NATIONAL EXAMS DECEMBER 2008

04-Env-A1, Principles of Environmental Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a Closed Book exam with a candidate prepared 8.5 x 11 double sided Aid-Sheet allowed.

3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator, on the first inside left hand sheet, of the exam work book.

3. Any five questions constitute a complete paper. Only the first five answers, to the seven questions, as they appear in your answer book(s) will be marked.

4. Each question is worth a total of 20 marks with the section marks indicated in square brackets [ ] at the end of the question. The complete Marking Scheme is also provided on the final page. A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.

1. Provide answers to the following questions related to population, economic growth, urbanization and energy use as causes of environmental pollution:

   i) What is an age structure (or population pyramid)? Explain the use of age structures, using sketches for expansive and constrictive scenarios. [6]

   ii) Identify three (3) specific environmental impacts of increased urbanization on the hydrosphere. For each impact identify a technology that has been used to minimize the impact and explain the key engineering principle of each technology. [6]

   iii) Increased economic growth has been linked to increased energy use and direct increases in emissions of air pollutants. Using a table, list the ecological effects of increased emissions of total suspended particulates, sulphur dioxide, photochemical oxidants and hydrocarbons on humans, plants and climate/atmosphere. [8]

2. Provide answers to the following questions related to material mass balance, carbonate system and transport mechanisms.

   i) A power plant, with an output of 2000 MW, converts fuel energy into electrical energy with an efficiency of only 30 percent. The other part of the energy content of the fuel is rejected to the environment as waste heat. About 20 percent of the waste heat goes up the smokestack and the rest is taken away by cooling water that is drawn from a nearby river with a flow of 200 m^3/s and a temperature of 15 °C. Estimate the elevated temperature of the stream just downstream from the cooling water discharge point. Assume that the specific heat of water as 4000 $J/(kg \cdot °C)$. [8]

   ii) Consider the carbonate system in a fresh water lake including the air-water-limestone interphase. Briefly describe the response of the lake to a strong alkaline spill in the lake and how the carbonate system works to buffer the pH change. In your description consider using relevant equations and a schematic(s). [6]

   iii) Briefly describe the following transport mechanisms and provide one example where each transport mechanism can be used to explain an environmental phenomenon:

      a) Molecular diffusion [2]
      b) Advective transport [2]
      c) Dispersion [2]

3. Provide answers to the following questions related to contaminant partitioning in water with solids, chemistry of species in equilibrium and reactor material balances:

   i) Briefly explain what two (2) physical-chemical properties of a contaminant would help environmental scientist predict the partitioning of the compound in a dual mixture of water and solids. **[6]**

   ii) A steady-state equilibrium exists between ammonia and ammonium in a sewage polishing lagoon at 25 °C and a pH of 9. Given the total ammonia-nitrogen (TAN) concentration is 15 mg/L calculate the percentage of ammonia-nitrogen (NH_3-N) and ammonium-nitrogen (NH_4^+-N) present in the lagoon. Assume the equilibrium ionization constant is 2.0×10^{-5} at 25 °C. **[6]**

   iii) Hydrogen sulphide (H_2S (aq)) dissolved in water undergoes first-order decay with rate constant k.

      a) Calculate the mean residence time (as a function of k) in a completely mixed flow reactor (CMFR) to achieve a 99% removal (i.e., $C_{out}/C_{in} = 0.01$, where C_{out} is the steady-state outlet concentration for a constant inlet concentration C_{in}). **[4]**

      b) If the single reactor is replaced with three (3) CMFRs of the same total volume in series, what is the total mean residence time (as a function of k) required to achieve the same 99% removal? **[4]**

4. Provide an answer to the following questions related to sustainable development, life cycle analysis, principles of environmental quality objectives, standards and guidelines:

   i) Briefly explain the principle of sustainable development and provide an example of its application. For your example you may consider some of the issues associated with the sustainable development of strip mining and the use of steam or solvents to extract oil from the Alberta oil (tar) sands. **[6]**

   ii) Briefly explain the key parts of a life cycle analysis commonly used by engineers to compare viable options during environmental assessment or similar planning initiatives. **[6]**

   iii) Explain the difference between a (1) quality objective; (2) a standard and (3) a guideline commonly used by environmental regulators. In your explanation provide one (1) example for each situation where an objective, standard and guideline is the most appropriate option in achieving an environmental goal. **[8]**

5. Provide answers to the following questions related to disinfection reaction kinetics, environmental ecology and water or wastewater treatment principles:

i) In answering questions (a) and (b) consider Chick's and Watson Law expressions:

Chick's Law: $$\frac{N(t_c)}{N(0)} = e^{-k \cdot t_c}$$

Watson Law: $$C \cdot t_c = \alpha$$

where $N(t_c)$ = number of viable organisms remaining after time t_c
$N(0)$ = number of viable organisms initially present
k = the reaction rate constant (min^{-1})
C = disinfectant concentration (mg/L)
α = constant for a given disinfection objective (min·mg/L)

a) It was shown that 99.9 % of the protozoan *Giardia lamblia* was inactivated using a $C \cdot t_c$ value of 300 min·mg/L. Determine the reaction rate constant k, corresponding to a chlorine concentration of 3 mg/L. [3]

b) Approximately what percentage of G. *lamblia* organisms would be inactivated at a chlorine concentration of 6 mg/L and a contact time of 20 minutes? [5]

ii) A basic phenomenon of environmental ecology is the conservation or cycling of nutrients through organisms and back to the environment. Briefly describe the Nitrogen Cycle and its role in sustaining life in the aquatic environment. [6]

iii) Select a typical water treatment plant or wastewater treatment plant and describe the key treatment principles associated with any three (3) of the following: (1) primary treatment, (2) secondary treatment, (3) disinfection, (4) filtration and (5) solids or residuals handling. In your description you may use diagrams, equations or narrative. [6]

6. Provide answers to the following questions related to the application of technical and non-technical environmental principles of air and noise pollution control, solid waste management, environmental impact assessment and environmental ethics:

   i) Briefly describe two (2) different engineering methods to reduce or eliminate environmental impacts associated with noise pollution and fine particulates (e.g., PM10) coming from a rock quarry operation (i.e., sand and gravel pit). **[6]**

   ii) Briefly describe three (3) solid waste management (SWM) practices normally adopted in industrialized countries as part of a SWM hierarchy. In your description prioritize each practice from the most to the least environmentally significant practice. **[6]**

   iii) An environmental impact assessment (EIA) is important to identify the critical environmental issues during the construction of a new automotive plant, gold mine or landfill site to serve a regional municipality. Briefly describe three (3) steps you would take as an engineer having been asked to conduct an EIA for any one of the above facilities. In your description provide a situation where environmental ethics would play an important part during the EIA. **[8]**

7. Provide answers to the following questions related thermal pollution, greenhouse gas effects, acid precipitation and ozone depletion:

   i) Thermal pollution can occur when water is discharged to the aquatic environment following its use as a coolant in a power plant or industrial plant. Briefly describe two (2) potential adverse impacts and two (2) corresponding engineering solutions to minimize the thermal impacts on the receiving aquatic environment. **[5]**

   ii) Briefly describe the global warming and its relationship to greenhouse gases. In your description explain two (2) atmospheric phenomena causing global warming and two (2) corresponding engineering measures that may be used to reduce the global warming effects. **[5]**

   iii) Briefly explain the production of acid precipitation from the burning of fossil fuels containing sulphur and nitrogen compounds. In your explanation include the key reactions that produce acids. **[5]**

   iv) Stratospheric ozone depletion has been identified as a global concern. Briefly explain the key cause of stratospheric ozone depletion and the potential damaging effects that may result. **[5]**

Marking Scheme

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December 2008

1. (i) 6 (ii) 6 (iii) 8 marks; 20 marks total

2. (i) 8 (ii) 6 (iii) a) 2 b) 2 c) 2 marks; 20 marks total

3. (i) 6 (ii) 6 (iii) a) 4 b) 4 marks; 20 marks total

4. (i) 6 (ii) 6 (iii) 8 marks; 20 marks total

5. (i) a) 3 b) 5 (ii) 6 (iii) 6 marks; 20 marks total

6. (i) 6 (ii) 6 (iii) 8 marks; 20 marks total

7. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks; 20 marks total