NATIONAL EXAMS MAY 2009

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.

4. 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) Briefly explain what a population pyramid is and show using diagrams a typical expansive and constrictive population age structure. Briefly explain two (2) environmental implications, for a community over the next 20-years, due to an expansive population pyramid. [5]

ii) Identify three (3) specific environmental impacts on the hydrosphere due to increased urbanization. For each impact identify an engineering technology or strategy that may be used to minimize the associated environmental pollution. [5]

iii) Increased economic growth has been linked to direct increases in emissions of air pollutants. List three (3) engineering technologies or strategies to mitigate environmental pollution due to increased air emissions of particulates. [5]

iv) Assuming lignite (CH$_{0.9}$O$_{0.2}$N$_{0.02}$S$_{0.01}$) is used as a fuel burned in air at an equivalent ratio of 0.90. Determine the total amount of exhaust gas produced per mole of carbon combusted. Assume that combustion is complete and that the nitrogen in the lignite is all emitted as NO. [5]

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

i) An electric generating station, with an output of 10,000 MW, converts fuel energy into electrical energy with an efficiency of only 25 percent. The other part of the energy content of the fuel is rejected to the environment as waste heat. About 25 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 100 m$^3$/s and a temperature of 10 °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 · °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 acid 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) Dispersion [2]
b) Turbulent diffusion [2]
c) Hydrodynamic 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) A water tank with 2000 L of water and an air space has been contaminated with 1 mol of toluene that has partitioned 78% to the water and 22% to the air. As the environmental engineer on the site, you suggest that 2 kg of activated carbon be added to the contaminated water for treatment. Assume that the equilibrium partitioning of toluene between the solid and aqueous phase is described by the Freundlich isotherm given by:

\[ q_e = 100 \cdot C_e^{0.45} \]

where \( q_e \) = sorbed mass of toluene per mass of activated carbon (mg/g), 
\( C_e \) = concentration of benzene in the water (mg/L)

calculate the new equilibrium concentration of toluene in the water. Note that the molar weight of toluene (\( C_8H_5CH_3 \)) is 92 g/mol. [5]

ii) A steady-state equilibrium exists between ammonia and ammonium in a sewage polishing lagoon at 20 °C and a pH of 10. Given the total ammonia-nitrogen (TAN) concentration is 20 mg/L, calculate the percentage of ammonia-nitrogen (\( \text{NH}_3\text{-N} \)) and ammonium-nitrogen (\( \text{NH}_4^+\text{-N} \)) present in the lagoon. Assume the equilibrium ionization constant is 2.0 x 10^{-5} at 20 °C. [5]

iii) Hydrogen sulphide [\( \text{H}_2\text{S (aq)} \)] 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 95% removal (i.e., \( C_{out}/C_{in} = 0.05 \), where \( C_{out} \) is the steady-state outlet concentration for a constant inlet concentration \( C_{in} \)). [5]

b) If the single reactor is replaced with four (4) CSTRs of the same total volume in series, what is the total mean residence time (as a function of \( k \)) required to achieve the same 95% removal? [5]
4. Provide answers to the following questions related to sustainable development, life cycle analysis, principles of environmental quality objectives, standards and guidelines:

i) Briefly explain the connection between sustainable development and environmental engineering through an example. For an example you may consider: (1) impacts of manufacturing laundry cleaning products, (2) energy use by mobile phones globally which is estimated to reach 2 billion by 2010 or (3) use and re-use of buildings and associated land areas by considering the natural habitat disruption, biodiversity levels, runoff water quality, contaminated land removal, employee journeys linked to gas emissions, demolition waste salvage, green space usage and energy consumption. [5]

ii) Briefly explain the key parts of a life cycle analysis commonly used by engineers to compare viable options during environmental assessments or similar planning initiatives. You may use an example to answer this question.[5]

iii) Briefly explain how the use of receiving waters quality objectives protect the aquatic organisms and assist in reducing drinking water treatment costs. [5]

iv) Explain the key differences between standards and guidelines commonly used by environmental regulators. Provide an example of the use of each or explain when one regulatory approach may be preferred over the other. [5]

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

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

ii) Noise barriers are commonly used to reduce noise impacts in residential areas from trains and highway traffic. Briefly describe how noise barriers are sized and made to ensure that the necessary decibel reductions within a typical residential neighbourhood from a nearby highway or railroad. [5]

iii) Briefly explain the production of acid precipitation from the burning of a coal fired power. 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]
6. Provide answers to the following questions related to disinfection reaction kinetics, environmental ecology and water or wastewater treatment principles:

i) Using the figure below, estimate the percent decrease in the volume of the disinfection contact chamber when converting from NH₂Cl to HCl as a disinfectant designed to provide a 99.9% E. coli inactivation. Assume that the maximum rating for the HCl metering pump is 4 mg/L and the figure below provides the concentration versus time for 99.9% kill of E. coli. State any assumptions that you used in your calculation. [5]

![Disinfection Contact Chamber Diagram](image)

ii) A basic phenomenon of environmental ecology is the adverse impacts of contaminants in the aquatic system. With respect to effluent discharge from a sewage treatment plant to a lake, identify three (3) nitrogen species in the effluent and explain a potential environmental due to each nitrogen species. [5]

iii) Briefly explain the key engineering or design principle and primary function of filters in drinking water treatment plants. [5]

iv) Briefly explain how soluble nutrients (N or P) may be removed in an activated sludge sewage treatment plant. In your explanation, describe the key engineering principle and typical operating conditions to optimize the reduction of N or P. [5]
7. Provide answers to the following questions related to the application of technical and non-technical environmental principles of air pollution control, solid waste management, environmental impact assessment and environmental ethics:

i) Briefly describe two (2) different engineering technologies typically used to reduce or eliminate environmental impacts associated with volatile organic compound (VOC) emissions. In your description provide the engineering principle associated with each technology. [6]

ii) Briefly describe two (2) solid waste management (SWM) strategies normally adopted in industrialized countries as part of a SWM hierarchy. In your description, prioritize each practice from the most to the least environmentally viable option. [6]

iii) An environmental impact assessment (EIA) is important to identify the critical environmental issues during the construction of a new hydro-electric dam, a nuclear plant or coal-burning power plant to serve a large municipality of 2 million people. Briefly describe three (3) steps you would take, as an environmental engineer, in conducting an EIA for any one of the above facilities. In your description, provide a situation where environmental ethics play an important part during the EIA. [8]
Marking Scheme

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1. i) 5  ii) 5  iii) 5  iv) 5  marks; 20 marks total

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

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

4. i) 5  ii) 5  iii) 5  iv) 5  marks; 20 marks total

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

6. i) 5  ii) 5  iii) 5  iv) 5  marks; 20 marks total

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