4D14 Contaminated land and waste containment 2018

Cribs

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1. a) The exact nature and composition of leachate produced depends on the relative composition of the constituent chemicals. This is dependent on the reactions that will take place within the landfill. Reaction types may be broadly classified into Biochemical and Chemical Reactions.

Biochemical reactions consist of converting complex organic compounds into simpler compounds, converting insoluble solids into water-soluble substances. These reactions consist of hydrolysis, oxidation, and reduction into liquid form. The organic matter is initially degraded by aerobic action and converted into nitrates, sulphates, CO2 and water (stable compounds). Once the free air and oxygen are exhausted, reactions take place under anaerobic conditions and converts unstable matter into gases such as methane, ammonia, CO2 and hydrogen sulphide (H2S). Other compounds such as alcohol's and carboxylic acids may be produced in this process.

Chemical Reactions that take place in the landfill are mainly (I) neutralisation (II) precipitation and (III) reduction. In the landfill the overall dissolved constituents may increase, the strength of the leachate may be decreased. For example, neutralisation may be due to mixing of acids and alkali waste causing precipitation of heavy metals as sulphides, hydroxides and carbonates, and reduction of sulphates to H_2S.

[20%]

1b) We are primarily concerned that the soil-waste interaction may effect the hydraulic conductivity of the soil. In this regard, we wish to understand the clay-water interaction and the effect of pollutants on hydraulic conductivity.

Clay-Water Interaction: Clay particles are negatively charged and attract (and tightly hold) cations(+). Hence there is a disparity in the electric fields next to clay surface. The charged surface and the adjacent distributed charge together are called diffused double layer. T

The soil-waste interaction may effect the hydraulic conductivity in the following ways;

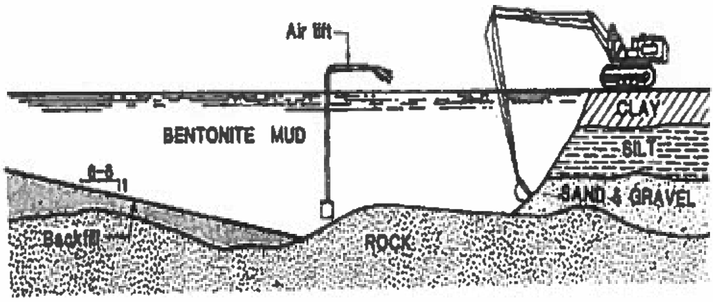
Dissolution of Soil Minerals: Acids and bases may dissolve certain soil minerals e.g., Al and Fe can be dissolved by acids and Silica can be dissolved by bases. The resulting fines may migrate with seeping fluids and can cause decrease in permeability by plugging the void space. In the long-term, however, migration of fines may increase the permeability due to piping and channel formation within the soil.

Changes in the clay structure: Changes in clay structure occur do cation exchange or by replacement of water by percolating organic fluids. Na, K, Ca and Mg may be attracted to the clay minerals there by changing the clay structure. This will effect the hydraulic conductivity.

Precipitation: As discussed before, precipitation of heavy metals, salts and carbonates may occur. This will cause reduction in hydraulic conductivity due to blocking of the pore space. Site specific tests must be conducted to measure in-situ permeability.

[15%]

1c) Construction of a slurry trench



Specifications

Permeability: Permeability (k) < 1 X 10-7 cm/s seems to be requirement most waste containment regulatory bodies are insisting on.

Slurry properties: 5 to 7% of bentonite mixed in good-quality water

slurry density at least 15% less than the back-fill density;

Typical slurry density 90 lb/ft3

Typical back-fill density 105 to 120 lb/ft3

Wall continuity: Properly keyed into low permeability strata across its full width. If keying is employed then, the wall must be keyed to a depth of atleast 2 to 3 feet.

Excavation stability

Loss of slurry due to buried pipes or encountering high permeable strata can be a problem. Quick pumping of slurry to maintain its level above the water table may be necessary. Sometimes dykes are constructed to do this, especailly if the soil is very soft, or water table is very close to ground level.

Wall thickness: Usually 3 to 7.5 feet. but is a function of slurry chosen, back fill properties, site characteristics etc.

Backfill material properties: Three kinds of backfill materials are used. The material properties of the back fill material will effect the overall performance of the slurry wall.

Soil-Bentonite (SB) backfill

Cement-Bentonite (SB) backfill

Plastic Concrete Backfill

[20%]

1d) using data sheets $P_c = P_o\left(1+\frac{r}{100}\right)^n$.

$P_o = 6000$ — waste

Year 1	2019-20	(12%) 6720	× 35 × 52	= 12230400
Year 2	2020-21	(12%) 7526.4	× 35 × 52	= 13698048
Year 3	2021-22	(12%) 8429.56	× 25 × 52	= 10958438.4
Year 4	2022-23	(7%) 9019.6	× 25 × 52	= 11725532
Year 5	2023-24	(7%) 9651.01	× 25 × 52	= 12546313
Year 6	2024-25	(7%) 10326.58	× 25 × 52	= 13424554

Total waste = 74583285.4 kg

(i) unit weight = 7.5 kN/m³.
density = 764.526 kg/m³.

volume = $\frac{74583285.4}{764.526}$ = 97554.94 m³ / depth = 12m

Area = 8129.578 m².

[20%]

size = 100m × 85m = 8500 m² > 8129.578 m² OK

ii) surface area = 8500 × 0.8 m/year.
= 6800 m³/year.

10% infiltrate = 680 m³.
10% leachate = 680
Total volume of leachate = 1360 m³/year to be pumped out.

[15%]

iii) To minimise leachate, use as square dimensions as possible. = $\sqrt{8129.578}$ = 90.16 m × 90.16 m

[10%]

Q2) a) Continental Shelf: Continental shelves are shallow platforms adjacent to land masses. Ocean floor here is characterised by irregular topography with banks, basins and valleys.

- Total width is around 75 km.
- The depth here ranges from 100 m to 200 m.

Continental Slope: This is the region between the Deep Ocean floor and the continental shelf.

- Their width ranges from 20 km to 100 km.
- They cover about 10 to 15 % of earth's surface.

Deep Ocean Regimes:

These include

Abyssal Plains: The Ocean floor under the deep waters which are nearly flat and are called the Abyssal plains.

These are sedimentary deposits consisting of
a) pelagic clays
b) hemipelagic muds
c) calcareous oozes
d) turbidite deposits

Stratification is very variable in these regions. Deep seated faults may exist with possible tectonic activity. Also thermal activity may be present.

Abyssal hills:
Relatively small hills on Abyssal plains with slopes ranging from 1 to 15%
May adversely effect the range of area through which waste deposited can migrate.
The deposited waste may be affected by physical and chemical processes.

[20%]

2b) The Ocean water is stratified due to variations in density, temperatures and salinity with depth.

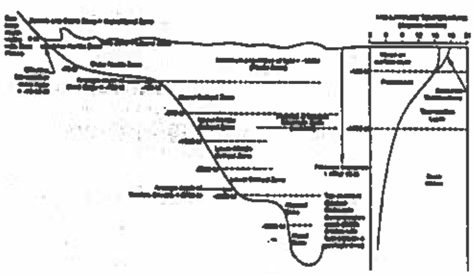


Figure Classification of benthonic marine environments in terms of depth and positions of critical oceanographic boundaries or transitional zones (modified after Ingle, 1980).

Circulation of water at shallow depth is effected by waves which depend on the prevailing wind conditions. Salinity is high here due to evaporation. The zones of rapidly changing temperature or density are called thermoclines or pycnoclines.

A water column can be divided into three zones namely

a) permanent pycnocline - shallow depth where changes in temperature take place continuously

b) intermediate waters and

c) deep waters

Dissolved oxygen content also reduces from shallow waters to deep waters.

Between 150m to 1000m relatively, low dissolved oxygen exists. This level is refereed to as 'oxygen minimum zone'.

Two important considerations regarding considering the ocean as a waste repository are

• permanent pycnocline and
• oxygen minimum zone

[15%]

2c) **Hydrogeological Considerations**

Injection zone characteristics:

The following are determined for each injection zone on a 'site-specific' basis;

- Hydraulic conductivity
- Porosity
- Stratigraphy (thickness, lateral extent and continuity of layers)
- Formation fracture gradient
- Reservoir pressure and temperature
- Residual oil, gas and water saturations
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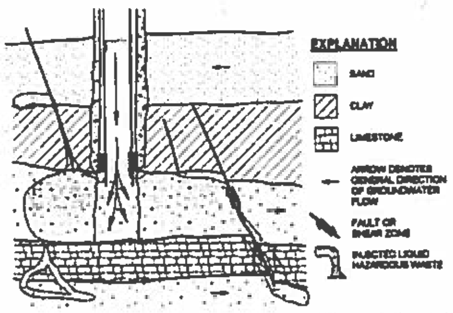
Confining zone characteristics:

- Presence of fracture or fault in confining zone is a worry



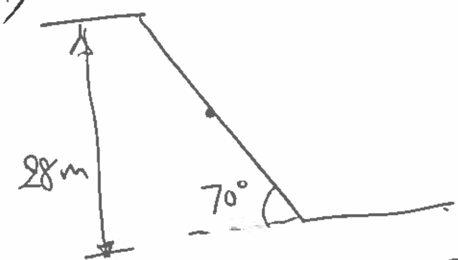
Schematic showing areas of concern during injection well installation and operation.

- All the characteristics of injection zone are determined for confining zone but with the aim of making sure no vertical propagation occurs through this zone.

- The following figure shows areas of concern for siting an injection well

[15%]

2d)



Weight of geomembrane

$$W = \frac{L}{\sin\beta} \times 1 \times 20 \times 9.81$$

$$= \frac{28}{\sin 70} \times 20 \times 9.81 = 5.846\ kN$$

$\delta_{top} = 8°$ $\delta_{side} = 14°$.

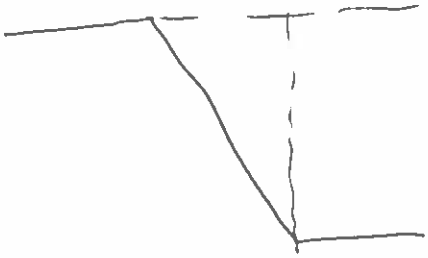
$$\sigma_{self\text{-}weight} = \frac{W \sin\beta - F}{1 \times t}$$

$$F = W \cos\beta \tan\delta_L = 5.846 \times \cos 70 \times \tan 14° = 0.4985\ kN$$

$$\therefore \sigma_{self\ weight} = \frac{5.846 \times \sin 70 - 0.4985}{1 \times 0.006} = 832.51\ kPa$$

or 0.832 MPa [10%]

2 d ii)



$W_{waste} = \frac{1}{2} \times 28 \times 10.1911 \times 9.6$ kN/m³

$= 1369.68$ kN/m.

Downdrag stress =

$(\sigma_T)_{downdrag} = \frac{1369.68 \times \cos 70^\circ \times \tan 8^\circ}{1 \times 0.006}$

$= 110972.95$ kPa.

$= 10.97$ MPa.

Total stress in the geomembrane

$= 0.832 + 10.97 = 11.802$ MPa < 13.9 MPa

So OK.

No redesign is necessary. [20%]

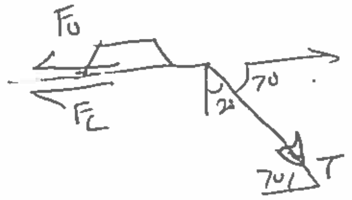
d iii) Flat bed anchor design:

Tensile force /m width $= 11.802 \times 10^6 \times 0.006$

$T = 70.812$ kN

vertical stress under the berm

$\sigma_v = 2m \times 17 = 34$ kPa.



$F_U = 34 \times \tan 8^\circ \times 1 \times L$

$F_L = (34 \times 1 \times L + T \sin 70)\tan 14^\circ$

$= (34 L + T \sin 70) \tan 14^\circ$.

$\therefore \quad F_U + F_L = T \cos 70^\circ$

$4.7784L + 8.4772L + 16.59066 = 70.812 \times \cos 70^\circ$

$= 24.21913$

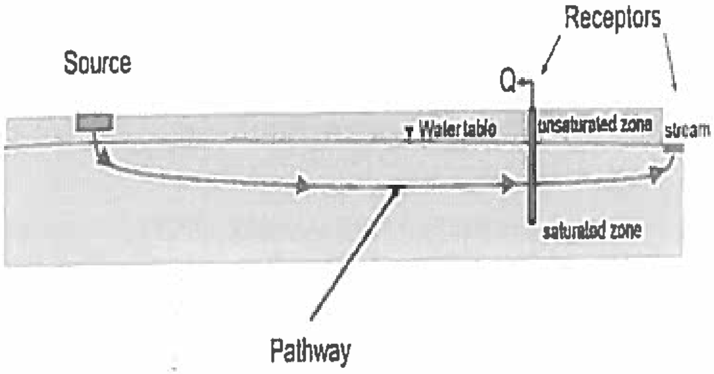
$13.2556 \times L = 7.6285$

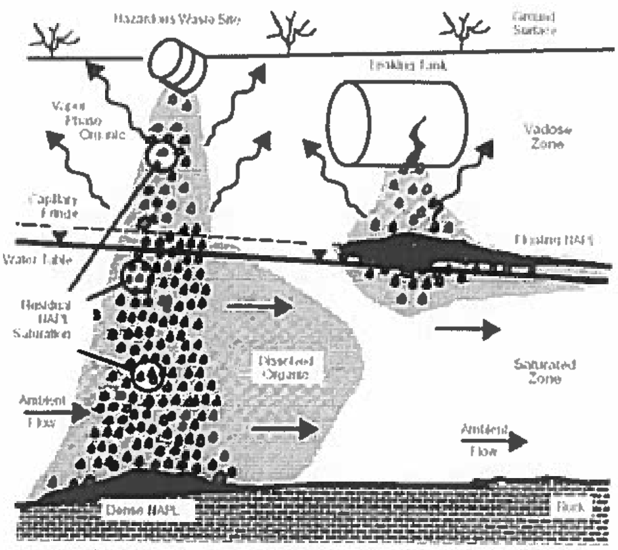
$L = 0.57549$ m

$L \approx 0.6$ m ✓ OK [20%]

3. (a) A large number of possible examples including landfill, chemical works, leaking underground tasks, disposal lagoons, etc etc. Potential risks include the spread of contamination and depending on their toxicology risk to human health, environment, ecosystems and infrastructure materials. Whether an activity pose a risk to a receptor is performed using a risk-based approach using the source, pathway, receptor model. All three components need to be present for a risk to be established and a significant pollutant linkage needs to be established. Examples include elevated levels of methods from a closed landfill site, which laterally migrates through the underlying geology and there is a linkages to residents in nearby residential properties with a potential for explosion. [20%]

(b) Role of a regulator in protecting the environment in the context of land contamination involves implementing government legislation with respect to environmental protection. For groundwater contamination there are specific policy documents. Remediation of contaminated land is covered by Part 2A of the 1990 Environmental Protection Act, which gives definition of contaminated land and , as part of this definition, requires pollutant linkage in the context of risk assessment. The cost-benefit analysis for remediation of land contamination, EA document provides guidance on remedial strategies. CLEA software and packages has been developed by the EA to cover all stages of dealing with land remediation. There are also other commercial computer software packages e.g. CONSIM have been developed to assist in the assessment of contaminated land. [10%]



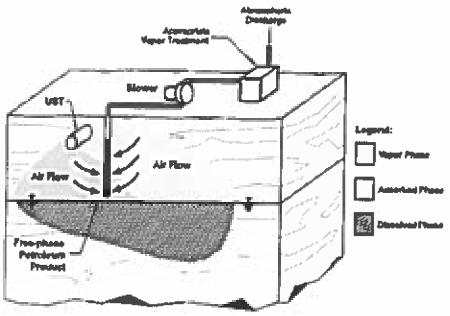


(c) Light NAPL float, while Dense NAPLs sink, also include volatiles which spread in the vadose zone, those with some solubility will migrate with the groundwater flow, collectively leading to significant spread in both above and below the water table where LNAPS are usually at depths above those of the DNAPLs. [20%]

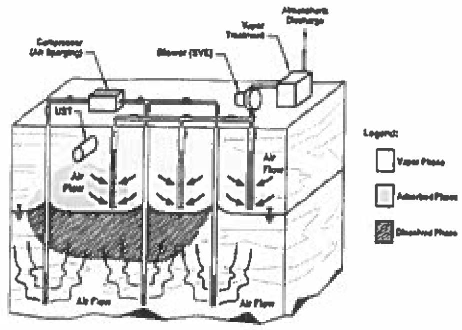
(d) Properties likely to influence the spread of NAPLs plumes. NAPL plumes are a mix of many compounds. These compounds will have different solubilities, which will control how easily the pollutants transfer to the groundwater, different adsorption constants which affect how easily the pollutants are retained by the soil, and also different vapour pressures, which control how easy they transfer to the vapour phase. The length of time that the spread was allowed to happen will also have an effect. [10%]

(e) Site investigation stages: boreholes, trial pits, samples from vadose and groundwater, samples across the whole site, appropriate sampling procedures (targeted and none targeted), mean and maximum value tests, send promptly for chemical analysis, beware of uncertainties associated with sample collection and analysis. [20%]

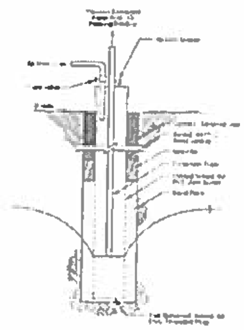
(f) LNAPL: Soil Vapour Extraction (SVE): In-situ technique of inducing airflow through soil to enhance volatilisation in vadose zone into soil atmosphere. Also referred to as in-situ volatilisation, soil vacuum extraction or soil venting. Recovered soil air is usually collected for subsequent treatment
Airflow is induced in the substrate, by applying a pressure gradient (negative) via a blower or a vacuum pump connected to wells placed in contamination zone resulting in movement of soil air and vapour-phase contaminants towards wells. Problem with making all contamination in treatment volume fully accessible to the treatment regime
DNAPL: Air Sparging: Involves the injection of compressed air (and occasionally steam) beneath the water table to promote remediation. Hybrid technology because it includes both physical & biological remediation processes. Aim is to remediate dissolved-phase of adsorbed organics. Although sometimes used in isolation, more commonly used to extend application of SVE to water-saturated soils. Air will penetrate an aquifer when the air injection pressure exceeds the sum of water column hydrostatic pressure and air entry pressure.
LNAPL & DNAPL: Dual-phase extraction combines vapour and groundwater (and sometimes free product) removal from a single well.



LNAPL



DNAPL



LNAPL & DNAPL

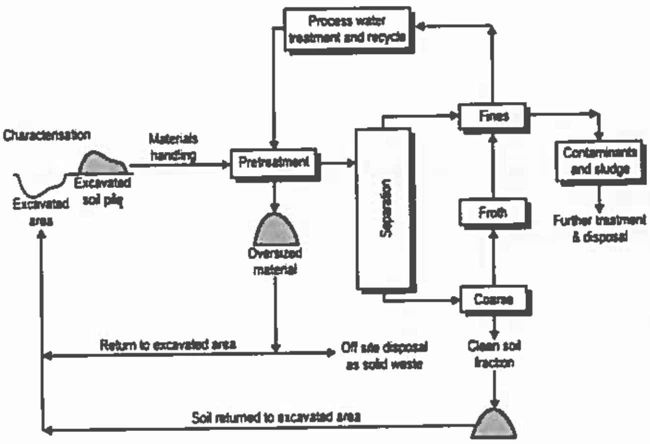
4. (a) Mining, landfilling, rifle site, ammunition manufacturing site, metal refinery. Heavy metals cannot be degraded so need to be immobilised or removed. They tend to sorb onto soil particles and hence heavy to dislodge. [10%]

(b) Immobilisation is usually performed using stabilisation/solidification: Solidification converts contaminated material into dense monolith with structural integrity suitable for storage, landfill or reuse. Stabilisation minimises hazardous potential and leachability of contaminated material by converting into less soluble, mobile or toxic form. Can be performed either in-situ or ex-situ, can deal with most heavy metals, many types of binders available, can also deal with cocktails with organics. Uses well established equipment and additives. Contaminants however remain in the ground, hence concern about long-term performance, effectiveness of some binders used unproven, potential volume increase due to the treatment.

Soil washing: process that employs either mechanical separation (volume reduction) and/or aqueous leaching to remove contaminants from contaminated soils. Properties exploited include: particle size, particle density, surface chemistry, magnetism, contaminant volatility, contaminant density, contaminant solubility, contaminant electrochemical properties. Uses washers, scrubbers, jets. Fundamental principles simple and exploit number of physical properties of contaminant and soil and the equipment is generally simple. Not usually associated with other remedial techniques except disposal to landfill – but could form part of sequential treatment methodology e.g. stabilisation/solidification and bioremediation. Currently limited to soil types which do not contain significant proportions of organic matter or clay, most effective if fine soil content does not exceed 30%. Soil washing systems either fixed at central location or installed on site. Process usually performed ex-situ only but can be carried out on-site.

Phytoremediation: use of plants to breakdown or remove contaminants. There are 6 different mechanisms. Those which are directly relevant to heavy metals are two: Phytostabilisation and phytoaccumulation. Phytostabiliastion (works for both organics and inorganics: Mechanism uses certain plant species to immobilise contaminants making them stable through: (i) precipitation or immobilisation within the root zone - using proteins and enzymes produced by plant. This mechanisms may reduce fraction of contaminant that is bioavailable, (ii) adsorption onto the roots – proteins and enzymes directly associate with root cell walls can bind and stabilise contaminants on exterior of the root membranes, (iii) absorption and accumulation into the roots – Proteins and enzymes present on root cell walls can also facilitate transfer of contaminants across root membrane, can be sequestered within roots or get transferred to shoots. Typical heavy metals: Cd, Cr, Cu, Pb, Zn. Phytoaccumulation (mainly for inorganics): Uses metal or salt accumulating plants that translocate and concentrate soil contaminants into the roots and aboveground shoots and leaves. Certain plants called hyperaccumulators absorb unusually large amounts of metals in comparison to other plants (1000-10,000 mg/kg dry weight) and halophytes, similarly with salts (NaCl, MgCl). Inorganic readily available for plant uptake: Ni, Zn, As, Cu. A relatively green remedial process although only well established in some countries, hence there is lack of expertise and track record in the technology. [45%]

(c) Field implementation of each technique:
Stabilisation/solidification: Implemented on site using in-situ or ex-situ: mixing tools including pugmills, augers, backhoe and blenders,
Soil washing: System of conveyor blends, mixers, water sprays, jets, scrubbers, screen and hydrocyclones, filtration and flocculation
Phytoremediation: Use of plants: trees.
Phytostabilisation and Phytoaccommuniation: both can use Herbaceous species, grasses, trees, wetland species. [15%]



(d) High levels of both heavy metals and nitrogen in the ground would be detrimental to bioremediation processes. In vitrifcation, high metal content could short the electrode. [10%]

(e) Measurements of Lead concentrations in the laboratory and in the field.
A suitable laboratory technique is ICP-OES (inductively-coupled plasma optical emission spectromentry for analysing either the soil or groundwater. If analysing the soil, lead must first be extracted into aqueous solution by treating it with an acid. Can use sketch. The high energy of a plasma causes light of a specific wavelength to be emitted from lead atoms. The log. of the light intensity is a measure of the concentration of lead. Alternative techniques which are acceptable: Atomic absorption spectrometry; ICP-MS (Inductively coupled plasma - mass spectrometry. (can accept spectroscopy instead of spectrometry)
A field measurement suitable for lead is X-Ray Fluorescence analyser. Can use a sketch. X-Rays from a radioactive source are absorbed by lead atoms which causes the emission of fluorescent (or secondary) X-Rays. Can also accept chemical field test-kit as an answer, which would also give an indication of the presence of lead but with less accuracy than an instrumental method. [20%]

4D14 – assessor's comments:

Q1 Waste characterisation and calculations of waste arising
The question tested the candidates on waste characterisation and estimation of waste arisings. In the early parts of the questions, the candidates were tested on types of reactions that occur within the waste and at the waste-liner interface. Most candidates could produce satisfactory answers to this part of the question. The later parts of the question tested them on estimating the waste arisings based on population growth and recycling initiatives. Again most candidates answered well, and were able to size the landfill cell accordingly. A few candidates made numerical errors.

Q2 Waste disposal and geomembranes in landfills
Early parts of this question were on waste disposal in ocean and hazardous waste disposal. Most candidates produced good answers however the detailed explanations varied in their depth. Marks were awarded accordingly. The later parts of the question were on stresses in geomembrane landfill liners and design of an anchorage berm. Again many candidates produced very good answers and provided good insight into the design of the anchorage systems. Invariably there were a few candidates who made numerical mistakes and lost marks.

Q3 Land remediation legislations and NAPL contamination
A 6-part question with the first two parts on general contamination and remediation: asking for example of activities which cause major contamination problems and the role of the regulator in protecting the environment. The remaining four parts relates to NAPLs asking for a schematic of the distribution of LNAPLs and DNAPLs in the subsurface, properties influencing their spread, relevant chemical investigation and suitable remediation techniques.

Q4 Heavy metal contamination and remediation
A five-part question on heavy metal contamination and remediation. It first asks about sources of contamination and relevant major issues, then on the description of and comparison between three suitable remediation techniques, namely stabilisation/solidification, soil washing & phytoremediation. It then asks about detrimental effects of heavy metals on remediation techniques and finally asks for techniques for the measurement of heavy metal concentrations both in the laboratory and in the field. The question was generally answered well, most of the errors were related to incomplete answers or not knowing the answer. The question required linkage of knowledge from across the whole course and some students only did partial linkage, hence only partly answered the question.