/day

$t = \frac{l}{v} = 4$ days

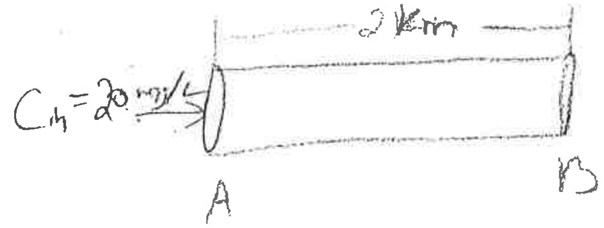
So at $t = 3 < 4$ waste won't reach C.

$$C_c = C_A e^{-kt} = 2\ \text{mg/L}\ e^{-0.25 \times 3}$$

$$\boxed{C_c = 0.954\ \text{mg/L}}$$

And $\underline{t = 3}$

(b) *(10 pts)* At time=3 days, what is the BOD$_u$ concentration at point B? Assume plug-flow behavior.



at point B after 3 days the original 2 mg/L will be "gone".

$\vartheta = 1$ km/day

$C_A = 20$ mg/L after mixing of WWT + stream water.

$$C_B = C_A e^{-kt}$$

$$= 20 \text{ mg/L}\, e^{-k\theta} =$$

$$= 20 \text{ mg/L}\, e^{-k\frac{V}{Q}} = 20 \text{ mg/L}\, e^{-k\frac{l}{\vartheta}}$$

$$C_B = 20 \text{ mg/L}\, e^{-\frac{0.25}{day} \times \frac{2}{1\frac{km}{day}}} = \underline{12.1 \text{ mg/L}}$$

5. *(5 pts)* The substrate utilization kinetics of a bacterium have been characterized and obey the following mixed-order relationship, based on the Monod Model.

$$\frac{dS/dt}{X} = \frac{\overset{\mu_{max}}{24}S}{\underset{K_s}{6} + S}$$

At what substrate concentration, S, will the specific utilization rate $\frac{dS/dt}{X}$ be one-half of its maximum value.

When the rate is half of the maximum

$S = K_s$

$$\boxed{S = 6 \text{ mg/L}}$$