Dr A Al-Tabbaa

4D14 Contaminated Land and Waste Containment. 2014.

Q1 a) The ocean environment can affect the area over which the waste is spread significantly. It can also affect the types of reaction that can take place within the waste.

The ocean can be classified as three zones with depth a) shallow region where constant mixing of waste occurs due to waves and wind b) mixed region where temperatures and sunlight can have effect the reactions that take place in the waste and c) deep regions where there is little sunlight and oxygen levels are minimum – this encourages anaerobic reactions to take place.

In addition to the above the ocean topography can also affect the spread of the waste. Waste deposited on continental shelf does not spread as much as that deposited on continental slopes. Similarly at the ocean bed, waste deposited on abyssal plains will not spread as much as the waste deposited on abyssal hills. [15%]

b) Room and Pillar construction method is used in mines to allow the support of the roof during the mining process. Ore is removed from spaces forming a room and the corners are left to form pillars supporting the roof. This helps in minimising the roof cave-in's and ensures the safety of miners.

If we were to utilise old mines constructed from room and pillar method to dispose toxic waste, we can utilise this type of construction effectively. We can place the toxic waste in individual rooms and then seal them off. This allows for good separation of the toxic waste and also facilitate controlled recovery of the toxic waste at a future date, if reprocessing techniques become available to treat the toxic wastes. Also different types of toxic waste can be disposed into different rooms, minimising the risk of mixing and unexpected reactions from occurring. [15%]

1 c i) Total precipitation $= \frac{580}{1000} \times 200 \times 400 = 46400 \text{ m}^3$.

Rainfall entering the landfill $=$ 10% . 46400 $= 4640 \text{ m}^3$

Leachate produced in the landfill $= 4640 \text{ m}^3$.

$\therefore$ Total leachate in the landfill $= \underline{9280 \text{ m}^3}$.

Height of the leachate in landfill $= \frac{9280}{200 \times 400 \times 0.4} = \underline{0.29 \text{ m}}$ [10%]

(Porosity of waste $= 0.4$)

1 c ii) Assume leachate stays just below the surface of drainage layer.

$\Rightarrow h_{max} = 1.2 \text{ m}$; $k = 2 \times 10^{-2}$

Flow rate $Q = \frac{9280}{365 \times 24 \times 3600} = 2.9427 \times 10^{-4} \text{ m}^3/\text{s}$

Flow rate per metre width into the drainage layer $= q = \frac{Q}{B} = \frac{2.94 \times 10^{-4}}{400} = 7.3567 \times 10^{-7} \text{ m}^2/\text{s}$

Using Data Book equation, Spacing 'L'

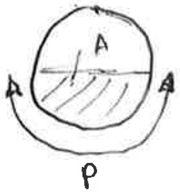
$$L = 2 \times 1.2 \times \sqrt{\frac{2 \times 10^{-2}}{7.3567 \times 10^{-7}}} = \underline{395.7 \text{ m}}$$

Choose a spacing of 350 m between HDPE pipes with 25 m space from the short edges [15%]

c(iii) $Q = 2.9427 \times 10^{-4}\ m^3/s$.

Each HDPE pipe carries half of this flow. $Q' = \frac{Q}{2} = 1.4713 \times 10^{-4}\ m^3/s$

From data sheets $v = \frac{1.486}{n} R_h^{2/3} S^{1/2}$; $n = 0.009$ & $S = 1/600$



$$R_h = \frac{A}{P} = \frac{\frac{\pi r^2}{2}}{\pi r} = r/2$$

v is limited to 0.5 m/s.

$$\therefore\ 0.5 = \frac{1.486}{0.009} \times \left(\frac{r}{2}\right)^{2/3} \left(1/600\right)^{1/2}$$

$r = 0.0404$ m or 40.4mm

$\therefore$ Diameter of the pipe = 80.8mm Use 100 mm diametre HDPE pipes. [15%]

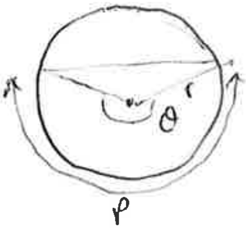
$Q = v \times A = 0.5 \times \frac{\pi}{4} \times 0.1^2 = 3.927 \times 10^{-3} >> Q' = 1.4713 \times 10^{-4}\ m^3/s$.

c(iv) Concrete pipe must carry total $Q = 2.9427 \times 10^{-4}\ m^3/s$.

$v = 0.5$ m/s $n = 0.0165$ (average). Slope = 1/2000

Pipe is running 60% full.

$$A_{segment} = \frac{1}{2} r^2(\theta - \sin\theta) = 0.6\pi r^2.$$



$$\theta - \sin\theta = 1.2\pi.$$

Solve by Trial & error $\theta = 1.1\pi$.

$$P = r\theta = 1.1\pi r.$$

$$\therefore\ R_h = A/P = \frac{0.6\pi r^2}{1.1\pi r} = 0.5454 r.$$

v is limited to 0.5m/s.

$$\therefore\ 0.5 = \frac{1.486}{0.0165} (0.5454 r)^{2/3} \left(\frac{1}{2000}\right)^{1/2}$$

$\therefore$ $r = 0.227$ m $\Rightarrow$ Diametre = 0.454 m

Use a Concrete pipe of 500mm Diametre. [40%]

$Q = v \times A = 0.5 \times 0.6\pi\, 0.5^2 = 0.2356\ m^3/s$ >> $2.94 \times 10^{-4}\ m^3/s$)

Q2

(a) Heavy metals: mining site, large sites, mining activities,
Organics: petrol stations, small sites generally, refinery related, larger sites
Mixed contaminants: various industrial site, chemicals, various manufacturing, etc [15%]

(b) Heavy metals: cannot be destroyed, can be precipitated
Organics: usually consist of a large number of compounds, different properties: boiling points, densities, hence separate in soil and groundwater environment
Cocktail: the above characteristics, combined effects: high heavy metal concentration can be detrimental to organic remediation. [15%]

(c) Heavy metals alone: Atomic absorption spectrophotometry or ICP-OES (inductively-coupled plasma optical emission spectrometry, or spectrophotometry) Or ICP-MS (inductively coupled plasma-mass spectrometry Or X ray fluorescence.
Organics: Gas chromatography, or GC-MS (MS= mass spectrometry) Or (for some larger molecules): liquid chromatography.
For cocktail of both heavy metals and organics: first need to separate them, e.g. acidify, then solvent extraction with something organic such as hexane to dissolve the organics, leaving heavy metals in the aqueous phase. Then analyse each phase as above.
Description as in lecture notes. [30%]

(d) LNAPL = light non-aqueous phase liquid. These float on water. Examples: any non-chlorine containing organic such as benzene, toluene, ethylbenzene, xylene, hexane, MTBE.

DNAPL = dense non-aqueous phase liquid. These sink in water. Examples: chlorine containing hydrocarbons such as TCE (trichloroethylene or trichloroethene, CCl_2CHCl), Perchloroethylene, PCE (tetrachlorothylene, or tetrachloroethene, CCl_2CCl_2), Methylene dichloride (dichloromethane CH_2Cl_2), TCA (trichloroethane, or methyl chloroform, CCl_3CH_3 [10%]

(e) Most common remediation method: heavy metals: stabilisation, soil washing; organics: bioremediation, chemical oxidation; cocktail of both: stabilisation/solidification or soil washing. [15%]

(f) methods not suitable for remediation: for heavy metals: bioremediation, for organics: stabilisation, for cocktail of both: thermal/vitrification. [15%]

4D14 Contaminated Land and Waste Containment Systems

(April 2014)

Q3 a) The main minerals that make up clay are:

i) Kaolonite

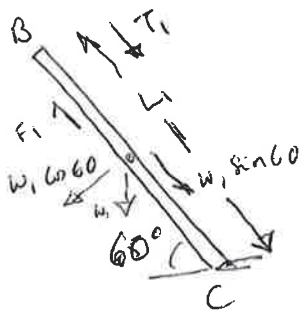
ii) Illite

iii) Montmorillonite. [10%]

b) Clay minerals have plate like structure and have a size of about 2 μm. The diffused double layer of water is the bonded between two plates of clay minerals and is held due to electrical charges. The thickness of the diffused double layer is given by the Mitchell equation.

The presence of hydrocarbons in the waste can affect the thickness of the diffused double layer of water. The hydrocarbons can disturb the electrical charges allowing the release of the held water between clay particles. This can make the clay more permeable and increase the hydraulic conductivity of clay by several orders of magnitude. This has serious impact on the design of landfill liners, as the time it takes for the contaminants to break through reduces with the increased hydraulic conductivity of the clay liners. [20%]

1c) Consider section BC for the geomembrane.



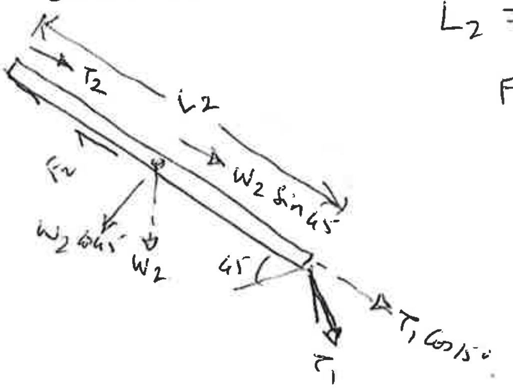
$L_1 = \frac{15}{\sin 60} = 17.32\ m$; $W_1 = 17.32 \times 1 \times 18 \times 9.81 = 3.0585\ kN/m$

$F_1 = W_1 \cos 60 \tan \delta_L = 3.0585 \times \cos 60 \times \tan 12 = 0.325\ kN/m$

$T_1 = W_1 \sin 60 - F_1 = \underline{2.324}\ kN$

Tensile stress at B (not required) $= \frac{T_1}{0.006 \times 1} = 387.3\ kPa$

Consider section AB



$L_2 = \frac{10}{\sin 45} = 14.14\ m$ $W_2 = 14.14 \times 1 \times 18 \times 9.81 = 2.497\ kN/m.$

$F_2 = W_2 \cos 45 \tan 12^\circ + T_1 \sin 15 \times \tan 12 = 0.503\ kN$

$= ($

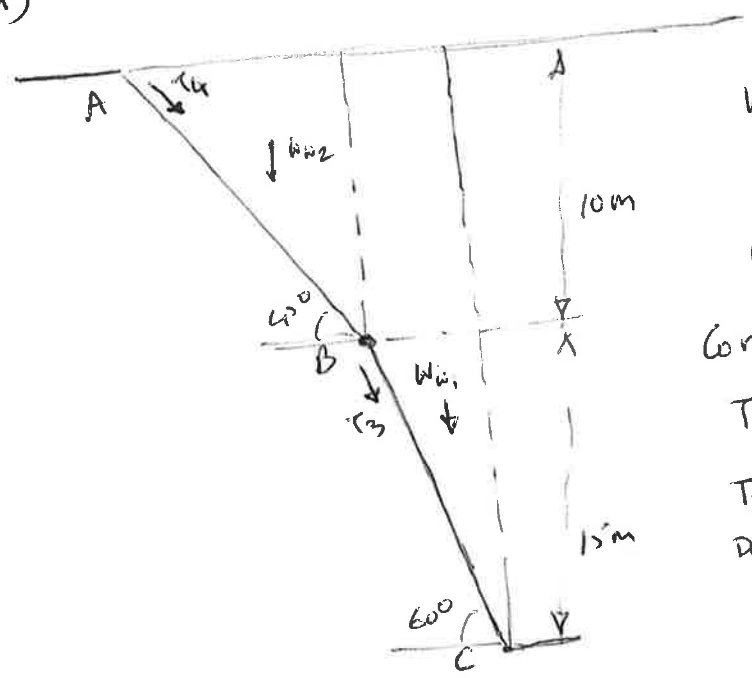
$T_2 = W_2 \sin 45 - F_2 + T_1 \cos 15 =$ kN $\underline{3.5075\ kN}$

$\therefore$ Self weight Stress at $A = \sigma_A = \frac{3.5075}{0.006 \times 1}$

$=$

$= \underline{\underline{584.58\ kPa}}$ [30%]

3d)



$\delta_L = 12^\circ \quad \delta_U = 10^\circ$ for geomembrane

$W_{W1} = \frac{1}{2}(25+10)[15 \times \tan 30] \times 8 \times 1$

$= 1212.44$ kN.

$W_{W2} = \frac{1}{2} \times 10 \times 10 \tan 45 \times 8 \times 1 = 400$ kN.

Consider section 'BC'.

$T_3 = W_{W1} \sin 60 \tan 10^\circ - W_{W1} \cos 60^\circ \tan 12^\circ$

$T_3 = 185.14 - 128.856 = \underline{56.284}$ kN

Down drag stress at B.

$\sigma_B = \frac{T_3}{0.006 \times 1} = 9.38$ MPa << 13.8 MPa

(Not required).

Consider section 'AB'.

$T_4 = W_{W2} \sin 45 \tan 10^\circ - W_{W2} \cos 45 \tan 12^\circ + T_3 \cos 15 - T_3 \sin 15 \tan 12$

$= 400[0.1247 - 0.1503] + 56.284 \cos 15 - 56.284 \sin 15 \tan 12$

$= -10.24 + 54.366 - 3.096$

$T_4 = 41.03$ kN

∴ Tensile stress due to down drag $= \frac{41.03}{0.006 \times 1} = 6.838$ MPa ✓ OK

(<< 13.5 MPa Yield stress for HDPE Geomembrane)

Significance of assumptions:

Here we assumed that the total weight of the waste will act as down drag on the geomembrane as the waste settles. However, waste will have some shear stresses generated in every vertical plane, which will reduce the vertical stress acting on the geomembrane.

Thus we are working out 'upper bound' of the down drag stress which is OK for design purposes. In reality downdrag stress will be somewhat lower. [40%]

Total tensile stress in geomembrane at A = 0.584 + 6.838

= 7.422 MPa (still << 13.8 MPa)

" at B = 9.38 + 0.387

= 9.767 MPa (<< 13.8 MPa)

so OK

Q4 Part (a) [60%]

(i). Project Drivers: Most remediation projects initiated for one of following reasons: Protect human health and/or the environment, Enable redevelopment, Repair previous remediation work and Other commercial reasons

(ii). Risk Management: Process of making informed decisions on acceptability of risks posed by site contamination, before and after treatment, acceptability of risks posed by remediation processes and how any necessary risk can be reduced efficiently and cost-effectively. This should also include consideration of emissions, off-site disposal and breakdown products from remediation.

(iii). Technical Suitability and Feasibility: A suitable technique is one that meets the technical and environmental criteria for dealing with remediation problem. Issues that affect suitability of remediation technology for particular situation include:

- Risk management application: Is application of source control or pathway control suitable or feasible for site?
- Treatable contaminants & soil properties: Contaminants, concentration range, phase distribution, source & age, bulk characteristics, geochemical, geological, microbiological limits
- Remedial approach: Type of remediation system (physical, chemical biological etc), each has own strength & weaknesses for specific site e.g. based on space requirements
- Location: Where the action takes place e.g. in-situ, ex-situ, on-site, off-site
- Overall strategy: Linking with further site investigation work, Integrated/combined approaches, active vs passive measures, long-term input (extensive) vs short term input (intensive), use of institutional measures (e.g. planning controls with long-term treatment)
- Implementation: Processes of applying remediation which differ between techniques: Planning remediation operations, site management, verification of performance, monitoring process performance, public acceptability and neighbourhood relationships (risk communication and risk perception), strategies for adaptation in response to changed or unexpected circumstances, aftercare
- Outcome: Destruction, removal, containment, stabilisation & how it affects site/soil properties.

A solution which appears to be suitable could still not be considered as feasible or practical because of concerns about: Previous performance of technology in dealing with particular risk management problem; Ability to offer validated performance information from previous projects; Expertise of service provider; Ability to verify effectiveness of solution when applied; Confidence of stakeholders in solution; Acceptability of solution to stakeholders, who may have expressed preference for favoured solution or have different perceptions and expertise; Availability of services (water, electricity) and facilities on site; Its duration; Its cost.

(vi). Stakeholder Satisfaction: Stakeholders are individuals or organisations with interest of some kind in the remediation project. Stakeholders include: Site owner, problem holder; Regulatory and planning authorities; Site users, workers, visitors; Financial community (banks, insurers, lenders); Site neighbours (tenants, local councils); Campaigning organisations and local pressure groups; Consultants, contractors, technology vendors; Stakeholders have their own perspectives, priorities, concerns; and ambitions regarding the site. For some stakeholders, end condition of site is more important than actual process used to arrive at this condition. Most appropriate remedial action is likely to offer a balance between meeting as many stakeholder needs as possible without unfairly disadvantaging any individual stakeholder. Main challenges usually include:

- Large number of stakeholders who might need to be involved
- How best to communicate technical information to the wide range of stakeholders

(v). Sustainable Development: At strategic level, remediation of contaminated land is seen to support goal of sustainable development by: (i) helping to conserve land as a resource; (ii) preventing spread of contamination and (iii) reducing pressure on development on greenfield land. But, remediation activities themselves have their own environmental, social and economic impacts. Negative impacts of remediation should not exceed the benefits of project. Core remediation goals are usually related to reduction of risk, time & money and do not usually consider overall environmental, economic and social effects of remediation. Examples of wider environmental effects of remediation activities: Negative: traffic, noise, emissions, dust, loss of soil function, use of landfill capacity. Positive: restoration of landscape value, restoration of ecological functions, improvement of soil fertility, recycling of materials, restoration to wider end uses. Examples of wider economic and social issues: Economic consequences: Impacts on local businesses and inward investment, Impacts on local employment, Occupancy of the site, Loss of revenue, through on going contamination/

remediation processes. Social consequences: Removal of blight, Community concerns about remedial approach, Amenity value of the site, Provision of infrastructure.
Achieving sustainable development is not widely used in an explicit way in contaminated land decision-making. However, achieving sustainable development is increasingly an important part of environmental policy generally. Hence sustainable development likely to become part of regulatory requirement for remediation project i.e. projects will increasingly need to demonstrate that they have been carried out in a sustainable fashion.

(vi) <u>Costs and Benefits:</u> Aim of assessing costs and benefits is to consider diverse range of impacts that differ between solutions e.g. effect on human health, land-use, issues of stakeholder concerns and acceptability. Achieved by assigning values to each impact in a common unit. Decision on what impacts to include or not varies between sites. Such a system reduces a set of complex information to relatively simple set of options to help with decision making. Combination of quantitative (monetary) and qualitative. Often information is limited or of limited reliability, hence need for sensitivity analysis to questions assumptions and judgement. Guidance on cost-benefit analysis provided by EA which includes many of sustainability and stakeholder involvement issues

Part (b) [40%]

(i) Multi-scale treatment train refers to the use of a combination of remediation technique in succession to enhance the treatment performance and provide a quicker and more efficient and cost effective remediation. It is generally acknowledged that the use of more than one technique would usually result in additional costs and complications due to the need to synchronise two different techniques and address logistics on site. However recent developments have shown that such issues can be mitigated with careful and detailed investigation and design leading to integrated logistics. In addition, some of those techniques are now offered by the same contractors hence reducing implementation logistics.
(ii) Examples: In-situ: initially a technique used to desorb contaminants from soil matrix into groundwater, then another technique used to target the dissolved phone; Ex-situ: contamination removed by one technique then a residual product treated by another to enable reuse. Examples are given schematically below. Other examples can be quoted as presented in the lecture material.