NATIONAL EXAMS MAY 2012

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 *8.5in x 11in* 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.

5. 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, industrialization, urbanization and energy use as causes of environmental pollution:

   i) Western Africa has an expanding population pyramid or distribution. Briefly explain the important characteristic of this type of population distribution and two (2) main factors that will contribute to environmental pollution over the next 25-years. Provide two (2) engineering measures, related to energy use that may be implemented over the next 25-years to ensure energy sustainability for Western Africa. **[7]**

   ii) Briefly describe two (2) different types of air toxics, caused by industrialization, an effect to the natural environment from each toxic and a possible engineering solution to reduce or eliminate the impacts of each. **[7]**

   iii) Identify two (2) specific environmental impacts of increased per capita energy utilization. For each impact provide a well established technology that may be used to minimize the impact and explain the key engineering principle of each technology. **[6]**

2. Provide answers to the following questions related to material and energy balance for engineering systems under steady state and unsteady state conditions.

   i) A power plant, with an output of 20,000 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 5 °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 base spill (pH > 10) in the lake and how the carbonate system works to buffer the pH change. In your description, consider using relevant equations and schematics. **[6]**

   iii) Consider unsteady water flow in a conduit or channel where flow or depth varies with both time and location. Explain what engineering methods and/or principles you would use to predict the future performance of this system with unsteady flow. **[6]**

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

   i) Residuals are materials left over after reusing, recycling and reducing measures are exhausted. These residuals need to be handled in an environmentally responsible manner. Briefly explain the major benefits and challenges associated with landfilling, incineration and open burning of residuals associated with the solid waste management (SWM) practices. **[10]**

   ii) An environmental impact assessment (EIA) is important to identify the critical environmental issues during the construction of a new gold mine, building of a dam for electricity generation or forestry operation in a remote community in northern Canda. Briefly describe four (4) steps you would take as an engineer having been asked to conduct an EIA for any one of the above cases. In your description, identify a situation where environmental ethics would play an important role during the EIA. **[10]**

4. Assume that you are the consulting engineer hired by the owners to help them resolve issues in the scenarios described in (i) to (iii). For each scenario provide good engineering advice, to the owners, based on your understanding of air toxics, sustainable development, life cycle analysis, principles of environmental quality objectives, standards and guidelines:

   i) Air toxics discharged due to a high rate industrial product manufacturing and the need to meet strict ambient air standards imposed by the environmental regulators. **[7]**

   ii) Raw material harvesting to meet a high demand while ensuring a sustainable development for future generations. **[7]**

   iii) Implementing life cycle analysis to ensure an auto assembly plant remains profitable and environmentally "green". **[6]**

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

i) The mobility and fate of organic chemicals in the soil (*S*)-water (*W*) environment are directly related to their equilibrium partitioning coefficient (K_d) which is often estimated by the following equation. Explain the meaning and significance of the three (3) terms in the equation below: **[6]**

$$K_d = \alpha \cdot f_{OC} \cdot K_{OW}$$

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 25 mg/L, calculate the quantity of ammonia-nitrogen (NH_3-N) and ammonium-nitrogen (NH_4^+-N) present in the lagoon. Assume the equilibrium ionization constant is 1×10^{-5} at 20 °C. **[6]**

iii) The water contaminant hydrogen sulphide (H_2S) 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 90% 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}). **[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 90% removal? **[4]**

6. 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 organism remaining after time t_c
$N(0)$ = number of viable organism 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 95 % of the Salmonella was inactivated using a $C \cdot t_c$ value of 40 min·mg/L. Determine the reaction rate constant k, corresponding to a free chlorine concentration of 2 mg/L. [3]

b) Approximately what percentage of Salmonella organisms would be inactivated at a free chlorine concentration of 3 mg/L and a contact time of 10 minutes? [5]

ii) A basic phenomenon of environmental ecology is the conservation or cycling of nitrogen through plants, organisms and environmental systems. Briefly describe the main components of the Nitrogen Cycle and its role in sustaining life. In your description, include the important nitrogen species. [6]

iii) Consider a water treatment plant or industrial wastewater treatment plant and briefly explain the key function associated with the following: (1) sedimentation, (2) disinfection and (3) membrane filtration. In your explanation you may use diagrams, equations or narrative. [6]

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

i) Briefly describe two (2) remedial engineering solutions to alleviate the thermal impacts from cooling tower effluent being discharged to a cold water fishery water source. [5]

ii) Briefly describe two (2) noise reduction strategies to ensure the necessary decibel reductions within a typical residential neighbourhood that is located within 100m from an adjacent rail line. [5]

iii) Briefly explain how global warming may be caused by greenhouse gas emissions and give one (1) engineering measure that may be used to reduce emissions and potentially save our planet. [5]

iv) Briefly explain how acid precipitation is formed from the burning of fossil fuels and provide an engineering solution to minimise the environmental damage. [5]

Marking Scheme

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1. (i) 7 (ii) 7 (iii) 6 marks; 20 marks total

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

3. (i) 10 (ii) 10 marks; 20 marks total

4. (i) 7 (ii) 7 (iii) 6 marks; 20 marks total

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

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

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