FE Exam Review: Environmental

- Civil Engineering afternoon: 12% EVEN
  - Water quality (ground and surface)
  - Air quality
  - Solid/hazardous waste
  - Sanitary sewer system loads
  - Basic tests (e.g., water, wastewater, air)
  - Environmental regulations
  - Water treatment and wastewater treatment (e.g., primary, secondary, tertiary)

Most info in the EVEN section of FE formula book pg. 170-192
Also Fluids, Chemistry, and Biology sections may help

FE Exam Review: Environmental

EVEN majors or if you concentrated in environ. & proficient in water

- EVEN afternoon: (60 ?s; pg. 170-192)
  - Water Resources (distrib/coll, hydrol, fluids) 25%
    - See CVEN pg. 159-161,
  - Water & WW (inc. micro/ecol see p. 91-99, env chem) 30%
  - Air Quality Engrg (stds, control, atm sci) 15%
  - Solid & Hazardous Waste Engrg 15%
    - SW, HazW, site remediation, geohydrology, geotechnology
  - Env Science & Management 15%
    - OSHA, radiation health/waste mgmt, env monitoring & sampling, pollutant fate & transport (soil/air/water), pollution prevention…

TIPS

- **Watch units!**
  - **Water: ppm = mg/L; ppb = µg/L;**
  - **Soil: ppm = mg/kg;**
  - **Air ppm IS NOT mg/L!**
    - **AIR conc in ppm-v = 100-1000x air in mg/L**
      - **Need molecular weight; molar volume**
  - **Pg. 19-20 of formula book has conversion factors**
- Frequently, you will use a MASS BALANCE approach
- Review your CVEN 3414 homeworks/text;
  - Review CVEN 3424 if you had the course
- Practice problems from: Metcalf & Eddy Wastewater Engrg; LaGrega Haz Waste; Wark & Warner Air Pollution; Vesilind et al. Solid Waste Engineering; Ray Environmental Engineering

Environmental Regulations

- Clean Water Act
  - NPDES permits for discharge to surface waters
- Safe Drinking Water Act (SDWA)
  - Sets MCLs for acceptable concentrations of contaminants in public drinking water supplies; sets treatment requirements for pathogens
- Clean Air Act (CAA) set National Ambient Air Quality Stds
  - Regulates criteria pollutants (CO, ozone, NOx, SOx, PM, lead)
  - Regulates hazardous air pollutants and sets Max Achiev Control Tech
- Resource Conservation and Recovery Act (RCRA)
  - Hazardous Waste Subtitle C (cradle to grave, defined HazW)
  - Solid waste Title D, Medical waste Subtitle J, Underground storage tanks Subtitle I
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; "Superfund")
  - Clean up worst historically contaminated sites in the US
- OSHA (Occupational Safety and Health Administration)
  - Safety for workers; such as HAP concs in air…
- National Environmental Policy Act (NEPA)
  - Requires Environmental Impact Statements (EIS) for federal projects

Water Quality

- Wastewater
  - Solids: TDS, VDS, TSS, VSS
  - BOD_5 or COD

p. 175

    - $BOD_5 = BOD_u (1 - e^{-kt})$, if k is base e deoxygenation rate constant (sometimes use base 10)
  - Organic nitrogen (as N)
  - Ammonia nitrogen (NH_3-N)
  - TKN = organic N + ammonia N
  - Total phosphorus

WasteWater Tmt (p. 186-190)

- Activated sludge: plug flow or CMFR, biomass eqn; typical operating parameters
- Clarifier [primary, secondary]
  - mass balance; design by overflow rate, HRT
  - SVI = sludge volume index (settlability)
- Aerobic digestion = HRT, solids load, O_2…
- Anaerobic digestion = SRT, solids load, CH_4…
- Facultative pond = BOD loading, depth, HRT
- Disinfection = chlorine (CT) or UV common

Water Tmt (w/ww class)

- GAC sorption & isotherms (also HazW)
  - Removes organics
- Air stripping (also HazW) – remove volatiles
- Sedimentation/clarifiers – remove particles
- Filtration – remove based on size
- Softening – remove hardness (Ca^{+2}, Mg^{+2},…)
- Flocculation – agglomerate to larger particles
- Membranes – RO (desalination), NF, UF, MF
- Disinfection – chlorine, UV, ozone, chloramine…

Fate and Transport

- Streeter Phelps for oxygen sag in stream when ww with BOD is discharged (p. 175)
  - DO sag curve
  - Oxygen saturation conc. at 20^{o}C is 9.1 mg/L
- Monod Kinetics – describe bacterial growth and substrate degradation;
  - $dX/dt = umax\ S\ X / Ks+S – bX = -YdS/dt - bX$
  - $-dS/dt = umax/Y * SX / Ks + S$

Fate & Transport: BCF, Kow, Koc, Ksw, R (HazWclass)

- If a chemical has a BCF of 20, what is the likely concentration of the chemical in fish that live in water containing 10 ppm of the chemical?
  - BCF * Cw = Cfish; ppm = mg/kg
- Chemicals A, B, and C have Koc values of 10, 100, and 1000. Which will travel fastest in GW?
  - If the soil has an organic carbon content of 3%, what is the Ksw of Chemical B?
  - P.176

Air Pollution

- Unit conversions
- Model by Gaussian dispersion
  - 4 pages in FE reference handbook!
- Treatment
  - remove particles:
    - Cyclone Baghouse Electrostatic precipitator
  - Remove organics (HAPs) by incineration
  - Wet scrubbing removes acid gases

Radiation (HazW)

- What type of nuclear radiation has the greatest penetrating power?
  - Gamma > Beta > Alpha
- Which type of nuclear radiation causes the greatest molecular damage when ingested?
  - Alpha (20x other particles)
- If a soil sample contains 10 mg/L of a radioisotope with a half life of 100 yrs, what will be the concentration of the radioisotope in the soil after 1000 yrs?
  - Pg. 178

Toxicology and risk assessment

- Threshold concept for non-carcinogens and acute effects
  - Risk if intake > threshold (such as RfD)
  - Hazard Index = chronic daily intake / RfD
  - Intake and dose in mg chemical/kg body wt/d
  - RfD usually estimated from animal studies with multiple orders of magnitude of UFs
- Carcinogens risk dose:response without threshold
  - Incremental cancer risk = dose * Carcinogen Slope Factor (CSF or CPF)
- Dose = Intake = CDI =

  Conc * CR * Abs * Ret * EF * ED / Body wt / Avg time

  avg time = ED for non-carcinogens or 70 yr lifetime for carcinogens

Pg. 184 for CDI formulas; Pg. 185 for CR and body wt

Example ?s

- A 5-day BOD and ultimate BOD are measured at 180 mg/L and 200 mg/L, respectively. What is the decay coefficient?
  - Use eqn. pg. 175

Example ?s

- The carbonaceous oxygen demand of 200 mg/L of $C_5H_7NO_2$ is

- The nitrogenous oxygen demand of 200 mg/L of $C_5H_7NO_2$ is

Write stoichiometry for mineralization to CO2 + NH3; then NH3 to HNO3;
Balanced stoichiometry rules: each element balanced on both sides;
charge balanced on both sides
Convert from moles to mg (use periodic table pg. 101)

Example ?s

- A lake with volume 5E6 m^3 has a freshwater flow of 20 m^3/s. Waste is dumped into lake at 50 g/s with a decay rate of 0.2/d. What is the steady state contaminant concentration in the lake in mg/L if the lake is completely mixed?

Mass Balance OR eqn. on pg. 176

W&WW

- A wastewater basin has a diameter of 20 m and water depth of 3 m. The pipe feeding the basin has a diameter of 40 cm, is flowing full, and has a water velocity of 0.28 m/s. What is the hydraulic residence time in the basin?

HRT = Volume / Q

Risk Assessment/Tox (HazW class)

- Calculate the chronic daily intake of arsenic by an average adult if their drinking water over their entire lifetime contains 10 ppm arsenic.
  - What is the CDI if the drinking water only contained arsenic for 10 yrs
    - Carcinogen (averaging time = 70 yr lifetime)
    - Non carcinogen (averaging time = exposure time)
  - What is the carcinogenic CDI if only the drinking water at their work contained this amount of arsenic, and they worked there for 10 yrs

Air Pollution

- Convert 20 ppm of NO_2 to μg/m^3 at 20C.
  - ppm = mol NO_2/ 1E6 mol * 46 g/mol * 1 mol air/24 L air = g/L * 1E6 ug/g * 1000 L/m^3
- An Illinois coal with a sulfur content of 3.00% is burned at a rate of 1 kg/sec. If 5% of the sulfur goes into the ash, what is the mass emission rate of SO_2 into the air per year?
  - Mass = 1 kg/sec * 0.03 kg S/kg coal * 0.95 * (MW SO2 / MW S) * sec/yr
- Determine the efficiency of a conventional cyclone with 0.5 m barrel diameter for removing 10 um particles with a density of 800 kg/m^3 from 4 m^3/s of air at 25C.
  - See p. 173: eff = 1/1+$(d50/dp)^2$ and d50 eqn.

Air Pollution

- It is estimated that 1700 g/s of SO_2 are emitted from a coal fired power plant. At 3 km downwind on an overcast summer afternoon, what is the centerline concentration of SO_2 if the windspeed is 4.5 m/s? The stack is 120 m high, 1.2 m diameter, with gas exiting at 1 m/s and 315^{o}C. The atmosphere is 25^{o}C.
  - Plume rise = 8 m = vs d / u * [const P (Ts-Ta/Ts)d] by Holland's formula (not given in book; 6% error neglect OK)

p. 170 and 171

More questions…

- How many grams of oxygen are required to burn 1 gram of methane (CH_4)?
  - Write balanced chemical reaction:
  - $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$
  - Convert from moles to g (see pg. 101 periodic table)
  - 1 g CH_4 * 1 mol/16 g * 2 mol/1 mol * 32 g
  - 4 g O_2

Disinfection: Which statements are correct?

1. Chlorination of wastewater effluents requires more chlorine than chlorination of drinking water
2. Chlorination of ww effluents requires 3 moles of chlorine for each mole of ammonia
3. Chlorination of ww is used to improve effluent quality
4. Chlorination of ww effluents oxidizes other chemicals such as ferrous iron

a) All above are true
b) None of above are true
c) Only 1 and 3 are true
d) Only 1, 3, and 4 are true

- You are designing a biological treatment reactor that is a CSTR to achieve an effluent concentration of 1 mg/L of benzene. The inlet of 1 MGD contains 50 mg/L benzene. Which bacteria will allow the smallest reactor?
  - A: Cell yield 0.5 g/g, maximum specific growth rate 1/day, half saturation constant 1 mg/L
  - B: Cell yield 0.5 g/g, maximum specific growth rate 10/day, half saturation constant 1 mg/L
  - C: Cell yield 0.5 g/g, maximum specific growth rate 10/day, half saturation constant 10 mg/L
  - D: Cell yield 0.2 g/g, maximum specific growth rate 1/day, half saturation constant 1 mg/L

p. 175 and 186

W/WW

- A water contains silt particles with a uniform diameter of 0.02 mm and a specific gravity of 2.6. What removal is expected in a clarifier with an overflow rate of 12 m/d?
  - Need Stokes Law formula p. 192
  - Need density and viscosity of water (p. 62 density); viscosity 1E-3 N s / m^2
  - Fractional removal = settling velocity / overflow

W&WW

- A completely mixed reactor with cell recycle is designed to treat a municipal waste. Assuming Monod removal kinetics, which of the following statements is correct
- A) effluent substrate concentration decreases with an increase in SRT
- B) food:microorganism ratio is independent of SRT
- C) microbe concentrations will be smaller than in the no-recycle case
- D) SRT is independent of effluent quality

p. 186

W&WW

- A wastewater contains contaminant A with an initial concentration of 1200 mg/L. A is biodegraded via a first order reaction with a rate constant of 2.5 per day. Determine the time needed in a batch reactor to degrade 75% of contaminant A.
- Under the same conditions as above, what detention time is needed if the ww is treated in a CSTR with a flowrate of 0.02 m3/s.

p. 176

W&WW

- A 25-m diameter secondary clarifier has an influent solids concentration of 2500 mg TSS/L. The flow rate to the clarifier is 17,500 m^3/d. If the effluent solids are assumed to be zero, what return or recycle flow rate is required to attain a return solids concentration of 7500 mg TSS/L.

- 1 liter of water is at equilibrium with an atmosphere containing a partial pressure of 0.1 atm of CO_2. How many grams of CO_2 are dissolved in the water (alpha = 1/H = 2.0 g/L/atm)

- How much HOCl is present in a solution containing 0.1 M chlorine at pH 8 if the equilibrium constant is $10^{-7.5}$?
  - Use pH to determine H+ concentration
  - Write equilibrium equation
  - $HOCl \rightarrow H^+ + OCl^-$
  - Use pg. 100 equilibrium constant formula to solve for HOCl (assume chlorine conc is total of HOCl + OCl^-)

- Wastewater with DO concentration of 1 mg/L is discharged to a river at 20C. The river is saturated with oxygen. If the flow of the river is 2.8 m^3/s and flow of the wastewater is 2.8E-2 m^3/s, what is the oxygen deficit immediately after mixing?
  - Find saturated oxygen conc (it is significantly impacted by temperature; should be given in the problem)

- A waste with flow 2.8 L/s (DO 1 mg/L) is discharged to a clean stream with flow 14 L/s (fully O_2 saturated). Waste has 5-d BOD of 200 mg/L (k=0.2/d). What is the DO after 1 day's travel in the stream? assume deoxygenation rate is 0.12/d and reaeration rate is 0.5/d

Problem

- Town A wants to discharge 0.28 m^3/s ww (temp 20C) with DO 1 mg/L and ultimate BOD of 6.44 mg/L into a stream (temp 20C) with flow 0.877 m^3/s at upstream DO 6 mg/L and BODu of 0.
- Will the DO at town A drop below 5 mg/L?
- At any point in the river will DO drop below 5 mg/L? assume deoxygenation rate is 0.12/d and reaeration rate is 0.5/d.

$$tc = \frac{1}{(reaer - deoxy)} * \ln\left[\frac{reaer}{deoxy}\left(1 - Do\,\frac{(reaer-deoxy)}{(deoxy\ BODu)}\right)\right]$$

$$D = deoxy\ BODu/(reaer-deoxy) * [\exp(-deoxy\ t) - \exp(-reaer\ t)] + Do \exp(-reaer\ t)$$

$$D = DOsat - DOactual$$

WW chloride ~100 mg/L; so DOsat ~9.16 mg/L (A-51)

1. Water Resources

A centrifugal pump has a flow rate of 1 L/s for a rotational speed of 2000 rpm. Assuming a constant impeller diameter, the flow rate for a rotational speed of 3000 rpm is most nearly

(A) 0.75 L/s

(B) 1.5 L/s

(C) 2.0 L/s

(D) 3.0 L/s

2. Water Resources

The population of a town was 1.1 million in 1980, 1.2 million in 1990, and 1.3 million in 2000. The per-capita consumption of water was 0.5 kg/person/d in 1970 and 0.7 kg/person/d in 1990. The total water consumption in 2010 is expected to be

(A) 9.0E5 kg/d

(B) 1.2E6 kg/d

(C) 1.3E6 kg/d

(D) 1.4E6 kg/d

3. Water and Wastewater

A sample of wastewater has a kinetic rate constant of 0.1/d. The initial dissolved oxygen reading is 8.00 mg/L. The reading after 2 d without any additional oxygen being added is 6.0 mg/L. Therefore, the ultimate BOD is most nearly

(A) 2.0 mg/L

(B) 9.0 mg/L

(C) 11 mg/L

(D) 21 mg/L

4. Water and Wastewater

The equilibrium constant, Keq, is 5E-11 mol/L for the reaction

$$HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$$

The molar concentration of HCO_3^- at a pH of 7.5 is most nearly

(A) 3.8E-10 mol/L

(B) 4.0E-5 mol/L

(C) 2.0E-5 mol/L

(D) 1.0 mol/L

5. Air Quality Engineering

A plume is emitted from a 20 m high stack. Wind speed is constant at 3 m/s, there is no wind shear, and the topography is flat. The plume's point of maximum rise occurs at a downwind distance of 600 m from the stack. The emissions from the stack have a buoyancy flux of 55 m^4/s^3. Prior to the point of maximum plume rise, the vertical distance between the top of the stack and the centerline of the plume can be modeled as

$$\Delta h=(1.6F^{1/3}x^{2/3})/\mu$$

The height of the plume's centerline above the ground at a distance of 0.4 km downwind of the stack is most nearly

(A) 110 m

(B) 130 m

(C) 140 m

(D) 160 m

6. Solid & Haz. Waste Engineering

A city has municipal solid waste with the following characteristics

Waste Component	Mass % (dry basis)
Food	3.2
Glass	0.2
Metal	1.2
Plastics	18.9
Wood debris	3.8
Paper	15.8
Yard waste	33.0

The pass percent of water in the solid waste is most nearly

(A) 12.0

(B) 23.9

(C) 35.9

(D) 47.8

7. Solid & Haz. Waste Engineering

Some soil has a discharge rate of 0.1 L/s, an area of 11 m^2, and a hydraulic head that is given empirically by the function

$$H = 0.03x + 0.3$$

The units of H and x in this equation are in meters. The hydraulic conductivity of this soil is most nearly

(A) 3E-4 m/s

(B) 3E-3 m/s

(C) 3E-2 m/s

(D) 3E-1 m/s