ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2013 SESSION

All documentation permitted
Calculators: Only authorized models permitted
Exam duration: 3 hours

Exam 04-ENV-A6 : Solid Waste Engineering and Management

1. Fundamentals (20 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 1800 mg/L. What is the BOD_5 if the BOD reaction specific rate is 0.09 d^{-1}?
   1.2. (3+2 points) Hydrologic cycle of a landfill: Calculate the infiltration rate for a sanitary landfill soil layer with a 100 cm^2 cross sectional area, a standing water depth of 25cm and a hydraulic conductivity of 10^{-7} cm/s. Explain what is 'Evapotranspiration' and 'Surface water runoff' and what you need to quantify them.
   1.3. (5 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. (5 points) Explain the use of the statistical values 'Average' and 'Standard Deviation' in the case of data obeying the law of normal distribution to validate your measurements and conclusions.

2. Solid Waste Energy Valorisation (30 points)

A city has a population of 700 000 inhabitants. Each inhabitant generates daily 1.3kg of residues (yearly average). 55% of these residues is recycled, 25% is valorised energetically through gasification+reforming, 15% is landfilled and 5% is composted. The average mass composition of the gasified part is: 75% combustible, 5% inert inorganics and 20% humidity. Gasification takes place at 32% of stoichiometric oxygen. Below some additional data and hypotheses:

- The average atomic composition of the gasified material is given by the following formula: $C_{12}H_{20}O_{10}N_{0.15}S_{0.02}$.
- Sulphur is converted to SO_2 and nitrogen to N_2.
- Gasification+Reforming reactions are characterized by the following :
  - 8% w/w of the gasified material is transformed into carbon-rich solids; the hypothesis that these solids contain only carbon (C) and all inert inorganics can be applied.
  - 95% w/w of the gasified material is transformed into gas which, apart from N_2 et le H_2S and after water condensation, is composed of CO, H_2, CO_2, CH_4 with the following molar ratios: 1/0.5/0.3/0.05.

2.1. (5 points) Calculate the annual quantity of the carbon-rich solids.
2.2. (10 points) If the Higher Heating Value (HHV) of the gaseous product is 7 MJ/kg what is the available average thermal power?
2.3. (10 points) What quantity of Green House effect Gases (GHG), given in CO_2 equivalent, is emitted per year, if 1/3 of the gasified carbon is converted into CO_2 and 1/20 in CH_4? Note: If you cannot calculate the exit flow rate make the calculation on a arbitrary basis.
2.4. (5 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 (20 points)

As indicated in Question 2, this city operates a composting center for 15% w/w of its waste. The following data are available:

- Composition :
  - 75% of the dry solid material is compostable (putrescible material)
  - The average humidity of the material arriving at the composting center is 45% w/w.
  - The global composition of the 'dry compostable solid material' is given approximately by the formula: $C_{13}H_{28}O_{12}N_{0.15}S_{0.02}$.
- 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 0.9.

3.1. (13 points) Estimate the average annual quantity and composition of the produced biogas at atmospheric (760mmHg) pressure and 15°C.
3.2. (7 points) 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 38% calculate the average available MW_{th}.

4. Sanitary landfills (15 points)

4.1. (5 points) Using the first-order decay model method, estimate the yearly gas generation for a landfill with the following characteristics:
- Open for 30 years.
- Still operative (accepting waste) at a rate of 25 000 tn/year.

Note: For the k and L_0 values make a reasonable hypothesis.
4.2. (5 points) What physical and biological principles are involved in the trickling filter and anaerobic pond treatment systems.
4.3. (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 (15 points)

5.1. (4 points) Describe the dangerous waste stabilization method of vitrification. Which are its main advantage and its inconvenients?
5.2. (6 points) Sketch a deep well injection system and explain briefly its various components.
5.3. (5 points) Which are the characteristics of a regulated sanitary landfill for dangerous waste? Which are the advantages and disadvantages of this technique?