Brownfield briefing  Belfast Apr 2018

Ground-Gas & VOCs: Practicalities of Continuous Monitoring

Simon Talbot  - MD GGS
Presentation Content

1 Challenges of ground-gas & VOC contamination

2 Key guidance

2 Why use continuous monitoring

3 Additional lines of evidence through continuous monitoring

4 New techniques

5 Case study
Loscoe Explosion, 1986 - 3 people injured
The Main Hazardous Gases

- CO$_2$
- N$_2$
- CH$_4$
- H$_2$
- O$_2$
- CO
- H$_2$S
- Rn
- VOCs

ACUTE
Environmental monitoring challenges

Solid

Liquid

Gas
Permeability Anisotropy

Gas movement in the unsaturated zone:
- Permeable soils
- Graded bedding
- Clay capping
Permeability anisotropy and borehole monitoring
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2. Key guidance
   - Why use continuous monitoring
3. Additional lines of evidence through continuous monitoring
4. New techniques
5. Case study
<table>
<thead>
<tr>
<th>Year</th>
<th>Document Title</th>
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<tbody>
<tr>
<td>1985</td>
<td>Pecksen: Methane and the Development of Derelict Land (GLC)</td>
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<td>1987</td>
<td>BRE 100: Measurement of Gas Emissions from Contaminated Land</td>
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<td>1991</td>
<td>BRE 212: Construction of New Buildings on Gas Contaminated Land</td>
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<td>1991</td>
<td>DOE Approved Document C (Building Regulations)</td>
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<td>1993</td>
<td>CIRIA 130: Methane: its occurrence and Hazards in construction</td>
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<td>1993</td>
<td>CIRIA 131: The Measurement of Methane and Other Ground Gases</td>
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<td>1995</td>
<td>CIRIA 149: Protecting Development from Methane</td>
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<td>1995</td>
<td>CIRIA 150: Methane Investigation Strategies</td>
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<td>1995</td>
<td>CIRIA 152: Risk Assessment for Methane and Other Ground Gases</td>
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<td>1997</td>
<td>DETR/PiT: Passive Venting of Soil Gases Beneath Buildings</td>
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<td>1999</td>
<td>WILSON &amp; CARD: Reliability and risk in gas protection design paper, published in Ground Engineering</td>
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<tr>
<td>2001</td>
<td>BRE 414: Protective Measures for Housing on Gas Contaminated Land</td>
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<td>2003</td>
<td>EA Consultation: Building Development on or within 250m of a Landfill Site (consultation closed Oct 2003)</td>
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<td>2004</td>
<td>ODPM: Approved Document C (Building Regulations 2000)</td>
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<td>2007</td>
<td>NHBC - Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present</td>
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<td>2007</td>
<td>CIRIA - C665 Assessing Risks posed by hazardous ground gases to buildings</td>
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<td>2007</td>
<td>BS8485 – Code of Practice for the characterisation and remediation from ground gas in affected developments</td>
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<td>2008</td>
<td>LA Guide to Ground Gas (Ground Gas handbook) – Wilson, Card and Haines</td>
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<tr>
<td>2012</td>
<td>CIRIA C716 remediating and mitigating risks from Volatile organic compound (VOC) vapours from land affected by contamination</td>
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</table>
Recent Guidance

**BS8576: 2013**
Guidance on investigations for ground gas – permanent gases and volatile organic compounds (VOCs)

**CIRIA C735: 2014**
Good Practice on the testing and verification of protection systems for buildings against hazardous ground gases

**BS8485: 2015**
Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings
Building Gas Protection

Investigate
Building Gas Protection

Investigate

Risk
Assess
Building Gas Protection

- Investigate
- Risk
- Assess
- Design
Building Gas Protection

- Investigate
- Risk Assess
- Design
- Install
Building Gas Protection

- Verify
- Investigate
- Install
- Risk Assess
- Design
Building Gas Protection

- Investigate
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Building Gas Protection

- Investigate
- Risk Assess
- Design
- Install
- Verify

CIRIA C735 2014
CIRIA - C665
BS8485 2015  BRE 414 2001
BS8576: 2013
Unqualified
• ground-worker

Qualified
• National Occupational Standards VR 612 and VR 613
• NVQ level 2 qualification in gas membrane installation
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Loscoe 1986 incident - Public Inquiry

Source - Pathway - Receptor

Pollutant Linkage

Driving mechanism
## History to continuous monitoring
- Traditional Spot Monitoring

| Exploratory hole | Time   | Response zone range (m) | Water level (m bgf) | Base level (m bgf) | Atm pressure (mbar) | CH₄ peak (%) | CH₄ steady (%) | LEL peak (%) | LEL steady (%) | CO₂ peak (%) | CO₂ steady (%) | O₂ high (%) | O₂ steady (%) | O₂ low (%) | H₂S peak (ppm) | H₂S steady (ppm) | Flow peak (l/hr) | Flow steady (l/hr) |
|------------------|--------|--------------------------|---------------------|-------------------|---------------------|---------------|---------------|--------------|---------------|--------------|---------------|-------------|----------------|-------------|---------------|---------------|----------------|----------------|----------------|
| BH08             | 08:45  | 5.0-6.0                  | 3.08                | 5.90              | 1000                | 0.3           | 0.0           | 2.6          | 0.0           | 0.0          | 0.0           | 20.2        | 20.2          | 20.2         | 0             | 0             | 0             |
| BH09             | 12:55  | 5.0-6.0                  | 1.86                | 6.03              | 999                 | 0.8           | 0.4           | 20.0         | 14.0          | 19.0         | 9.6           | 6.7         | 6.0           | 6.0          | 0             | 0             | 0             |-12.0         |
| BH11**[6]**      | 08:35  | 3.0-4.3                  | 3.28                | 4.30              | 1000                | 18.8          | 4.0-18.8      | +++          | +++           | 0.0          | 0.0           | 8.0         | 2.4-8.0        | 2.4          | 0             | 0             | 0             | 0             |
| BH12             | 14:15  | 6.5-7.5                  | 1.55                | 6.85              | 998                 | 0.0           | 0.0           | 0.0          | 0.0           | 0.4          | 0.4           | 20.2        | 20.2          | 20.2         | 0             | 0             | 0             | 0.9          |
| BH13             | 12:35  | 3.0-4.0                  | 4.05                | 4.05              | 1000                | 0.0           | 0.0           | 0.0          | 0.0           | 0.5          | 0.5           | 18.3        | 18.3          | 18.3         | 0             | 0             | 0             | 0             |
| BH15             | 10:35  | 3.5-4.5                  | 2.40                | 4.36              | 1000                | 0.8           | 0.0           | 18.0         | 0.0           | 2.2          | 0.9           | 19.5        | 19.5          | 19.5         | 0             | 0             | 0             | 0             |
| BH16**[3]**      | 13:30  | 1.0-4.0                  | 2.46                | 2.55              | 999                 | 0.0           | 0.0           | 0.0          | 0.0           | 0.3          | 0.3           | 20.1        | 20.1          | 20.1         | 0             | 0             | 0             | 4.0          |
| BH18             | 10:05  | 4.0-5.0                  | 2.40                | 4.64              | 1000                | 0.9           | 0.9           | 15.2         | 15.2          | 2.9          | 2.3           | 15.2        | 15.2          | 15.2         | 0             | 0             | 0             | 0             |
| BH19             | 14:05  | 12.5-13.5                | 1.27                | 13.50             | 999                 | 0.0           | 0.0           | 0.0          | 0.0           | 0.0          | 0.0           | 20.2        | 20.2          | 20.2         | 0             | 0             | 48.0²       |
| BH23**[3]**      | 13:55  | 5.0-6.0                  | 1.62                | 5.10              | 999                 | 0.0           | 0.0           | 0.0          | 0.0           | 0.2          | 0.2           | 20.5        | 20.5          | 20.5         | 0             | 0             | 10.5         |
| BH26             | 09:50  | 7.0-8.0                  | 2.10                | 7.82              | 1000                | 0.4           | 0.4           | 10.6         | 10.6          | 4.6          | 4.6           | 15.8        | 15.8          | 15.8         | 0             | 0             | 0             | 0             |
| BH29             | 09:26  | 1.0-5.0                  | 0.80                | 5.05              | 1001                | 0.0           | 0.0           | 0.0          | 0.0           | 0.8          | 0.8           | 20.1        | 19.9          | 19.9         | 0             | 0             | 0             | 0             |
| BH30**[2]**      | 11:20  | 9.0-10.0                 | 1.83                | 7.75              | 1000                | 0.0           | 0.0           | 0.0          | 0.0           | 0.3          | 0.3           | 20.4        | 20.4          | 20.4         | 0             | 0             | 0             |-15.8         |

[ggs]
Experts in Continuous Monitoring
Continuous Monitoring

When the frequency of monitoring **exceeds** the frequency of change of the measured parameter, the monitoring can be termed ‘continuous’
Continuous Ground-Gas Monitoring

1\textsuperscript{st} Generation
In-borehole device
GasClam®

Ambisense

2\textsuperscript{nd} Generation
In-borehole device
Gas Sentinel®
Lines of Evidence - Environmental Correlations

Multi-parameter continuous data...

Identify or eliminate correlations with the environment

Identify or rule out ground-gas drivers
Atmospheric Pressure as a Ground-Gas Driver

![Graph showing atmospheric pressure and methane concentration over a few days.](image-url)
Atmospheric Pressure as a Ground-Gas Driver

Atmospheric Pressure (mbar)

Methane (% v/v)

Pressure (mbar)

Concentration (% v/v)

20 Dec, 22 Dec, 24 Dec, 26 Dec, 28 Dec, 30 Dec
Temperature as a Driver

- **Temperature (°C)**
- **TVOC**

The graph shows the daily variations in temperature and TVOC concentration from 16 August to 06 September. The temperature data is represented by a dashed line, while the TVOC concentration is shown as a solid line. The data indicates that TVOC concentration is highest during the hottest days of the period, suggesting a relationship between temperature and TVOC levels.
Water Level as a Driver
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Purge & Recovery Test (PRT)

Measures Gas Flux
PRT recovery curves
Calculating Gas Flux

• Back calculate the borehole volume then:

\[ Q = \frac{V \times \Delta c}{\Delta t} \]

Where:

- \( Q \) = Gas Flux
- \( V \) = Volume of the internal vadose zone of the borehole
- \( c \) = Change in gas concentration expressed as a percentage
- \( t \) = change in time over which the change in concentration was measured

Repeatability demonstrates that the gas flux is a valid characteristic of that location.
Differential Pressure Assessment

Atmospheric pressure
Borehole pressure

‘Barometric Pumping’
New Tools - Ternary Plots

- Consider ratios with large data sets
- Useful for looking at trends and source
Receptor Monitoring (Sub-floor Void Monitoring)

Continuous monitoring on the down-wind side

Air Vents

Prevailing Wind
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Gas Sentinel® telemetry
Gas Sentinel®

Continuous Flow
GSV with Continuous Data

- **Pressure (mbar)**: Shows variations over time, indicating changes in atmospheric conditions.
- **Concentration (% v/v)**: Graphs for 
  - Methane (CH₄)
  - Carbon Dioxide (CO₂)
  - Oxygen (O₂)
- **Flow (L/hr)**: Demonstrates fluctuations and peaks in flow rates.

The data covers the period from 17/07/2017 to 27/07/2017.
GSV with Continuous Data

- Pressure (mbar)
- Concentration (% v/v)
- Flow (L/hr)

Legend:
- CH₄
- CO₂
- O₂
- Flow Ltr/hr
- GSV
- CS2
- CS3
- CS4

Graph shows data from 17/07/2017 to 27/07/2017.
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Gorebridge CO$_2$ Incident April 2014

- Incident Management Team set up in April 2014
  - NHS
  - Midlothian Council
  - Coal Authority

- By Sept 2014, 22 people had attended A&E or local GP
- By Oct 2014 housing estate evacuated
- March 2017 Council demolished 65 homes
2013/14 Coal Authority Investigations
87 Newbyres Crescent found to have:

- 8% CO₂ in downstairs toilet
- 12% CO₂ in Lounge (where son had been sleeping)
- 19% CO₂ beneath kitchen flooring
- 21% CO₂ measured in hole drilled through raft
- 23% CO₂ in wall cavity

Borehole drilled to the shallowest coal seam at 13m bgl:

- 25.1% CO₂ & 4.6% O₂
- No grout was found in the coal seam
Coal Authority continuous gas monitoring

Gorebridge Gas Data-87 Newbyres Crescent (under stairs)

Highest CO2 associated with falling atmospheric pressure

Experts in Continuous Monitoring
2017 IMT Report Conclusions

- Source confirmed as worked coal seam
- Workings not fully grouted
- Grout holes beneath houses possibly not sealed
- SI boreholes beneath houses possible not sealed
- Vibro stone column foundations
- Service entries through raft not sealed
- No gas protection measures installed
- Highest CO2 associated with falling atmospheric pressure

“Was this was an entirely preventable incident?”

(IMT Report – from Fairhurst)
In Summary

- All the elements of ground gas protection are important
- Continuous monitoring has come of age
- Better quality monitoring data informs less conservative risk assessments and more cost effective solutions
Thank you

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