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<th>1. REPORT DATE</th>
<th>2. REPORT TYPE</th>
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<td>31 MAR 2011</td>
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<td>New Continuous Monitoring Technologies for Vapor Intrusion,</td>
<td>Remediation and Site Assessment. Benefits of Time series Data</td>
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<table>
<thead>
<tr>
<th>5a. CONTRACT NUMBER</th>
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<td>5b. GRANT NUMBER</td>
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<td>5c. PROGRAM ELEMENT NUMBER</td>
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<th>6. AUTHOR(S)</th>
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<tr>
<td>Ion Science LLC, Advanced Gas Sensing Technologies, 33 Commercial Drive, Waterbury, VT, 05676</td>
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12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
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14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:

<table>
<thead>
<tr>
<th>a. REPORT</th>
<th>b. ABSTRACT</th>
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17. LIMITATION OF ABSTRACT

<table>
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18. NUMBER OF PAGES

| 36 |

19a. NAME OF RESPONSIBLE PERSON

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
New Continuous Monitoring Technologies for Vapor Intrusion, Remediation and Site Assessment.

Benefits of Time series Data

Dr Peter Morris, Geoff Hewitt
Why do we monitor Ground-Gas/Vapours?

Health and Safety – range of toxic affects explosion, suffocation

Contaminated land site investigation and remediation design – cost implications

More recently green house gas agenda - Carbon auditing

Ozone depletion
Objectives of ground gas/vapour monitoring

- Determine the true subsurface vapour/gas regime
- Predict how this may change in the future

Currently achieved by:

Discrete periodic static measurements of vapour/gas concentrations and the vapour/gas regime is inferred
Flawed approach

• Many environmental parameters show high temporal variability, therefore, their representative measurement requires multiple measurement.
• In the case of vapour/ground-gas risk assessment flaws in the existing multiple measurement approach have been identified explicitly in the literature in the UK (Wilson & Card, 1999) and are subject to continuing correction (e.g. CIEH).
• The two underlying causes of these flaws are that, whilst accurate quantification of risk requires accurate measurement of vapours,

1. They are not measured directly:
• concentration of vapour/gas in the ground is inferred from periodic (weekly – monthly) sampling of vapour/gas accumulated within a borehole (or soil sample)

• The relationships these inferences are based on will be highly site-specific.

2. Likely to be temporally variable.
GasClam - Key features

- Continuous monitoring of VOC, CH₄, CO₂, O₂, H₂S, CO barometric & borehole pressure and water level
- CSA C US approved (Class I, Zone I, Ex d ib IIB T4/ Class I, Zone I, AEx d ib IIB, T4)
- Extended deployment, up to 1 months based on hourly sampling
- Robust stainless steel design
- Fits directly in 50mm borehole (easy to adapt)
- Venting and vented modes
- Easy to use and deploy

Safe and secure
Easily installed, easily relocated

0:00 mins
Arrive

Install

1:30 mins/s
Go!

Advanced Gas Sensing Technologies
www.ionscience.com
### Variable VOC concentrations?

<table>
<thead>
<tr>
<th>Compound</th>
<th>WS1 June 09</th>
<th>WS1 July 09</th>
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<tbody>
<tr>
<td>Methylcyclohexane</td>
<td>&lt;0.6</td>
<td>150</td>
</tr>
<tr>
<td>Methylisobutylketone</td>
<td>&lt;0.5</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>Dimethylsulfide</td>
<td>&lt;1</td>
<td>&lt;0.8</td>
</tr>
<tr>
<td>Toluene</td>
<td>25</td>
<td>370</td>
</tr>
<tr>
<td>Butyric Acid</td>
<td>&lt;4</td>
<td>&lt;3</td>
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<tr>
<td>n-Octane</td>
<td>37</td>
<td>580</td>
</tr>
<tr>
<td>Ethyl Butyrate</td>
<td>&lt;0.9</td>
<td>&lt;0.8</td>
</tr>
<tr>
<td>Butyl Acetate</td>
<td>&lt;0.8</td>
<td>&lt;0.7</td>
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<tr>
<td>Tetrachloroethene</td>
<td>&lt;0.3</td>
<td>&lt;0.3</td>
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<tr>
<td>EthylCyclohexane</td>
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<td>190</td>
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<tr>
<td>Chlorobenzene</td>
<td>29</td>
<td>550</td>
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<tr>
<td>EthylBenzene</td>
<td>640</td>
<td>1900</td>
</tr>
<tr>
<td>m-Xylene + p-Xylene</td>
<td>33</td>
<td>840</td>
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<tr>
<td>n-Nonane</td>
<td>17</td>
<td>780</td>
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<tr>
<td>Styrene</td>
<td>&lt;0.4</td>
<td>150</td>
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</tbody>
</table>

Variability of VOC’s as detected by ‘spot’ sampling – suma canister Brownfield site NW UK

Confusing data, problem with sampling?
Variable VOC concentrations?

Continuous VOC data indicates concentrations are variable.
Detection

- Demonstrates the variability of concentrations from different sites

- The possibility of relevant risk prediction

- However, reduction in interpolation errors but potential for extrapolation error remains
Prediction

- Worst case must be predicted rather than detected
- Understanding of generic processes must be improved in order to increase confidence in prediction
Continuous monitoring improves prediction

because of the increased certainty in recognising and quantifying relationships between gas concentration and other environmental parameters because:

1. many more pairs of gas concentration and environmental data points are available to correlate,
2. sampling frequency matches the variability of the parameters measured so data can reasonably be regarded as a time series and the influence of conditions in altering relationships can be recognised,
Processes controlling intrusion/migration

The principal controls on gas migration are:

• Differences in fluid pressure – *atmospheric pressure* and water table changes

• Change in temperature

• ground permeability – vegetation, meteorology, development
Observing concentration and atmospheric pressure

![Graph showing concentration and atmospheric pressure trends with R² = 0.9174]

- VOC (ppm)
- Baro

- 17-Sep to 19-Sep
- CH4%
- Baro
- R² = 0.9174
Observing concentration and atmospheric pressure

\[ R^2 = 0.9174 \]
Longer monitoring period
Longer monitoring period

![Graph showing monitoring data over a longer period with peaks and dips in CH4, Baro, VOC levels.]
Periods with the inverse relationship with pressure

House adjacent to petrol station – Owner complaining of VOC smell
Local Authority sent in-door air quality team but nothing detected!
Highest concentrations at night – low in day time
Observing Temperature and Concentration

Bangor Gardens, Maine

1960’s Military Housing with underground storage tanks

UST were supposed to be removed and replaces with above ground storage tank

However 2010 VOC leak reported.
Observing Temperature and Concentration

High VOC concentrations Prior to SVE

Increase concentration with temp
Observing Temperature and Concentration

Bangor Gardens, Maine – Military Housing
UST leaking
Concentration much lower following SVE but clear dependency on temperature

1°C change results in 35 ppm!
Sometimes other environmental parameters are responsible for change in gas/vapour regime.
Characterising the borehole

What does the concentration I measure tell me?

Pump test data

Concentration recovers after a pump test can be very different. The absolute concentration in both cases is the same, but which poses a **greater risk**?
Site characterisation and Real time monitoring of Remediation

Industrial facility with VOC Leak

Acetone
Site characterisation

![Graph showing CH4, CO2, and VOC levels outside and inside a building over a period from 30 April to 20 May.](image-url)

- **Outside Building**
  - CH4 levels remain relatively stable with minor fluctuations.
  - CO2 levels are consistently lower than CH4.
  - VOC levels vary slightly but are generally lower.

- **Inside Foundations**
  - CH4 levels show a slight increase with more variability.
  - CO2 levels are stable and lower than outside.
  - VOC levels are constant with minor fluctuations.

[www.ionscience.com](http://www.ionscience.com)

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Real time monitoring of Remediation

Dual Phase Extraction

Advanced Gas Sensing Technologies
www.ionscience.com
Respirometry

to detect and quantify soil contamination e.g. suppression of aerobic respiration

• Sensitive
• Responds only to bioavailable toxins

BUT

• Only ex-situ;
• Findings less representative
In-situ respirometry

- Gasclam is ideal for in-situ respirometry
- Monitoring health of soil (active aerobic respiration)
- Monitoring contaminant impacts (suppression of respiration)
- Monitoring breakdown of organic contaminants by soil microbiota
For same resource and effort

Correlations

Concentration duration

Pump Test

Visit  | VOC (ppm) | mBar  | Temp °C |
---    | ---       | ---   | ---     |
1      | 2         | 1010  | 15      |
2      | 10        | 1005  | 13      

Or? You decide!

Advanced Gas Sensing Technologies

www.ionscience.com
Telemetry

GPRS Network

GPRS Gateway

Internet

User

Gasclam

Advanced Gas Sensing Technologies
www.ionscience.com
Reporting

GasClam In-borehole gas monitoring

Charts showing data from 07-Feb to 18-Mar:
- mBar
- % v/v CH₄
- % v/v CO₂
- % v/v O₂
Area Monitoring
Hierarchy of Cost-Benefits

Unmanned data Collection
Efficiency savings in meeting existing legislative requirements.

Reduced uncertainty about vapour regime (improved conceptual model)
Optimisation of design of remediation/vapour protection measures
Optimisation of operations for biogas production/greenhouse-gas emissions.

Pre and Post development condition monitoring with telemetry
Demonstration of low risk by monitoring rather than as a consequence of remedial engineering.