ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2010 SESSION

Open-book examination
Calculators: Only authorized models
Exam duration: 3 hours

04-ENV-A6 Solid Waste Engineering and Management

1. Fundamentals (15 points)
   1.1. (5 points) In a leachates sample collected in a sanitary landfill, the ultimate biological oxygen demand (BOD_U) has been measured at 1400 mg/L. What is the BOD_5 if the BOD reaction specific rate is 0.09 d^{-1}?
   1.2. (3 points) Describe the method used to evaluate the chemical oxygen demand (COD). How COD and BOD_U are compared? Explain.
   1.3. (4 points) What do you need to calculate the diameter of a wastewater transport pipeline, if the flow rate is 5m^3/s and the maximum velocity 0.4m/s? Is the calculation influenced by the wastewater load in suspended solids and why?
   1.4. (3 points) Give an example of a 'Cost/Benefit' analysis and explain its usefulness.

2. Solid Waste Energy Valorisation (30 points)

A city has a population of 800 000 inhabitants. Each inhabitant generates daily 1.5kg of residues (yearly average). 50% of these residues is recycled, 30% is valorised energetically through pyrolysis, 15% is landfilled and 5% is composted. The average mass composition of the pyrolysed part is : 70% combustible, 12% inert inorganics and 18% humidity. Pyrolysis takes place without air. Below some additional data and hypotheses :

- The average atomic composition of the pyrolysed material is given by the following formula: $C_{12}H_{25}O_{11}N_{0.15}S_{0.02}$.
- Sulphur is converted to H_2S and nitrogen to N_2.
- Pyrolysis reactions are characterized by the following :
  - 25% w/w of the pyrolysed matter is transformed into carbon-rich solids; the hypothesis that these solids contain only carbon (C) and inert inorganics can be applied.
  - 15% w/w of the pyrolysed matter is transformed into gas which, apart from N_2 and the H_2S, is composed of CO, H_2, CO_2, CH_4, C_2H_4 with the following molar ratios: 1/0.5/0.3/1/0.5.
  - The remaining 60% of the pyrolysed matter is transformed into a liquid product.

2.1. (10 points) Calculate the annual quantity of the carbon-rich solids and of the liquid products.

2.2. (7 points) If the Higher Heating Value (HHV) of the liquid product is 20 MJ/kg and the liquid product is used to produce energy with an efficiency of 80% what is the available average thermal power? Note: If you did not calculate the quantity of the liquid product, choose an arbitrary calculation basis.

2.3. (7 points) What quantity of GreenHouse effect Gases (GHG), given in CO_2 equivalent, is emitted per year, if half of the pyrolysed material carbon is converted in CO_2 and 1/20 in CH_4?

2.4. (6 points) Use 'thump rules' to estimate roughly the biogas produced by the landfilled material. What amount of energy can be recovered from this biogas?

3. Anaerobic Composting (30 points)

As indicated in Question 2, this city operates a composting center for 5% w/w of its waste. The following data are available :

- Composition :
  - 80% of the dry solid material is compostable (putrescible material).
  - The average humidity of the material arriving at the composting center is 40% w/w.
  - The global composition of the 'dry compostable solid material' is given approximately by the formula: $C_{15}H_{27}O_{10}N_{0.15}S_{0.02}$.
- Under anaerobic conditions, these putrescible materials decompose in CO_2, CH_4, H_2O, H_2S and NH_3. The average molar ratio CO_2/CH_4 is 0.8.

Estimate the average annual quantity and composition of the produced biogas at atmospheric (760mmHg) pressure and 15°C. If the combustion heat of CH_4 at these conditions is 890 MJ/kmol CH_4, and this energy can be converted in electricity with an efficiency of 30%, calculate the average available MW_{th}.

4. Sanitary landfills (20 points)

4.1. (7 points) Describe briefly (10 lines max) a method used to collect leachates from sanitary landfills.

4.2. (4 points) Describe the aerobic trickling bed reactor used as technology for the biological treatment of leachates.

4.3. (4 points) Give schematically the bloc flow diagram of an aerobic leachates biological treatment (from the entrance of the leachates to the exit of the process effluents).

4.4. (5 points) Which is the most commonly used technique for the removal of soluble heavy metals from leachates? Describe briefly the 3 in-series treatment modules used in this technique.

5. Dangerous waste and contaminated sites (10 points)

5.1. (4 points) Describe the dangerous waste stabilization method of thermoplastic micro-encapsulation. Which are its main advantage and its inconvenients?

5.2. (3 points) Describe briefly the method of thermal destruction used for contaminated sites remediation (max 10 lines).

5.3. (3 points) Which are the characteristics of a regulated sanitary landfill for dangerous waste? Which are the advantages and disadvantages of this technique?