ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II

Tuesday 22 April 2003 2.30 to 4

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.*

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

1 It is found that PCE (Tetrachloroethylene) has been leaking from a storage tank into the subsurface for the past 20 years. The spill generated contamination of the sandy aquifer, which had soil porosity of 0.4 and bulk density of 1.8 g/cm^3. For site investigation, eight ground water samples were taken near the leakage area. The measured PCE concentrations are listed in Table 1. The sample mean and unbiased standard deviation are 16.1 mg/L and 8.7 mg/L, respectively.

(a) Using the maximum value test, show that the largest value in the table should not be treated as an outlier. [20%]

(b) Calculate the normalised upper bound concentration for 95 percentile confidence. [20%]

(c) By comparing the normalised upper bound concentration to the maximum solubility value of PCE, discuss whether any nonaqueous phase PCE is left near the leakage area. [20%]

(d) The soil contained 2 % of organic carbon. Using the normalised upper bound concentration calculated in (b), estimate the PCE concentration adsorbed on the soil around the leakage area. Assume that adsorption follows a linear isotherm model. [20%]

(e) The hydraulic conductivity and gradient of the sandy aquifer were found to be 40 m/day and 0.01, respectively. Estimate the travel distance of PCE downstream. [20%]

Table 1. Measured concentrations of ground water samples

Sample No.	Concentrations in mg/L
1	8
2	16
3	13
4	9
5	21
6	12
7	35
8	15

2 Gasoline has been leaking from an underground storage tank at a petroleum station.

(a) What types of chemicals are contained in gasoline? [10%]

(b) How do the chemicals in the nonaqueous phase move in the subsurface? Draw a schematic diagram. [15%]

(c) What are the potential pathways to harm the receptor (human)? Identify at least five different pathways. [15%]

(d) Identify possible remediation technologies to remove the nonaqueous phase chemicals. List at least two different technologies and use diagrams to show how they work. [15%]

(e) Identify possible remediation technologies to control the ground water contaminant plume. List at least three different technologies and use diagrams to show how they work. [15%]

(f) A soil vapour survey was conducted at the site and the gas contained 2000 ppmV of benzene. Estimate the benzene concentration (in mg/L) in soil moisture. Assume the subsurface temperature to be 25 °C. [15%]

(g) The average benzene concentration in the soil samples was 1000 mg/kg. A child inhales 2 m^3 of air and ingests a mouthful (10 cm^3) of the contaminated soil daily. Which system (inhalation or ingestion) is exposed to more benzene? The bulk density of the soil is 1.8 g/cm^3. [15%]

3 (a) What are the main design criteria for a domestic waste landfill? Give at least five. [20%]

(b) Which geotechnical materials would you choose for constructing

(i) the base liner;

(ii) the batter (slope) liners; and

(iii) the top cover of the landfill.

Assume that the underlying soil is predominantly silty sand. [20%]

(c) What additions to the design would be necessary if the landfill were to be used only for hazardous waste? [20%]

(d) Assuming that the batter (side slope) angle is limited by the operation of the construction plant to 1 in 2.5, sketch an approximate design (both a section and a plan view with dimensions) for a landfill which would be appropriate for disposing of waste from a town over a five year period. The volume of waste for landfill in the first year is estimated to be 100,000 m^3 when compacted. Assume a 3 % annual reduction in waste for the remaining time. Assume the depth of waste to be 20 m. [40%]

4 (a) During the construction of a landfill, the composite base liner was unfortunately damaged, resulting in a 1 cm^2 hole in the membrane. However, it is reasonable to assume that the membrane remained in good contact with the lower layer. If the leachate was maintained at 1 m above the membrane, estimate the leakage flow rate (in m^3/day) which is likely to result from this defect. Assume that the hydraulic conductivity of the lower layer is 1×10^{-9} m/sec. [30%]

(b) Analysis of the leachate in the landfill showed that the concentration of copper was 500 times greater than the level of the drinking water standard. Is this leak likely to pose a threat to the quality of ground water passing underneath the landfill in the sandy subsoil? Discuss this by comparing the relative flow rates of leachate leakage and ground water. The approximate width of the landfill is 100 m; the depth of the sandy soil stratum is 5 m; the hydraulic conductivity in this layer is 1×10^{-4} m/sec; the difference in water level in two boreholes which are down gradient from the landfill, and 50 m apart is 0.75 m. [35%]

(c) What remedial action may be taken to prevent an old leaking landfill site from contaminating a water abstraction borehole situated about 1 km down gradient? Sketch a possible solution and explain its function. [35%]

END OF PAPER