Assigned assessment of contaminated land risks; Radon, Carbon Dioxide, Methane and VOCs – Design approach and verification strategy

Currently in Ireland we have a gap in our guidance when looking at potentially contaminated sites from ground gases or vapour risks which leads to a potential risk to human health. Technical Guidance Document C (TGD C)[1], provides guidance to designers and contractors alike when looking at the risk of radon gas. However its guidance on sites affected with Carbon Dioxide (CO_2), Methane (CH_4) or Volatile Organic Compounds (VOCs) is limited as it stands. Potential sources and contaminants by what it terms as 'dangerous substances' like CO_2 and CH_4 are discussed within section 2 in TGD C. It goes on to state that ground investigation should fall in line with BS5930: Code of practice for ground investigations – (1999)[2] and a reference to a now out of print document, DOE – Protection of new buildings and occupants from landfill gas – (1994)[3]. One of the main risks and misconceptions currently in our industry is the thought process that if providing radon protection to a development you are also providing protection against all other ground gas and vapour risks which isn't necessarily the case.

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The Risk

Due to the confusion between radon protection and other ground gases and vapour risks currently, the design process employed can be creating a risk to human health. As discussed further on, the type of ventilation and membranes employed differ when protecting against other ground gases/VOCs alongside independent verification techniques from solely radon.

A housing site in Gorebridge in Scotland has shown us how mistakes in gas membrane installation and verification can cause major implications. In 2013 there were 6 people from a street admitted to hospital with carbon dioxide poisoning due to a leak from an old coal mine. In 2014 the street was evacuated and in 2016 the 64 homes were demolished. Inadequate gas protection measures had been installed and verified during the original construction process. The overall cost of the works was in the region of £12m. This doesn't take into account costs for tenants hospitalised or re-housing during demolition and construction works. The final figure of tenants who complained of headaches, dizziness, anxiety and coughs was around 22.

In 2018 at another housing site in Newtongrange, Midlothian a project manager was found guilty of forging validation and testing reports. The court ruled that his actions had potentially put 11 families at risk from toxic gases. He was convicted and jailed for 7 months.

Given that radon protection is used on sites without sometimes proper assessment of other contaminants in Ireland. This asks the question of whether adequate protection is being provided and therefore a potential risk to human health is created.

Site characterisation and risk assessment

Site characterisation is imperative when setting out a conceptual site model to assess the risk to human health when dealing with ground gas and vapour contamination. By using the Source, Pathway and Receptor methodology and whether pollutant linkage is present. When looking at radon the process of characterisation is based on an assumption of risk aligned to the radon maps[4] provided by the EPA and TGD C. This uses a rating of either the site falling within a 'High Radon Area' or an 'Other than High Radon Area' and will dictate the use of either a radon membrane and sump system or a stand by sump system. These assumptions are based upon a potential of dwellings within the 10km grid square being above the national reference level for dwellings (200Bq/m^3) or workplaces (300Bq/m^3). Monitoring for radon should be carried out post construction to assess the actual site risk.

When looking at site characterisation for other ground gases or contamination the process is carried out during the site investigation prior to development. TGD C references the use of BS5930 for the ground investigation which states in the foreword, that *"it does not provide guidance on investigations for contaminated or naturally elevated concentrations of hazardous substances (see BS10175: Investigation of potentially contaminated sites; code of practice – 2011 + A1 – 2013)[5]. Nor does it provide guidance on investigations for ground gas (see BS8576: Guidance on investigations for ground gas; Permanent gases and VOCs – 2013)[6]."*

The use of BS10175 provides the process of setting out a conceptual site model and putting together the site investigation from desk study to intrusive investigation. The process of investigation and monitoring techniques for ground gas and VOCs in soils is set out in BS8576. These documents allow for adequate monitoring data to be created in order to provide a proper site

characterisation of risk and reference other best practice guidance;

- CIEH/LQM Safe for use levels (S4ULs) – (2014)[7];
- CIEH Ground Gas Handbook – (2009)[8]:
- BS8485: Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings – (2015)[9] + A1 – (2019);
- CIRIA Report C716: Remediating and mitigating risks from VOC vapours from land affected with contamination – (2012)[10];
- CIRIA Report C735: Good practice on the testing and verification of protection systems for buildings against hazardous ground gases – (2014)[11];
- CIRIA Report C748: Guidance on the use of plastic membranes as VOC vapour barriers – (2014)[12].

Most of these guidance documents are also referenced in Engineers Ireland: Specification and related documents for ground investigation in Ireland – (2016)[13].

Once gas monitoring has been completed, it is possible to carry out gas screening value (GSV) calculations set out in BS8485 in order to provide a site characterisation between 1 and 6 for CO_2 and CH_4 risk sites. The total organic carbon (TOC) content of the source can be assessed to eliminate the requirement for gas monitoring but is dependent on a range of factors again set out in BS8485. It may be necessary to look at Detailed Quantitative Risk Assessment (DQRA) if the site risks are very high based on GSV calculation or there are VOC risks present also.

Design process

Once a site characterisation has been provided it is possible to begin putting together a design in order to protect the structure against the ingress of gas. The guidance provided in TGD C would state the requirement of a radon barrier and/or sump system dependent on the map risk. It does not offer specific guidance for sites with CO_2/CH_4 or VOCs. But suggests the use of BS5930 and BS8102: Code of practice for protection of below ground structures against water from the ground – (2009)[14] in relation to site investigation and waterproofing, and if following these documents would eventually refer the reader to BS8485.

When looking at other gas risks such as CO_2 or CH_4 a point scoring system is employed in BS8485. This methodology uses the building type/receptor sensitivity alongside the site characterisation to set a required amount of points to be achieved in the protection system. Points are allotted dependent on slab type, venting and gas membrane installation and require a combination of two or more to provide a solution. This provides a robust design methodology looking at a number of protection measures in the system. The importance of each element of protection being explained in the document in order to justify the amount of points selected in the design approach. The document also includes guidance on sites with radon and VOC risks referencing detailed guidance such as CIRIA C716 and C748.

Slab and foundation types

The use of different types of floor slabs is discussed in BS8485 and their benefits when used on gas contaminated sites. Table 5: BS8485 details the points that can be achieved in the design process for precast suspended slabs, ground bearing, raft foundation or suspended slabs.

It also discusses basement floor and wall construction in line with BS8102. This relates to basements achieving grade 2 or 3 waterproofing and is dependent on Type B: Structural protection design. A score cannot be applied if utilising Type A: Waterproof membrane or Type C: Drained cavity wall design. If a waterproofing membrane is being installed beneath and around the basement a gas protection score in line with Table 7: BS8485 can be applied but the membrane must meet the table criteria.

Design solutions using solely waterproof concrete are not discussed in detail in either document. Therefore if this is put forward as a gas resistant solution then justification for gas or vapour modelling should be sought.

Radon sump design opposed to passive ventilation

The use of radon sump layouts in design tends to be a number of sumps installed below the slab with connecting pipe work which is then taken out to the structure perimeter and either capped off or extended up the side of the building. As mentioned before, it is then ***important to carry out post construction radon monitoring*** to assess whether the radon sump requires to be enacted with fans if the monitoring shows there is a radon risk internally in the structure.

Passive or active ventilation used in BS8485 is very different to this. When dealing with CO_2/CH_4 or VOCs the importance of the movement of air whether as a pressure relief pathway, a passive or active system is assessed during the design process. A void former is used to create an area of air flow below the slab to allow gas a pathway to follow to perimeter inlet/outlet vents. These systems should be designed to suit the site specific risks with the performance of the ventilation system proven by calculation, again specific to the gas monitoring data and background of the site itself. Points are allotted in table 6; BS8485 depending on the type of passive or active ventilation system employed in the design.

A radon sump system **does not work in the same process** as a passive ventilation system and should not be used on sites with CO_2/CH_4 or VOCs as a venting solution. Contrarily, if a passive ventilation system is being employed, a designed system will provide protection against the build-up of radon below the slab.

Gas membrane specification

BS8485 provides requirements for a gas barrier to achieve in the way of a CH_4 transmission rate <40 ml/day/m^2/atm tested to BS ISO 15105-1, suggested thickness and mass weight guidance, alongside considerations on the importance of robustness, durability and protection dependent on where the membrane will be installed. It also states that the membrane must be independently verified in line with CIRIA C735. To achieve points from Table 7 in the document the membrane installation must adhere to the criteria set out, otherwise it renders 0 points.

BS8485 highlights that if there are VOC contamination risks highlighted in the remediation strategy then there is guidance provided in; CIRIA C748. This document assessed the use of different types of membranes and their ability to protect against different VOCs. The guidance advises manufacturers to provide permeation testing on 9 challenge chemicals in order for modelling and assessment of a membranes suitability specific to the actual contamination on site. The guidance offers test procedures on;

- Benzene
- Toluene
- Ethyl Benzene
- Xylene
- Hexane
- Vinyl Chloride
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Naphthalene

Other considerations where selecting a gas membrane tend to be around if there is a waterproofing issue on the site. TGD C does reference BS8102 where there are waterproofing concerns. BS8102 references BS8485 where contamination or ground gas is present and therefore these two documents should work in tandem when working on a site with contamination.

Care must also be taken if a geosynthetic clay liner is being proposed as a water and gas proof membrane system. Membranes relying on bentonite clay solely becoming wet should not be used in gas protection design. BS8485 states that even if the material is pre-wetted during installation the clay can dry out and protection cannot be guaranteed.

Table 3 in TGD C provides minimum performance criteria for LDPE radon barriers. This criterion has provided parameters for NSAI IAB 3rd party certification of a radon barrier.

> *Due to the misconception however that radon membranes may also provide protection against CO_2, CH_4 and VOCs it is worth pointing out that of the **13 membranes** currently certified by NSAI **only 3 of these membranes*** hold and meet the methane test data set out as a requirement in BS8485. Of the certified membranes, **0 hold the test data*** set out for VOCs in CIRIA C748.*
>
> *Similarly by looking at the most popular waterproofing membranes available on the market only **1 membrane*** provides and meets the CH_4 test data required in line with BS8485. **None of these waterproofing membrane manufacturers could provide any VOC data*** in line with CIRIA C748. When looking at a basement tanking system there could be a higher risk of VOCs if present on site as they could be in direct contact with the membrane in liquid form as well as vapour.*
> *(*at the time of writing)*

Therefore the importance of requesting actual test data in line with the requirements of BS8485 and CIRIA C748 guidance where dealing with gas and VOC risks is critical to ensure the membrane being used is fit for purpose within the design process.

Independent verification strategy

Although verification is not currently discussed in TGD C the introduction of the Building Regulations 2014 have increased the scrutiny of all areas of construction and importantly sign off. Due to an assigned assessor not being able to be present on site at all times the building regulations uses a 'competent person sign off' in a lot of cases. The definition of this is termed as;

> *A person is deemed to be a competent person where, having regards to the task he or she is required to perform and taking account of the size and/or complexity of the building or works, the person possess sufficient training, experience and knowledge appropriate to the nature of the work to be undertaken*

From a contaminated land point of view, whether Radon, CO_2/CH_4 or VOCs there is no independently accredited body of gas membrane installers in Ireland or the UK meaning it is very difficult to justify a competent person. Importantly no Irish qualifications in gas membrane installation are available either. There are qualifications available in the UK from an installation perspective in the way of construction skills NVQ Level 2 in gas membrane installation. This covers an assessment of the installer in welding techniques, taping, sealing and setting out sites and is carried out over a period of months to assess a number of areas and includes a written paper as well as on-site assessment. Regardless of qualification however the conflict of interest of an installer signing off their own work is not best practice on contaminated land and not acceptable in line with BS8485/CIRIA guidance. The verification process involves not only membrane installation, but potentially venting, soil testing and pathway intervention. A membrane installer will not necessarily be present on site during these other elements and is also unlikely to have a full understanding of the conceptual site model.

CIRIA C735, provides the process of setting out verification strategy by risk assessment to provide a frequency of inspection and any integrity testing

required in line with the site risks. This risk assessment process looks at the *gas regime on site, design complexity, size or number of building(s) and the installation contractor's competency* i.e. do the site operatives hold the NVQ L2 qualification. If the installer is qualified a portion of CQA can be provided by them to the independent verifier to include in the overall sign off. This means the amount of independent inspection and testing may be decreased but the process of verification is always managed independently.

The verification strategy should be assessed and set by a suitably qualified independent engineer or consultant from the installation contractor. The verification engineer will provide a photographic file detailing the visual inspections; integrity testing (seam testing and leak detection) and remediation carried out and is covered by their professional indemnity. Currently this is normally carried out by environmental engineers who specialise in contaminated land but there is coming assessment and alignment through CL:AIRE and the national quality mark scheme. This is to provide regulators and contractors further confidence in the verification process being carried out.

It is also important to highlight that a gas membrane installation company cannot dictate the verification strategy or provide the verification and sign off of a gas membrane either directly or through a related company which has been designed in line with BS8485 or CIRIA guidance. Similarly a gas or waterproofing membrane manufacturer's sales representative QA is not acceptable when looking at the verification requirements set out in the documents above due to their lack of qualification, conflict of interest and lack of insurance.

Assigned assessment

As highlighted the risks to assigned assessors currently are whether the gas protection system being employed on site is **actually fit for purpose to the actual site risks**. A radon membrane and sump system does not necessarily work as protection if there are other contaminants to consider. There is a higher responsibility on membrane manufacturers to provide adequate test data specific to the site risks in line with specified test procedures.

The importance of a proper site characterisation of risk and a written design is set out in BS8485 and other guidance documents in the UK. TGD C will be reviewed at some point in the future, however in the short term there is a risk that some sites are being afforded inadequate protection due to a lack of assessment to the actual site risks.

On the verification side of things it is important assigned assessors look at the **suitability and quality of the BCar sign offs provided for a site**. If on a contaminated land site, an installation contractor carrying out self-certification either themselves or through a side company related to the contractor or a gas or waterproof membrane manufacturer sales person would not be acceptable in line with best practice guidance available. The risk to the assigned assessor directly would be the conflict of interest, lack of understanding of the overall conceptual site model and lack of insurance.

When putting an inspection plan together for a site as the assigned assessor the importance of design, installation and independent verification measures can be set out early to avoid these issues and importantly provides a more adequate protection system. Ultimately if a designer is working to BS8485 the importance of a proper design and verification are imperative to achieve accordance to the guidance.

References

1. DOE – Technical guidance document C: 2004
2. BS5930 – Code of practice for ground investigation: 2015
3. DOE – Protection of new buildings and occupants from landfill gas: 1994
4. Radon maps – http://www.epa.ie/radiation/radonmap/
5. BS10175 – Investigation of potentially contaminated sites; Code of practice: 2011 + A1: 2013
6. BS8576 – Guidance on investigations for ground gas; Permanent gases and VOCs: 2013
7. CIEH/LQM – Safe for use levels (S4ULs): 2014
8. CIEH – Ground gas handbook: 2009
9. BS8485 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for the new buildings: 2015
10. CIRIA C716 – Remediating and mitigating risks VOC vapours from land affected by contamination: 2012
11. CIRIA C735 – Good practice on the testing and verification of protection systems for buildings against hazardous ground gases: 2014
12. CIRIA C748 – Guidance on the use of plastic membranes as VOC vapour barriers: 2014
13. Engineers Ireland – Specification and related documents for ground investigation in Ireland: 2016
14. BS8102 – Code of practice for protection of below ground structures against water from the ground: 2009