Version AAT/2

EGT3
ENGINEERING TRIPOS PART IIB

Thursday 30 April 2.00 – 3.30

Module 4D14

CONTAMINATED LAND AND WASTE CONTAINMENT

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 4D14 Contaminated Land and Waste Containment data sheet (3 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 Landfills are engineered sites that receive Municipal Solid Waste (MSW) from various communities. Different types of reactions can take place within the waste deposited in landfills. In that context:

(a) Explain the term leachate. [10%]

(b) Explain the terms BOD and COD. Why are these important in the context of a landfill? [15%]

(c) Under what conditions do you expect inorganic and organic reactions to take place within a waste deposited in a landfill? Give two examples of the products of these reactions that you would expect to see. [15%]

(d) The population of a new township in Australia will reach 8000 by December 2015. The population is expected to grow at a rate of 5% per calendar year until December 2017 and thereafter at a rate of 3%. It is expected that on average each household has 2.5 persons and that each household produces around 30 kg of municipal solid waste (MSW) per week. You are tasked with sizing a suitable landfill that can receive waste from January 2016 until December 2020. The waste deposited in the landfill will be compacted to a unit weight of 6.5 kN m^{-3}.

(i) Determine the plan area of a landfill cell that can receive this waste assuming that the depth of waste below ground level is 10 m and you are allowed to deposit waste to a height of 2.5 m above ground level. . [30%]

(ii) The landfill operator charges 50 AUD per tonne for non-hazardous waste and 120 AUD per tonne for hazardous waste. Assuming that around 2% of the MSW is hazardous, estimate the annual revenue that the operator will receive until 2020. [20%]

(iii) If the landfill tax is 25 Australian Dollars (AUD) per tonne for non-hazardous waste and 75 AUD per tonne for hazardous waste, how much annual revenue will the landfill generate for the local government until 2020? [10%]

2 (a) Explain briefly the following forms of geosynethics, identifying their function and their uses in landfill components: [20%]

(i) Geomembrane;
(ii) Geotextile;
(iii) Geogrid;
(iv) Geosynthetic clay liner (GCL)

(b) What is the main source of leakage through a geomembrane? How can one estimate the leakage rate? [10%]

(c) Describe the hydro-geological conditions you would look for before siting an injection well. How would you estimate the areal extent that the injection well will influence? [15%]

(d) A water reservoir is located 1 km from a chemical factory. The hydraulic gradient that drives the ground water flow was found to be 0.4 in the direction of the water reservoir. The natural soil in this area is silty sand with a hydraulic conductivity of 9×10^{-5} m s^{-1} and a porosity of 0.45. Calculate the time it takes for any accidental spillage from the chemical factory to reach the water reservoir. [15%]

(e) A slurry wall is to be constructed around the water reservoir to protect it from contamination. The cross-section of the slurry wall extends to the base of the reservoir where it has a width of 2 m. Assume the water table is at the ground surface. Bentonite slurry with a unit weight of 12 kN m^{-3} is to be used during construction. The backfill material mixed with bentonite and the silty sand has a unit weight of 14 kN m^{-3}, angle of internal friction of 34^{o} and a hydraulic conductivity of 4.6×10^{-6} m s^{-1}. A filter cake that is 4 mm thick and is expected to form, has a hydraulic conductivity of 8×10^{-8} m s^{-1}.

(i) Determine the factor of safety against slope failure during construction of the slurry wall. [15%]

(ii) Determine the overall hydraulic conductivity of the slurry wall. [15%]

(iii) How long will the contamination from the chemical factory take to reach the water reservoir following the construction of the slurry wall? [10%]

3 Petroleum products, which are a complex mix of hundreds of chemical compounds with different properties, are common pollutants encountered on many contaminated sites. They are usually classed into five groups: gasoline, diesel, kerosene, heating oils and lubricating oils, mainly according to their boiling point range. The individual compounds also have different Henry's Law constants and vapour pressures, which are commonly employed when selecting appropriate remedial measures.

(a) What is the major issue with ground contamination with petroleum products? [10%]

(b) List five potential pathways to human receptors from such contamination. [10%]

(c) Benzene is a particular toxic hydrocarbon compound with no threshold effect. Explain the meaning and impact of a 'no threshold effect'. [10%]

(d) Define Henry's Law constant and vapour pressure, and explain how they can determine whether a petroleum product is amenable to soil vapour extraction. [10%]

(e) What are the most favourable soil conditions for soil vapour extraction? [10%]

(f) Explain how the solubility of a petroleum compound can hinder its extraction from the ground via air sparging and use a particular petroleum compound to illustrate your explanation. [10%]

(g) Compare the suitability of the five groups of petroleum products above for soil vapour extraction and bioremediation. [10%]

(h) Briefly explain the main differences between soil vapour extraction and bioventing in relation to their treatment of petroleum products. [10%]

(i) Pump and treat, air sparging and a permeable reactive barrier system are being considered for the control and remediation of a groundwater hydrocarbon contamination plume. Briefly discuss when each of the methods would be more suitable than the other two. [20%]

4 Accurate sampling and analysis of pollutant compounds during a chemical site investigation on contaminated land are crucial in understanding the nature and extent of the contamination on a particular site and in the design of the most appropriate remediation strategy.

(a) Both laboratory and field analyses can be performed on contaminants. Compare and contrast the advantages and disadvantages of both approaches. [20%]

(b) Briefly explain the principles of operation of one technique employed for each of the two approaches of laboratory and field analysis. [20%]

(c) List five potential sources of uncertainties associated with the sampling and analysis of pollutants from a contaminated site. [20%]

(d) Despite strong sustainability pressures for the implementation of in-situ treatment techniques on contaminated sites, in-situ containment is sometimes considered as the most appropriate solution on particular sites. Give four reasons why this is likely to be the case. [20%]

(e) What are the main design requirements for and characteristics of a cover system. Give an example of when a cover system would be an ideal remedial measure for a contaminated site. [20%]

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4D14 Contaminated Land and Waste Containment

2015

Numerical Answers

Q1 d(i): 3413 m^2

(ii): 1,452,921 AUD

(iii): 734,938 AUD.

Q2 d: ~4.7 months

e(i): 1.91

(ii): 3.74 x 10^{-6}m/s

(iii): ~9.5 years