# 4D14

## Contaminated Land & Waste Containment Systems.
## Cribs

Q1 a) MSW from residential area can contain a wide variety of Hazardous waste. Usually Hazardous waste can comprise between 0.01 to 0.1% of the total MSW. Many types of Hazardous waste can be present in MSW from batteries to cleaning products such as bleaches.

Examples can include: silver or brass polish, hair sprays, paints, bleach, oven cleaners, sink/bathroom unblockers etc

[10%]

b) A well engineered landfill consists of the following components.

1) Top cover
2) Side slopes
3) Base Layer. Following geo-synthetics are used in each of the components.

The top layer can consist of a geo-net, geotextile & geomembrane.
The side slopes can contain, geomembranes & geotextiles.
The base layer can employ geo-nets for monitoring layers, geomembranes, geotextiles & on occasion geo-grids to cover soft patches in the ground.

[15%]

c) Distance between factory & reservoir = 1600 m.

Silty sand void ratio $e = 0.65$

Porosity $n = \frac{e}{1+e} = 0.394$

Pressure drop between two points separated by 12m is 30 kPa.

$\Rightarrow dh = \frac{30 \text{ kPa}}{9.8 \text{ kN/m}^3} = 3.06 \text{ m}$

Hydraulic gradient $i = \frac{dh}{ds} = \frac{3.06}{12}$

$i = 0.2551$

Darcy velocity $v = ki = 3.2 \times 10^{-4} \times 0.2551$
$= 8.163 \times 10^{-5}$ m/s.

$v_f = \frac{v}{n} = \frac{8.163 \times 10^{-5}}{0.394} = 2.0712 \times 10^{-4}$ m/s

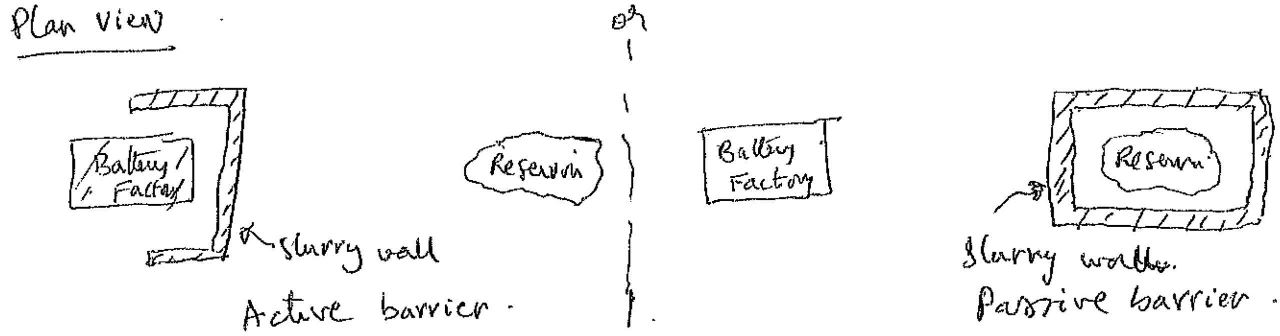
i) Time for spillage to reach the reservoir:

$= \frac{1600}{2.0712 \times 10^{-4}} = 7.7224 \times 10^{6}$ sec $= 89.37$ days.

This is just 3 months, for contaminant to reach the drinking water reservoir. Therefore some remediation measure should be put in place.

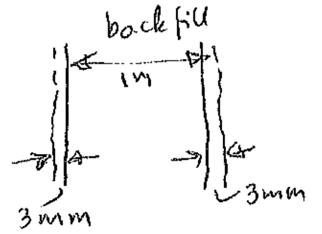
[20%]

1c (ii) The remedial measures can involve in constructing a slurry wall downstream of the battery factory as shown below.




Both of the above schemes can delay/prevent contamination of drinking water due to chemical spillage. The depth of the slurry wall must be through the 10m of silty soil with adequate 'key' into the bed rock. [15%]

d) i)




Hydraulic conductivity of the wall = K

$$K = \frac{t_s}{\frac{t_s}{K_s} + 2\frac{t_c}{K_c}}$$

$t_s = 1.0$ m

$t_c = 0.003$ m

$K_s = 8.3 \times 10^{-8}$ m/s

$K_c = 1.8 \times 10^{-9}$ m/s.

$$K = \frac{1.0}{\frac{1}{8.3\times10^{-8}} + \frac{2\times3\times10^{-3}}{1.8\times10^{-9}}} = \frac{1}{1.2048\times10^{7} + 3.3\times10^{6}}$$

$K_{slurry\ wall}$ = ~~3.333 x 10^-12 m/s~~ $= 6.5 \times 10^{-8}$ m/s. [20%]

ii) Pressure dpr = 20 kpa.

$$dh = \frac{20}{9.8} = 2.041$$

$$i = \frac{2.041}{12} = 0.17$$ Assuming that silty sand is >> permeable than the barrier.

$v = Ki = 6.5\times10^{-8} \times 0.17 = 1.1054\times10^{-8}$ m/s.

$$v_f = \frac{1.1054\times10^{-8}}{0.394} = 2.8056\times10^{-8} \text{ m/s}.$$

$$\therefore \text{Time of arrival} = \frac{1600}{2.8056\times10^{-8}} = 5.7\times10^{10} \text{ sec}$$

$= 1808.31$ Years!

The slurry wall delays the arrival of the contaminants by a very large time. Therefore it is highly effective. [20%]

Q2 a) The Ocean environment can be classified as shallow region, where wave & wind action can cause constant mixing and deeper regions where there is very little wave action. The oxygen (dissolved) content also ~~regs~~ reduces with the depth of water. The oxygen minimum zone is the depth of water in the ocean that contains very little dissolved oxygen.

Waste disposed into oxygen minimum zone will undergo anerobic reactions. This can lead to production of gases like methane, $H_2S$ etc.

[10%]

b) The seabed can be classified as

i) continental shelf ii) continental slopes iii) Abyssal plains & iv) Abyssal hills.

Waste disposed onto continental shelf can be disturbed and moved due to wave action. Waste disposed onto continental slope can spread a long distance and therefore should be avoided. Waste disposed onto Abyssal plains will be stable and does not spread much. On the other hand, waste disposed onto Abyssal hills can spread a long distance over a long period of time, as these hills have gentle slopes between 3 to 6%.

[15%]

c) From a hydro-geological perspective an injection well should be sited ~~between~~ at locations which satisfy following criteria

1) absence of potable water at shallow depths.

2) Presence of high permeability strata that is well confined above & below by low permeability soil or rock strata.

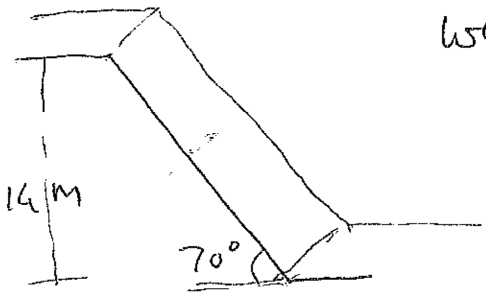
3) Absence of any faults, ruptures or slip planes.

4) Absence of any erosion, seismic activity etc.

Generally porous soil strata that are saturated with salt water are preferred.

[10%]

Q2 d) i) Self weight stress:




Weight of the strip $= \frac{14\,m}{\sin 70} \times 1 \times 23$

$W = 342.67$ kg/m.

$= 3.361$ kN/m.

Tensile stress $\sigma_{TA} = \frac{W \sin\beta - F}{1 \times t}$.

$F = W \cos\beta \tan\delta_L$

$= 3.361 \times \cos 70 \times \tan 12°$.

$= 0.2443$ kN/m.

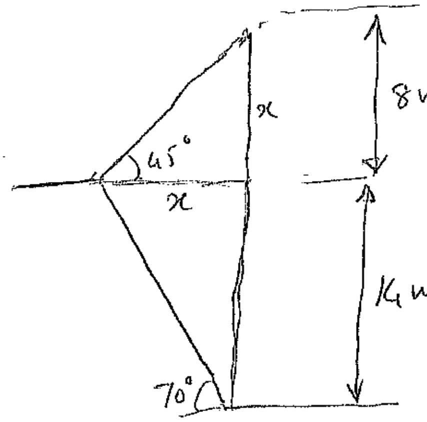
$\therefore \sigma_{TA} = \frac{3.361 \times \sin 70 - 0.2443}{1 \times 4 \times 10^{-3}} = 728.5$ kN/m².

$= 0.73$ MPa << 13.8 MPa (Yield stress of HDPE)

So OK

[20%]

ii)




$\tan 20 = \frac{x}{14}$

$x = 14 \tan 20 = 5.095$ m.

$\therefore$ Area of waste $\Delta = \frac{1}{2} x (x + 14)$

$= 48.6445$ m².

$W_{waste} = 48.6445 \times 1 \times 7.5$ kN/m³.

$= 364.8338$ kN/m width

Assumption: The worst case of geomembrane tension occurs if all of this waste drags the geomembrane down. ie we will ignore the shear strength of the waste. This is a conservative assumption.

$(\sigma_T)_{downdrag} = \frac{W_{waste} \cos\beta \tan\delta_U}{1 \times t} = \frac{364.83 \times \cos 70 \times \tan 8}{1 \times 4 \times 10^{-3}}$

$= 4384.189$ kPa

or 4.38 MPa

[25%]

Total tensile stress in geomembrane $= 4.38 + 0.73 = 5.1127$ MPa << 13.8 MPa

So OK

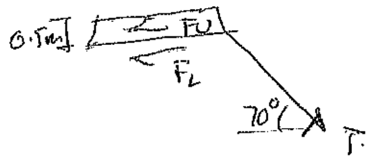
2d iii) Design of flat bed Anchor:

Tensile Stress in geomembrane from before

$= 5.1127 \text{ MPa}$.

$\therefore$ Tensile force $= T = 5.1127 \times 10^3 \times 1 \times 4 \times 10^{-3}$

$= 20.45 \text{ kN}$.




$\sigma_v$ due to berm $= 0.5 \times 17 \text{ kN/m}^3$

$= 8.5 \text{ kPa}$

For equilibrium.

$T \cos 70 = F_U + F_L$.

$F_U = 8.5 \tan 8° L$

$F_L = 8.5 \tan 12° L + T \sin 70 \tan 12°$

$T \cos 70 = 1.1946 L + 1.8067 L + T \sin 70 \tan 12°$

$T [\cos 70 - \sin 70 \times \tan 12°] = 1.1946 L + 1.8067 L$

$20.45 \times 0.14228 = 3.001 L$.

$\underline{\underline{L = 0.9694 \text{ m}}}$

Use an Anchor length of $\underline{\underline{1 \text{m}}}$ [20%]

3 (a) (i) Any two of the following techniques: Soil washing, Soil stabilisation/solidification (locking in the contaminants), bioremediation. Soil washing: using scrubbers, water jets, solvents to grade the soils and separate clean from contaminated and then use specific properties to separate the contaminants from the soils, hence is quite versatile and can apply to a range of contamination, organic and inorganic. S/S: using binders to immobilise the contaminants, physically making into a monolith or chemically by reducing availability or toxicity, is also quite versatile and can apply to a range of contamination, organic and inorganic. Bioremediation: using natural microorganisms to immobilise or biodegrade contaminants, usually most effective for pure organic contamination and in particular hydrocarbons, but can be used for cocktails as well. Contaminants and contaminant groups to be targeted include: metals e.g. arsenic, lead, zinc, organics e.g. polycyclic aromatic hydrocarbons, chlorinated solvents, ammonia, (bitumen tar and other heavy metals are also acceptable). These contaminant groups are present in the Olympic site soils due to their association with past industrial usage including oil refineries, chemical works, cold storage facilities, power stations, gas works, saw mills, black filled reservoirs as well as warehouse/ distribution centres. [30%]

(ii) For arsenic, lead, zinc or heavy metals, appropriate analysis methods could be atomic absorption spectroscopy (AAS) analysis; ICP-OES (inductively coupled plasma – optical emission spectrometry (or spectroscopy). ICP also acceptable. Another alternative is X-ray fluorescence (XRF). Principle: AAS: light shines through a flame which is decomposing the sample. The wavelength is very specific for one metal only. The amount of light absorbed is a measure of the concentration. ICP-AES: A very hot plasma causes most elements to emit light at their characteristic wavelengths. So it is possible to analyse more components simultaneously. Challenges in sample preparation includes proper sampling from the site, ensuring standards used for the various heavy metals presents, sample preparation might require dilution, the precision of the analytical devise also needs to be checked.

For organic compounds such as polycyclic aromatic hydrocarbons, or chlorinated solvents, gas chromatography (GC) is the favoured method. Principle: GC: separates organic molecules by volatility and/or by affinity for a thin coating on the walls of a tube. A mixture of components are heated up and passed down a thin tube. The wall is coated with a material which is attractive to a particular type of organic compound e.g. non-polar organics. At the outlet the components have been separated and are typically detected by burning them in a flame, which generates ions. The output can be compared with that from a known compound, so that concentrations can be calculated. The sampling of organic contaminants is usually quite challenging and more challenging than that of heavy metals. This is mainly due to the volatility of many organic compounds and also the need to extract them into solvents as many are hydrophobic. Hence care needs to be taken at all stages to ensure little loss initially and then most capture for the analysis. [30%]

(b) Receptors include: people (critical in residential areas, allotments, those living near landfill sites), Controlled waters, including both groundwater and surface water (critical for underground spillages where there is shallow groundwater or near water bodies), Ecological systems (pollution of waters, farm land, natural reserves etc), Property: crops, including timber, produce grown domestically for consumption, livestock, wild animals subject to shooting or fishing rights, buildings (critical when close to buildings, gardens, natural habitats etc). [10%]

(c) Phytoremediation mechanisms: [20%]
(i) Phytostabilisation, sorption onto root or precipitation within root zone (organics & inorganics)
(ii) Rhizodegradation, enzymes/acid metabolising contaminants (organics)
(iii) Phytoaccumulation, metal or salt accumulated within plant, hyperaccumulators (inorganics)
(iv) Phytodegradation, update or contaminants and transformation within plant (organics)

(v) Phytovolatilisation, uptake, translocation and release to atmosphere (organics and inorganics)
(vi) Evapotranspiration, interception of clean water and evaporation back into air (clean water)

(d) Environmental Impacts of land remediation [10%]
Positive: Restoration of landscape value, Restoration of ecological function, Improvement of soil fertility, Recycling of materials, Restoration to a wider range of stakeholders.
Negative: Noise, Dust, Traffic, Emissions, Loss of soil function, Use of material resources, Use of landfill capacity.

4 (a) (i) Soil properties [25%]

- Chemical: chemical oxygen demand, oxidant demand factors, intrinsic permeability, soil structure and stratification, hydraulic gradient, iron and other reduced inorganic compounds dissolved in groundwater.
- Thermal: heat capacity, concentration of humic material, soil plasticity, moisture content, meal content, bulk density
- Biological: water content, ~70% of field capacity, oxygen content, redox potential, pH, nutrients and concentration, temperature. Also microbial presence, permeability,

(i) Contaminant properties [25%]

- General: contaminant concentration, toxicity.
- Chemical: chemical class, solubility, Koc factor, susceptibility to chemical oxidation, degradation pathways of organics or reduced toxicity for inorganics.
- Thermal: contaminant concentration, boiling point range, vapour pressure, thermal stability, Koc, Dioxin formation, presence of heavy metals, vapour & gases expected, aqueous solubility.
- Biological: mainly organic contamination, so length of carbon chain, the longer the slower the remediation process. Also presence of high heavy metal concentration will inhibit the bioremediation process. Vapour pressure, Henry's constant, product composition, boiling point.

(b) From the chemical site investigation the following information would be obtained:

- potential harmful substance. pose a short or long term hazard to human health
- potential for chemical attack on construction materials e.g. foundations, services
- presence of combustible materials, would lead to fire below ground
- emission of toxic flammable gases and their migration routes
- presence of phytotoxic compounds which inhibit or prevent plant growth
- suitable licensed disposal sites for the material on the site
- whether dewatering operations will require treatment before disposal
- advantages & disadvantages of different sites and parts of same site [15%]

(c) Non-threshold chemicals are those for which a threshold cannot be assumed e.g. carcinogens and mutagenic etc. Usually TDSI = Tolerable daily intake (TDI) – mean daily intake (MDI)
For contaminants with no threshold effects, TDI = 0. But MDI might not be 0. Hence TDSI does not apply and Index Dose is usually used. This is usually based on drinking water standards, from which a value for the TDSI can be calculated in terms of $\mu g\ kg^{-1}\ bw\ d^{-1}$. [10%]

(d) Three elements of risk based land management: [10%]
Fitness for purpose – ensuring safe use of the land – significant because the contaminants are not eliminated and hence the risk needs to be reduced to a level acceptable for the purpose.
Protection of the environment – preventing harm and protecting resources – because the contaminants are not eliminated the process needs to ensure minimal risk to the environment from the remaining contamination.

Long-term care – allowing more rigorous assessment of the way in which the above goals are achieved to ensure that that it is a sustainable way. Because the contaminants are not eliminated, the processed need to ensure that there is regular monitoring and potential reassessment if any of the conditions above change.

(e) (i) For a large and controversial project like HS2, there are the general stakeholder groups: Site owner; problem holder, Regulatory and planning authorities, Site users, workers, visitors, Financial communities, Site neighbours, campaigning organisations/local pressure groups and consultants, contractors, technology vendors. The specific stakeholder groups include:

1. Station working groups: Groups with local transport and planning responsibilities for the relevant stations.
2. Rolling stock and infrastructure maintenance depot stakeholders: local planning authorities of depot locations
3. Wider stakeholder groups: local and regional planning authorities, business groups, and other interest groups in the relevant areas.
4. Challenge panels: independent expect who scrutinise all approaches and decisions.
5. Appraisal of sustainability reference group: from central government departments and statutory agencies to challenge sustainability appraisal methodologies.

(ii) two main challenges from the following:

(1) Large number of stakeholders who might need to be involved.
(2) how best to communicate technical information to the wide range of stakeholders.
(3) How to deal with those groups who oppose the development and the general controversial nature of the project.

[15%]

**4D14 – Contaminated Land & Waste Containment**

**2020-2021**

**Assessor's comments:**

**Q1 Slurry wall design**

A very popular question attempted by all candidates. Parts (a) and (b) were answered well by most candidates. Part (c) tests the time taken by contaminant to travel to a water reservoir and most candidates did this part well. Part (d) requires the candidates to include a slurry wall and recalculate the time taken by the contaminant to reach the water reservoir. While all candidates got the concept right, many made numerical errors in their calculations. Overall well answered question though.

**Q2 Landfill design**

A very popular question and all the candidates attempted it. The initial parts of the question were on waste disposal in ocean environment and through injection wells. While some candidates answered these parts very well there were a few who seem to make up the answers based on general knowledge rather than what they learnt in the course, thus producing vague answers. The later part of the question tested the candidates on design of landfill liners. Part d(i) was answered very well by most candidates. However many candidates made numerical errors for Part (d- ii and iii).

**Q3 Olympic park contamination and remediation plus others**

This question tested the candidates synthesis of information from different parts of the course as well as a video. The video was on the Olympic park redevelopment project. It addressed contamination and remediation solutions as well as analyses of the contaminants. The other smaller parts to this question assessed interpretations of land remediation models, phytoremediation processes and environmental impacts of land remediation.

**Q4 Soil & contaminant properties, risk management and stakeholders involvement**

The first half of this question required the students to identify both the soil and contaminant parameters relevant to the selection of chemical, thermal and biological remediation techniques. The latter half focused on risk management, toxicity and HS2 stakeholders. The question was answered poorly with most students writing 5-6 lines for the 50% mark part of the question. Also some completely missed the question and gave answers that were not relevant. It looked like the students had run out of time when answering this question.