Version AAT/8

EGT3
ENGINEERING TRIPOS PART IIB

Friday 28 April 2023 9.30 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 Sheet – 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.

You may not remove any stationery from the Examination Room.

1 (a) Explain briefly what type of reactions occur within Municipal Solid Waste (MSW), giving examples of the products that can form. Consider all states in which MSW can be present. [15%]

(b) What type of reactions occur at the clay liner – MSW interface in a landfill? What engineering implications can these reactions have? [15%]

(c) What types of hazardous waste would you expect to arrive at a landfill site when the waste is collected from residential areas? [10%]

(d) The new township of Northstowe near Cambridge is planned to have a total of 10,000 houses. In the first phase 6000 houses were constructed and are fully occupied. The number of people per house on average will be 2.4. Each person, on average, is expected to produce solid waste of 28 kg and wastewater of 120 litres per week. The population is expected to grow at a rate of 8% for the first three years and at a reduced rate of 5% from thereon. At the end of year 3, the 4000 houses of phase 2 are completed and are fully occupied.

(i) Design a landfill cell that is able to receive waste for a period of 5 years i.e., 2 years after the completion of the second phase. Assume the waste will be compacted to unit weight of 8.5 kN m^{-3}. [20%]

(ii) Estimate the quantity of wastewater that needs to be treated. [10%]

(iii) Estimate the quantities of $CaCO_3$, Ca and Mg if the average concentration of these chemicals in the wastewater are 7500 mg L^{-1}, 2200 mg L^{-1} and 730 mg L^{-1} respectively. [10%]

(iv) Estimate the revenue generated for the landfill operator if they charge £40 per tonne of MSW and £150 per tonne of hazardous waste, if the MSW contains about 5% hazardous waste. [10%]

(v) Estimate the revenue generated for the district council if they levy a landfill tax of a flat £15 per tonne for all the waste types. [10%]

2 (a) You are designing a cut-off wall to protect a drinking water reservoir from contaminants in the groundwater. The site has an 8 m thick silty clay layer with a hydraulic conductivity of 3.25×10^{-7} m s^{-1}, overlying bedrock. The unit weight of the silty clay is 17.5 kN m^{-3} and its undrained shear strength is 50 kPa. A slurry wall with a nominal thickness of 1 m, is to be designed. The surcharge exerted by the construction machinery will be 40 kPa.

(i) Estimate the maximum unsupported height of the vertical trench. [10%]

(ii) Estimate the density of the slurry that would be required to keep the slurry wall open to the depth of 8 m for the case when the water table is at the bedrock level and then for the case when the water table is at the surface. [15%]

(iii) A filter cake of 3 mm thickness with a hydraulic conductivity of 6.5×10^{-9} m s^{-1} is expected to form. Determine the overall hydraulic conductivity across the wall, if the backfill material has a hydraulic conductivity of 4.25×10^{-8} m s^{-1}. Comment on effectiveness of the slurry wall. [15%]

(b) Describe four types of geosynthetics that are used in landfills and explain briefly their functional use. [20%]

(c) Explain with a suitable sketch how toxic waste can be stored in solution-mined caverns. [20%]

(d) Considering ocean topography, how would you choose potential locations for the case of disposal of liquid waste and for the case of low-level radioactive wastes, into the ocean. [20%]

3 (a) Drainage from an old copper mine was shown to contain almost 100mg/L of copper. The water ambient conditions were: temperature 10 ºC, pH = 6. Suggest a convenient way of reducing the concentration to a safer, more environmentally acceptable level. Explain how it would work. [20%]

(b) Name a laboratory method for measuring the concentration of copper in water and suggest a direct method for use in field analysis, for measuring copper in soils. [10%]

(c) Compare the advantages and disadvantages of laboratory and field analysis for the survey of a new construction site which has issues of previous industrial pollution. [20%]

(d) The table below presents typical values of a number of parameters related to the human Daily Intake (DI) and corresponding Soil Guideline Values (SGVs), for three different contaminants, as derived from the Contaminated Land Exposure Assessment (CLEA) model.

	Nickel	Arsenic	Benzene
TDI_{oral} and $*TDI_{inh}$ ($\mu g\ kg^{-1}$ bw d^{-1})	5	N/A	*N/A
MDI_{oral} and $*MDI_{inh}$ ($\mu g\ kg^{-1}$ bw d^{-1})	(160 $\mu g\ d^{-1}$) 2.3 (8 for child)	(5 $\mu g\ d^{-1}$) 0.07 (0.19 child)	*(200 $\mu g\ d^{-1}$) *2.9 (7.4 child)
$TDSI_{oral}$ and $*TDSI_{inh}$ or ID** ($\mu g\ kg^{-1}$ bw d^{-1})	2.7 (1 for child)	0.3** (DWS)	~0.29** (DWS)
SGV Residential (mg kg^{-1} dry soil)	130	32	0.33
SGV Allotment (mg kg^{-1} dry soil)	230	43	0.07
SGV Commercial (mg kg^{-1} dry soil)	1800	640	95

(i) Define the terms TDI, MDI, TDSI, ID included in the table above. [15%]

(ii) Explain how each of the numbers for each of the three contaminants was arrived at. [25%]

(iii) Explain the relevance of the values in the table when remediating a site that contains all three contaminants. [10%]

4 In-situ remediation of contaminated land is generally achieved through either containment strategies or treatment technologies. Containment restricts the movement of contaminants outside the site. Physical treatment technologies, e.g. soil vapour extraction (SVE), exploit differences in physical properties between contaminants and the soil/water system while biological treatment technologies, e.g. bioventing, use natural microbes to degrade contaminants. Chemical treatment technologies use oxidising or reducing agents to convert contaminants to less toxic compounds.

(a) Briefly describe the operating principles of SVE and of bioventing. [10%]

(b) What are the most favourable contaminated site conditions for the application of SVE and of bioventing? [10%]

(c) What are the main similarities and differences between SVE and bioventing. [10%]

(d) For each of the following three petroleum products: gasoline, diesel and lubricating oils, which of the two techniques in (a) would be more suitable and why? [10%]

(e) What are the risks associated with both approaches and what signs would you look for on a site to check if there are problems with the performance of those techniques? [10%]

(f) If a chemical investigation revealed organic contamination both above and below the groundwater level, what remediation approach would be recommended? [10%]

(g) Give an example of a contaminant class which is more effectively remediated using chemical processes, rather than SVE or bioventing, explaining why and how this could be implemented in practice. [10%]

(h) What are the most favourable site conditions for chemical treatment and how best is it applied in situ? [10%]

(i) What is the difference between cut-off walls and permeable reactive barriers in the application of a containment system on a contaminated site? [10%]

(j) When would it be appropriate to combine a physical, biological or chemical remediation technique with a containment approach and why? Illustrate your answer with an example. [10%]

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Engineering Tripos Part IIB/EIST Part II
FOURTH YEAR

Module 4D14: Contaminated Land and Waste Containment

Data Sheets - WASTE CONTAINMENT

Population rise:

$$P_{new} = P_{current}\left[1 + \frac{r}{100}\right]^{n}$$

where r is percentage rate of increase of population, n is the number of years.

Darcy's Law:

$$v = K\ i$$

where K is the hydraulic conductivity and i is the hydraulic gradient.

Manning's formula for flow velocity in Open Channels:

$$V = \frac{1.486}{n} R_h^{\ 2/3} . S^{1/2}$$

where R_h is the hydraulic radius defined as **Area** divided by **Wetted Perimeter**, n is the Manning's constant and S is the slope.

Values of Manning's constant:

Material of pipes	n
PVC	0.01
HDPE	0.009
Concrete	0.016 ~ 0.017
Steel	0.016

Flow through pipes:

$$Q = A\,V$$

where A is the cross-sectional area and V is the velocity of flow.

Allowable deflection of HDPE pipes:

$$\Delta y = 0.0025.\frac{D^2}{t}$$

where D is the diameter of the pipe in m and t is the wall thickness of the pipe in m.

LCRS analysis:

Assuming leachate will distribute equally between the pipes under gravity flow; we have following relations;

$$Q = q.\frac{L}{2}$$

$$Q = 2k.\frac{h_{\max}^2}{L}$$

$$L = 2h_{\max}\sqrt{\frac{k}{q}}$$

Q - flow into the drainage layer
q - flow rate into the drainage layer
k - permeability of the drainage layer
L - spacing between the drainage pipes
h_{max} - maximum height to which leachate is allowed to raise in the drainage layer (usually taken as the thickness of the drainage layer so that at worst location the leachate is just at the interface between the waste and the drainage layer)

Injection well radius – Empirical correction for diffusion:

$$r' = r + 2.3\sqrt{\left(D_d r\right)}$$

where

r is the radius of influence obtained by volumetric method
r' is the corrected radius of influence
D_d is the diffusion coefficient

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Michaelmas 2013