

CVG2132 – FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING

Homework 1:

Professor: Narbaitz

Due Date: Sept. 30, 2015 (5:00pm) – Submit **both** electronically and hardcopy to the Cubby « CVG 2132 », Mezzanine A (0.5) CBY

Question 1:

There are numerous landmarks in the environmental incidents that raised our environmental consciousness and in some environmental policy are Rachel Carson's book "Silent Spring", the Minimata disease in Japan, the Donora episode, Cuyahoga River fire, the Love Canal incident and the Milwaukee Cryptosporidium epidemic. There are many others, some described in our textbook others elsewhere. Using at least two sentence answer the following:

- a) What was the main finding of "Silent Spring"?
- b) What happened during the Donora episode?
- c) What policy changes were triggered by the Cuyahoga River fire?
- d) What was the Love Canal incident?
- e) What changes occurred as a result of the Love Canal incident?

Answer:

- a) Published in 1962 this book presented a great deal of evidence that pesticides were indirectly greatly reducing bird populations. Pesticides were being used in quantities greater than necessary and in many cases were not controlling very well the pests they were intended to control. The vast use of the pesticide caused the DDT to enter the food chain and resulted in bioaccumulation up the food chain. Resulting in high concentrations of DDT found in tissues of species high in the food chain. The use of DDT has detrimental effects on ecosystems and to humans alike.
- b) The Donora incident occurred in the town of Donora, Pennsylvania located on the Monongahella River valley during the fall of 1948. This was a severe smog event lasting six days that was directly responsible for the death of at least 21 individuals and made about 7000 residents sick, many of whom had to be hospitalized. It also killed many pets and plants. The incident occurred due to: 1) the bowl shape of the river valley; 2) the emissions from a steel plant, a wire mill and zinc plant; and 3) the immersion climatic conditions. This incident led to the creation of the 1955 Clean Air Act.
- c) The Cuyahoga River is a river that goes through Cleveland Ohio. Many industries are located in its shores and oils and paints were discharged into this river. On several occasions the river caught fire, burning boats and some adjacent infrastructure. The 1969 burning received a lot of publicity and this led to the National Environment Protection Act (NEPA), which led to the formation of the

Environmental Protection Agency (USEPA). Then, the EPA established the 1972 Clean Water Act that aims to make all rivers in the US swimmable, fishable and navigable. As the result of this act many wastewater treatment plants were built or upgraded and the quality of river waters has improved over time.

- d) Love Canal was canal that was lined and used by Hooker Chemical to dispose of chemical waste. The facility was filled and covered with dirt. Later on Hooker Chemical sold the site to the Niagara Falls School Board for \$1 on the condition they would not liable for any future problems. The city built a school on the site, and metal piles used as part of the building's foundation punctured the impermeable liner layer. Thus the hazardous chemicals started to leach from the site into the surrounding groundwater and migrating through the soil into the surrounding neighborhood. Chemicals seeped into basements and the air. It caused a number of different health effect including miscarriages and birth defects.
- e) The Love canal incident led to creation of hazardous waste legislation that: a) created a system for the inventory and management of hazardous chemical; and b) greatly tightened the control of the disposal of hazardous and non-hazardous waste on land. Also, this incident led to the creation of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). Funds from the act help clean toxic pollution from sites contaminated by companies that no longer existed so could not be made responsible for the damage they caused.

Question2: Other than the greenhouse effect what are other environmental impacts of the combustion of coal?

Answer:

- a) Sulfur in coal results in sulfate air emissions that when absorbed by precipitation form acid precipitation
- b) Tracer quantities of mercury and other metals in the coal result in air emissions of these metals that are transported for large distances, upon cooling it condenses and precipitates. Once in the water environment it enters the aquatic food web, and its concentration (and impact) increases as it bioaccumulates as it proceed up the food chain.

Question 3:What is the most common, used method for disinfection of drinking water in the Canada? Why is it important to remove the naturally occurring organic matter (NOM) before disinfecting drinking water?

Answer:

- a) The most common drinking water disinfection method in Canada is chlorination, this is because of its low cost.
- b) The natural organic matter (NOM) reacts with chlorine and chloramines to form hundreds of different disinfection by-products (DBPs). Two major classes are trihalomethanes (THMs) and haloacetic (HAAs) acids; they are suspected carcinogens.

Question 4: Mirex (MW = 540 g/mol) is a fully chlorinated organic pesticide that was manufactured to control fire ants. Due to its structure, Mirex is very unreactive; thus, it persists in the environment for a very long time. It is no longer used in North America because of its toxicity. Lake Erie water samples have had Mirex concentrations measured as high as 0.002 mg/L and lake trout samples with 0.002 mg/g. **(a)** In the water samples, what is the aqueous concentration of Mirex in units of (i) ppb, (ii) ppt, (iii) μM ? **(b)** In the fish samples, what is the concentration of Mirex in fish in (i) ppm, (ii) ppb?

Answer:

a) Water samples

i) in ppb

$$\frac{1 \text{ mg}}{\text{L}} = 1 \text{ ppm}$$

$$0.002 \frac{\text{mg}}{\text{L}} = 0.002 \text{ ppm} \times \frac{1000 \text{ ppb}}{\text{ppm}} = 2 \text{ ppb}$$

ii) in ppt

$$0.002 \frac{\text{mg}}{\text{L}} = 0.002 \text{ ppm} \times \frac{1000 \text{ ppb}}{\text{ppm}} \times \frac{1000 \text{ ppt}}{\text{ppb}} = 2000 \text{ ppt}$$

iii) in μM

$$\frac{0.002 \text{ mg}}{\text{L}} \times \frac{1000 \mu\text{g}}{1 \text{ mg}} \times \frac{1 \text{ mol}}{540 \text{ g}} = 3.70 \times 10^{-3} \mu\text{M}$$

a) Within the trout

i)

$$\frac{0.002 \text{ mg}}{\text{g}} \times \frac{1000 \text{ g}}{\text{L}} = 2 \text{ ppm}$$

ii) Dans les solides, ppb = $\mu\text{g}/\text{kg}$

$$\frac{0.002 \text{ mg}}{\text{g}} \times \frac{1000 \text{ g}}{\text{L}} = 2 \text{ ppm} \times \frac{1000 \text{ ppb}}{\text{ppm}} = 2000 \text{ ppb}$$

Question 5: A water sample contains 10 mg NO_3^-/L . What is the concentration in a dilute water in units of **(a)** ppm **(b)** moles/L, **(c)** mg NO_3^- -N/L, and **(d)** ppb?

Answer:

10 g NO_3^-/L in various units.

a) ppm

1 L water = 1 kg water (in dilute water solutions: mg/L = ppm)

$$\frac{10 \text{ mg} / \text{L}}{1 \text{ kg} / \text{L}} = \boxed{10 \text{ ppm as } \text{NO}_3^-}$$

b) moles/L

62 grams $\text{NO}_3^- = 1 \text{ mole } \text{NO}_3^-$

$$\frac{10 \text{ mg}}{\text{L}} \times \frac{1 \text{ g}}{1,000 \text{ mg}} \times \frac{1 \text{ mole}}{62 \text{ g}} = \boxed{1.6 \times 10^{-4} \text{ moles } \text{NO}_3^- / \text{L}}$$

c) mg NO_3^- -N/L

62 grams $\text{NO}_3^- = 1 \text{ mole } \text{NO}_3^-$; 14 grams N = 1 mole N; 1 mole $\text{NO}_3^- = 1 \text{ mole N}$

$$\frac{10 \text{ mg } \text{NO}_3^-}{\text{L}} \times \frac{1 \text{ mole } \text{NO}_3^-}{62 \text{ g } \text{NO}_3^-} \times \frac{1 \text{ mole N}}{1 \text{ mole } \text{NO}_3^-} \times \frac{14 \text{ g N}}{1 \text{ mole N}} = \boxed{2.3 \text{ mg } \text{NO}_3^- \text{-N/L}}$$

d) ppb

1 L water = 1 kg water; 1 kg = 10^6 mg; 1 billion = 10^9 million

$$\frac{10 \text{ mg} / \text{L}}{1 \text{ kg} / \text{L}} \times \frac{1000 \text{ million}}{1 \text{ billion}} = \boxed{10,000 \text{ ppb as } \text{NO}_3^-}$$

Question 6: Determine the equilibrium pH of aqueous solutions of the following strong acids or bases: **(a)** 15 mg/L of HSO_4^- ; **(b)** 10 mM NaOH; **(c)** 2500 $\mu\text{g/L}$ of HNO_3 .

Answer:

Because this problem states that these are strong acids and strong bases, we can assume that they will dissociate 100% of their H^+ and OH^- when added to water (we can also see this assumption by observing the magnitude of the pK_a and pK_b for these compounds).

a)

$$15 \text{ mg } \text{HSO}_4^- / \text{L} \times (1 \text{ mmol } \text{HSO}_4^- / 97 \text{ mg } \text{HSO}_4^-) \times (1 \text{ mmol } \text{H}^+ / 1 \text{ mmol } \text{HSO}_4^-) \times (1 \text{ mol} / 1000 \text{ mmol}) = 1.55 \times 10^{-4} \text{ mol } \text{H}^+$$

$$\text{pH} = -\log(1.55 \times 10^{-4}) = 3.81$$

b)

$$\frac{10 \text{ mmole } \text{NaOH}}{\text{L}} \times \frac{1 \text{ mole}}{1,000 \text{ mmole}} \times \frac{1 \text{ mole } \text{OH}^-}{1 \text{ mole } \text{NaOH}} = 0.01 \text{ mole } \text{OH}^-$$

$$[\text{OH}^-] = 10^{-2} \quad \text{so} \quad [\text{H}^+] = 10^{-12}$$

$$\boxed{\text{pH} = 12}$$

c)

$$2500 \mu\text{g } \text{HNO}_3 / \text{L} \times (1 \mu\text{mol } \text{HNO}_3 / 63 \mu\text{g } \text{HNO}_3) \times (1 \mu\text{mol } \text{H}^+ / 1 \mu\text{mol } \text{HNO}_3) \times (1 \text{ mol} / 10^6 \mu\text{mol}) = 3.97 \times 10^{-5} \text{ mol } \text{H}^+$$

$$\text{pH} = -\log(3.97 \times 10^{-5}) = 4.40$$

Question 7.

a) A liquid sample has an iron concentration of 5.6 mg/L. The density of the liquid is 2000g/L. What is the iron concentration in ppm?

Answer:

a)

$$5.6 \frac{\text{mg } \text{Fe}}{\text{L solution}} \times \frac{\text{L solution}}{2000 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 2.8 \times 10^{-6} \frac{\text{mg}}{\text{mg}} \times \left(\frac{10^6 \text{ ppm}}{\text{mass fraction}} \right) = 2.8 \text{ ppm}$$

- b) Near three rural wells nitrate concentrations were reported as 12 mg NO₃⁻ - N/L, 12 mg NO₃⁻/L, and 20 mg NO₃⁻ -N/L. Do any of these three wells exceed the 44.3 ppm level?

NOTE: Nitrate (NO₃⁻) concentrations exceeding 44.3 mg NO₃⁻/L are a concern in drinking water due to the infant disease, methemoglobinemia. Nitrate concentrations are often recorded in units of NO₃⁻ -N/L to be compared with other nitrogen constituents. NO₃⁻ - N/L is read as nitrate as nitrogen per liter. This example is similar to the methane example that was done together in class, where we express methane concentrations as carbon dioxide as carbon per liter.

Answer:

- c) Convert the critical value to mg NO₃/L.

$$44.3 \frac{\text{mg NO}_3^-}{\text{L}} \times \frac{1 \text{ mole NO}_3^-}{62000 \text{ mg NO}_3^-} \times \frac{1 \text{ mole N}}{1 \text{ mole NO}_3^-} \times \frac{14000 \text{ mg N}}{1 \text{ mole N}} = 10 \frac{\text{mg N}}{\text{L}}$$

Thus, the first well water exceeds the critical value (44.3 mg/L as NO₃ or 10 mg/L as N), the second one does not, and third one also exceeds the critical criteria

Question 8: A groundwater is being considered for use as a domestic supply. The water has a temperature of 15°C and the following chemical analysis:

Constituent	Concentration <i>g/m³</i>
Ca ²⁺	190
Mg ²⁺	84
Na ⁺	75
Fe ²⁺	0.1
Cd ²⁺	0.2
HCO ₃ ⁻	260
SO ₄ ²⁻	64
CO ₃ ²⁻	30
Cl ⁻	440
NO ₃ ⁻	35

- What is the hardness of the water in units of mg/L as CaCO₃?
- Determine the alkalinity of the water in units of mg/L as CaCO₃.
- Estimate the sample pH.
- Check if the analysis meets the acceptable error limits.

$$Is \left[\sum \text{anions} \left(\text{in } \frac{\text{meq}}{\text{L}} \right) - \sum \text{cations} \left(\text{in } \frac{\text{meq}}{\text{L}} \right) \right] \leq \left[0.1065 - 0.0155 \times \sum \text{cations} \left(\text{in } \frac{\text{meq}}{\text{L}} \right) \right]$$

NOTE: Assume $K = 10^{-10.3} = \frac{[\text{H}^+][\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$

Answer:

(a) Total hardness

$$[\text{Ca}^{2+}] = 190 \frac{\text{mg Ca}}{\text{L}} \times \frac{\text{g Ca}}{1000 \text{mg Ca}} \times \frac{\text{mole Ca}}{40 \text{ g Ca}} = 4.75 \times 10^{-3} \frac{\text{mole Ca}}{\text{L}}$$

$$[\text{Ca}^{2+}] = 4.75 \times 10^{-3} \frac{\text{mole Ca}}{\text{L}} \times \frac{1 \text{ mole CaCO}_3}{1 \text{ mole Ca}} \times \frac{100 \text{ g CaCO}_3}{1 \text{ mole CaCO}_3} \times \frac{1000 \text{mg}}{\text{g}}$$

$$= 475 \frac{\text{mg as CaCO}_3}{\text{L}}$$

Similarly

$$[\text{Mg}^{2+}] = 345.54 \text{ mg CaCO}_3 / \text{L}$$

$$[\text{Fe}^{2+}] = 0.179 \text{ mg CaCO}_3 / \text{L}$$

$$[\text{Cd}^{2+}] = 0.178 \text{ mg CaCO}_3 / \text{L}$$

$$\text{Total hardness (TH) in mg/L as CaCO}_3 = [\text{Ca}^{2+}] + [\text{Mg}^{2+}] + [\text{Fe}^{2+}] + [\text{Cd}^{2+}]$$

$$= 475 + 345.54 + 0.179 + 0.178 = 820.90$$

mg CaCO₃/L

(b) Alkalinity

$$[\text{CO}_3^{2-}] = 30 \text{ mg Ca /L}$$

$$\text{MW CO}_3^{2-} = 60$$

$$[\text{CO}_3^{2-}] = 30 \frac{\text{mg CO}_3^{2-}}{\text{L}} \times \frac{\text{g CO}_3^{2-}}{1000 \text{mg CO}_3^{2-}} \times \frac{\text{mole CO}_3^{2-}}{60 \text{ g CO}_3^{2-}} = 0.5 \times 10^{-3} \frac{\text{mole Ca}}{\text{L}}$$

$$[\text{CO}_3^{2-}] = 0.5 \times 10^{-3} \frac{\text{mole CO}_3^{2-}}{\text{L}} \times \frac{1 \text{ mole CaCO}_3}{1 \text{ mole CO}_3^{2-}} \times \frac{100 \text{ g CaCO}_3}{1 \text{ mole CaCO}_3} \times \frac{1000 \text{mg}}{\text{g}}$$

$$= 50 \frac{\text{mg as CaCO}_3}{\text{L}}$$

$$[\text{HCO}_3^-] = 260 \text{ mg HCO}_3^-/\text{L}$$

$$\text{MW HCO}_3^- = 61$$

$$[\text{HCO}_3^-] = 260 \frac{\text{mg HCO}_3^-}{\text{L}} \times \frac{\text{g HCO}_3^-}{1000 \text{mg HCO}_3^-} \times \frac{\text{mole HCO}_3^-}{61 \text{ g HCO}_3^-} = 4.2623 \times 10^{-3} \frac{\text{mole HCO}_3^-}{\text{L}}$$

$$[\text{HCO}_3^-] = 4.2623 \times 10^{-3} \frac{\text{mole HCO}_3^-}{\text{L}} \times \frac{1 \text{ mole CaCO}_3}{2 \text{ mole HCO}_3^-} \times \frac{100 \text{ g CaCO}_3}{1 \text{ mole CaCO}_3} \times \frac{1000 \text{mg}}{\text{g}}$$

$$= 213 \frac{\text{mg as CaCO}_3}{\text{L}}$$

$$K_a = \frac{[\text{H}^+] \times [\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$$

$$\text{so } [\text{H}^+] = \frac{K_a \times [\text{HCO}_3^-]}{[\text{CO}_3^{2-}]} = \frac{(10^{-10.3}) \times [4.2623 \times 10^{-3} \frac{\text{mole HCO}_3^-}{\text{L}}]}{[0.5 \times 10^{-3} \frac{\text{mole Ca}}{\text{L}}]}$$

$$= 4.27 \times 10^{-10} \frac{\text{mole H}^+}{\text{L}}$$

$$[\text{H}^+] = 4.27 \times 10^{-10} \frac{\text{mole H}^+}{\text{L}} \times \frac{1 \text{ mole CaCO}_3}{2 \text{ mole H}^+} \times \frac{100 \text{ g CaCO}_3}{1 \text{ mole CaCO}_3} \times \frac{1000 \text{mg}}{\text{g}}$$

$$= 2.135 \times 10^{-5} \frac{\text{mg as CaCO}_3}{\text{L}}$$

At 15°C, K_w = 4.46 × 10⁻¹⁵ while at 25°C K_w = 1 × 10⁻¹⁴

$$K_w = [\text{H}^+] \times [\text{OH}^-]$$

$$[OH^-] = \frac{K_W}{[H^+]} = \frac{4.46 \times 10^{-15}}{4.27 \times 10^{-10}} = 1.044 \times 10^{-5} \text{ mole/L}$$

$$[OH^-] = 1.044 \times 10^{-5} \frac{\text{mole } OH^-}{L} \times \frac{1 \text{ mole } CaCO_3}{2 \text{ mole } OH^-} \times \frac{100 \text{ g } CaCO_3}{1 \text{ mole } CaCO_3} \times \frac{1000 \text{ mg}}{g}$$

$$= 0.52 \frac{\text{mg as } CaCO_3}{L}$$

[H⁺] et [OH⁻] are very small and considered negligible

$$\text{Alk (in mg/L as } CaCO_3) = [CO_3^{2-}] + [HCO_3^-] + [OH^-] - [H^+]$$

$$= 213 + 50 + 0.52 - (1 \times 10^{-5}) = 263.5 \text{ mg } CaCO_3 / L$$

(c) pH

$$\text{and } pH = -\log_{10}[H^+] = -\log_{10} \left[4.27 \times 10^{-10} \frac{\text{mole } H^+}{L} \right] = 9.37$$

(d) Check

$$Is \left[\sum \text{anions (in } \frac{\text{meq}}{L}) - \sum \text{cations (in } \frac{\text{meq}}{L}) \right]$$

$$\leq \left[0.1065 + 0.0155 \times \sum \text{anions (in } \frac{\text{meq}}{L}) \right] ?$$

Constituent	Concentration	MW	EW	Conc.	Conc.
Cations	g/m^3			Mole/m ³	meq/L
Ca ²⁺	190	40	20	4.75	9.5
Mg ²⁺	84	24.3	12.15	3.45679	6.91358
Na ⁺	75	23	11.5	3.26087	6.521739
Fe ²⁺	0.1	55.85	27.925	0.001791	0.003581
Cd ²⁺	0.2	112.4	56.2	0.001779	0.003559

$$\text{SUM} = 22.94246 \text{ meq/L}$$

Constituent Anions	Concentration g/m^3	MW	EW	Conc. Mole/m ³	Conc. meq/L
HCO ₃ ⁻	260	61	61	4.262295	4.262295
SO ₄ ²⁻	64	96.1	48.05	0.665973	1.331946
CO ₃ ²⁻	30	60	30	0.5	1
Cl ⁻	440	35.45	35.45	12.41185	12.41185
NO ₃ ⁻	35	62	62	0.564516	0.564516

SUM = 19.5706 meq/L

$$\left| \sum \text{anions} \left(\text{in } \frac{\text{meq}}{\text{L}} \right) - \sum \text{cations} \left(\text{in } \frac{\text{meq}}{\text{L}} \right) \right| = 3.371$$

If the analysis was perfect the above quantity would be zero, but there is always some error in the analysis. The term in the right hand side is the accepted error. In this particular case the LHS term is in the order of 15% of the sum of anions, which is very large. The right hand side term equals

$$\left[0.1065 + 0.0155 \times \sum \text{anions} \left(\text{in } \frac{\text{meq}}{\text{L}} \right) \right] = 0.41$$

So the acceptable tolerance is not met and there is likely an error in the analysis of some of the components.