# Appendix I Ground Gas Assessment Approach

**Introduction**

Over the past 10 - 15 years a wealth of information has been published regarding ground gas assessment. Much of this has centred around risk from gas generating landfills when, in terms of development activities in the UK, only a small proportion of development sites are situated close to gassing landfill sites.

There has been, and to a point still is, a tendency to focus on absolute numbers when undertaking ground gas assessments rather than good conceptualisation of a site. The WSP Environmental approach is based on appropriate site characterisation based on the principals set out in DETR guidance 'Guidelines for Environmental Risk Assessment and Management' (2000), and the EA Document 'Model Procedures for the Management of Land Contamination, CLR 11' (2004).

These documents set out the principals for risk assessment methodology in the UK and centre on the determination of **Source-Pathway-Receptor** relationships following the formulation of a **Conceptual Model**. They discuss tiered approaches to risk assessment as follows:

Tier 1: Risk Screening (e.g. establishing potential pollutant linkages);

Tier 2: Generic Quantitative Risk assessment (GQRA) (e.g. the composition of contaminant concentrations against Soil Guideline Values or Gas Screening Values);

Tier 3: Detailed Quantitative Risk Assessment (DQRA) (e.g. the comparison of contaminant concentrations against site specific assessment criteria).

**WSP Environmental Gas Assessment Approach**

It can be seen from the following summary of the available guidance that assessment of ground gases has moved away from solely comparing monitoring results to guideline levels towards a more site specific conceptual and holistic approach, involving both qualitative and quantitative assessments as deemed necessary. Indeed this method of assessment is already widely used to assess the significance of chemical testing results. Therefore, in line with these general trends WSP Environmental Limited have adopted the following approach to gas assessment:

1. From the desk study information, derive an understanding of the likely potential sources of hazardous gases and their proximity to the site in question (e.g. mine, landfill and geologic (e.g. peat) gases) and develop a preliminary conceptual model (Tier 1).

2. From the information derived from the desk study, design a suitable intrusive investigation to obtain sufficient information to derive a detailed conceptual ground model for the site and assess the most likely sources of the gas and their generation potential.

3. The investigation and subsequent gas monitoring will be undertaken in general accordance with the guidance set out in CIRIA C659[15].

4. During the monitoring phase, determine the likely effects of atmospheric pressure and groundwater levels on the gas monitoring results recorded.

5. Using the assessment procedures set out in CIRIA C659[15] determine, where appropriate, the extent of any mitigation measures which may be required to protect the proposed development from ground gas ingress (Tier 2). The key elements in making this decision are:

   i) nature and generation potential of the source.

   ii) gas concentrations and gas flows recorded (with reference to factors such as atmospheric pressure).

   iii) due consideration of the Gas Screening Values as detailed in Tables 8.5 and 8.7 below (see Section 1.3.8).

It should be borne in mind that in certain circumstances it will be necessary to quantitatively assess the risk posed by ground gases to a development. However, such assessment methodologies should be determined on a site specific basis and are beyond the scope of this document.

This approach considers that ground gas assessment is the assessment of acute risks to human health and buildings. As a result it should be clarified that the assessment of volatile vapours (chronic risk from hazardous vapours to human health) forms part of general human health risk assessment.

**Summary of Available Guidance**

Introduction

The following sections summarise the guidance listed below in relation to the assessment of hazardous ground gases:

1 DoE (1991): Waste Management Paper No 27, Landfill Gas, Department of the Environment.

2 BRE (1991) Construction of New Buildings on Gas-Contaminated Land, Report 212.

3 Hooker and Bannon (1993): Methane: Its Occurrence and Hazards in Construction, CIRIA Report 130.

4 Crowhurst and Manchester (1993): The Measurement of Methane and Other Gases from the Ground, CIRIA Report 131.

5 Card (1995): Protecting Development from Methane, CIRIA Report 149.

6 Raybould, Rowan and Barry (1995): Methane Investigation Strategies, CIRIA Report 150.

7 Harries, Witherington and McEntee (1995): Interpreting Measurements of Gas from the Ground, CIRIA Report 151.

8 O'Riordan and Milloy (1995): Risk Assessment for Methane and Other Gases from the Ground, CIRIA Report 152.

9 Barry, Summersgill, Gregory and Hellawell (2001): Remedial Engineering for Closed Landfill Sites, CIRIA Report C557.

10 DETR (1997): Passive Venting of Soil Gases Beneath Buildings, Department of the Environment, Transport and the Regions Partners in Technology.

11 Wilson and Card (1999): Reliability and Risk in Gas Protection Design, Ground Engineering, February 1999.

12 BRE (2001): Protective measures for housing on gas-contaminated land, Report 414.

13 Environment Agency (2003): Consultation on Agency Policy: Building Development on or Within 250 Metres of a Landfill Site. Draft for consultation, July 2003.

14 The Building Regulations, Approved Document C, Section 2 (2004).

15 Wilson, Oliver, Mallet, Hutchings and Card (2006): Assessing Risks Posed by Hazardous Gases to Buildings, CIRIA Report C659.

In addition to those documents listed above, RSK ENSR in conjunction with the NHBC has produced a draft document on the assessment of risks from methane and carbon dioxide. BSI / EIC currently have a Code of Practice document currently under production.

The summary below is limited to a selection of the documents listed above and is not intended to be exhaustive.

**Department of the Environment**

The principal constituents of landfill gas are methane and carbon dioxide. Waste Management Paper No. 27[1] provides information on the hazards of methane and carbon dioxide when present in confined spaces (i.e. within buildings or services).

Methane can form flammable and potentially explosive mixtures in air when ignited. The flammable or explosive range of methane is between 5% and 15% by volume in air (v/v). The concentration limits are commonly known as the "Lower Explosive Limit" (LEL) and the "Upper Explosive Limit" (UEL) respectively. Concentrations above the UEL should not be considered safe because dilution with air will cause the composition to fall within the flammable range.

The presence of carbon dioxide will affect the flammable range of methane but not unless present in significant concentrations. Methane can also act as an asphyxiant either alone or when mixed with air, when the oxygen content is depleted. A concentration of greater than 1% methane in a confined space is considered hazardous in Waste Management Paper No 27.

Carbon dioxide affects the respiration and central nervous systems at concentrations greater than 0.5% by volume in air. It can cause unconsciousness leading to death at concentration greater than 10% to 15% by volume in air. Waste Management Paper No. 27 considers that carbon dioxide is a hazard to health at concentrations greater than 1.5% by volume in air, at which level evacuation of an affected area is recommended.

Waste Management Paper No 27 was published in 1991 and since that time a substantial amount of research into methane gas in the ground has been undertaken. It is currently being substantially revised by the Environment Agency.

Waste Management Paper 26A, DOE (1994) gives guidance on borehole gas volume flow rates and the completion of a landfill. The borehole gas volume flow rates for completion are:

- methane - <15 l/hr.
- carbon dioxide - <22 l/hr.

**Building Regulations**

The Building Regulations Approved Document Part C2 (revised 2004)[14] gives guidance for methane and carbon dioxide concentrations in the ground with respect to new developments. The former version of this document (1991) considered that gas protection measures should be considered when the concentrations of methane and/or carbon dioxide exceed 1% and 5% by volume in air respectively. However, the revised document considers the use of risk assessment more appropriate to determine the potential risks from ground gas and no longer uses the above threshold concentrations.

**Building Research Establishment**

BRE Report 212[2] provides general recommendations on the provision of gas protection membranes and under-floor ventilation. It also recommends that wall cavities and roof spaces are ventilated. However, this document has been replaced by BR 414.

BRE Report 414[12], which was published in association with the Environment Agency, provides specific construction details for gas protection measures, including membrane locations and sealing around services.

**CIRIA**

The Construction Industry Research and Information Association (CIRIA) provide comprehensive guidance in a series of guidance documents relating to the construction of new developments over sites where methane is present, References 3, 4, 5, 6, 7, 8, 9, 14).

In summary, the CIRIA guidance recommends that the provision of gas protection measures should be based on a comprehensive desk study, ground investigation and gas monitoring (including measurement of borehole emission rates). This will help identify ground conditions, potential sources of gas, migration pathways and generation potential.

The level of risk may then be assessed and an appropriate gas protection system designed. Account should also be taken of the sensitivity of the proposed end use.

There are many techniques to protect development from methane and associated gases (Card 1995) and each measure has its own advantages and disadvantages. Furthermore no protective measure on its own is immune from factors unknown to or out of the control of the designer. Such factors might lead to failure and for this reason it is normal practice to combine individual protection measures to form a gas control system. In this way the probability of failure or of gas passing each individual protection measure in the system is minimised.

The combinations of gas protection measures are presented in Table 28 of CIRIA 149.

CIRIA Report 149 reflects current building industry practice more closely than Waste Management Paper 27[1] (currently being re-written).

CIRIA Report C659[15] was published in December 2006 and is discussed in more detail in Section 1.3.9 below.

**Partners in Technology**

At the time of preparing CIRIA Report 149 borehole flow rates were generally not capable of being measured with great accuracy, therefore, the requirement for assessing the gas regime based on the maximum parameter was adopted. However, the standard of measuring gas concentrations and particularly borehole flow rates has improved greatly in recent years. This is due to environmental legislation associated with the waste management industry and the requirements of Waste Management Paper 26A for landfill completion.

It is now standard practice to assess gas regimes on the basis of the volumes of gas flowing from the ground (i.e. a combination of the gas concentrations and borehole flow rates). This principal is used in the DETR / Partners in Technology report[10], which considers both concentrations and flow rates to define characteristic gas situations.

The Partners in Technology Research Report also provides criteria for the assessment of passive under-floor ventilation systems. For methane a passive ventilation system is deemed to have very good performance characteristics when the equilibrium concentrations of methane are maintained below 1% by volume in air at wind speeds of 0.3 m/s and 3.0 m/s.

**Wilson and Card, 1999**

Wilson and Card identified that the levels of risk posed by the presence of methane should be based on a holistic approach taking consideration of the generation potential of gas sources as well as gas monitoring results. Tables 5 and 6 of Wilson and Card[11] provide guidance on the appropriate gas control measures that may be appropriate, based on the measured borehole gas volume flow (the volume of gas passing through the ground surface to atmosphere which is the product of gas concentration and surface emission rate).

Table 3 summarises the method for characterising gassing sites, taking into account borehole gas volume flow rates in addition to gas concentrations. The classification system is similar to that proposed in the Partners in Technology guide to design.

**CIRIA Report C659**

CIRIA Report C659[15] was published in December 2006 and provides guidance on the assessment of hazardous gases. Pulling from and developing previous guidance such as that published by CIRIA[5], Partners in Technology[10] and Wilson and Card[11], this document discusses all aspects of hazardous gas generation, monitoring, sampling, assessment and remediation.

However, the document does not provide guidance on issues surrounding gas derived from licensed landfill sites or detailed guidance on organic vapours.

The guidance is written considering a general legal framework comprising:

- Environmental Protection Act 1990: under which gas could be considered as a 'source' in a 'Pollutant Linkage' that could lead to a determination by a regulator that 'significant harm' is being caused or that there is a 'significant possibility of such significant harm' being caused as set out in Part IIA of the EPA 1990.
- PPS23: The planning system, via PPS23, requires developers to undertake gas assessment sufficient to demonstrate that their proposals are sufficient to mitigate any potential hazards associated with contamination, including ground gas.
- Building Regulations (2004): provide a requirement to protect the health and safety and welfare of people in and around buildings and included the assessment of ground gases.

In addition, the document has been prepared to and is generally consistent with the Model Procedures for the Management of Contaminated Land (Defra and the Environment Agency 2004).

A summary of the main elements of CIRIA C659 is presented below.

*Development of a Conceptual Model (Tier 1)*

Great emphasis is put on developing a conceptual model that focuses on ground gases, particularly during the desk study phase of an investigation. The use of schematic drawings is encouraged to present a clear and simple demonstration that the ground gas regime is understood or to highlight gaps in the understanding.

*Site Investigation and Monitoring Methodology (Tier 2)*

The document discusses site investigation techniques and methodology. The main recommendations presented concern designing gas wells to ensure response zones are placed in the correct strata and the spacing of gas wells across a site to ensure adequate coverage is achieved.

The production of a conceptual model during the desk study phase can assist the placement of wells on a site but the site investigation layout should be reassessed during the site works and additional wells installed as necessary if a change in the expected ground conditions is observed.

Gas well spacing is considered to be important as monitoring wells have a specific zone of influence and more wells will be required on higher risk sites to ensure complete coverage is achieved. Table 4.2 summarises the recommended spacing of wells (the full document should be consulted in conjunction with the table below as other guidance is presented including EA guidance in Table 4.3).

Table 4.2 Spacing of gas monitoring wells for development sites (Wilson et al, 2005)

| Gas hazard | Typical examples | Sensitivity of end use | Initial nominal spacing of gas monitoring wells[1,2] |
|---|---|---|---|
| High | Domestic landfill sites | High[3] | Very close (<25m) |
| | | Moderate | Close (25 – 50m) |
| | | Low | Close (25 – 50m) |
| Moderate | Older domestic landfills, disused shallow mine workings[4] | High | Close/very close (<25 – 50m) |
| | | Moderate | Close (25 – 50m) |
| | | Low | Close/wide (25 – 75m) |
| Low | Made Ground with limited degradable material, organic clays of limited thickness | High | Close (25 – 50m) |
| | | Moderate | Wide (50 – 75m) |
| | | Low | Wide/very wide (50 - >75m) |

1 The initial spacing may need to be reduced if the results indicate this is necessary to give a robust indication of the gas regime below a site. To prove the absence of gas closer spacing may be required.
2 The spacing assumes relatively uniform ground conditions and the gas source present below the site. The spacing will need to be reduced if ground conditions are variable or if the investigation is an attempt to assess migrations patterns off site.
3 Placing high sensitivity end use on a high gas hazard is not normally acceptable unless source is removed or treated to reduce gassing potential.
4 Petrol stations and other sources of vapours are most likely to be classified as gas hazard moderate; however site specific assessment would be required.

Guidance on monitoring techniques, frequency and duration of monitoring and data presentation is included in the document. Table 5.5 details typical or idealised frequency and periods of monitoring:

Table 5.5 Typical/idealised frequency and period of monitoring (after Wilson et al, 2005)

| Sensitivity of development | Generation potential of source | | | | |
|---|---|---|---|---|---|
| | Very Low | Low | Moderate | High | Very high |
| Low (Commencial) | 4/1 | 6/2 | 6/3 | 12/6 | 12/12 |
| Moderate (Flats) | 6/2 | 6/3 | 9/6 | 12/12 | 24/24 |
| High (Residential with gardens) | 6/3[5] | 9/6 | 12/6 | 24/12 | 24/24 |

1 First number is minimum number of readings and second number is minimum period in months, for example 4/1 – Four sets of readings over 1 month.
2 At least two sets of readings must be at low and falling pressure (but not restricted to periods below <1000mb) known as worst case conditions (see Boyle and Witherington, 2006).
3 The frequency and period stated are considered to represent typical minimum requirements. Depending on specific circumstances fewer or additional readings may be required (e.g. any such variation subject to site specific justification). The NHBC guidance is also recommending these periods/frequency of monitoring (Boyle and Withington, 2006).
4 Historical data can be used as part of the data set.
5 Not all sites will require gas monitoring however, this would need to be confirmed with demonstrable evidence.
6 Placing high sensitivity end use on a high gas hazard is not normally acceptable unless source is removed or treated to reduce gassing potential. Under such circumstances long-term monitoring may not be appropriate or required.

Interpretation and Assessment of Risks

The interpretation of gas monitoring results is considered with emphasis on assuring that the type, quality and quantity of data obtained is sufficient to undertaken a sufficiently robust risk assessment. The assessment methodology is split into two, one for low rise housing with gardens (with a clear ventilated floor) and one for all other situations.

The methodology for situations except low rise housing with gardens is based on the system proposed by Wilson and Card[11] which in turn was a development of that published in CIRIA 149[5]. The classification system is summarised in Table 8.5.

Table 8.5 Modified Wilson and Card Classification

| Characteristic Situation (CIRIA 149) | Comparable partners in technology gas regime (see Box 8.2) | Risk classification | Gas screening value ($CH_4$ or $CO_2$) (l/hr) | Additional factors | Typical source of generation |
|---|---|---|---|---|---|
| 1 | A | Very low risk | <0.07 | Typically methane ≤ 1% and/or carbon dioxide ≤ 5%. Otherwise consider increase to Situation 2. | Natural soils with low organic content "Typical" Made Ground. |
| 2 | B | Low risk | <0.7 | Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3. | Natural soil, high peat/organic content. "Typical" Made Ground. |
| 3 | C | Moderate risk | <3.5 | | Old landfill, inert waste, mine-workings flooded. |
| 4 | D | Moderate to high risk | <15 | Quantitative risk assessment required to evaluate scope of protective measures. | Mine-working – susceptible to flooding, completed landfill (WMP 26B criteria). |
| 5 | E | High risk | <70 | | Mine-working un-flooded inactive with shallow workings near surface. |
| 6 | F | Very high risk | >70 | | Recent landfill site. |

1 Gas screening values: litres of gas/hour is calculated by multiplying the gas concentration (%) by the measured borehole flow rate (l/hr) – see Glossary.
2 Site characterisation should be based on gas monitoring of concentrations and borehole flow rates for the minimum periods defined in Table 5.5.
3 Source of gas and generation potential/performance must be identified.
4 Soil gas investigation to be in accordance with guidance provided in Chapters 4 to 6.
5 If there is no detectable flow use the limit of detection of the instrument.
6 The boundaries between the partners in technology classifications do not fit exactly with the boundaries for the CIRIA classification.

The guidance document does stress that the Gas Screening Values (GSV) are guidelines only and not absolute thresholds.

The low rise housing methodology is based on the RSK ENSR / NHBC draft document (Boyle and Witherington 2006). The GSV is calculated in the same way but this value is then compared to Table 8.7.

Table 8.7 NHBC Traffic light system for 150mm void

| Traffic light | Methane[1] | | Carbon dioxide[1] | |
|---|---|---|---|---|
| | Typical maximum concentration[5] (% v/v) | Gas screening value (GSV)[3,4,6] (litre per hour) | Typical maximum concentration[5] (% v/v) | Gas screening value (GSV)[2, 3,4,6] (litre 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 | | | | |

1 The worst gas regime identified at the site, either methane or carbon dioxide, recorded from monitoring in the temporal conditions, will be the decider for which Traffic Light or GSV is allocated.
2 Generic GSV's are based on guidance contained within latest revision of the Environment and the Welsh Office (2004 edition) "The Building Regulations: Approved Document C" and used a sub-floor void of 150mm thickness.

3 The small room is considered to be a downstairs toilet, with dimensions 1.50 x 1.50 x 2.50m, 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 judgement 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.

Table 8.7 details 'Typical Maximum Concentrations' for initial screening purposes and risk based Gas Screening Values for consideration where the Typical Maximum Concentrations are exceeded. Additional details are provided in CIRIA C659 regarding the assumptions that need to be made and limitations that apply when using this assessment.

It is also noted that the Gas Screening Values quoted are guidelines only and not absolute thresholds.

# Notes on Limitations

**Methodology**

This Environmental Assessment has been designed to provide information relating to:

- the current and former land uses on and surrounding the site;
- the environmental sensitivity of the site location as determined by factors including geology, hydrogeology, surface watercourses and neighbouring land uses; and,
- relevant records held by the environmental regulators.

Any relevant information provided by the client has been reviewed, with appropriate action taken to ensure this information is taken into account and/or verified where necessary. All information is then assessed to define the potential for the site to give rise to environmental liabilities for the freehold/leasehold owner (as appropriate). Recommendations are made for additional work where this is necessary to fully define the site's environmental liabilities, and cost estimates of the financial implications of the findings can be provided under separate cover, where appropriate.

**Risk Classification**

This assessment has been undertaken with due regard to Contaminated Land Guidance documents issued by the Department for Environment, Food and Rural Affairs (and its Predecessors), the British Standards Institute (the BSi), the Royal Institution of Chartered Surveyors (RICS) and the American Society for Testing and Materials (ASTM) Standard E 1527-00. The methods used follow a risk-based approach, with the potential environmental risk assessed qualitatively using the 'source-pathway-target pollutant linkage' concept introduced in the Environmental Protection Act 1990.

Specific comment is made regarding the site's status under the Contaminated Land Regime implemented on the 1st April 2000 as Part IIA of the Environmental Protection Act 1990, and the actual or potential designation of the site as 'Contaminated Land' as defined in Section 78A(2). Unless specifically stated as relating to this definition, references to 'contamination' and 'contaminants' relate in general terms to the Presence of potentially hazardous substances in, on or under the site.

In addition, consideration has been given to a wide range of related topics including (where appropriate): environmental processes; current and foreseeable environmental legislation; the practices and duties of environmental regulators; the health and safety of occupiers and neighbours as affected by contamination; effects on the structure of buildings; and financial implications. References to risk classifications are made according to the following definitions:

**Low Risk** - It is unlikely that the issue will arise as a liability/cost for the freehold/leasehold owner (as appropriate) of the site.

**Medium Risk** - It is possible that the issue could arise as a liability/cost for the freehold/leasehold owner (as appropriate) of the site. Further work is usually required to clarify the risk.

**High Risk** - It is likely that the issue will arise as a liability/cost for the site freehold/leasehold (as appropriate) owner of the site.

**Environmental Risk Assessment**

The presence of contaminated materials on a site is generally only of concern if an actual or potentially unacceptable risk exists. Within the context of current UK Legislation (i.e. Section 57 of the Environment Act 1995), the interpretation of a "significant risk" is termed to be one where:

- Significant harm is being caused or there is a significant possibility of such harm being caused, (where harm is defined as harm to health of living organisms or other interference with the ecological systems of which they form a part and, in the case of man, includes harm to his property); and / or, pollution of Controlled Waters is being caused.

The potential for harm to occur requires three conditions to be satisfied:

- Presence of substances (potential contaminants/pollutants) that may cause harm (Source of Pollution).
- The presence of a receptor which may be harmed, e.g. the water environment or humans, buildings, fauna and flora (The Receptor).
- The existence of a linkage between the source and the receptor (The Migration Pathway).

Therefore, the presence of measurable concentrations of contaminants within the ground and subsurface environment does not automatically imply that a contamination problem exists, since contamination must be defined in terms of pollutant linkages and unacceptable risk of harm.

The nature and importance of both pathways and receptors, which are relevant to a particular site, will vary according to the intended use of the site, its characteristics and its surroundings.

In order to assess the contamination risk at the subject site the above rational has been applied and is discussed within section 6 in the context of Contamination Sources and Potential Pollutant Linkages.

**Limitations**

WSP Environmental Limited has prepared this report solely for the use of the Client and those parties with whom a warranty agreement has been executed, or with whom an assignment has been agreed. Should any third party wish to use or rely upon the contents of the report, written approval must be sought from WSP Environmental Limited; a charge may be levied against such approval.

WSP Environmental Limited accepts no responsibility or liability for:

a) the consequences of this document being used for any purpose or project other than for which it was commissioned, and

b) this document to any third party with whom an agreement has not been executed.

The work undertaken to provide the basis of this report comprised a study of available documented information from a variety of sources (including the Client) and discussions with relevant authorities and other interested parties. The opinions given in this report have been dictated by the finite data on which they are based and are relevant only to the purpose for which the report was commissioned. The information reviewed should not be considered exhaustive and has been accepted in good faith as providing true and representative data pertaining to site conditions. Should additional

information become available which may affect the opinions expressed in this report, WSP Environmental Limited reserves the right to review such information and, if warranted, to modify the opinions accordingly.

Where no site inspection is undertaken (for example a Desk Study Assessment or due to restricted site access), WSPE cannot comment on the potential for environmental concerns associated with the current use or structure including the Presence of asbestos.

It should be noted that any risks identified in this report are perceived risks based on the information reviewed; actual risks can only be assessed following a physical investigation of the site.