Version AAT/3

EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 27 April 2016 2 to 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 Sheets (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 (a) How would you classify waste based on its origin? Give one example of each class of waste. [10%]

(b) What is the main function of the top cover of a landfill? What criteria would you use to design such a top cover? [15%]

(c) How does the design of a top cover change depending on whether hazardous or non-hazardous waste is being deposited in a landfill? [15%]

(d) A petro-chemical factory is planned to be sited at a distance of 1.2 km from a potable water reservoir. Site investigations revealed that bedrock is located 10 m below the ground. The soil stratigraphy consists of a silty, sand layer with a void ratio of 0.6, extending from the ground surface to the bedrock. Two boreholes that were located 20 m apart revealed a potential head difference of 2.75 m with groundwater flow in the direction from the factory towards the water reservoir. The hydraulic conductivity of the silty sand is 3.2×10^{-4} m s^{-1}.

(i) Estimate the time it takes for an accidental spillage at the petro-chemical factory to reach the water reservoir. Comment on whether such spillage can be a cause for concern. [20%]

(ii) Comment on the remedial measures that may be taken to protect the water reservoir from becoming contaminated. [10%]

(e) A slurry wall that is 1 m thick is to be constructed upstream of the water reservoir to protect it from accidental spillage as described in part (d). A filter cake thickness of 3 mm is expected to form on the sides of the slurry wall. The backfill material and the filter cake have hydraulic conductivities of 3.3×10^{-8} and 1.8×10^{-9} m s^{-1} respectively.

(i) Calculate the overall hydraulic conductivity of the slurry wall. [15%]

(ii) Estimate the time it takes for the accidental spillage to reach the water reservoir once the slurry wall is constructed, if the potential head difference described in part (d) now reduces to 0.75 m. Comment on the effectiveness of this protection scheme. [15%]

2 (a) How may the ocean environment affect water disposed into the ocean? [10%]

(b) Describe briefly how the seabed topography can affect the spread of waste disposed into the ocean. [15%]

(c) Describe the siting criteria for locating a high level radioactive waste repository. [10%]

(d) List the advantages and disadvantages of using a 'domal salt' formation to locate a high level radioactive waste repository. [15%]

(e) The Milton Waste Services near Cambridge are planning to build a landfill cell with a plan area of 250 m x 400 m. The average rainfall at this site is 650 mm per annum. Assume that 10% of the rainfall will end up as leachate in the landfill and that an equal amount of leachate is produced due to in-waste reactions. The porosity of waste may be taken as 0.5. The thickness of the drainage layer at the base is 0.5 m and its permeability is 5.5×10^{-2} m s^{-1}. The design brief assumes that the level of leachate will be kept at 50 mm below the top surface of the drainage layer. Design a leachate collection and removal system (LCRS) for this landfill cell. You may assume that the pipes will be made from PVC and run quarter-full with a limiting flow velocity of 0.25 m s^{-1}. The natural slope at the site in the short direction is 1:1500. Sketch the layout of the LCRS system in both plan and elevation. [50%]

3 A contaminated site at an anonymous location in the UK was remediated in 1995. The site is 6 ha in size and is bound by a river along one side of its roughly square plan area. The ground conditions consist of 4-5 m of made ground, overlying 3-4 m of natural sand and gravel deposits, which in turn are underlain by bedrock. The groundwater table is at the top of the sand and gravel, and the groundwater flow is towards the river. Both the site soils and groundwater are contaminated with a cocktail of organics and heavy metals. Documented evidence showed that no signs of contamination in the river water were detected prior to remediation. Because of the wide range of contaminants and the high concentration and heterogeneity of the contamination, the remedial solution adopted was a cement-bentonite slurry wall that was constructed around the whole site perimeter and which was keyed into the bedrock. However a recent chemical site investigation in both the soil and groundwater detected signs of contamination outside the site boundary.

(a) Suggest four factors that could have caused this external contamination. [20%]

(b) On closer inspection, it was found that this external contamination was mainly of organic contaminants. Suggest two possible reasons for this. [10%]

(c) The organics detected outside the site boundaries were found not to be the same as the organic contaminants within the site. Suggest two possible reasons for this. [10%]

(d) What chemical investigation would you suggest to further investigate the problem of the external presence of contamination? [15%]

(e) Techniques for soil sampling and analysis of contaminant compounds have significantly improved over the last 20 years. What specific aspects would you focus on in a new set of sampling and analysis specifications? [20%]

(f) The original remediation project used the ‘ICRCL trigger concentrations’, developed by the Interdepartmental Committee on the Redevelopment of Contaminated Land, which were withdrawn in 2002. What potential new unidentified problems could arise from their use at the time. [10%]

(g) Considering that remediation technologies have also advanced significantly over the last two decades, what repair and/or further remediation strategy would you recommend for this site and why? [15%]

4 (a) An underground storage tank is leaking petroleum hydrocarbons. Explain, with the use of a sketch, what would happen to the leak over a number of years in terms of the movement and fate of the various hydrocarbon compound groups in the soil and groundwater environment? [20%]

(b) Draw a schematic of the various aerobic and anaerobic zones that will form within the groundwater region as a result of the petroleum plume spread and give an example of a reaction or a process that will take place in each zone. [20%]

(c) Describe two different chemical methods that can be used for the analysis of short and long chain organic compounds present in a petroleum hydrocarbon product. [30%]

(d) What are the advantages and disadvantages of the following remediation techniques in dealing with the contamination problem in part (a), if the site is to remain operational, and how would you decide when to employ each technique in preference to the others:

(i) a combination of soil vapour extraction and air sparging;

(ii) a combination of ex-situ and in-situ bioremediation;

(iii) monitored natural attenuation. [30%]

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4D14 Contaminated Land and Waste Containment

2015-2016

Numerical Answers

1. (d) (i) 118.4 days

   (e) (i) 2.97×10^{-8} m/s

   (ii) 12,799.2 years