4D14 – Contaminated Land and Waste Containment - 2019
Cribs

1 (a) The CLEA model deals with the assessment of risks to human health arising from long-term exposure to soil contamination. It is intended for use by those responsible for assessment of land contamination: Las, EA, landowners, developers, professionals and technical advisors on investigations, risk assessment and remediation. It is used to derive soil guideline values (SGVs) to assist in decision making about the need for action to ensure that a new use of land does not pose any unacceptable risks to health. [10%]

(b) Chemicals with threshold effects: chemicals for which there is a threshold that needs to be present to produce an effect.
Chemicals with no threshold effects: chemicals for which a threshold cannot be assumed e.g. mutagenic and genotoxic carcinogens for which in theory a single molecule exposure could results in a tumour or mutation. [10%]

(c) For Nickel: TDI 5, MDI 2.3 and TDSI 2.7 – TDSI = TDI – MDI, hence 2.7 is simply 5-2.3.
For Arsenic: TDI 0, MDI 0.07, ID is 0.3. Since for Arsenic there is no threshold effect, TDI = 0 and given we already take in some, the ID is taken from the drinking water standards which is 0.3. [20%]

(d) The most relevant exposure pathways: ingestion of soil; injection of household dust, dermal contact with soil, dermal contact with household dust. [10%]

(e) The three land-use categories are: residential, allotment and commercial/industrial. For the contaminant present only the latter would be suitable. [10%]

(f) There are barriers to the redevelopment of contaminated land. These include: fear of the unknown, regulatory control, delays, increased costs and stigma. Hence the advice would be: need to carry out extensive planning at all stages to fully understand the challenges, allow time, allow budget, understand and comply with regulatory requirements and work closely with the EA, take out insurance, and involve professional advisors. [10%]

(g) For the soil: deep soil mixing – stabilisation with cementitious additives. Or soil washing?
For the groundwater – pump and treat. Book work describing details of the techniques. [20%]

(h) Cost: stabilisation is relatively cheap and effective – as heavy metals cannot be destroyed. For heavy metals in ground water as they cannot be destroyed, best way it so remove them, although pump and treat is expensive, it would remove the contamination effectively. [10%]

Assessor comments:
An 8-part question covering many aspects of a remediation project. The question tested the candidates on their knowledge of bringing together different parts of the course and addressing a real site problem. The relatively low marks are due to the students providing completely wrong answers to some parts of the question.

2 (a) (i) Any 3 of : Refuelling: petroleum hydrocarbons: benzene, toluene, ethylbenzene, xylene, polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, straight chain hydrocarbons, branched hydrocarbons, diesel. Repair shop: Degreasing bath: TCE, trichloroethylene, PCE, perchloroethylene,
(ii) TCE, trichloroethylene, PCE, perchloroethylene
(iii) Lead, heavy metals (possibly) [15%]

(b) The most likely to have deep contamination is the dry-cleaning site. This is due to the presence of DNAPLs (chlorinated solvents). These chemicals have a density considerably greater than that of water and therefore sink deeply into the ground, below the water table. The garage site may also have had a degreasing bath containing chlorinated solvents, so this site may also have deep contamination. [10%]

(c) (i) organic compounds such as: any organic compounds which are volatile or semi volatile) E.g. benzene, toluene, ethylbenzene, xylenes, PAH's + others.

(ii) any heavy metals, + sodium, calcium, + practically any element except carbon, hydrogen, nitrogen; (i.e. excluding organic compounds). [25%]

(d) Bioremediation vs phytoremediation for pure hydrocarbon contamination.
Bioremediation is an effective solution for hydrocarbon contamination through straight forward biodegradation processes. This can be achieved either ex-situ or in-situ. Bioremediation particularly effective for C_{13}-C_{32} hydrocarbons. Effectiveness will depend on the environmental conditions: 65-75% soil water, oxygen content, redox potential, pH, nutrients. Would generally be cost effective. Phytoremediation is less practiced in the UK, although popular in the USA. Could employ a number of remediation mechanisms including: Phytostabilisation, Rhizodegradation Phytodegradation, Phytovolatisation. The selection will be based on the soils type, contaminant depth, groundwater level, etc. Site might need to be used for greening only. There is far less experience generally with phytoremediation and likely to be more difficult to implement in a way to ensure similar success to bioremediation. Also duration of remediation process not clear. [25%]

(e) (i) – helps to converse land as a resource
- prevents spread of contamination
- reduces pressure on development of greenfield land. [10%]

(ii) negative effects: Traffic, emissions, noise, dust, loss of soil function, use of materials resources, use of landfill capacity.

Positive effects: restoration of landscape value, restoration of ecological functions, improvement of soil fertility (for some biological techniques), recycling of materials, restoration to wider ranges of end-uses. [15%]

Assessor comments:
This is a two part question with the first part testing the students' knowledge on different contaminant sources and their laboratory analyses. The second compares and contracts bioremediation and phytoremediation. A mixed response with marks lost due to very brief answers or completely incorrect answers.

4D14 - Contaminated Land & waste containment systems
Lent 2019 - Cribs.

3a) The MSW deposited in the landfill can have chemicals that react with the clay liner. Clay particles are predominatly made of chemicals like Kaolinite, Illyte or Montmorillionite and clay minerals have silica tetrahedral structure or Mg/Al octahedral structure. Chemical reactions can occur between the clay minerals and the chemicals in the waste, leading to precipation of dissolved chemicals. The precipitation products can move with the seeping leachate forming new voids primarily due to piping and channel formation within the clay liner. This will lead to increased hydraulic conductivity of the clay liner and can compromise its functionality [15%]

b) Clay minerals have plate-like structure and water molecules are adsorbed to the clay minerals. This is called a diffused double layer whose thickness is calculated using Mitchell's equation. Presence of hydrocarbons in the waste can effect the thickness of the diffused double layer. This can change the hydraulic conductivity of the clay liner by several orders of magnitude and can reduce its effectiveness as a barrier. [15%]

c) Unsupported cut height $h_c = \frac{4C_u}{\gamma}$

$$= \frac{4 \times 25}{19.6} = \underline{\underline{5.1 m}}.$$

The permeability of the silty clay is 4.4×10^{-5} m/s, which is relatively high. So undrained strength should not be relied upon. Also H&S regulations restrict the max height of unsupported cuts to a few feet. [15%]

d) Slurry wall Design.

i) $H_c = \frac{4C_u - 2q}{\gamma - \gamma_f}$ $\doteqdot$ $\gamma = 19.6$ kN/m³. $\gamma_f = ?$

$H_c = 12 m$

$$12 = \frac{4 \times 25 - 40}{19.6 - \gamma_f}. \Rightarrow \gamma_f = \underline{\underline{14.6}} \text{ kN/m}^3.$$

∴ The soil-bentonite slurry must have a unit weight of at least $\underline{\underline{14.60}}$ kN/m³.

1 d) ii) water table at ground surface; use buoyant unit weights.

$$H_c = \frac{4c_u - 2q}{\gamma' - \gamma'_f}.$$

$\gamma = 19.6\ \text{kN/m}^3$ $\gamma_w = 9.81\ \text{kN/m}^3$

$\gamma' = 19.6 - 9.81 = 9.79\ \text{kN/m}^3.$

$$12 = \frac{4 \times 25 - 40}{9.79 - \gamma'_f}.$$

$\Rightarrow \gamma'_f = \overset{4.79}{\cancel{\text{[illegible]}}}\ \text{kN/m}^3.$

$\Rightarrow \gamma_f = \underset{4.79}{\cancel{\text{[illegible]}}} + 9.81 = \underline{\underline{\overset{14.6}{\cancel{\text{[illegible]}}}}}\ \text{kN/m}^3$ (as expected) [20%]

e) $$k_{overall} = \frac{t_s}{\frac{t_s}{k_s} + 2\frac{t_c}{k_c}}$$ Slurry wall

$t_s = 1.5\text{m}$ $t_c = 4\ \text{mm}$

$k_s = 1.6 \times 10^{-7}\ \text{m/s}$ $k_c = 2.8 \times 10^{-10}\ \text{m/s}.$

$$k_{overall} = \frac{1.5}{\frac{1.5}{1.6 \times 10^{-7}} + \frac{2 \times 4 \times 10^{-3}}{2.8 \times 10^{-10}}} = 3.95 \times 10^{-8}\ \text{m/s}.$$

We can redo this calculation for 6mm or 8mm thick filter cake and overall permeability of the wall only changes marginally. So no! What is important is that the filter cake forms and a hydrostatic pressure is exerted on walls of the cut. Its thickness is less important. [25%]

f) During construction several factors govern the stability of the slurry wall.

1. Formation of the filter cake and it should be continuous.
2. Loss of slurry should be carefully monitored, excessive loss may indicate instability as the slurry may have escaped
3. Continuous construction as much as possible, with minimum stoppage times.
4. Monitoring of slurry recovery when placing the backfill.

[10%]

4.a) LCRC Analyses.

Land fill dimensions 400 m × 500 m.

Rainfall = 1.3 m / year.

$\therefore$ Total volume = $400 \times 500 \times 1.3$ m = 260,000 m^3.

15% of this ends up in the landfill = $\frac{15}{100} \times 260000$

= 39000 m^3.

+ leachate = 39000

Total = 78000 m^3.

Porosity of drainage layer = $n = 0.4 = \frac{v_v}{V}$.

Height of fluid = $\frac{78000}{400 \times 500} = 0.39$ m.

within the drainage layer = $\frac{0.39}{0.4} = 0.975$ m.

0.975 m < 1.2 m. So OK. ✓

(Thickness of drainage layer).

Flow rate = $Q = \frac{78000}{365 \times 24 \times 3600} = 2.47 \times 10^{-3}$ m^3/s.

$q = \frac{Q}{W} = \frac{2.473 \times 10^{-3}}{500} = 4.94 \times 10^{-6}$ m^2/s.

spacing of pipes = L = . $2 h_{max} \sqrt{\frac{k}{q}}$

(From data sheets)

Use h_{max} = 1.2 m full thickness of the drainage layer.

$L = 2 \times 1.2 \times \sqrt{\frac{6 \times 10^{-2}}{4.94 \times 10^{-6}}} = 264.3$ m.

Use a spacing of 250 m ie 2 pipes for 500 m.

Total Q = 2.473×10^{-3} m^3/s so each pipe carries Q/2

$Q/2 = 1.236 \times 10^{-3}$ m^3/s.

Manning formula $v = \frac{1.486}{n} R_h^{2/3} s^{1/2}$ (from data sheet)

$s = 1/1500$ n for PVC pipe = 0.009 $v = 0.25$ m/s

$0.25 = \frac{1.486}{0.009} \times (r/2)^{2/3} (1/1500)^{1/2}$

2a) Contd

$$r = \frac{\sqrt{1500 \times 0.009}}{1.486} \times 2^{2/3} \times 0.25 = 0.093\ m \simeq 93\ mm.$$

$$D = 186\ mm$$

Existing pipes with 120 mm ϕ are not sufficient. Use pipes with 200 mm outer dia with 10mm wall thickness.

Deflection $\Delta y = 0.0025 \times \frac{0.42^2}{0.01} = 0.01''_m$

or 0.254 mm. This is too small.

Do better analyses to ensure deflections are small. Consider the pipe on base layer as a winkler beam. [60%]

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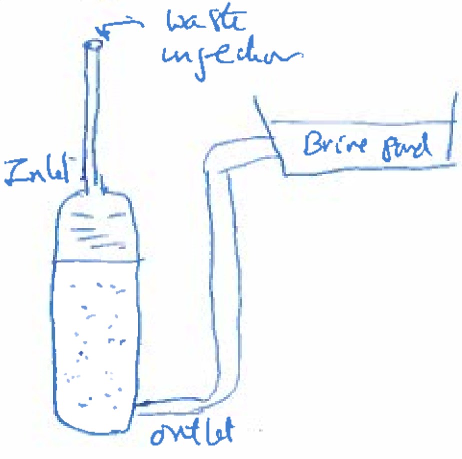
2 b) Waste deposited in deep ocean

i) Abyssal plains → The waste will remain close to the deposition site, very little spread occurs.

ii) Abyssal hills → These are very gently sloping hills and waste deposited on abyssal hills will spread over a very large area, relative to the deposition site. [20%]

2c) Waste in liquid form can be injected into deep underground caverns. These caverns are normally filled with brine. The caverns are formed due to solution mining with brine.



i) If the brine is heavier than the waste, then the waste will float on the top of the cavern. So as the waste is injected, brine comes out from the outlet and is collected in a brine pond, as shown in the sketch.

ii) If the waste is heavier than brine then the waste is injected at the base of the cavern and brine is collected from the top of the cavern into the pond, ie the inlet and outlet are reversed. [20%]

Assessor comments on Q3

This question tested the candidates on the waste-liner reactions in the initial part. Then candidates were tested on the stability of slurry walls, in the presence of a surcharge and were asked to recommend suitable slurry densities to ensure stability. The last part was on the practical aspects of slurry wall construction. The question was largely well answered with surprisingly few numerical errors.

Assessor comments on Q4

The first half of this question was on the design of a leachate collection and removal system (LCRS). A few candidates struggled to estimate the flow rates into the drainage layer and consequently made errors in the pipe analysis. However a few candidates managed to get near perfect answers. The second half of the question was on the disposal of hazardous waste and ocean waste disposal. Candidates provided reasonable answers for this part.