National Exams December 2018

16-Chem-B10, Life Cycle Assessment (LCA)

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.
   Approved Casio or Sharp calculator is permitted.
   One double-sided aid sheet is permitted.

3. Question 1 MUST be completed. Any THREE (3) of the remaining four questions (i.e. Questions 2 to 5) constitute a complete exam paper. Only the first four questions as they appear in the answer book will be marked.

4. 28 marks are for Question 1, and 24 marks for each of Questions 2 to 5. Marks for question parts are indicated beside each question (i.e. [10], [5], etc.)

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

MANDATORY: Question 1 MUST be completed

Question 1 (28 Marks)

[10] (a) Discuss the importance of properly selecting the System Boundaries and Functional Unit for LCA-based comparisons of competing products / processes. Present your discussion within the context of an example which illustrates how the conclusions of a comparative LCA would be affected by the selection of different boundaries.

[6] (b) List the general Life-Cycle Phases associated with a product's development and distribution. Within the context of a real-world example, select one of the phases and discuss the inputs and/or outputs which would be investigated as part of a comprehensive LCA.

[6] (c) For the example you've provided in (b), discuss the likely Classification, Characterization and Evaluation results which would be obtained during the Life-Cycle Impact Assessment. List any assumptions you make regarding the nature and severity of the impacts in question.

[6] (d) CO_2, NO_X, SO_X and VOC's are commonly used as benchmark compounds for the relative assessment of environmental impact. Briefly describe the environmental concern associated with each of these compounds.

REMAINDER: Answer THREE (3) of the remaining four (4) questions. Be sure to indicate the question number in your Answer Paper.

Question 2 (24 Marks) Heat Integration

The following three process streams are being considered for heat integration:

Stream Name	Mass Flow kg/s	C_p kJ/(kg°C)	T_{in} °C	T_{out} °C
H101	11.0	3.00	190	50
C102	12.0	4.00	85	175
C103	8.0	2.50	50	115

The following Utilities are available within the facility in question:

Utility Name	ΔH kJ/kg	T_{in} °C	T_{out} °C
Low Pressure Steam (LPS)	-2000	160	159
High Pressure Steam (HPS)	-1700	250	249
Cooling Water (CW)	63	30	45

Assuming a minimum approach temperature of 10°, perform the following:

[4] (a) Determine the utility type and mass flow rate (kg/s) needed for each stream if no heat integration were performed.

[10] (b) Construct a Temperature Interval Diagram for this system, identifying the pinch point. Determine utility requirements (in kJ/s) above and below the pinch.

[10] (c) Sketch a diagram illustrating a Heat Exchange Network that could be used to integrate the heat in this system, including additional exchangers for utilities. Specify inlet and outlet temperatures, and utility flow rates in kg/s where applicable.

Question 3 (24 Marks)

A chemical in the wastewater from a manufacturing facility is sent to a publicly owned wastewater treatment facility at a rate of 5000 kg/day. The treatment process removes 90% of the organic before discharging to a local river. 50 kilometers downriver of the discharge point is the intake to a public drinking water treatment system, which removes 95% of the remaining chemical. Given the following information, complete each part of this question:

The river flows at a rate of 700,000 m^3 per day
The river velocity is 0.5 m/s
Organic solids concentration in suspended sediment: 40 mg / kg water
Biota concentration: 75 g per 100 m^3 water
Soil Sorption Coefficient: 150 kg in soil / kg in water
Bio-concentration Factor: 30 kg in biota / kg in water

[4] (a) Determine the relative concentration of the chemical in water, soil and Biota at the initial discharge point.

[5] (b) Discuss whether or not performance modifications are needed to either treatment system if this chemical had a regulated maximum concentration in drinking water of 10 ppt (by mass).

[5] (c) Discuss the potential impact on the local ecology if the LC50 for local organisms is 15 ppm (mg chemical/kg fish).

[10] (d) A number of gross simplifications have been applied in this analysis. Identify and discuss at least two additional environmental factors which would affect the chemical concentrations and describe how you might take a more comprehensive approach to solving this problem.

Question 4 (24 Marks)

Perform a streamlined LCA comparison on one of the following topics, **OR**, a topic of your choice which would offer a similar extent of discussion:

i) Nuclear, Coal, Natural Gas, Solar, and Wind-based power (pick two)
ii) Hybrid electric vehicles vs gas/diesel vehicles
iii) Pipeline vs. rail transportation of liquid fuel from western to eastern Canada
iv) Ammonia vs CFC refrigerants
v) Alternative methods for hand drying in a large public entertainment complex: paper towels vs electric hand drying

This is a broad-based essay-style question, with a length reflective of the relative marks assigned (expect to spend ~ ¼ of the exam length on this question).

Your response will be evaluated based on the following guidelines:

[5] Topic description, identification of suitable system boundaries, and appropriate selection of functional units and targeted outcome of your comparison.

[15] Application of engineering judgment in the scope of the system inventory and assignment and evaluation of impact factors. Breadth of discussion and depth of understanding of the selected topic. While accurate numerical values are not expected, relative assessments and identification of affected systems are required.

[4] Organization, legibility, cohesiveness of response.

It is important to note that your response will be assessed based on the analysis process and your ability to provide an impartial assessment, not based on the final conclusions reached.

Question 5 (24 Marks)

Answer THREE (3) of the following five questions. Only the first three answered questions will be marked:

[8] (a) Discuss the principles of Industrial Ecology, providing at least one detailed example illustrating its useful application.

[8] (b) Briefly describe the difference between a Tier 1, Tier 2 and Tier 3 environmental assessment of an industrial process, outlining the stages in development when each would be applied and the purpose and level of detail of each.

[8] (c) Define Hazard and Exposure in the context of Risk Assessment. In the context of health and safety, describe the routes of chemical exposure and discuss the importance of the dose-response curve in assessing toxicity and exposure risk.

[8] (d) Describe the procedure for performing an Environmental Release Assessment for an industrial process. Highlight the types of releases and associated environmental compartments, and briefly describe the methodology for estimating release rates.

[8] (e) Discuss one example for each of the following sectors which illustrates the application of LCA results: industrial operations, public policy, and business management/marketing.