Version AAT/2

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 23 April 2019 09.30 to 11.10

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: Module 4D14 Data Sheets – Waste Containment (3 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

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

1 A site, contaminated with a cocktail of heavy metals and organics present both in the soil and groundwater, is being considered for redevelopment. The ground conditions consist of ~6m of a sandy soil overlying a sand and gravel aquifer. A chemical site investigation identified nickel, arsenic and benzene as the main contaminants. The site developer plans to use the Contaminated Land Exposure Assessment (CLEA) model to carry out a risk assessment on the site.

(a) What does the CLEA model do and what are its outputs? [10%]

(b) Explain the difference between chemicals with and without a threshold effect. [10%]

(c) As part of the analysis using the CLEA model, the following information was revealed:

- the oral Tolerable Daily Soil Intake (TDSI) of nickel is 2.7 mg kg^{-1} bw d^{-1}.
- the Index Dosage (ID) for arsenic is 0.3 mg kg^{-1} bw d^{-1} based on drinking water standards.

Explain the meaning of the above findings in the light of the following information. The oral Tolerable Daily Intake (TDI) of nickel for an adult is 5mg kg^{-1} bw d^{-1}, and there is no such threshold value for arsenic. The oral Mean Daily Intake (MDI) by an adult of nickel and arsenic is 2.3 mg kg^{-1} bw d^{-1} and 0.07 mg kg^{-1} bw d^{1-} respectively. [20%]

(d) What are the most relevant exposure pathways on this site to potential receptors? [10%]

(e) What are the three different land uses that the CLEA model considers? Discuss in the context of your findings to part (c). [10%]

(f) What advice would you give the new site developer who has not dealt with a contaminated site before? [10%]

(g) Suggest and briefly describe one remediation technique to treat the contaminated soil and another to treat the contaminated groundwater at the site. [20%]

(h) What factors did you take into account in your selection of the two remediation measures in part (g)? [10%]

2 (a) Which groundwater contaminants might you expect to find on an inner city development site whose previous use had been:

(i) a garage (refuelling and repair shop)

(ii) a clothes dry-cleaning business

(iii) a rifle shooting range. [15%]

(b) Suggest which of the above sites is likely to have contamination below 10 m, giving reasons for your answer. [10%]

(c) What type of contaminants can be analysed in the laboratory by:

(i) Gas chromatography (GC)

(ii) Inductively coupled plasma optical emission spectrometry (ICP-OES)?

Give three examples of contaminants for each technique. [25%]

(d) Bioremediation and phytoremediation are two biological approaches to the remediation of contaminated sites. Compare and contrast the two methods for application to a site contaminated with pure hydrocarbons. [25%]

(e) At a strategic level, the remediation of contaminated land is seen to support the goal of sustainable development.

(i) Explain why this is the case. [10%]

(ii) Give examples of the wider environmental impacts of remediation activities, both positive and negative. [15%]

3 (a) Explain what types of reactions can occur between the clay liner of a landfill and the waste deposited in it. What effect can the products of these reactions have on the performance of the landfill liner? [15%]

(b) What is a 'diffused double layer' of water in between clay particles? How can this affect the performance of a clay liner if hydrocarbons are present in the waste. [15%]

(c) At a site in Norwich a vertical slurry wall is to be constructed in a silty clay layer with a saturated unit weight of 19.6 kN m^{-3} and undrained shear strength of 25 kPa. The permeability of the silty clay was determined to be 4.4×10^{-5} m s^{-1}. Calculate the theoretical limit on the unsupported vertical cut that can be made in this soil. Can cuts of this depth be used in practice? Discuss. [15%]

(d) The depth of the slurry wall required to form a vertical barrier against contaminant migration was determined to be 12 m excluding the keying depth. The construction machinery is expected to apply a surcharge of 20 kPa on the ground surface. Estimate the unit weight of the soil-bentonite slurry required to maintain stability of the trench if:

(i) the water table is well below the 12 m depth of the slurry wall

(ii) the water table is at the ground surface.

[20%]

(e) The permeability of the backfill into the soil-bentonite slurry was determined to be 1.6×10^{-7} m s^{-1}. The thickness of the slurry wall is to be 1.5 m. Assuming that a 4 mm thick filter cake with a permeability of 2.8×10^{-10} m s^{-1} forms, estimate the overall permeability of the slurry wall. Does the thickness of the filter cake have an important effect on the overall permeability? Comment. [25%]

(f) Briefly describe the important factors that govern the stability of the slurry wall. [10%]

4 (a) A landfill with a plan area of 400 m × 500 m is to be constructed near Liverpool. The rainfall in Liverpool is approximately 1300 mm $year^{-1}$ and 15% of this is expected to be infiltrated through the top cover of the landfill. You may assume that an equal amount of leachate will be produced due to the reactions within the waste.

The thickness of the drainage layer at the base is 1.2 m and its permeability is 6.0×10^{-2} m s^{-1}. The porosity of the drainage layer is 0.4. You may assume that the level of leachate will be kept just below the top surface of the drainage layer. PVC pipes with an outer diameter of 120 mm and wall thickness of 10 mm are available at this site. The PVC pipes can be designed to run half full but the flow velocity should be limited to 0.25 m s^{-1}. The natural slope at the site is 1:1500 in the width direction as shown in Fig. 1.

Design a suitable Leachate Collection and Removal (LCR) system for this landfill. Sketch the plan and sectional views of the landfill showing the LCR system. [60%]

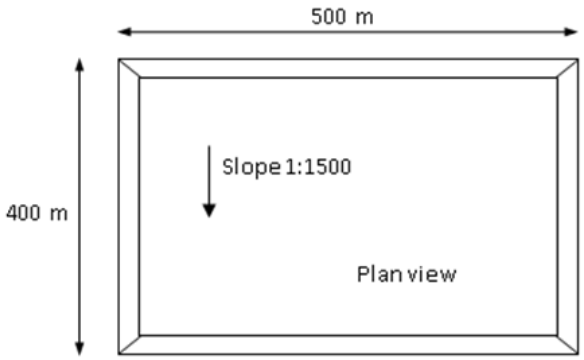

Fig. 1.

(b) Explain how abysall plains and abysall hills affect the area of spread of the waste deposited in the ocean. [20%]

(c) Describe briefly how waste can be disposed off into underground caverns formed by solution mining if the waste is:

(i) lighter than brine solution

(ii) heavier than brine solution.

[20%]

END OF PAPER

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Numerical Answers

3. (c) 5.1m

(d) (i) 14.6 kN/m^3

(ii) 14.6kN/m^3.

(e) 3.95 x 10^{-8} m/s.

4. (a) Pipe size of 200mm diameter.