Ground Gas Hazards, Desk Studies, CSM's and when not to monitor

Simon Talbot, Founder and Managing Director of GGS
January 2024

Introduction

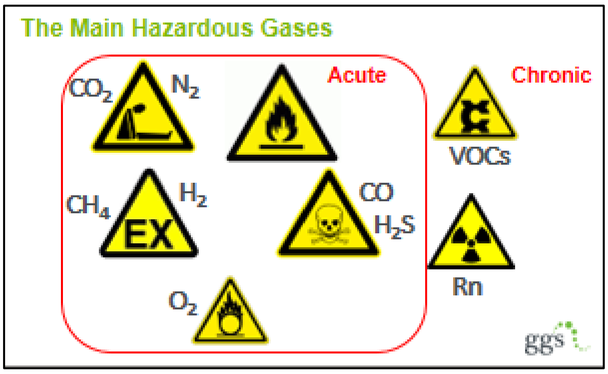
One of the first incidents that was a wake-up call for the geo-environmental sector was the Loscoe incident of 1986[1]. The Public enquiry that came after this event identified a number of the key factors that underpin the UK's contaminated land regime. That is the Source-Pathway-Receptor Contaminant Linkage. However, the inquiry also identified a fourth factor which is unique to ground gas contamination. That is a driving mechanism. In the case of Loscoe the driving mechanism was a low-pressure system which passed over the country in the preceding hours. The drop in pressure effectively sucked the landfill gas from the adjacent unlined landfill through the fractured sandstone pathway into the sub-flow void of number 51 Clarke Avenue. When the central heating system tripped in at 6 30 in the morning an explosive mixture was ignited, and the house was destroyed.

The Loscoe event was a catalyst that generated the early ground gas guidance documents that discussed the sources of ground gases, their hazards, and how to monitor, risk assess and protect new development. Many of these documents are still relevant and contain useful information.

However, despite the considerable number of guidance documents that are now available, disastrous, and occasionally tragic, events still occur. Many of these go unreported but one of the more well-publicized events took place in Gorebridge[2], in Scotland in 2013. This was a new housing estate built in 2009 by Midlothian Council. Unfortunately, in 2013, a number of council tenants were overcome by carbon dioxide. They were taken to hospital and the affected properties were evacuated. Over the course of the next few months a total of 22 tenants had sought medical help. At this point the local NHS Trust set up an incident management team to investigate the causes of health impacts. The cause was identified as mine gas from shallow abandoned mine workings beneath the estate. The solution chosen by Midlothian Council was to demolish the whole estate and rebuild it with appropriate gas protection measures.

Ground gas hazards require proper consideration and can be effectively managed by appropriate interventions. This paper summarises some of these hazards and highlights good practice in the investigation, risk assessment and protection of new developments on potentially gas contaminated sites.

Potential Gas Hazards



Asphyxiation, explosion, and toxic contamination can occur very quickly and represent 'acute' hazards. The hazards associated with exposures to carcinogens and naturally occurring radon may only be realised over long periods of time measured in many months, or years and constitute 'chronic' hazards. Therefore, time scales are an important factor in considering potential contaminant linkages.

Also, monitoring instrument resolutions need to be appropriate for the gas of concern. For instance, the toxic concentrations of carbon monoxide are measured in the ppm range while the explosive range of methane is above 5% by volume.

[1] CIRIA 130, Methane: its occurrence and hazards in construction, 1993.

[2] Carbon Dioxide Incident in Gorebridge, Midlothian, April 2014. Final Report of the Incident Management Team. NHS Midlothian, November 2017.

Source Risk Factors
Source risk factors are a combination of concentration and volume of available gas. The volume of gas can be determined by a gas generation rate within a source or the insitu column of gas already present within a source.

At one end of the spectrum, we have modern licensed landfills. These will be containment sites with active gas management systems. A municipal landfill containing a high proportion of putrescible waste will generate 10 cubic meters of landfill gas per ton, per year. At the other end there are naturally occurring organic rich soils such as peat deposits. Below the water table there will be anaerobic, methanogenesis generating methane at concentrations of 90% or more. But the generation rate will be very low. So low that the volume of gas involved will almost certainly be too low to form an explosive environment within a building.

Somewhere between most two extremes you have older former landfills: typically dating from the sixties, seventies and eighties. Following the 1956 clean air act, the use of domestic coal fires was banned in many towns and cities. Consequently, the character and volume of municipal waste changed dramatically. Relatively low volumes of inert ash waste was replaced by large quantities of putrescible waste that needed to be disposed of. The most convenient sand and clay pits and quarries, beyond the town boundaries, were used. The Environment Agency have catalogued over 23,000 former landfills in England and Wales around every town and city. There is a similar density and distribution in Scotland. These sites are categorised as 'dilute and disperse' landfills and many of them are still generating landfill gas. The question is how much.

The current challenge is that these sites, which were once beyond the town of city boundary, are now in prime development locations and are subject to planning applications. The question is can they be safely re-developed.

Former industrial sites which have fallen into disuse are also prime re-development targets. However, by accident or design, the ground beneath may contain a variety of chemicals, including VOCs, that constitute a hazard to future occupiers.

Finally, Great Britain has been blessed by extensive coal fields. The Coal Authority estimate that 11 % of the area of our island is underlain by coal – much of this has been mined at shallow depth at some point in the past. Where mine-workings remain open, large quantities of mine gas may be present. This represents a real hazard to overlying developments.

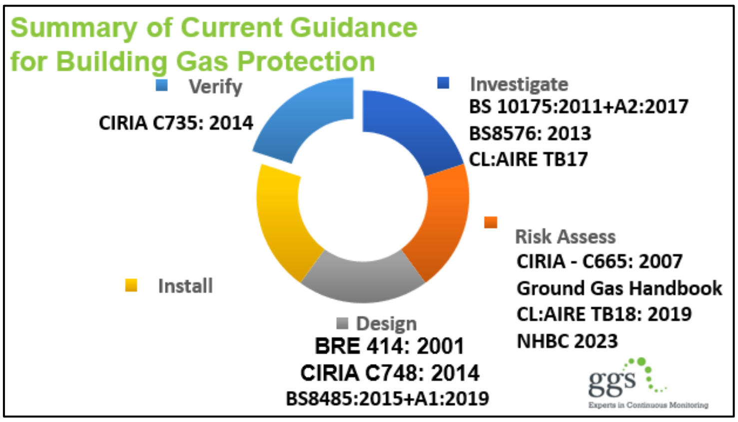
Pathways
Earlier in my career, a lot of my work was associated with understanding the lateral migration of ground-gases from a source to a receptor. This involved understanding the geology and permeabilities of potential and actual pathways and devising interventions to prevent lateral migration.

Today, most of my work is associated with understanding the gassing potential of a source located directly underneath the footprint of a proposed development. These may be developments on a former industrial site or a former landfill. The emphasis is now on accurately characterizing the ground gas risk and design and installing appropriate measures to prevent ground gases penetrating the building envelope.

Receptors
The design of the gas protection measures will depend on the sensitivity of the development. Private residential housing is considered the most sensitive as occupants may be present for 24 hours a day. Offices and retail premises are considered slightly less sensitive as they are likely to only occupied during the working day. Less sensitive again are large portal frame commercial or industrial buildings which have large open interiors within which ground gases would be effectively diluted. The exception to this latter category are those parts of a warehouse containing smaller offices or welfare rooms which may constitute confined spaces.

Construction sites may also be considered receptors if they contain open trenches or excavations. Carbon dioxide is heavier than air and can build up to dangerous concentrations in below-ground voids, even if they are exposed to the atmosphere.

Ground Gas Management Process



The ground gas management process has five elements as shown in the accompanying figure. For a development to be safely protected from a ground-gas hazard all five elements need to be completed to a good standard. Unfortunately, that is not always achieved.

For reference, I've included some of the key guidance documents associated with each element in the figure.

It wasn't until CIRIA C735 was published that the circle was closed, and the spotlight was shone on the quality of the installation of gas protection systems. However, shortcuts or errors are occasionally made in each of the five elements.

Phase 1 Investigations. The first stage of an investigation must be a Phase 1 Desk Study and Walk Over Survey (site reconnaissance). Guidance on what should be included in a desk study and site reconnaissance is set out in BS10175[3]. There is also a useful checklist in the Environment Agency's on-line LCRM[4] guidance. This information should be presented in a Preliminary Conceptual Site Model (PCSM) setting out the potential sources, pathways and receptors (S-P-Rs) for likely hazardous gases.

To comply with BS8576[5] the PCSM should be set out in a schematic cross-section that clearly identifies the inter-relationships between the S-P-Rs. Drawing a cross-section is the ideal way of consolidating understanding of a site and it informs decisions on the Phase 2 physical site investigations – specifically, the type and location of sampling and testing methods. Cross-sections are also an ideal tool for communicating information to colleagues, clients and regulators. Unfortunately, such schematic cross-sections are not always included in Phase 1 reports.

Phase 2 Site Investigations. The Phase 2 physical investigations should be designed to validate the PCSM. Specifically, to confirm the character, extent and composition of the S-P-R elements and confirm whether there are credible contaminant linkages. The physical investigations will often involve trial pitting, boreholes, soil sampling and laboratory analysis carried out by a SI contractor under the direction of a lead consultant. If the contractor will be drilling boreholes it is prudent and cost effective to install ground-gas monitoring wells at the same time.

The terms 'borehole' and 'monitoring well' are often used interchangeably. However, strictly speaking the monitoring well is a scientific instrument constructed within a borehole. As a scientific instrument, it will need to be carefully designed with the response zone to target a specific strata of interest. Also, as a scientific instrument it also needs to be carefully installed and verified through a form of CQA.

---

[3] BS10175:2011 +A2:2017. Investigation of potentially contaminated sides – Code of practice.

[4] https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm/lcrm-stage-1-risk-assessment#tier-1-preliminary-risk-assessment

[5] BS8576:2013. Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs).

Unfortunately, unsupervised monitoring well construction does occur resulting in low quality installations leading to ambiguous monitoring results. The whole purpose of site investigations is to confirm the CSM[6] and reduce uncertainty. A monitoring well installation which has a slotted pipe from top to bottom (see figure) installed because the driller, "forgot to pick up lengths of plain pipe from the yard this morning," is unacceptable. What would be worse is if the 'monitoring well' was installed with plain pipe from top to bottom.

The truth is that once the monitoring well headworks are cemented in place, it is very difficult to verify the quality of the installation.

When not to monitor
It is only after when the physical investigation is completed that an accurate picture of the site geology and the characteristics of gas sources and pathways are known. At this point in time, a decision can be made as to whether a 'credible S-P-R contaminant linkage' exists. If no credible linkage exists, then <u>no monitoring should be carried out.</u>

CL:AIRE RB17[7] sets out a flow chart and the following questions that addresses whether there is a credible linkage or not:

Has any of the following been identified?

a) A credible source and pathway from off-site.
b) A registered landfill on site.
c) On-site Made Ground >5m or an average >3m.
d) Representative TOC results from Made Ground exceeding the maximum values for CS3.

A fifth question, which isn't in RB17, is whether there are shallow abandoned mine workings beneath the site?

If the answer is 'No' to all of these, then no ground gas monitoring is needed and the site can be considered CS1. Also, if the site is underlain by natural, impermeable soils, no ground gas monitoring is needed, and the site can be considered CS1.

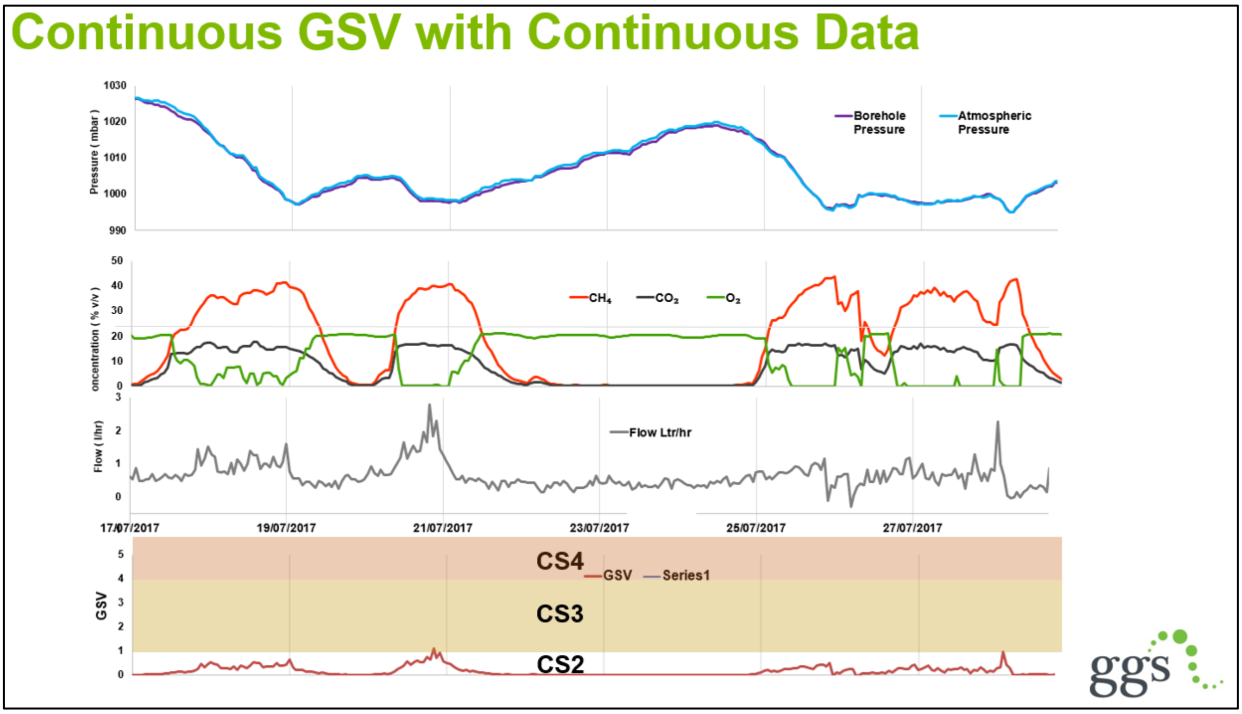
The mistake that is often made when there are monitoring wells on site, is to carry-out some gas monitoring, "just-in-case." This will run contrary to any statement made that there is no credible linkage and will raise question marks over the professional judgement of the consultant in the eyes of the regulator. The result may be greater scrutiny of the construction details of the monitoring wells and of the quality of the gas monitoring results unless the monitoring results confirms that there is no linkage.

How much monitoring?
When there is a credible contaminant linkage, monitoring is carried out to inform a ground gas risk assessment. The amount of monitoring data that is required is down to the professional judgement of the risk assessor. They must have sufficient data to be confident in the conclusions made. A small number of weekly 'spot monitoring' readings which are consistent and capture worst-case conditions, together with other lines of evidence, may be sufficient. However, if there is uncertainty and the spot monitoring results are highly variable then there are only two options; to collect many more weekly readings to provide sufficient confidence that the full range of ground gas behaviours has been captured, or use continuous ground gas monitoring techniques to capture high quality data within a shorter period of time.

---

[6] Where the CSM is specific to ground gas source-pathway-receptor pollutant linkages the abrevation 'gCSM' should be used.
[7] CL:AIRE RB17 A Pragmatic Approach to Ground Gas Risk Assessment, 2012.

One advantage of current continuous monitoring technologies, such as the Gas Sentinel®, is that you can produce a continuous Gas Screening Value (GSV) graph (see figure). The different Characteristic Situation (CS) thresholds can be superimposed. In this example the gas regime occasionally spikes into CS3 conditions. It is important to apply professional judgment and other lines of evidence, such as the sensitivity of the development and the site-specific context, to decide on the appropriate CS status.



Risk Assessment

There are further details of how to interpret continuous ground gas data in CL:AIRE TB18[8] based on hundreds of projects carried out on a wide variety of sites. Also, there is up to date guidance in the recent NHBC[9] publication. This document, together other British Standards, stresses the importance of using professional judgement.

In forming a judgement, it is important to use multiple lines of evidence that all point to a certain conclusion. In that way both you and the regulator can have confidence in the risk assessment.

Designing Gas Protection

The two key guidance documents are BS8485[10] and CIRIA C735[11].In the UK, gas protection must include a preferential pathway to atmosphere and a method of excluding ground gases from the building. BS8485 sets out the points that the different elements of protection can attract and the total number of points that a particular class of development will require for different Characteristic Situations. CIRIA C735 sets out the level of verification that will be required for different scenarios. To get the protection points for a particular design, BS8485 requires that independent verification is carried out in accordance with CIRIA C735.

Installation and Verification of Gas Protection Systems

---

[8] CL:AIRE TB 18. Continuous Ground-Gas Monitoring and the Lines of Evidence Approach to Risk Assessment.

[9] NHBC. Hazardous Ground Gas – An essential guide for housebuilders. May 2023.

[10] BS 8485:2015 +A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.

[11] CIRIA C735. Good practice on the testing and verification of protection systems for buildings against hazardous gases.

As the installation and verification of gas protection systems are relatively expensive, developers will tend to opt for the cheapest solutions. Unfortunately, the cheapest solutions may turn out to be the most expensive. Best practice requires qualified installers and qualified verifiers. Unqualified installers, such as general ground-workers, will be cheaper than qualified gas-membrane installers. However, CIRIA C735 indicates that if unqualified installers are used then the level and detail of verification must be increased. The result is often increased cost and time to repair defects, along with high verification costs to ensure that these defects are repaired correctly.

To comply with BS8485, the verifier must be independent. There are occasions when both the installer and verifier are commercially connected. Such arrangements are unacceptable as defects may be overlooked resulting in the protection systems being compromised.

The investigation, risk assessment, protection design and installation costs will be a waste of money if the risk from the identified gas hazard is not effectively managed.

Conclusions

- Good quality cross-section CSMs are essential. They demonstrate the inter-relationships between the Source, Pathway and Receptors, allow decisions on appropriate physical investigations to be made, and are an excellent communication tool for colleagues, clients and regulators.
- Better quality site data reduces uncertainty. Uncertainly leads to poor decision making and ultimately additional costs through unforeseen problems or overdesigned protection measures or measures that were not required.
- Only monitor if there is a credible contaminant linkage. Monitoring when there is no credible linkage may lead to one's professional judgement being questioned and greater scrutiny of the monitoring results.
- Multiple lines of evidence provides justification for decisions. Robust evidence from a range of sources improves the confidence of clients and regulators and can save time and money.
- Avoid 'just in case' decisions. This approach can expose uncertainty and poor professional judgment.
- Independent verification of gas protection installations is essential. Without independent verification, defects may go unrepaired. Defective gas protection systems will not effectively protect future occupiers from identified hazards.