FINAL EXAM FOR CVEN 4474 - HAZARDOUS WASTE TREATMENT
MAY 8 11:30 AM - 2:30 PM TOTAL POINTS: 200

You may use 1 sheet of notes for the final. Please turn in notes sheet with your exam.

Multiple Choice (circle the letter of the most correct answer):

1. [2 pts] Given that hazardous waste leaked from a transfer pipeline buried in the saturated zone, and the waste contained anthracene, bromide, and trichloroethylene (with retardation factors of 1000, 2, and 10). Which compound would you expect to reach down-gradient drinking water wells first?
a) anthracene b) bromide c) trichloroethylene d) all would arrive at the same time

2. [4 pts] Given that packed tower air stippers are being designed for treatment of xylene-contaminated liquid, which would achieve a higher liquid treatment efficiency in each of the following cases (a OR b)?

a. column with stripping factor of 2 OR b. column with stripping factor of 20
a. column with Kla of 0.01 / sec OR b. column with Kla of 0.1 / sec
a. column with HTU of 1 m OR b. column with HTU of 3 m
a. column 5 NTU's tall OR b. column 50 NTU's tall

3. [2 pts] Which of the following are NOT tests which are used to assess the performance of a stabilization or solidification process?
a. corrosion test b. EP TOX c. paint filter test d. TCLP

4. [2 pts] Given that you receive a dose of radiation of 1 milli-rad, the highest tissue damage would result if the radiation adsorbed was in the form of:
a. Alpha b. Beta c. Gamma d. X-rays e. all the same

5. [2 pts] When a radioactive isotope decays by emission of an alpha particle:
a. an element with a lower atomic number results
b. the same element with a different molecular weight results
c. an element with a higher atomic number results results
d. there is no change in the element or its molecular weight

6. [2 pts] When a radioactive isotope decays by emission of a beta particle:
a. an element with a lower atomic number results
b. the same element with a different molecular weight results
c. an element with a higher atomic number results results
d. there is no change in the element or its molecular weight

Fill in the Blank:

7. [3 pts] The types of radioactive waste for which Yucca Mountain is being designed to dispose of includes _____ and _____.

8. [2 pts] The type of radioactive wastes which are intended to be disposed at WIPP (the Waste Isolation Pilot Plant) are _____ .

9. [2 pts] (higher lower) It will be easier to remove a compound with a _____ Henry's coefficient in an air stripping tower.
In an air stripping tower, a _____ contact surface area between the liquid and air is desirable.

10. [6 pts] Steps in Contaminated Site Clean-up Under CERCLA. Fill in the blanks **and define** the acronymns listed in **bold**:

Site Discovery
↓
_____ -> not on **NPL**
↓
on NPL
↓
_____&_____
↓
ROD
↓
RD -> RA -> site meets _____ -> post-closure monitoring

Short Answer:

11. [5 pts] List the four characteristics which can lead to classification of a waste as "hazardous" under the RCRA definition.

What is another way the waste may fall under RCRA regulations for hazardous wastes?

12. [4 pts] List the types of samples and sampling methods you would use to **fully** characterize contaminant distribution at the Manufactured Gas Plant (MGP) site used as the basis for design project 2.

13. [3 pts] List 3 non-biological ex-situ methods that could be used to remove non-volatile organic compounds from groundwater.

14. [3 pts] List 3 ex-situ methods that can be used to remove inorganic contaminants from groundwater.

15. [3 pts] List 3 non-biological methods that can be used to treat organics-contaminated soils ex-situ.

16. [3 pts] List 3 non-biological methods that can be used to treat inorganics-contaminated soils ex-situ.

17. [4 pts] List the Four steps which should be conducted "pre" bioventing design.

18. [2 pts] What are two differences between bioventing and air sparging designs for in-situ bioremediation?

19. [3 pts] List three methods which are used for biological ex-situ treatment of contaminated soils and two things which you would monitor or measure to ensure treatment effectiveness.

20. [4 pts] Green plants (phytoremediation) can be used as a site remediation or risk management strategy. List 4 different ways that plants could be used to aid remediation or containment.

21. [4 pts] Given a site that you wish to remediate by in-situ vitrification, list the specific costs associated with the process.

22. [6 pts] Given that a strong cation exchange resin (with Na+ mobile charges) is used to treat contaminated water containing high levels of CrO_4^{-2}, Cs^{+1}, I^-, and Pb^{+2}, sketch the approximate "active sorption ranges" for each compound in a downflow ion exchange column and the anticipated compounds in the column effluent at the two times listed:

Fresh Resin Column Partially Exhausted Column

23. [4 pts] List one **complete** exposure pathway for which risk calculations would be needed for risk assessment of the manufactured gas plant site which was studied for Design Project 2.

24. [4 pts] What are the “three T’s” of incineration that determine the destruction efficiency of organics in the incinerator?

What additional factor will influence combustion efficiency?

25. [4 pts] List 4 components in the “stack gas” or gas effluent from the incinerator that must be measured to ensure regulatory compliance.

26. [4 pts] List the “heirarchy of hazardous waste management” in order from the “most preferred” to “least preferred” options.

27. [4 pts] What is the general purpose of a waste minimization plan and some common, general methods or “target areas” for achieving these goals?

28. [4 pts] List the phases in Life Cycle Analysis (LCA), and the primary difference between LCA and waste minimization plans.

29. [8 pts] List the 4 major new requirements for hazardous waste landfills mandated by the RCRA regulations.

List 4 of the other 8 requirements for hazardous waste landfills.

30. [2 pts] What is the primary DIFFERENCE between a geotextile and a geomembrane?

31. [3 pts] What is the primary ADVANTAGE of slurry trench construction of a cutoff wall versus traditional trenching methods?

What is a secondary advantage?

32. [2 pts] What are two current methods used to "treat" or "dispose" of radioactive wastes used by European countries or Japan, but which are NOT currently used in the U.S.?

33. [4 pts] List two **current** practices that are used in the U.S. to dispose or treat radioactive wastes, and the type of radioactive waste that this method is used for.

34. [4 pts] List two "by-product" waste stream(s) that result from **each** of the following treatment processes:
a. incineration

b. thermal desorption

35. [7 pts] List 4 types of additives that are used to stabilize or solidify hazardous wastes.

What are three primary considerations or criteria that determine which type of stabilization or solidification agent is selected for use?

36. [6 pts] List three types of bioaugmentation approaches that can be used to aid site remediation, and an advantage and disadvantage of each.

37. [10 pts] Based on the class presentations of remediation approaches for the BG&E Manufactured Gas Plant site studied for design project 2 and the associated class discussion, discuss what combination of treatment strategies you think would be best to remediate the site and why. (use back of sheet for extra space)

Work-Out (use attached sheets for working out each problem):

W1. [10 pts] Partitioning

a. Given that a compound is partitioned between air and water in a closed system at 20°C that is believed to be at equilibrium, and the concentration of the compound in air is 10 mg/L and the concentration in water is 100 mg/L. What is the Henry's coefficient of the compound?

b. If in the above case, the compound was initially added to the water, and the measured gas and liquid concentrations were made before the system had fully equilibrated, the true Henry's coefficient of the compound is likely _____ than listed in part a.

Lower Same Higher

c. Given that a compound has a (unitless) Henry's coefficient of 2 and a soil:water partitioning coefficient (Kp) of 10 L/kg at the temperature of interest .

- If the compound is in the saturated zone at a site with a porosity of 0.5, the specific gravity of the solids is 2, and the concentration of the compound in the groundwater is 10 mg/L:

- What is the concentration of the compound associated with the soil? (in mg/kg)

- What is the total mass of compound in a 1 L volume of the saturated zone? (in mg)

- If the compound is in the vadose zone at the same site in an area at 0% moisture content, and the same concentration is associated with the soil, what is the total mass of the compound in a 1 L volume of the vadose zone? (in mg)

W2. Risk

Compound	Oral RfD mg/kg-d	Inhalation RfD mg/kg-d	Oral CPF kg-d/mg	Inhalation CPF kg-d/mg
Benzene	pending	pending	0.025	0.029
Chromium(III)	1.00	pending	pending	pending
Nickel	0.02	pending	no data	no data

a. [5 pts] Given that the drinking water in a local well contains 12.4 mg/L chromium(III) and 0.6 mg/L nickel, is there an acceptable hazard to adults of average body weight 70 kg who drink 2-L of the water per day?

b. [5 pts] What is the maximal number of excess lifetime cancer cases expected for a population of 100,000 adults with an average daily intake of 0.14 mg benzene via inhalation (from multiple sources including second-hand cigarette smoke, gasoline vaports, etc)?

c. [5 pts] Describe (qualitatively) how to calculate an acceptable maximum concentration of benzene in air inhaled by workers on the job at a chemical manufacturing plant, assuming that "1 in a million" excess cancer cases per lifetime is acceptable.

W3. [10 pts] Given a completely mixed reactor (CSTR) without biomass recycle treating 50 gpm of water containing 50 mg/L benzene, that is operated with a 5 day hydraulic residence time (HRT). The required effluent concentration of benzene from the reactor is 10 µg/L. ***CSTR eqns at bottom of pg*

a. What is the solids retention time in the reactor (SRT)?

b. What is the volume of the reactor?

c. Given that you could seed the reactor with one of the following types of bacteria, which would you select, on the basis of the following measured Michaelis-Menten biokinetics?

A. K = 1 g/g-d, Ks = 1 mg/L, Y = 0.5 g/g, b = 0.01 day-1
B. K = 1 g/g-d, Ks = 0.1 mg/L, Y = 0.5 g/g, b = 0.01 day-1
C. K = 10 g/g-d, Ks = 1 mg/L, Y = 0.5 g/g, b = 0.01 day-1
D. K = 10 g/g-d, Ks = 0.1 mg/L, Y = 0.5 g/g, b = 0.01 day-1

d. Would this reactor design achieve the needed effluent concentration?

e. Assuming that the influent water contains 8 mg/L dissolved oxygen, would additional oxygen need to be added to the reactor to maintain aerobic conditions in the reactor?

W4. [5 pts] Given that the soil at a site is contaminated with sorbed organics to a depth of 10 m and the groundwater table is 5 m deep. The volume of contaminated soil is 1000 m3, and exists in an approximately circular extent. The hydraulic conductivity of the soil is 10^-4 cm/s, and the natural hydraulic gradient at the site is 0.001 m/m. Design a system to **minimize off-site migration** of the contamination; show a sketch. [specific gravity of BULK soil (solids + voids) is 1.5; retardation factor of organics in the soil averages 100]

W5. [12 pts] Landfill Design. You are designing a landfill to dispose of hazardous wastes. All the waste accepted by your landfill will be received in 55-gallon drums (drum dimensions: 3' x 1.77' dia), and assume that the total landfill capacity will be 10,000 drums.
Sketch a cross-section of the final landfill, showing the dimensions of the initial excavation, final cap, and including cap and liner details. (List any assumptions that were used in your calculations.)

W6. [12 pts] Given that you are treating liquid that contains 20% by mass toluene in a liquid injection incinerator at a rate of 1000 lb/hr using 20% excess air. Assuming that there is sufficient heat released from the toluene to maintain the temperature in the incinerator at 1800°F:

a. What should the air flow rate into the incinerator be in ft3/hr (assume air fed in at STP)?

b. If the DRE of toluene in the incinerator is 99.999%, what is the concentration of toluene in the stack gas, assuming that the total gas flowrate is 60,000 ft3/hr?

Equations:
Complete mix system without solids recycle (assuming Michaelis-Menten kinetics):
$S = [Ks(1+bSRT)]/[SRT(YK-b)-1]$; $X = [Y(So-S)]/[1+bSRT]$; $1/SRT\text{-min} = [YKS/(Ks+S)]-b$
General: Benzene = C6H6, MW 78; Toluene = C7H8, MW 92; Air at STP = 0.0805 lb/ft3;
1 mol gas = 22.4 L @ STP; 1 lb = 453.6 g; 1 lb/ft3 = 16017 mg/L; Air 20% O2 by volume;
Darcy's Law: $Q = K(dh/dl)A = KiA$