APPENDIX A
GENERAL NOTES

Generic Notes – Encia Geoenvironmental Investigations

Environmental Setting

General

Third party information obtained from the British Geological Survey (BGS), the Coal Authority, the Local Authority etc is presented in the Correspondence Appendix of this Geoenvironmental Report.

Geology, Mining & Quarrying

In order to establish the geological setting of a site, Encia refer to BGS maps for the area, and the relevant geological memoir.

A coal mining report is obtained from the Coal Authority. Further information is sourced from the Local Authority and by reference to current and historical OS plans.

Landfills

Encia obtain data from the Landmark Information Group, the Environment Agency and the Local Authority with respect to known areas of landfilling within 250m of the proposed development site. Reference is also made to historical OS plans, which are inspected for evidence of backfilled quarries, railway cuttings, colliery spoil tips etc.

Radon

Radon is a colourless, odourless gas, which is radioactive. It is formed in strata that contain uranium and radium (most notably granite), and can move though fissures eventually discharging to atmosphere, or the spaces under and within buildings. Where radon occurs in high concentrations, it can pose a risk to health.

In order to assess potential risks associated with radon gas, Encia refer to BRE Report BR211, 1999: "*Radon: guidance on protective measures for new dwellings*".

BR211 provides a preliminary indication of the measures required for a particular site, but it is also often necessary to request a Stage 2 Protective Measures Site Report from the BGS.

The level of protection needed is site-specific and is determined by reference to the radon potential map for the area followed by a geological assessment of the site. This information is contained in the Annexes of BR211.

Annex A **–** derived from statistical analysis of radon measurements in existing houses carried out by the NRPB and grouped on a 5km grid.

Annex B **-** based on an assessment of the same radon measurements grouped by geological units. The maps show the 5km grid squares underlain completely or in part, by geological units which potentially exceed the action levels for radon protective measures. The grid squares are coded according to the highest potential within the square. In many cases the actual geological radon potential varies considerably within a grid square.

Encia adopt the following procedure when assessing risk associated with radon.

Firstly, Annex A maps are reviewed to see whether the site requires full, basic or no measures. If the site is in a dark brown square, full radon protection measures are required. If the site is in a light brown square, reference should be made to Annex B.

Secondly, Annex B maps are reviewed to see whether a further geological assessment is required which may result in upgrading the result from Annex A. If a site lies within a shaded square, it may require radon protection, and Encia request a Stage 2 Protective Measures Site Report from the BGS.

If the site is in a square that is not coloured or shaded in either set of maps then no radon protection is needed and therefore a BGS Report is not normally necessary.

The BGS geological assessment involves checking whether the site is on or close to a geological unit that has statistically been found to have elevated radon potential. The geological assessment is based on either 1:50,000 or the 1:250,000 scale data. The search area specified as part of the request is increased by 50m in areas where 1:50,000 data is available and by 500m in areas with 1:250,000 scale data to allow for potential inaccuracies in the position of boundaries. The BGS report indicates the highest level of protection required within the search area and its buffer zone.

When requesting a BGS report, Encia select the search radius carefully, since too large a search radius may result in the inclusion of areas underlain by geological units of a higher radon potential, thereby giving rise to recommending too high a level of protection.

The report also includes (where available), a list of the geological units included in the assessment. Encia check that these actually underlie the site, rather than the buffer zone only.

On the basis of radon measurements in dwellings and on their geological interpretation, the BGS report stipulates the level of protective measures required for the proposed development site, and this could be:

1. no measures,
2. basic measures, or
3. full measures.

Details of these measures are provided in the Hazardous Gas section of this Geoenvironmental Report.

Hydrogeology

Encia obtain information from the Environment Agency (EA) and the Landmark Information Group with respect to:

- groundwater quality
- recorded pollution incidents
- licensed groundwater abstractions

Reference is also made to the EA document "*Policy and Practice for the Protection of Groundwater*" (1998) and the relevant Groundwater Vulnerability Map.

Bedrock and any overlying granular Drift deposits are classified by the EA:-

- **Major aquifers:** *"Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public water supply and other purposes".*
- **Minor aquifers**: *"Fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Although these aquifers will seldom produce large quantities of water for abstractions, they are important both for local supplies and in supplying base flow to rivers".*
- **Non-aquifers**: *"Formations which are generally regarded as containing insignificant quantities of groundwater. However groundwater flow through such rocks, although imperceptible, does take place and needs to be considered in assessing the risk associated with persistent pollutants. Some non-aquifers can yield water in sufficient quantities for domestic use".*

Groundwater vulnerability is determined by 4 variables:

1. The presence and nature of overlying soil (the weathered zone affected by living organisms; soil in the UK can extend up to 2m in depth). Physical properties of the soil affect the downward passage of water and it's ability to attenuate pollutants. The EA make reference to a three-fold classification of soil types:-

    - Soils of **low** leaching potential are defined as *"soils in which the pollutants are unlikely to penetrate the soil layer because either water movement is largely horizontal, or they have the ability to attenuate diffuse pollutants".*
    - Soils of **intermediate** leaching potential are defined as *"soils which have a moderate ability to attenuate diffuse source pollutants or in which it is possible that some non-adsorbed diffuse source pollutants and liquid discharges could penetrate the soil layer".*
    - Soils of **high** leaching potential are defined as *"soils with little ability to attenuate diffuse source pollutants and in which non-adsorbed diffuse source pollutants and liquid discharges have the potential to move rapidly to underlying strata or to shallow groundwater".*

    In urban areas and restored mineral workings the soil information is based on fewer observations than elsewhere. A worst-case vulnerability (H) is therefore assumed for these areas and for current mineral workings by the EA. All are given a designation of **HU** unless proved otherwise.

2. The presence and nature of Drift, which often overlies bedrock. Where Drift is of substantial thickness and low permeability, it can provide an effective barrier to surface pollutant migration. Permeable Drift is classified as a Minor Aquifer except where it is in probable hydraulic continuity with a Major Aquifer, where it is regarded as part of the Major Aquifer unless proven otherwise by site investigation.

3. The nature of the geological strata (bedrock). Rocks that contain groundwater in exploitable quantities are called aquifers.

4. The depth of the unsaturated zone; ie that part of the aquifer which lies above the water table

The EA have also designated Source Protection Zones, which are based on proximity to a groundwater source (springs, wells and abstraction boreholes). The size of a Source Protection Zone is a function of the aquifer, volume of groundwater abstracted and the effective rainfall, and may vary from tens to several thousand hectares.

Hydrology

Encia obtain information from the Environment Agency and the Landmark Information Group with respect to:

- surface water quality
- recorded pollution incidents
- licensed abstractions (groundwater & surface waters)
- licensed discharge consents
- site susceptibility to flooding

The EA have set **water quality** targets for all rivers. These targets are known as River Quality Objectives (RQOs). The water quality classification scheme used to set RQO planning targets is known as the River Ecosystem scheme. The scheme comprises five classes (RE1 to RE5) which reflect the chemical quality requirements of communities of plants and animals occurring in our rivers.

General Quality Assessment (GQA) grades reflect actual water quality. They are based on the most recent analytical testing undertaken by the EA. There are six GQA grades (denoted A to F) defined by the concentrations of biochemical oxygen demand, total ammonia and dissolved oxygen.

The susceptibility of a site to **flooding** is assessed by reference to a Flood Map on the Environment Agency's website. These maps provide show natural floodplains - areas potentially at risk of flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas.

There are two different kinds of area shown on the Flood Map:

1. Dark blue areas could be flooded by the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year, or by a river by a flood that has a 1% (1 in 100) or greater chance of happening each year

2. Light blue areas show the additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to a 0.1% (1 in 1000) chance of occurring each year.

These two colours show the extent of the natural floodplain if there were no flood defences or certain other manmade structures and channel improvements

The maps also show all flood defences built in the last five years to protect against river floods with a 1% (1 in 100) chance of happening each year, or floods from the sea with a 0.5% (1 in 200) chance of happening each year, together with some, but not all, older defences and defences which protect against smaller floods.

The Agency’s assessment of the likelihood of flooding from rivers and the sea at any location is based on the presence and effect of all flood defences, predicted flood levels, and ground levels.

It should also be noted that as the floodplain shown is the 1 in 100 year (or 1 in 200 year as appropriate), areas outside this may be flooded by more extreme floods (e.g. the 1 in 1000 year flood). Also, parts of the areas shown at risk of flooding will be flooded by lesser floods (e.g. the 1 in 5 year flood). In some places due to the shape of the river valley, the smaller floods will flood a very similar extent to larger floods but to a lesser depth.

If a site falls within a floodplain, it is recommended that a flood survey be undertaken by a specialist consultant who can advise on appropriate mitigating measures; ie raising slab levels, provision of storage etc.

COMAH & Explosive Sites

Encia obtain information from the Landmark Information Group with respect to COMAH or explosive sites within 1km of the proposed development site. Encia's report refers to any that are present, and recommends that the Client seeks further advice from the HSE.

Areas around COMAH sites (chemical plants etc) are zoned with respect to the implementation of emergency plans. The HSE are a statutory consultee to the local planning authority for all COMAH sites. The COMAH site may have to revise it's emergency action plan if development occurs. This might be quite straightforward or could entail significant expenditure. Consequently, the COMAH site may object to a proposed development (although it is the Local Authority who have final say, and they are likely to place more weight on advice from the HSE).

Preliminary Conceptual Ground Model

The site's environmental setting (and proposed end use) is used by Encia to assess the significance of any contamination encountered during the subsequent ground investigation

Assessment of contaminated land is based on an evaluation of pollutant linkages (source-pathway-receptor). Contaminants within the near surface strata represent a potential source of pollution. The environment (most notably groundwater), site workers and end users are potential targets.

Potential pollutant linkages are shown on a preliminary conceptual site model, presented as a Drawing in an Appendix to this Geoenvironmental Report. The preliminary model is revised in light of data arising from the subsequent ground investigation.

Generic Notes – Encia Geoenvironmental Investigations

2. Ground Investigation Fieldwork

General

Encia Ground Investigations are undertaken in accordance with current UK guidance including:

- BS5930:1999 "*Code of practice for site investigation*"
- BS10175:2001 "*Code of practice for the identification of potentially contaminated sites*".
- "*Technical Aspects of Site Investigation*" – EA R&D Technical Report P5-065/TR (2000)
- "*Development of appropriate soil sampling strategies for land contamination*" – EA R&D Technical Report P5-066/TR (2001)
- Contaminated Land Reports 1 to 6, most notably CLR Report No. 4 "*Sampling strategies for contaminated land*"
- "*Guidance on the protection of housing on contaminated land*" – NHBC & EA R&D Publication 66 (2000)
- AGS: 1996 "*Guide to the selection of Geotechnical Soil Laboratory Testing*"

Exploratory hole logs are presented in Appendices to this Geoenvironmental Report. These logs include details of the:

- Investigation technique adopted
- Samples taken
- Descriptions of the solid strata, and any groundwater encountered.
- Results of any in-situ testing
- Any gas\groundwater monitoring well installed

Exploratory Hole Locations

Exploratory hole locations are selected by Encia, prior to commencement of fieldwork, to provide a representative view of the strata beneath the site and to target potential contaminant sources identified during the preliminary investigation (desk study). Additional exploratory locations are often determined by the site engineer in light of the ground conditions actually encountered; this enables better delineation of the depth and lateral extent of organic contamination, poor ground, relict structures etc.

Investigation Techniques

Ground conditions can be investigated by a number of techniques; the procedures used are in general accordance with BS5930: 1999 and BS1377: 1990. Techniques most commonly used by Encia include:

- Machine excavated trial pits, usually equipped with a backactor and a 0.6m wide bucket.
- Cable percussive (Shell & Auger) boreholes, typically using 150mm diameter tools and casing.
- Window or Windowless Sampling boreholes. Constraints associated with existing buildings, operations and underground service runs can render some sites partly or wholly inaccessible to a mechanical excavator. In such circumstances, window sampling is often

the most appropriate technique. A window sampling drilling rig can be manoeuvred in areas of restricted access and results in minimal disturbance of the ground (a 150mm diameter tarmac/concrete core can be lifted and put to one side). However, it should be noted that window sampling allows only a limited inspection of the ground (especially made ground with a significant proportion of coarse material).

- Rotary percussive open-hole probeholes are typically drilled using a tricone rock roller bit with air as the flushing medium. Probeholes are generally lined through made ground with temporary steel casing to prevent hole collapse.

Where installed, gas\groundwater monitoring wells typically comprise a lower slotted section, surrounded by a filter pack of 10 mm non-calcareous gravel and an upper plain section surrounded in part by a bentonite seal and in part by gravel or arisings. The top of the plain pipe is cut off below ground level and the monitoring well protected by a square, stopcock type manhole cover set in concrete, or the plain pipe is cut off just above ground level and the well protected by 100mm diameter steel borehole helmet set in concrete.

Monitoring well details, including the location of the response zone and bentonite seal are presented on the relevant exploratory hole logs.

In-situ Testing

Where relative densities of granular materials given on the trial pit and window sample logs are based on visual inspection only, they do not relate to any specific bearing capacities. However, wherever possible Encia employ a Mackintosh probe to assess relative density. Mackintosh probe results can be related to approximate allowable bearing capacities.

The relative densities of granular materials encountered in cable percussive boreholes are based on Standard Penetration Test (SPT) results. SPTs are carried out boreholes, in accordance with BS 1377 1990, Part 9 Section 3.3. Where full penetration (600mm) is not possible, N values are calculated by linear extrapolation and are shown on the logs as N* = x.

The strength of cohesive deposits is determined using a hand shear vane.

Shear strength test results reported on trial pit logs are considered to be more reliable than those reported on window sample logs. Significant sample disturbance occurs during window sampling and consequently shear strength results on disturbed window samples are generally lower than results obtained during trial pitting, in-situ or in large excavated blocks.

Sampling

Representative soil/fill samples are taken at regular intervals from the exploratory holes to assist in description of the ground and to allow selected laboratory testing to be performed. The type of sample taken is dependent on the nature of the stratum and the purpose of the analysis.

Where the soils encountered contain a significant proportion of coarse grained material, truly representative samples are not typically obtained - only the finer fraction is placed in sample containers. However, a visual estimate of the amount of coarse material is made on site.

NB: Coarse constituents not sampled are defined as: coarse gravel, cobble and boulder. (i.e. any 'particles' with an average diameter greater than 20mm).

Occasionally, unrepresentative 'spot' samples are also taken from some exploratory locations for contaminant analysis, typically where unusual, localised pockets of materials are encountered.

Samples of soil for chemical testing are placed into 1 litre plastic tubs prior to delivery to the selected laboratory. Samples of water are taken in one litre, brown glass bottles and stored in cool boxes, at a temperature of approximately 4ºC, until delivery to the selected laboratory. Soil\fill samples for organic analysis are also stored in cool boxes.

Groundwater

Where encountered during fieldwork, groundwater is recorded on exploratory hole logs. If monitoring wells are installed, groundwater levels are also recorded on one or more occasions after completion of the fieldwork.

It should be borne in mind that the rapid excavation rates used during a ground investigation may not allow the establishment of equilibrium water levels. Water levels are likely to fluctuate with season/rainfall and could be substantially higher at wetter times of the year than those found during this investigation.

Long-term monitoring of standpipes or piezometers is always recommended if water levels are likely to have a significant effect on earthworks or foundation design.

Description of Strata

The soils encountered during an Encia ground investigation are described (logged) in general accordance with BS 5930. The descriptions and depth of strata encountered are presented on the exploratory hole logs and summarised in the Ground Conditions section within the main body of text.

The materials encountered in the trial pits are logged, samples taken, and tests performed on the in-situ materials in the excavation faces, to depths of up to 1.2m; below this depth these operations are conducted at the surface on disturbed samples recovered from the excavation.

Key to Exploratory Hole Logs

Keys to logs are presented in the Appendix(ces) containing the logs. There are two Keys – Symbols & Legends and Terms & Definitions.

Generic Notes – Encia Geoenvironmental Investigations

3. Geotechnical Laboratory Tests

General

Soil samples are delivered to the laboratory for testing along with a schedule of testing drawn up by Encia. All tests are carried out in accordance with BS 1377:1990.

The test results are presented as received in an Appendix to this Geoenvironmental Report.

The following laboratory testing are routinely carried out on a selection of samples:

- Atterberg limits & moisture contents
- Soluble sulphate & pH

The additional tests are typically only scheduled where significant earthworks regrade is anticipated:

- Grading.
- Compaction tests
- Particle density.

Atterberg Limits & Moisture Content

The Liquid and Plastic Limits of samples of natural in-situ clay are determined using the cone penetrometer method and the rolling thread test. These tests enable determination of an average Plasticity Index (PI) for each "type" of clay, although judgement is applied where variable results are reported.

PI can be related to shrinkability (low, medium or high) and then to minimum founding depth. Encia typically only consider a soil to be shrinkable if the proportion finer than 63µm is >35%.

PI results are compared against guidance given in the NHBC Standards, Chapter 4.2 (revised April 2003), which advocates the use of modified Plasticity Index (I'p), defined as:

I'p = Ip * (%< 425µm/100)

ie if PI is 30%, but the soil contains 80% < 425µm, then: I'p = 30 * 80/100 = 24%.

It should be noted that in accordance with the requirements of BS 1377, the % passing the 425µm sieve is routinely reported by testing labs.

Encia apply engineering judgment where PI results are spread over a range of classifications. Consideration is given to:

- the average values for each particular soil type (ie differentiate between residual soil and alluvium),
- the number of results in each class and
- the actual values.

Unless the judgment strongly indicates otherwise, Encia typically adopt a conservative approach and recommend assumption of the higher classification.

Soluble Sulphate and pH

Sulphates in soil and groundwater are the chemical agents most likely to attack sub-surface concrete, resulting in expansion and softening of the concrete to a mush. Another common cause of concrete deterioration is groundwater acidity.

The rate of chemical attack depends on the concentration of aggressive ions and their replenishment at the reaction surface. The rate of replenishment is related to the presence and mobility of groundwater.

Encia refer to BRE Special Digest 1 (SD1) "Concrete in aggressive ground. Part 1: Assessing the aggressive chemical environment" (2001). SD 1 provides definitions of:

- the nature of the site (greenfield, brownfield or pyritic)
- the groundwater regime (static, mobile or highly mobile)
- the Design Sulphate Class (DC Class) and
- the Aggressive Chemical Environment for Concrete (ACEC Class)

Encia reports clearly state each of the above for the site being considered.

The concentrations of sulphate in aqueous soil/fill extracts are determined in the laboratory using the gravimetric method. The results are expressed in terms of SO_4 for direct comparison with BS 5328:1997. The pH value of each sample was determined by the electrometric method.

SD1 also discusses determination of "representative" sulphate concentration from a number of tests. Essentially if <10 samples of a given soil-type have been tested, the highest measured sulphate concentration should be taken. If >10 samples have been tested, the mean of the highest 20% of the sulphate test results can be taken. With respect to groundwater, the highest sulphate concentration should always be taken.

With respect to pH (soil & groundwater) the value used is the lowest value if <10 samples have been tested and the mean of the lowest 20% if >10 samples have been tested.

Generic Notes – Encia Geoenvironmental Investigations

4A. Contamination Laboratory Analysis & Interpretation (including WAC)

Waste Classification & WAC

In the context of waste soils generated by remediation and\or groundworks activities on brownfield sites, the following definitions (from the Landfill Regulations 2002) apply:

- Inert (e.g. uncontaminated 'natural' soil, bricks, concrete, tiles & ceramics).
- Non-Hazardous (e.g. soil excavated from a contaminated site which contains dangerous substances, but at concentrations below prescribed thresholds).
- Hazardous (e.g. soil excavated from a contaminated site which contains dangerous substances at concentrations above prescribed thresholds).

Dangerous substances include compounds containing a variety of determinants commonly found in contaminated soils on brownfield sites, for example arsenic, lead, chromium, benzene etc.

From 16th July 2005, landfill operators will require Waste Acceptance Criteria (WAC) laboratory data, if soil waste is classified as **hazardous**, and such waste must have been subjected to pre-treatment. However, subject to WAC testing it may be possible to classify it as stable, non-reactive hazardous waste, which can be placed within a dedicated cell within the non-hazardous landfill.

Encia typically only include WAC analysis in site investigation proposals and reports, if significant off-site disposal (of soil classified as hazardous waste) is anticipated, for example where redevelopment proposals include basement construction etc.

If off-site disposal of soils classified as hazardous waste were undertaken during redevelopment, then WAC analysis should be scheduled at an early stage in the remediation programme.

However, organic compounds (BTEX, TPH, PAH etc) are the most common contaminants that result in soils being classed as hazardous. These contaminants can often be dealt with by alternative technologies (eg by bioremediation or stabilisation) and consequently retention on site is often possible.

It should be noted that **non-hazardous** soil waste can go to a non-hazardous landfill facility; no further testing (eg WAC) is required.

Contamination Laboratory Analysis & Interpretation

An assessment of potential contaminants associated with the former usages of the site is undertaken with reference to CLR 8 "*Potential contaminants for the assessment of land*" and the relevant DETR Industry Profile(s).

Common Inorganic Contaminants

These include:

- metals, most notably cadmium, copper, chromium, mercury, lead, nickel, and zinc.
- semi-metals, most notably arsenic, selenium, and (water soluble) boron
- non-metals, most notably sulphur
- inorganic anions, most notably cyanides (free & complex), sulphates, sulphides, and nitrates.

With respect to the terminology used by most analytical laboratories:

Total cyanide = Free cyanide + Complex cyanide

Total cyanide (CN) is determined by acid extraction; whereas free cyanide is the water soluble fraction.

Complex cyanide is "bound" in compounds and is hard to breakdown. Laboratory determination of complex CN involves subjecting the sample to uv digestion for determination of both free and total CN.

Thiocyanate (SCN) is a different species combined with sulphur.

Elemental sulphur (S) and free sulphur are the same. Total sulphur is all forms, including that present in sulphates (SO_4), sulphides etc

There are 2 forms of chromium (Cr), chromium VI and chromium III. Chromium VI is the more toxic of these. In soils, total chromium is determined by a strong aqua regia acid digestion. Chromium VI is an empirical method based on a water extract test.

Common Organic Contaminants

Petroleum hydrocarbons are a mixture of hydrocarbons produced from the distillation of crude oil. They include aliphatics (alkanes, alkenes and cycloalkanes), aromatics (single or multi benzene ringed compounds) and hydrocarbon-like compounds containing minor amounts of oxygen, sulphur or nitrogen.

Petroleum hydrocarbons can be grouped based on the carbon number range:-

GRO – Gasoline Range Organics (typically C_6 to C_{10}). Also referred to as PRO – Petroleum Range Organics
DRO – Diesel Range Organics (typically C_{10} to C_{28})
LRO - Lubricating Oil Range Organics (typically C_{28} to C_{40})
MRO – Mineral Oil Range Organics (typically C_{18} to C_{44})

However, it should be borne in mind that the terms "GRO" and "DRO" analysis are purely descriptive terms, the exact definition of which varies.

Total Petroleum Hydrocarbons (TPH) is also a poorly defined term; some testing laboratories regard TPH as hydrocarbons ranging from C_5-C_{40}, whereas other define TPH as C_{10}-C_{30}.

The composition of a TPH plume migrating through the ground can vary significantly; this is primarily dictated by the nature of the source (eg petrol, diesel, engine oil etc). Furthermore, different hydrocarbons are affected differently by weathering processes, and this can result in further variation in the chemical composition of the TPH.

Gasoline contains light aliphatic hydrocarbons (especially within the C4 to C5 range) that will rapidly evaporate. The aromatic hydrocarbons in gasoline are primarily benzene, toluene, ethylbenzene and xylenes, referred to as BTEX. Small amounts of polyaromatic hydrocarbons (PAHs) such as benzo(a)pyrene may also be present.

Diesel and light fuel oils have higher molecular weights than gasoline. Consequently, they are less volatile and less water soluble. About 25 to 35% is composed of aromatic hydrocarbons. BTEX concentrations are generally low.

Heavy Fuel Oils are typically dark in colour and considerably more viscous than water. They contain 15 to 40% aromatic hydrocarbons. Polar nitrogen, sulphur and oxygen-containing compounds (NSO) compounds are also present.

Lubricating Oils are relatively viscous and insoluble in groundwater. They may contain 10 to 30% aromatics, including the heavier PAHs. NSO compounds are also common.

Polycyclic Aromatic Hydrocarbons (PAHs) have more than two fused benzene rings as a structural characteristic. PAH compounds are present in both petrol and diesel, although in significantly lower concentrations than in coal tars. Certain PAH compounds are carcinogenic (Benzo(a)pyrene) and\or mobile in the environment (naphthalene).

Semi-Volatile Organic Compounds (sVOCs) include a variety of compounds, which as the names suggest have relatively low boiling points; however, VOC's are much more volatile than SVOC's. Examples of VOC's include benzene, chloroform and toluene; SVOC's include phenol, fluorene. Both groups of chemicals are readily absorbed through skin and some, such as benzene, are believed to be linked to tumour growth.

Phenols are compounds that have a hydroxyl group attached to an aromatic ring (ie include a benzene ring and an –OH group). Most are colourless solids. A solution of phenol in water is known as carbolic acid, and is a powerful antiseptic. However, phenol vapour is toxic, and skin contact can result in burns.

Polychlorinated Biphenyls (PCBs) were used in pre-1974 transformers as dielectric fluids. PCB's are of increasing toxicity relative to the degree of chlorination. Acute symptoms of PCB poisoning are irritation of the respiratory tract leading to coughing and shortness of breath. Nausea, vomiting and abdominal pain are caused by ingestion of PCB's.

Dioxins and furans (polychlorinated dibenzodioxins and polychlorinated dibenzofurans) are some of the most toxic chemicals known. In the environment, they tend to bio-accumulate in the food chain. Dioxin is a general term that describes a group of hundreds of chemicals that are highly persistent in the environment. The most toxic compound is 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD.

Dioxin is formed by burning chlorine-based chemical compounds with hydrocarbons. The major source of dioxin in the environment comes from waste-burning incinerators and also from backyard burn-barrels. Dioxin pollution is also affiliated with paper mills which use chlorine bleaching in their process and with the production of Polyvinyl Chloride (PVC) plastics and with the production of certain chlorinated chemicals (like many pesticides).

Methods of Analysis (Organic Compounds)

TPH by GC-FID is a more refined analytical technique which only detects hydrocarbons (aliphatic and aromatic) in the range C_{10} to C_{40} (volatiles, heavy tars, humic material and sulphur are not detected). The laboratory can provide a breakdown of the TPH results into diesel range organics (**DRO**) and heavier lubricating oil range organics (**LRO**).

GRO (PRO) by GC-FID analysis detects the more volatile C_6-C_9 hydrocarbons (aliphatic and aromatic), including those organic compounds present in petrol.

Speciated VOC (by GC-MS) analysis quantifies the concentrations of 30 USA-EPA priority compounds. These include chlorinated alkanes and alkenes (in the molecular weight range chloroethane to tetrachloroethane); trimethylbenzenes; dichlorobenzenes; and the 4 BTEX compounds (benzene, ethyl-benzene, toluene & xylene).

Speciated sVOC by (GC-MS) analysis quantifies the concentrations of a variety of organic compounds, including the 16 USA-EPA priority PAHs, phenols, 7 USA EPA priority PCB congeners, herbicides & pesticides.

Note: PAHs are hydrocarbons and consequently (where present) will be picked-up when scheduling TPH. by GC-FID. Naphthalene (the lightest PAH) is also one of the 58 US EPA VOCs.

Speciated TPH by GC-FID provides a "banded" TPH, initially split into aromatic and aliphatic fractions and then further divided into fraction specific carbon bandings based upon behavioural characteristics.

Note: Risk assessment models require physiochemical properties (solubilities, toxicities etc) of compounds in order to model their behaviour in the environment. These physiochemical properties cannot be derived from a single "TPH", "GRO" or "DRO" value. However, the carbon banded fractions can be used in risk assessment models.

Current UK Guidance

The UK approach to contaminated land is set out in Contaminated Land Report No. 11 (2004) "*Model Procedures for the Management of Land Contamination*". The approach is based upon risk assessment, where risk is defined as the combination of the probability of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

In the context of land contamination, there are three essential elements to any risk: (1) a contaminant source, (2) a receptor (eg controlled water or people) and (3) a pathway linking the (1) and (2). Risk can only exist where all three elements combine to create a pollutant linkage. Risk assessment requires the formulation of a conceptual model which supports the identification and assessment of pollutant linkages.

Encia adopt a tiered approach to risk assessment, consistent with UK guidance and best practice. The initial step of such a risk assessment (or Tier 1) is the comparison of site data with appropriate UK guidance levels, Encia risk-derived screening values, or remedial targets.

Tier 1 **groundwater** risk assessments are undertaken by comparing leachate or groundwater concentrations with the appropriate water quality standard. Depending upon the specific characteristics and environmental setting of the site the appropriate standard is likely to be one of the following:

- Water Supply (Water Quality) Regulations 1989
- Environmental Quality Standards (for Freshwater)
- The Surface Waters (Abstraction for Drinking Water) Regulations

The tier 1 risk assessment of **landfill gas** is undertaken through reference to the following documents:

- Approved Document C, Building Regulations 1991
- CIRIA Report 149, "Protecting Development from Methane", 1995

Further information is presented in Generic Note No. 5 – Hazardous Gas.

In March 2002 DEFRA and the Environment Agency published a series of technical research papers (R & D Publications CLR 7, 8, 9 and 10) introducing the UK approach to the assessment of risk to **human health** from land contamination. This methodology and approach represents current scientific knowledge and thinking. The overall methodology also included the Contaminated Land Exposure Model (CLEA) and some Soil Guideline Values (SGV's).

At the time of writing this report, SGV's were only available for a limited number of contaminants, the development of both the CLEA model and additional SGV's is ongoing. Where published, SGV's have been utilised as intervention values for the purpose of an initial Tier 1 assessment.

It should be noted that exceedance of Tier 1 does not necessarily mean that remedial action will be required.

With respect to the assessment of potential **phytotoxic effects** of contaminants, Encia refer to "*The Soil Code*" (MAFF, 1998) for copper and zinc. The CLEA SGV is adopted for nickel due to its human health effects.

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"*In general…………..it seems likely that materials whose CV's exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn".*

Current Guidance derived by Encia

In the absence of UK SGVs for a number of "common" organic compounds, Encia have derived generic screening values for use as "Tier 1" values. These values have been derived using the RISC model, and taking account of UK policy decisions, Health Criteria Values and CLEA defaults.

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Similarly, TPH cannot be assessed as a single "total" value, and reference has been made to the Environment Agency's document P5-080/TR3, "*The UK approach for evaluating human health risks from petroleum hydrocarbons in soils*". This document supports the assumptions and recommendations made by the US Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG).

The TPHCWG have broken down "TPH" into thirteen representative constituent fractions or "EC Bandings". EC Bandings are based around Equivalent Carbon numbers and the TPHCWG have derived a series of physiochemical and toxicological parameters for each of the thirteen EC bandings. The methodology for the derivation of these banding-specific properties is outlined in the TPHCWG series volumes 1-4.

Encia have calculated a screening value for each of the thirteen constituent fractions. These fractions have then been considered in terms of GRO, DRO and LRO to provide simpler, conservative initial Tier 1 screening values.

Encia's derivation of Tier 1 values is based on a number of assumptions, most notably:

a. The site's environmental setting, in terms of proximity to **Controlled Waters**, is not sensitive. It is not possible to derive generic Tier 1 values for waters, because distance and ground permeability are key factors, and both are extremely site-specific. Consequently, detailed quantitative risk assessment is required.

b. Contamination identified is located in the top 0.5m of soil on site. The CLEA model assumes that all exposure pathways are relevant within 0.5m of ground level.

c. A conservative **Soil Organic Matter** of 1%.

   (Note: TOC = SOM x 0.58; and FOC = TOC/100).

   Hydrocarbons tend to be "bind" with SOM, and therefore become less mobile. Consequently, Tier 1 values can be revised if the amount of organic matter within the soil exceeds 1%.

d. Some determinands reach **residual saturation** before a vapour risk is predicted to occur. Prior to residual saturation, as the concentration of a contaminant in soil increases, so does the concentration of the same contaminant in the associated vapour phase. However, once saturation is reached, the concentration of contaminant in the vapour phase remains constant (for any given atmospheric conditions – temperature and pressure).

   However, Encia recognise that it is unacceptable to leave free product in the ground and therefore arbitrary Tier 1 values have been ascribed to such contaminants. These values have been selected on the basis that they are below the limit of olfactory detection (ie at concentrations below Tier 1, odours are not readily identified).

Table 1 - Encia Tier 1 values

Contaminant	Tier 1 Value (mg/kg)	Comments/Notes
PCB	1.2	Based on PCB EU Seven
Benzene	0.3	
Xylene	6	
Benzo(a)pyrene	1.4	This value should also be used for the other most toxic PAHs, namely: Benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3,c,d)pyrene & Dibenz(a,h)anthracene.
Naphthalene	22	Risk at surface driven by direct ingestion pathway
total PAH	1.4	The higher toxicity of Benzo(a)pyrene makes it the most problematic PAH in near surface soils. Consequently, Encia have adopted the Tier 1 value for Benzo(a)pyrene (1.4mg/kg) as an initial Tier 1 screening value for total PAH, on the conservative assumption that all the PAH is Benzo(a)pyrene.
TPH $<C_{10}$ Gasoline range organics (GRO)	0.3	Based on conservative assumption that all TPH$<C_{10}$ is benzene. If concentrations >0.3 mg/kg are recorded, but no benzene present, a Tier 1 value of 16mg/kg could be adopted for the gasoline range or reference can be made to Refined Tier 1 Values for speciated TPH (see below).
TPH $C_{10} – C_{20}$ Diesel range organics (DRO)	330	If DRO above tier 1 value and speciated fraction bandings are available, refer to Refined Tier 1 Values for speciated TPH (see below).
TPH $C_{21} – C_{40}$ Lubricating range organics (LRO)	580	Risk at surface driven by direct ingestion/dermal contact/veg uptake pathway of heavy aromatic fractions, if speciated fraction bandings are available, refer to Refined Tier 1 Values for speciated TPH (see below).

If site concentrations of any of the three broad TPH bandings (GRO, DRO or LRO) exceed the Tier 1 values quoted in Table 1 above, further assessment, with reference to speciated TPH results, will be required:

Table 2 - Refined Tier 1 values (TPH Bands)

Contaminant	Refined Tier 1 values (mg/kg)	Comments/notes
Aliphatic C5-C6	92	
Aliphatic C6-C8	500	Residual saturation reached due to lower toxicity of aliphatic compounds (cf aromatics), therefore no inhalation or ingestion risk. Tier 1 value selected on the basis that a concentration of 500 mg/kg is well below the limit of olfactory detection.
Aliphatic C8-C10	40	
Aliphatic C10-C12	1,000	Risk at surface driven by direct ingestion pathway, but (more conservatives value) adopted based on odour threshold
Aliphatic C12-C16	1,000	
Aliphatic C16-C21	1,000	
Aliphatic C21-C34	5,000	Residual saturation reached via inhalation; 5,000 selected based on direct contact.
Aromatic C5-C7	16	
Aromatic C7-C8	36	
Aromatic C8-C10	63	
Aromatic C10-12	330	
Aromatic C12-16	620	Driven by direct contact and vegetable uptake
Aromatic C16-C21	540	Driven by direct contact and vegetable uptake
Aromatic C21-35	580	Driven by direct contact and vegetable uptake

The significance of speciated TPH results can be assessed by following the 3 steps outlined in Table 3 below.

Note: This 3-step assessment is **not** required if concentrations of GRO, DRO & LRO are all below their respective Tier 1 values (see Table 1).

Table 3 – Assessment of TPH

Step	Result	Action
1 – Consider indicator compounds: Are BTEX, Naphthalene, Benzo(a)pyrene (and the other toxic PAHs) above their respective screening values (refer to Table 1 above)?	Yes	Detailed Quantitative Risk Assessment (DQRA) required
	No	Proceed to Step 2
2 – Consider individual TPH fractions: Are they above respective screening values (refer to Table 2 above)?	Yes	DQRA required
	No	Proceed to Step 3
3 – Assess Cumulative effects (use the equation below): Is the calculated Hazard Index for each source >1	Yes	DQRA required
	No	TPH compounds pose no significant risk.

Equation used to determine Hazard Index (Step 3).

$$HI = \sum_{F_i=1}^{16} HQ\ F_i = \frac{Measured\ concentration\ F_i\ (mg\ kg^{-1})}{SGV\ F_i\ (mg\ kg^{-1})}$$

where HI = Hazard Index
HQ = Hazard Quotient
F_i = Fraction $_i$
SGV = Soil Guideline Value

UK physiochemical properties, environmental properties, receptor and pathway parameters assumed within the assessment are detailed in the table below.

Table 4 - RISC amended parameters to reflect UK position and data source.

Parameter	Data Source
Chemicals of concern	- Individual chemical SGV and Tox reports
	- Environment Agency Publication - Review of the Fate
	and Transport of Selected Contaminants in the Soil
	Environment. Technical Report P5-079/TR1
	- TPH Criteria Working Group Vol 1-4
Surface soil and pathways selection	assumed direct ingestion of soil and dust, dermal contact, vegetable uptake
	and consumption and inhalation pathways.
Vapour Inhalation and pathways selection	Johnson and Ettinger model used as default in RISC model considering vapours
	from a contaminated soil. Default model acceptable as is also UK adopted
	model for inhalation
Determine receptor point concentration	
Indoor Air – Building parameters (residential house)	Environment Agency and Defra Publication CLR 10
	'Technical basis and algorithms', CLEA briefing notes
Cross-sect. area of basement = 40m2	CLEA Briefing note 3
Volume of building = 196.6m3	CLEA Briefing note 3
No. air changes per day = 12	CLEA Briefing note 3
Foundation thickness = 0.15m	CLEA Briefing note 3
Fraction of cracks = 0.001	CLEA Briefing note 3
Porosity of cracks = 0.25	CLEA Briefing note 3
Water content in cracks = 0	Assume 0 – no moisture restriction to vapour migration
Flow rate of soil gas into building = 0	CLEA Briefing note 3
Length of foundation perimeter = 34.4m	CLEA Briefing note 3
Depth of foundation = 0.15m	CLEA Briefing note 3
Pressure difference = 30g/cm-s2	CLEA Briefing note 3
Permeability of soils = 1x10-9cm2	Representative of current UK house building practice
Lens - material above source	Scenario specific
Thickness: 'clean' cover in garden areas assumed = 0mm	
Porosity = 0.46	CLEA Briefing note 2 and CLR 10
Water content = 0.15	CLEA Briefing note 2 and CLR 10
Source data –data regarding material contamination located in	
Porosity of source material = 0.46	CLEA Briefing note 2 and CLR 10
Water content of source material = 0.15	CLEA Briefing note 2 and CLR 10
Fraction organic carbon = 0.006	CLR 10
Bulk density = 1.6	CLEA Briefing note 2 and CLR 10
Unsaturated zone – data regarding material surrounding source	
Distance to building from source or groundwater = 0.15	Scenario specific
Total porosity = 0.46	CLEA Briefing note 2 and CLR 10
Water content = 0.15	CLEA Briefing note 2 and CLR 10
Source concentration – maximum recorded site concentrations	Site Specific (assumed 100 for all single compounds and 10,000 for all TPH fractions)
Describe receptor	
Receptor and analysis type	
Deterministic analysis, one receptor of a child resident (RME)	CLR 10 default parameter for a residential development
Exposure Data	
Based on a female child of 0-6 years.	
Averaging time/lifetime = 6yrs	CLR10
Body weight = 14.5kg	CLR 10 Table 5.6
Exposure Frequency = 365days/yr	CLR 10
Exposure duration = 6yrs	CLR 10
Soil ingestion rate = 100mg/day	CLR 10 Table 6.1
Total skin surface area = 6166cm^2	CLR 10 Table 5.8
Fraction skin exposed = 0.265	CLEA Briefing Note 1
Soil/skin adhesion factor = 1	CLEA Briefing Note 1 and SGV reports
Exposure frequency for veg uptake = 365days	CLR 10
Exposure duration for veg uptake = 6yrs	CLR 10

Parameter	Data Source
Root Veg ingestion rate = 103.6g/day	CLR 10 Table 6.3
Above ground veg ingestion rate = 38.5g/day	CLR 10 Table 6.3
Fraction of home grown veg = 0.28	CLR 10 Table 6.4
Fraction organic carbon in soil = 0.006	Site Specific
Exp. Frequency indoor air = 365 days	CLR 10
Exp. Duration = 6yrs	CLR 10
Lung retention factor = 1	Assumed
Inhalation rate = 0.43m3/hr	CLR 10 Table 5.9
Time indoors = 20.6hr/day	Sniffer Framework Table 10.3

Note: The information contained within the table above reflects all parameters within the RISC model that were amended to reflect current UK guidance and scenarios. The model summary is not included with this text but is available upon request.

Possible Action in event of Tier 1 exceedance

Should any of the Tier 1 criteria detailed above be exceeded, then three potential courses of action are available. (The first is only applicable in terms of human health, but the second and third could also be applied to groundwater or landfill gas).

- Undertake further statistical analysis following the approach set out in Appendix A of CLR 7 in order to determine whether contaminant concentrations of inorganic contaminants within soil\fill actually present a risk (only applicable to assessing the risk to human health).
- Carry out a more detailed quantitative risk assessment in order to determine whether contamination risks actually exist.
- Based on a qualitative risk assessment, advocate an appropriate level of remediation to "break" the pollutant linkage - for example the removal of the contaminated materials or the provision of a clean cover.

Prior to undertaking any statistical analysis (as set out in Appendix A of CLR 7) the issue of the **averaging area** requires further consideration. CLR 7 suggests the averaging area should be representative of the receptors behaviour, such as a single garden or an open area used by the local community as a play area. This approach to averaging areas is considered applicable within the context of Part IIA of the Environmental Protection Act (EPA) 1990, in terms of an existing residential development.

However, Encia consider the concept of a single garden as an averaging area to be inappropriate with respect to brownfield redevelopment, which is regulated by the planning regime. In this context, contamination across the entire site needs to be characterised by reference to the Conceptual Site Model. Consequently, Encia gather and analyse sample results by fill type, and\or by former use in a given sub-area of the site, before undertaking statistical analysis; ie the averaging area is associated with the extent of a particular fill type, or an area affected by spillage\leakage.

In terms of brownfield redevelopment, this is considered a more appropriate methodology which provides a more representative sample population for statistical analysis. As such the entire site is considered in terms of the proposed end use, be this residential with, or without gardens.

Analysis by soil\fill type is appropriate for essentially immobile contaminants associated with a particular fill type, for example arsenic in colliery spoil, metals in ash & clinker, sulphate in plaster-rich demolition rubble etc.

Analysis by former use is appropriate where more mobile contaminants have entered the ground, for example diesel associated with leakage from a former fuel tank, downward migration of leachable metals through granular materials, various soluble contaminants present in a wastewater leaking into the ground via a fractured sewer etc. In these circumstances, it may be appropriate to undertake statistical analysis of sample results from a variety of different soil\fill types. However, consideration would have to be given to factors such as porosity which might influence impregnation of a mobile contaminant into the soil mass; ie contamination would normally be more pervasive and significant in granular soils than cohesive soils.

Generic Notes – Encia Geoenvironmental Investigations

4B. Contamination Laboratory Analysis & Interpretation (including WAC)

Waste Classification & WAC

In the context of waste soils generated by remediation and\or groundworks activities on brownfield sites, the following definitions (from the Landfill Regulations 2002) apply:

- Inert (e.g. uncontaminated 'natural' soil, bricks, concrete, tiles & ceramics).
- Non-Hazardous (e.g. soil excavated from a contaminated site which contains dangerous substances, but at concentrations below prescribed thresholds).
- Hazardous (e.g. soil excavated from a contaminated site which contains dangerous substances at concentrations above prescribed thresholds).

Dangerous substances include compounds containing a variety of determinants commonly found in contaminated soils on brownfield sites, for example arsenic, lead, chromium, benzene etc.

From 16th July 2005, landfill operators will require Waste Acceptance Criteria (WAC) laboratory data, if soil waste is classified as **hazardous**, and such waste must have been subjected to pre-treatment. However, subject to WAC testing it may be possible to classify it as stable, non-reactive hazardous waste, which can be placed within a dedicated cell within the non-hazardous landfill.

Encia typically only include WAC analysis in site investigation proposals and reports, if significant off-site disposal (of soil classified as hazardous waste) is anticipated, for example where redevelopment proposals include basement construction etc.

If off-site disposal of soils classified as hazardous waste were undertaken during redevelopment, then WAC analysis should be scheduled at an early stage in the remediation programme.

However, organic compounds (BTEX, TPH, PAH etc) are the most common contaminants that result in soils being classed as hazardous. These contaminants can often be dealt with by alternative technologies (eg by bioremediation or stabilisation) and consequently retention on site is often possible.

It should be noted that **non-hazardous** soil waste can go to a non-hazardous landfill facility; no further testing (eg WAC) is required.

Contamination Laboratory Analysis & Interpretation

An assessment of potential contaminants associated with the former usages of the site is undertaken with reference to CLR 8 "*Potential contaminants for the assessment of land*" and the relevant DETR Industry Profile(s).

Common Inorganic Contaminants

These include:

- metals, most notably cadmium, copper, chromium, mercury, lead, nickel, and zinc.
- semi-metals, most notably arsenic, selenium, and (water soluble) boron
- non-metals, most notably sulphur
- inorganic anions, most notably cyanides (free & complex), sulphates, sulphides, and nitrates.

With respect to the terminology used by most analytical laboratories:

Total cyanide = Free cyanide + Complex cyanide

Total cyanide (CN) is determined by acid extraction; whereas free cyanide is the water soluble fraction.

Complex cyanide is "bound" in compounds and is hard to breakdown. Laboratory determination of complex CN involves subjecting the sample to uv digestion for determination of both free and total CN.

Thiocyanate (SCN) is a different species combined with sulphur.

Elemental sulphur (S) and free sulphur are the same. Total sulphur is all forms, including that present in sulphates (SO_4), sulphides etc

There are 2 forms of chromium (Cr), chromium VI and chromium III. Chromium VI is the more toxic of these. In soils, total chromium is determined by a strong aqua regia acid digestion. Chromium VI is an empirical method based on a water extract test.

Common Organic Contaminants

Petroleum hydrocarbons are a mixture of hydrocarbons produced from the distillation of crude oil. They include aliphatics (alkanes, alkenes and cycloalkanes), aromatics (single or multi benzene ringed compounds) and hydrocarbon-like compounds containing minor amounts of oxygen, sulphur or nitrogen.

Petroleum hydrocarbons can be grouped based on the carbon number range:-

GRO – Gasoline Range Organics (typically C_6 to C_{10}). Also referred to as PRO – Petroleum Range Organics
DRO – Diesel Range Organics (typically C_{10} to C_{28})
LRO - Lubricating Oil Range Organics (typically C_{28} to C_{40})
MRO – Mineral Oil Range Organics (typically C_{18} to C_{44})

However, it should be borne in mind that the terms "GRO" and "DRO" analysis are purely descriptive terms, the exact definition of which varies.

Total Petroleum Hydrocarbons (TPH) is also a poorly defined term; some testing laboratories regard TPH as hydrocarbons ranging from C_5-C_{40}, whereas other define TPH as C_{10}-C_{30}.

The composition of a TPH plume migrating through the ground can vary significantly; this is primarily dictated by the nature of the source (eg petrol, diesel, engine oil etc). Furthermore, different hydrocarbons are affected differently by weathering processes, and this can result in further variation in the chemical composition of the TPH.

Gasoline contains light aliphatic hydrocarbons (especially within the C4 to C5 range) that will rapidly evaporate. The aromatic hydrocarbons in gasoline are primarily benzene, toluene, ethylbenzene and xylenes, referred to as BTEX. Small amounts of polyaromatic hydrocarbons (PAHs) such as benzo(a)pyrene may also be present.

Diesel and light fuel oils have higher molecular weights than gasoline. Consequently, they are less volatile and less water soluble. About 25 to 35% is composed of aromatic hydrocarbons. BTEX concentrations are generally low.

Heavy Fuel Oils are typically dark in colour and considerably more viscous than water. They contain 15 to 40% aromatic hydrocarbons. Polar nitrogen, sulphur and oxygen-containing compounds (NSO) compounds are also present.

Lubricating Oils are relatively viscous and insoluble in groundwater. They may contain 10 to 30% aromatics, including the heavier PAHs. NSO compounds are also common.

Polycyclic Aromatic Hydrocarbons (PAHs) have more than two fused benzene rings as a structural characteristic. PAH compounds are present in both petrol and diesel, although in significantly lower concentrations than in coal tars. Certain PAH compounds are carcinogenic (Benzo(a)pyrene) and\or mobile in the environment (naphthalene).

Semi-Volatile Organic Compounds (sVOCs) include a variety of compounds, which as the names suggest have relatively low boiling points; however, VOC's are much more volatile than SVOC's. Examples of VOC's include benzene, chloroform and toluene; SVOC's include phenol, florene. Both groups of chemicals are readily absorbed through skin and some, such as benzene, are believed to be linked to tumour growth.

Phenols are compounds that have a hydroxyl group attached to an aromatic ring (ie include a benzene ring and an –OH group). Most are colourless solids. A solution of phenol in water is known as carbolic acid, and is a powerful antiseptic. However, phenol vapour is toxic, and skin contact can result in burns.

Polychlorinated Biphenyls (PCBs) were used in pre-1974 transformers as dielectric fluids. PCB's are of increasing toxicity relative to the degree of chlorination. Acute symptoms of PCB poisoning are irritation of the respiratory tract leading to coughing and shortness of breath. Nausea, vomiting and abdominal pain are caused by ingestion of PCB's.

Dioxins and furans (polychlorinated dibenzodioxins and polychlorinated dibenzofurans) are some of the most toxic chemicals known; in the environment, they tend to bio-accumulate in the food chain. Dioxin is a general term that describes a group of hundreds of chemicals that are highly persistent in the environment. The most toxic compound is 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD.

Dioxin is formed by burning chlorine-based chemical compounds with hydrocarbons. The major source of dioxin in the environment comes from waste-burning incinerators and also from backyard burn-barrels. Dioxin pollution is also affiliated with paper mills which use chlorine bleaching in their process and with the production of Polyvinyl Chloride (PVC) plastics and with the production of certain chlorinated chemicals (like many pesticides).

Methods of Analysis (Organic Compounds)

TPH by GC-FID is a more refined analytical technique which only detects hydrocarbons (aliphatic and aromatic) in the range C_{10} to C_{40} (volatiles, heavy tars, humic material and sulphur are not detected). The laboratory can provide a breakdown of the TPH results into diesel range organics (**DRO**) and heavier lubricating oil range organics (**LRO**).

GRO (PRO) by GC-FID analysis detects the more volatile C_6-C_9 hydrocarbons (aliphatic and aromatic), including those organic compounds present in petrol.

Speciated VOC (by GC-MS) analysis quantifies the concentrations of 30 USA-EPA priority compounds. These include chlorinated alkanes and alkenes (in the molecular weight range chloroethane to tetrachloroethane); trimethylbenzenes; dichlorobenzenes; and the 4 BTEX compounds (benzene, ethyl-benzene, toluene & xylene).

Speciated sVOC by (GC-MS) analysis quantifies the concentrations of a variety of organic compounds, including the 16 USA-EPA priority PAHs, phenols, 7 USA EPA priority PCB congeners, herbicides & pesticides.

Note: PAHs are hydrocarbons and consequently (where present) will be picked-up when scheduling TPH. by GC-FID. Naphthalene (the lightest PAH) is also one of the 58 US EPA VOCs.

Speciated TPH by GC-FID provides a "banded" TPH, initially split into aromatic and aliphatic fractions and then further divided into fraction specific carbon bandings based upon behavioural characteristics.

Note: Risk assessment models require physiochemical properties (solubilities, toxicities etc) of compounds in order to model their behaviour in the environment. These physiochemical properties cannot be derived from a single "TPH", "GRO" or "DRO" value. However, the carbon banded fractions can be used in risk assessment models.

Current UK Guidance

The UK approach to contaminated land is set out in Contaminated Land Report No. 11 (2004) "*Model Procedures for the Management of Land Contamination*". The approach is based upon risk assessment, where risk is defined as the combination of the probability of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

In the context of land contamination, there are three essential elements to any risk: (1) a contaminant source, (2) a receptor (eg controlled water or people) and (3) a pathway linking the (1) and (2). Risk can only exist where all three elements combine to create a pollutant linkage. Risk assessment requires the formulation of a conceptual model which supports the identification and assessment of pollutant linkages.

Encia adopt a tiered approach to risk assessment, consistent with UK guidance and best practice. The initial step of such a risk assessment (or Tier 1) is the comparison of site data with appropriate UK guidance levels, Encia risk-derived screening values, or remedial targets.

Tier 1 **groundwater** risk assessments are undertaken by comparing leachate or groundwater concentrations with the appropriate water quality standard. Depending upon the specific characteristics and environmental setting of the site the appropriate standard is likely to be one of the following:

- Water Supply (Water Quality) Regulations 1989
- Environmental Quality Standards (for Freshwater)
- The Surface Waters (Abstraction for Drinking Water) Regulations

The tier 1 risk assessment of **landfill gas** is undertaken through reference to the following documents:

- Approved Document C, Building Regulations 1991
- CIRIA Report 149, "Protecting Development from Methane", 1995

Further information is presented in Generic Note No. 5 – Hazardous Gas.

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The potential risk to **building materials** is considered through reference to relevant BRE Digests, with particular emphasis on BRE Special Digest 1, 'Concrete in aggressive ground', 2005.

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Encia's derivation of Tier 1 values is based on a number of assumptions, most notably:

a. The site's environmental setting, in terms of proximity to **Controlled Waters**, is not sensitive. It is not possible to derive generic Tier 1 values for waters, because distance and ground permeability are key factors, and both are extremely site-specific. Consequently, detailed quantitative risk assessment is required.

b. Ground encountered during the site investigation will be isolated beneath a cover of "clean" soil. **Soil cover** in garden areas is "standard" remediation practice during the residential redevelopment of brownfield sites, where the contaminants of concern are inorganic and\or non-volatile organic. The majority of brownfield sites require a minimum 600mm soil cover. The CLEA model assumes that all pathways, other than inhalation of vapours, occur within 0.5m of ground level, consequently after placement of a 600mm thick soil cover, the only pathway of significance is vapour migration.

   It should be noted that where the underlying ground is "clean", but includes undesirable elements (eg a significant proportion of demolition rubble, colliery spoil etc), a minimum 300mm thickness of soil cover is acceptable, in accordance with NHBC Standards, Chapter 9.2. However, before advocating a 300mm soil cover, consideration must be given to other potential pathways, most notably inhalation of dust, ingestion and dermal contact.

   The ingestion and dermal contact pathways have a significant effect on the Tier 1 values for benzo(a)pyrene, and petroleum hydrocarbons (TPH) in the Diesel (C_{10} to C_{20}) and Lubricating Oil (TPH C_{21} to C_{40}) ranges.

c. A conservative **Soil Organic Matter** of 1%.

   (Note: TOC = SOM x 0.58; and FOC = TOC/100).

   Hydrocarbons tend to be "bind" with SOM, and therefore become less mobile. Consequently, Tier 1 values can be revised if the amount of organic matter within the soil exceeds 1%.

d. Some determinands reach **residual saturation** before a vapour risk is predicted to occur. Prior to residual saturation, as the concentration of a contaminant in soil increases, so does the concentration of the same contaminant in the associated vapour phase. However, once saturation is reached, the concentration of contaminant in the vapour phase remains constant (for any given atmospheric conditions – temperature and pressure). Consequently, even if free product were encountered at depths >600mm, it would not pose a significant risk via the inhalation exposure pathway.

   However, Encia recognise that it is unacceptable to leave free product in the ground and therefore arbitrary Tier 1 values have been ascribed to such contaminants. These values have been selected on the basis that they are below the limit of olfactory detection (ie at concentrations below Tier 1, odours are not readily identified).

Table 1 - Encia Tier 1 values

Contaminant	**Tier 1 Value (mg/kg)**	**Comments/Notes**
PCB's	1.4	Based on PCB EC seven. Driven by soil ingestion (very conservative assumption).
Benzene	0.3	
Xylene	86	
Benzo(a)pyrene	39	Residual saturation reached at 39mg/kg. 39mg/kg selected as Tier 1 value although no inhalation risk identified at 600mm depth.
Naphthalene	23	
total PAH	23	The higher volatility of Naphthalene makes it the most problematic PAH in ground overlain by a soil cover. Consequently, Encia have adopted the Tier 1 value for Naphthalene (23mg/kg) as an initial Tier 1 screening value for total PAH, on the conservative assumption that all the PAH is Naphthalene.
TPH $<C_{10}$ Gasoline range organics (GRO)	0.3	Based on conservative assumption that all TPH$<C_{10}$ is benzene. If concentrations >0.3 mg/kg are recorded, but no benzene is present, a Tier 1 value of 16 mg/kg could be adopted for the gasoline range or reference can be made to Refined Tier 1 Values for speciated TPH (see below).
TPH C_{10} – C_{20} Diesel range organics (DRO)	330	If DRO above tier 1 value and speciated fraction banding for all sources on site are available, refer to Refined Tier 1 Values for speciated TPH (see below).
TPH C_{21} – C_{40} Lubricating range organics (LRO)	5,000	Residual saturation reached for all fractions; therefore no inhalation risk at 600mm depth. Tier 1 value selected on the basis that a concentration of 5,000 mg/kg is well below the limit of olfactory detection.

If site concentrations of any of the three broad TPH bandings (GRO, DRO or LRO) exceed the Tier 1 values quoted in Table 1 above, further assessment, with reference to speciated TPH results, will be required:

Table 2 - Refined Tier 1 values (TPH Bands)

Contaminant	**Refined Tier 1 values (mg/kg)**	**Comments/notes**
Aliphatic C5-C6	92	
Aliphatic C6-C8	500	Residual saturation reached due to lower toxicity of aliphatic compounds (cf aromatics), therefore no inhalation risk at 600mm depth. Tier 1 value selected on the basis that a concentration of 500 mg/kg is well below the limit of olfactory detection.
Aliphatic C8-C10	40	
Aliphatic C10-C12	1,000	Residual saturation reached; therefore no inhalation risk at 600mm depth. Tier 1 value selected on the basis that a concentration of 1,000 mg/kg is well below the limit of olfactory detection.
Aliphatic C12-C16	1,000	
Aliphatic C16-C21	1,000	
Aliphatic C21-C34	5,000	Residual saturation reached at 16mg/kg; therefore no inhalation risk at 600mm depth. Tier 1 value selected on the basis that a concentration of 5,000 mg/kg is well below the limit of olfactory detection.
Aromatic C5-C7	16	
Aromatic C7-C8	36	
Aromatic C8-C10	63	
Aromatic C10-12	330	
Aromatic C12-16	1,000	Residual saturation reached; therefore no inhalation risk at 600mm depth. Tier 1 value selected on the basis that a concentration of 1,000 mg/kg is well below the limit of olfactory detection.
Aromatic C16-C21	1,000	
Aromatic C21-35	5,000	Residual saturation reached at 16mg/kg; therefore no inhalation risk at 600mm depth. Tier 1 value selected on the basis that a concentration of 5,000 mg/kg is well below the limit of olfactory detection.

The significance of speciated TPH results can be assessed by following the 3 steps outlined in Table 3 below.

Note: This 3-step assessment is **not** required if concentrations of GRO, DRO & LRO are all below their respective Tier 1 values (see Table 1).

Table 3 – Assessment of TPH

Step	Result	Action
1 – Consider indicator compounds: Are BTEX and Naphthalene above their respective screening values (refer to Table 1 above)?	Yes	Detailed Quantitative Risk Assessment (DQRA) required
	No	Proceed to Step 2
2 – Consider individual TPH fractions: Are they above respective screening values (refer to Table 2 above)?	Yes	DQRA required
	No	Proceed to Step 3
3 – Assess Cumulative effects (use the equation below): Is the calculated Hazard Index for each source >1	Yes	DQRA required
	No	TPH compounds pose no significant risk.

Equation used to determine Hazard Index (Step 3).

$$HI = \sum_{F_i = 1}^{16} HQ\ F_i = \frac{Measured\ concentration\ F_i\ (mg\,kg^{-1})}{SGV\ F_i\ (mg\,kg^{-1})}$$

where HI = Hazard Index
HQ = Hazard Quotient
F_i = Fraction $_i$
SGV = Soil Guideline Value

UK physiochemical properties, environmental properties, receptor and pathway parameters assumed within the assessment are detailed in the table below.

Table 4 - RISC input parameters to reflect UK position and data source.

Parameter	**Data Source**
Chemicals of concern	- Individual chemical SGV and Tox reports
	- Environment Agency Publication - Review of the Fate
	and Transport of Selected Contaminants in the Soil
	Environment. Technical Report P5-079/TR1
	- TPH Criteria Working Group Vol 1-4
Surface soil and pathways selection	As 600mm cover assumed no direct ingestion of soil or dust, dermal contact or
	vegetable uptake and consumption. Inhalation pathway only.
Vapour Inhalation and pathways selection	Johnson and Ettinger model used as default in RISC model considering vapours
	from a contaminated soil. Default model acceptable as is also UK adopted model
	for inhalation
Determine receptor point concentration	
Indoor Air – Building parameters (residential house)	Environment Agency and Defra Publication CLR 10
	'Technical basis and algorithms', CLEA briefing notes
Cross-sect. area of basement = 40m2	CLEA Briefing note 3
Volume of building = 196.6m3	CLEA Briefing note 3
No. air changes per day = 12	CLEA Briefing note 3
Foundation thickness = 0.15m	CLEA Briefing note 3
Fraction of cracks = 0.001	CLEA Briefing note 3
Porosity of cracks = 0.25	CLEA Briefing note 3
Water content in cracks = 0	Assume 0 – no moisture restriction to vapour migration
Flow rate of soil gas into building = 0	CLEA Briefing note 3
Length of foundation perimeter = 34.4m	CLEA Briefing note 3
Depth of foundation = 0.15m	CLEA Briefing note 3
Pressure difference = 30g/cm-s2	CLEA Briefing note 3
Permeability of soils = 1x10-9cm2	Representative of current UK house building practice
Lens - material above source	Scenario specific
Thickness: 'clean' cover in garden areas assumed = 600mm (cover depth	
Porosity = 0.46	CLEA Briefing note 2 and CLR 10
Water content = 0.15	CLEA Briefing note 2 and CLR 10
Source data –data regarding material contamination located in	
Porosity of source material = 0.46	CLEA Briefing note 2 and CLR 10
Water content of source material = 0.15	CLEA Briefing note 2 and CLR 10
Fraction organic carbon = 0.006	CLR 10
Bulk density = 1.6	CLEA Briefing note 2 and CLR 10
Unsaturated zone – data regarding material surrounding source	
Distance to building from source or groundwater = 0.15	Scenario specific
Total porosity = 0.46	CLEA Briefing note 2 and CLR 10
Water content = 0.15	CLEA Briefing note 2 and CLR 10
Source concentration – maximum recorded site concentrations	Site Specific (assumed 100 for all single compounds and 10,000 for all TPH fractions)
Describe receptor	
Receptor and analysis type	
Deterministic analysis, one receptor of a child resident (RME)	CLR 10 default parameter for a residential development
Exposure Data	
Based on a female child of 0-6 years.	
Averaging time/lifetime = 6yrs	CLR10
Body weight = 14.5kg	CLR 10 Table 5.6
Exposure Frequency = 365days/yr	CLR 10
Exposure duration = 6yrs	CLR 10
Soil ingestion rate = 100mg/day	CLR 10 Table 6.1
Total skin surface area = 6166cm^2	CLR 10 Table 5.8
Fraction skin exposed = 0.265	CLEA Briefing Note 1
Soil/skin adhesion factor = 1	CLEA Briefing Note 1 and SGV reports
Exposure frequency for veg uptake = 365days	CLR 10

Parameter	Data Source
Exposure duration for veg uptake = 6yrs	CLR 10
Root Veg ingestion rate = 103.6g/day	CLR 10 Table 6.3
Above ground veg ingestion rate = 38.5g/day	CLR 10 Table 6.3
Fraction of home grown veg = 0.28	CLR 10 Table 6.4
Fraction organic carbon in soil = 0.006	Site Specific
Exp. Frequency indoor air = 365 days	CLR 10
Exp. Duration = 6yrs	CLR 10
Lung retention factor = 1	Assumed
Inhalation rate = 0.43m3/hr	CLR 10 Table 5.9
Time indoors = 20.6hr/day	Sniffer Framework Table 10.3

Note: The information contained within the table above reflects all parameters within the RISC model that were amended to reflect current UK guidance and scenarios. The model summary is not included with this text but is available upon request.

Possible Action in event of Tier 1 exceedance

Should any of the Tier 1 criteria detailed above be exceeded, then three potential courses of action are available. (The first is only applicable in terms of human health, but the second and third could also be applied to groundwater or landfill gas).

- Undertake further statistical analysis following the approach set out in Appendix A of CLR 7 in order to determine whether contaminant concentrations of inorganic contaminants within soil\fill actually present a risk (only applicable to assessing the risk to human health).
- Carry out a more detailed quantitative risk assessment in order to determine whether contamination risks actually exist.
- Based on a qualitative risk assessment, advocate an appropriate level of remediation to "break" the pollutant linkage - for example the removal of the contaminated materials or the provision of a clean cover.

Prior to undertaking any statistical analysis (as set out in Appendix A of CLR 7) the issue of the **averaging area** requires further consideration. CLR 7 suggests the averaging area should be representative of the receptors behaviour, such as a single garden or an open area used by the local community as a play area. This approach to averaging areas is considered applicable within the context of Part IIA of the Environmental Protection Act (EPA) 1990, in terms of an existing residential development.

However, Encia consider the concept of a single garden as an averaging area to be inappropriate with respect to brownfield redevelopment, which is regulated by the planning regime. In this context, contamination across the entire site needs to be characterised by reference to the Conceptual Site Model. Consequently, Encia gather and analyse sample results by fill type, and\or by former use in a given sub-area of the site, before undertaking statistical analysis; ie the averaging area is associated with the extent of a particular fill type, or an area affected by spillage\leakage.

In terms of brownfield redevelopment, this is considered a more appropriate methodology which provides a more representative sample population for statistical analysis. As such the entire site is considered in terms of the proposed end use, be this residential with, or without gardens.

Analysis by soil\fill type is appropriate for essentially immobile contaminants associated with a particular fill type, for example arsenic in colliery spoil, metals in ash & clinker, sulphate in plaster-rich demolition rubble etc.

Analysis by former use is appropriate where more mobile contaminants have entered the ground, for example diesel associated with leakage from a former fuel tank, downward migration of leachable metals through granular materials, various soluble contaminants present in a wastewater leaking into the ground via a fractured sewer etc. In these circumstances, it may be appropriate to undertake statistical analysis of sample results from a variety of different soil\fill types. However, consideration would have to be given to factors such as porosity which might influence impregnation of a mobile contaminant into the soil mass; ie contamination would normally be more pervasive and significant in granular soils than cohesive soils.

Generic Notes – Encia Geoenvironmental Investigations

5. Hazardous Gas

General

Hazardous gas is considered to be any mixture of potentially explosive, toxic or asphyxiating gases, most notably methane, carbon dioxide and oxygen (deficiency).

In addition, radon, a naturally occurring radioactive gas is also considered. Further information about radon is included in Notes 1. – Environmental Setting.

Assessment of potential risks associated with hazardous gas are based on a review of data obtained from the Landmark Information Group, the Environment Agency and the Local Authority and the British Geological Survey.

Reference is also made to historical OS plans, which are inspected for evidence of backfilled quarries, railway cuttings, colliery spoil tips etc.

Where landfilling has occurred within 250m of the site boundary, the Local Planning Authority may request a landfill gas investigation in accordance with the Town and Country Planning General Development Order, 1988.

Sources

Potential sources of hazardous gas are:

- Landfill sites
- Made ground, especially where significant depths are present
- Shallow mineworkings associated with coal extraction
- Geological strata, including peat, organic silts, coal-bearing strata and limestone (reaction with acidic waters), granite (radon)
- Groundwater can sometimes act as a "carrier" for hazardous gas.
- Leakages from pipelines or storage tanks
- Sewers, septic tanks and cess pits

Generation

Wherever biodegradable material is deposited, landfill gas (principally a mixture of methane and carbon dioxide) is likely to be generated by microbial activity. Carbon dioxide is an asphyxiant and toxic; methane is flammable and a mixture containing between 5% and 15% methane by volume in air is explosive. Landfill gas in the ground is unlikely in itself to pose a significant risk, though it may damage vegetation. However, infiltration of landfill gas into confined spaces (e.g. cellars, services, etc) may give rise to considerable risk.

There is no typical figure for the length of time that landfill gas will be evolved, but at many sites significant gas generation continues for at least 15 years after the last deposit of waste.

Migration

Gas migration from a landfill site may occur in several ways. It may migrate through adjacent strata; the distance of migration being dependent on the pressure gradients, volume of gas and permeability of the strata. Where there are faults, cavities and fissures within the strata, gas may move considerable distances. Other migration pathways for gas include man-made features such as mine shafts, roadways and underground services.

Gas migration is influenced by a number of climatic factors, such as atmospheric pressure variations, water table level variations and the influence of a covering of snow or ice over the surface of the site and surrounding area.

Gas Monitoring Procedure

Encia adopt a standard gas monitoring procedure, in accordance with CIRIA guidance. This procedure involves the measurement, in the following order of:

- Atmospheric temperature, pressure and ambient oxygen concentration on site immediately prior to and on completion of monitoring.
- Gas emission rate.
- Methane, oxygen and carbon dioxide concentrations using an infra-red gas analyser.
- Standing water level using a dipmeter.

In addition, ground conditions at each sampling location are recorded together with prevailing weather conditions and any other observations such as any vandalism.

Where samples of gas are required for laboratory analysis, Gresham Tubes are used. Gas concentrations in the well are typically recorded immediately before and after retrieval of a sample.

Current Guidance

CIRIA Report 151 (1995)[i] identified that there was inadequate guidance on trigger concentrations for ground gases. CIRIA concluded that the most important aspect of a gas regime below or adjacent to a site was the surface emission rate, i.e. how quickly the gas is coming out of the ground. The lower the surface emission rate the lower the risk.

CIRIA Report C659 (2006)[ii] advocates two methodologies for characterising sites:

A – All developments except low rise housing. The advocated methodology is that proposed by Wilson & Card, 1999[iii].

B – Low rise housing. An alternative (traffic light) methodology, derived by Boyle and Witherington, 2006[iv] for NHBC

Both methodologies refer to Gas Screening Values (GSV); previously referred to as limiting borehole gas volume flow.

A – All developments except low rise housing.

(Wilson & Card, 1999)[v] revised Table 28 of CIRIA 149[v] in terms of borehole gas volume flow rate (now GSV) in order to achieve a more consistent design of protection measures. This was done to reflect the importance of recognising the gas surface emission rate.

Wilson & Card then developed a method for classifying gassing sites (Table 1 below), which took into account the combined gas concentration and GSV.

Table 1 – Site Classification (Wilson & Card)

Characteristic Situation (Wilson & Card, 1999)	Gas Screening Value, CH_4 or CO_2 (l/hr)	Additional limiting factors	Typical source of generation
1	<0.07	Methane not to exceed 1% v/v and carbon dioxide not to exceed 5% v/v	Natural soils with low organic content
2	<0.7	Borehole air flow rate not to exceed 70 litre/hr otherwise increase to Characteristic Situation 3	Natural soil, high peat/organic content
3	<3.5		Old landfill, inert waste, mineworking flooded.
4	<15	Quantitative Risk Assessment required to evaluate scope of protection measures.	Mineworking – susceptible to flooding, completed landfill, inert waste (WMP 26B criteria)
5	<70		Mineworking unflooded, inactive
6	>70		Recent landfill site

Notes:

Borehole flow rate = volume of gas (regardless of composition) which is escaping from well (l/hr).

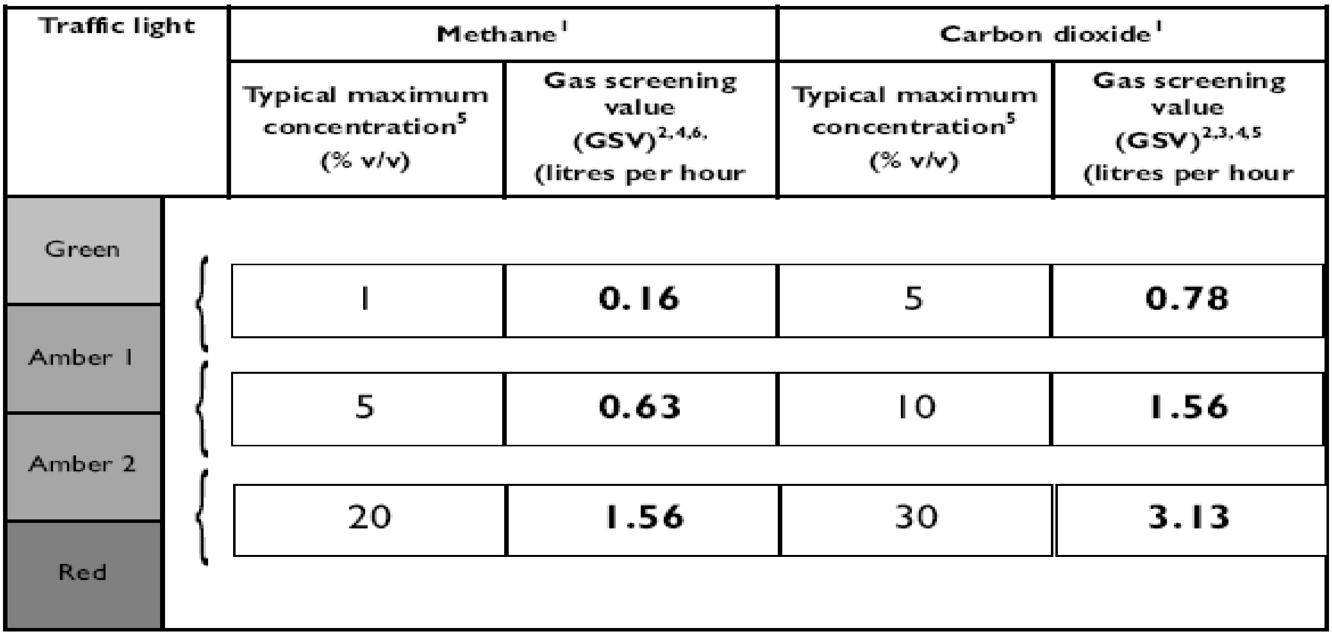
Gas Screening Value (litre/hour) = gas concentration (%) / 100 x borehole flow rate (l/hr).

To facilitate design implementation, the limiting values for both methane and carbon dioxide are identical.

B – Low rise housing.

NHBC have developed a characterisation system similar to that of Wilson & Card above, but specific to low-rise housing development (Boyle and Witherington[xii]) (Table 8.7). This approach compares measured gas emission rates with generic "Traffic Lights". The Traffic Lights include "Typical Maximum Concentrations" for initial screening, and risk-based Gas Screening Values (GSVs) for consideration of situations where the Typical Maximum Concentrations are exceeded. Calculations are carried out for both methane and carbon dioxide and the worse case adopted in order to establish the appropriate protection measures.

Table 8.7 *NHBC Traffic light system for 150 mm void*



Traffic light	Methane[1]		Carbon dioxide[1]	
	Typical maximum concentration[5] (% v/v)	Gas screening value (GSV)[2,4,6.] (litres per hour	Typical maximum concentration[5] (% v/v)	Gas screening value (GSV)[2,3,4,5] (litres per hour
Green				
	1	**0.16**	5	**0.78**
Amber 1				
	5	**0.63**	10	**1.56**
Amber 2				
	20	**1.56**	30	**3.13**
Red				

Notes:

1. The **worst gas-regime** identified at the site, either methane or carbon dioxide, recorded from monitoring in the worst temporal conditions, will be the decider for which Traffic Light and GSV is allocated.
2. Generic GSVs are based on guidance contained within "The Building Regulations: Approved Document C" (2004) and assume a **sub-floor void** of 150 mm thickness.
3. The **small room** is considered to be a downstairs toilet, with dimensions of 1.50 × 1.50 × 2.50 m, with a soil pipe passing into the sub-floor void.
4. The **GSV**, in litres per hour, is as defined in Wilson and Card (1999) as the borehole flow rate multiplied by the concentration in the air stream of the particular gas being considered.
5. The Typical Maximum Concentrations can be exceeded in certain circumstances should the conceptual site model indicate it is safe to do so. This is where professional **judgment** will be required, based on a thorough understanding of the gas regime identified at the site where monitoring in the worst temporal conditions has occurred.
6. The GSV thresholds should not generally be exceeded without completion of a detailed gas risk assessment taking into account site-specific conditions.

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[i] Harries CR, Witherington PJ and McEntee JM (1995). Interpreting measurements of gas in the ground. CIRIA Report 151

[ii] CIRIA (2006) – Assessing risks posed by hazardous ground gases to buildings.

[iii] Wilson SA and Card GB (February 1999). Reliability and Risk in Gas Protection Design. Ground Engineering.

[iv] Boyle & Witherington (2006) – Guidance on evaluation on development proposals on sites where methane and carbon dioxide are present, incorporating "traffic lights". Report Ref. 10627-R01-(02), for NHBC

[v] Wilson SA and Card GB (February 1999). Reliability and Risk in Gas Protection Design. Ground Engineering.