GasClam: Continuous Ground-Gas Monitoring Becomes A Reality

Introduction

Ground-gas monitoring is an important aspect of contaminated land site investigation and landfill management as the data is critical to the risk assessment process. The objectives of gas monitoring programs are to determine the true subsurface gas regime and predict how this may change in the future. This is currently achieved by discrete periodic static measurements of gas concentrations from which the gas regime is inferred.

Flaws in the current approach to quantifying and predicting risk arising from ground-gas are identified explicitly in the literature and are implicit in the continuing evolution of guidance notes. The underlying cause of flaws is that whilst accurate quantification of risk should require accurate measurement of ground-gas concentration and of ground-gas fluxes, neither is measured directly and both are likely to be temporally variable.

Measurement is indirect because ground-gas concentration is inferred from periodic sampling of gas accumulated within a borehole and flux is then inferred from these borehole gas concentrations. The unit of flux is volume/time, therefore it can not be measured directly without time series data.

With the ability to collect time series data, an improved measurement of flux can be made and temporal variablity can be quantified and accounted for. This will improve understanding of processes, thereby reducing the uncertainty which is inherent in the inferences required in using measurements that are indirect and lacking in temporall resolution.

Contaminated land and landfill industry regulators recognise the need for more representative data but cost has prevented the collection of continuous records of ground-gas measurements. However, the availability of reliable miniature infra-red sensors has recently been combined with innovative engineering to produce a new instrument; GasClam, which will allow the collection of continuous data to become widely used. This article, therefore, provides an overview of the technology, demonstrates the benefits of time-series data over traditional methods and introduces new risk assessment tools.

GasClam® Overview

The Gasclam® (www.ionscience.com), pictured below in Figure 1, allows secure, unmanned collection of continuous ground-gas data. It is manufactured from stainless steel, is intrinsically safe with ingress protection rated IP-68. It is designed to fit in a 50 mm borehole and measures methane, carbon dioxide, oxygen and hydrogen sulphide concentrations, as well as atmospheric pressure, borehole pressure and temperature. Water level can also be measured with an optional pressure transducer. The device fits securely within a borehole (see figure 2), whilst also allowing for controlled venting of the borehole. Sampling frequency is variable from 2 minutes to once daily and this can be set and data downloaded through a notebook PC using an RS 232 communication cable. It can be powered for 3 months by two alkaline D-cells based on hourly sampling.

Figure 1. GasClam®

Figure 2. The GasClam® fits in to a standard borehole making it safe and secure on site.

Benefits of time-series data and new risk assessment tools

The current approach relies on discrete measurements of concentration from which representative ground gas concentrations and gas migration potential are inferred. However, as system data is poorly resolved temporally uncertainties in these inferences remain large. For example, the frequency of variation in gas concentration may be higher than the sampling frequency, in which case measurement will not be representative. The benefit of continuous monitoring in overcoming the mismatch in sampling frequency and variability in the gas concentration is clearly shown in data from a site which from analysis of periodoc sampling was thought to show high gas concentration only at Christmas (Figure 3).

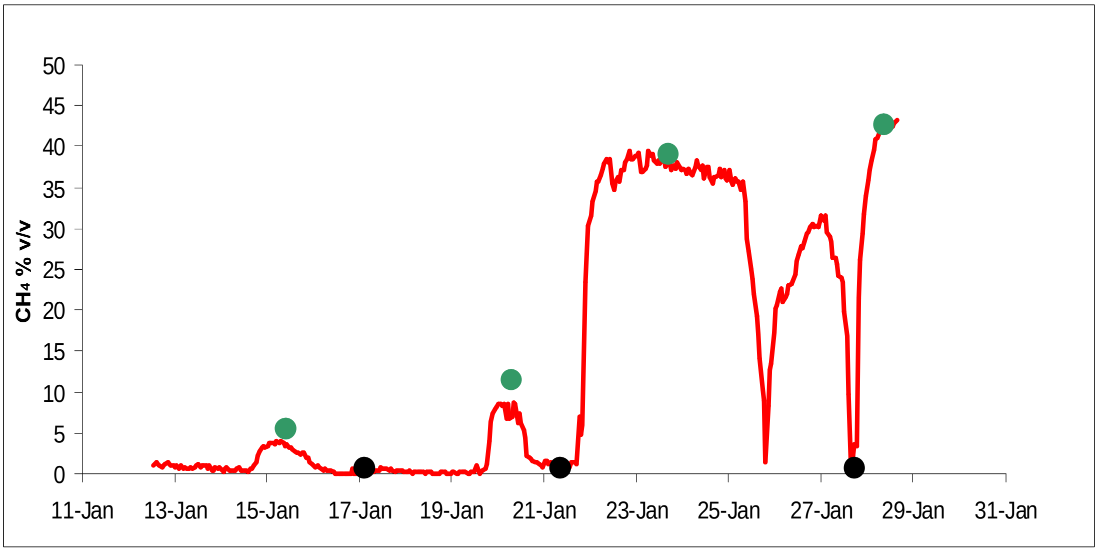


Figure 2. Continuous gas concentration data from ñThe Christmas Boreholeò a landfill perimeter borehole thought to indicate gas migration problems only at Christmas time. A period of continuous data collection has overcome the artefact arising from the sampling frequency (monthly) mismatching with the variability of concentration. The continuous data clearly showed that though the CH_4 concentration is variable it is not only high at Christmas. Collecting spot samples on days with the green dots compared to days with the black dots would result in an extremely different perception of risk.

Importantly, time series data also reveals that the frequency of variation in gas concentration is highly variable. In the above example the rate of change is on a daily/weekly timescale, however data collected at another site indicates gas concentrations changing by up to 40% in minutes, see figure 4. Between 19th - 22nd November the sampling frequency was 10 minutes, after this the frequency was reduced to 1 hour and the variability is not observed. This highlights the importance of choosing the correct sampling frequency, which in fact can only be identified following an intense period of continuous monitoring.

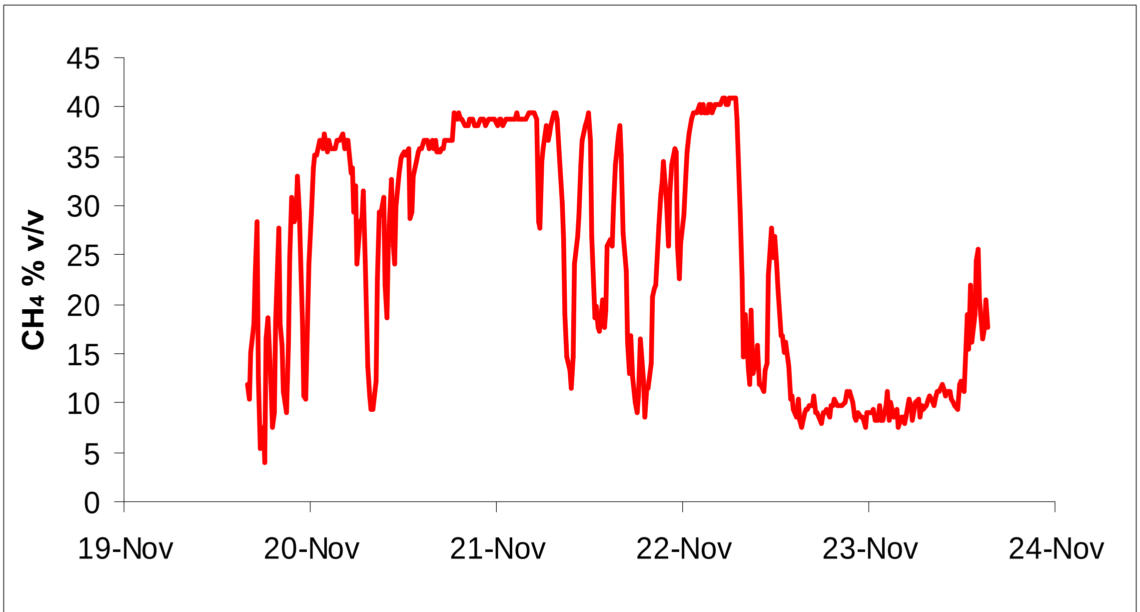
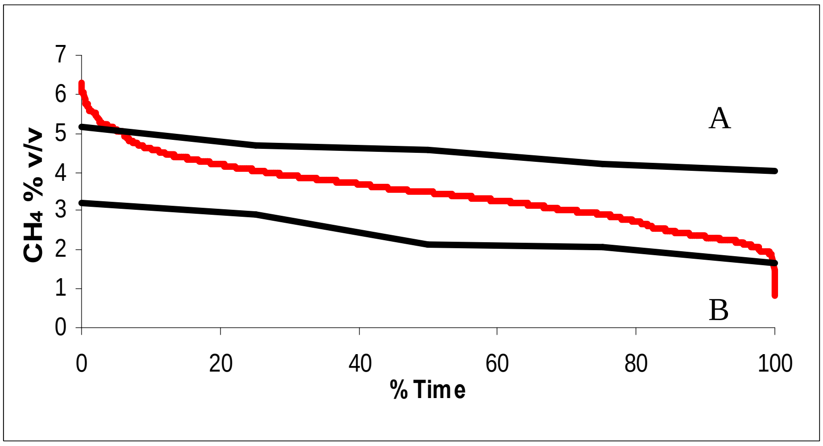


Figure 4. Continuous data from a borehole located on reclaimed land. The ground-gas concentration varies on a timescale of minutes, this demonstrates the need to collect data on appropriate time scale otherwise important information will be missed.

Concentration Duration Curves

Collection of more highly time-resolved data allows the construction of meaningful óconcentration duration curvesô Analogous to hydrological flow duration curves, these provide a more direct interpretation of risk than available from conventional monitoring. The value of continuous measurement is best shown by comparing concentration duration curves from the Gasclam® with data representing conventional periodic weekly sampling taken from the continuous data set. Two such sets are shown in Figure 5.



Spot Sampling A

Visit 1	4.6
Visit 2	5.1
Visit 3	4
Visit 4	4.2
Visit 5	4.5

Spot Sampling B

Visit 1	2
Visit 2	3.2
Visit 3	2.1
Visit 4	1.6
Visit 5	2.8

Figure 5. Concentration duration curves for CH_4. The red line is constructed from the high frequency continuous data and the black lines compiled from random samples taken from the continuous data set to represent conventional periodic weekly sampling (see spot sampling A and B).The data from set A indicate that the methane concentration is always near 5%, this is near the lower explosive limit of methane (5%) and would indicate a very high risk. The data from set B indicate a much lower concentration and therefore lower risk. In reality the real gas regime is somewhere in between the two.

Correlations

Higher temporal resolution of not only gas concentration but also other environmental variables allows their inter-relationships to be more clearly defined. This in turn allows dominant controls on gas concentration to be recognised and for better prediction of gas concentration as other parameters change. Atmospheric pressure is considered to be a strong driving force for gas migration (*Wilson et al, 2008*). In general it is assumed that concentrations are higher when pressure is low and vice versa and because of this current guidance (e.g. CIRIA Report 665) recommends collecting at least one spot sample below 1000mbar in falling pressure. Continuous monitoring data in Figure 6, shows the expected relationship between pressure and concentration. However, the arbitrary nature of the 1000mbar limit is clear as concentration continues to vary depending on changes in atmospheric pressure, rather than displaying a clear dependency on the absolute atmospheric pressure.

Furthermore, the widely reported relationship between pressure and concentration (see Figure 7) does not always exist; the inverse relationship is observed at a neighbouring borehole. This further demonstrates the need to characterise gas production in each borehole in order to quantify risk.

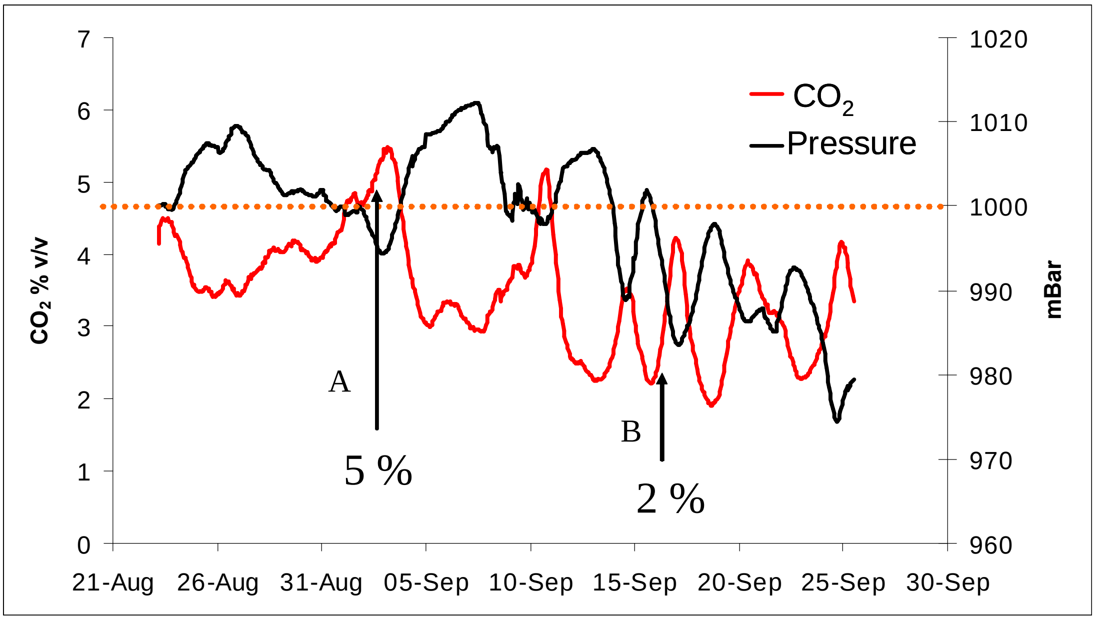


Figure 6. The expected relationship between atmospheric pressure and gas concentration is clear, when pressure falls concentration increases and vice-versa. The current guidance states that a spot sample should be taken when the atmospheric pressure is 1000 mbar and falling to represent worst case scenario. If a sample was taken at point (a) compared to point (b), both of which satisfy this condition, a very different risk would be perceived indicating the arbitrary nature of this value.

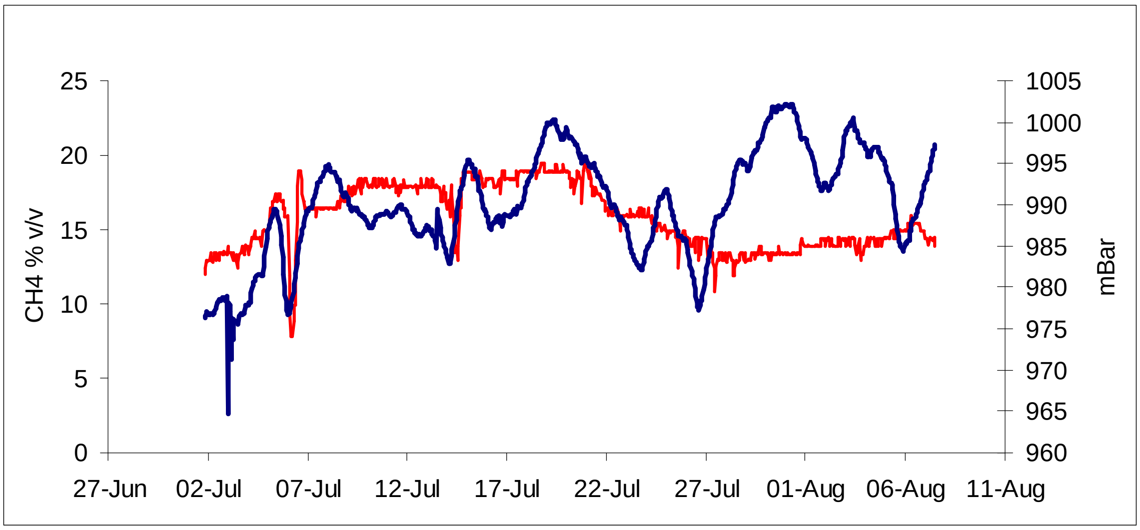


Figure 7. In this continuous data set the expected relationship between atmospheric pressure and concentration does not exist. Between 2 ï 22nd July the inverse relationship is observed i.e, when pressure increases the concentration increases.

Collecting Time Series Data

With the ability to collect continuous data it is possible to purge a borehole and collect information on how the concentration recovers. This information is important because the rate at which the concentration recovers is directly related to the migration/generation potential. In figure 8 the recovery profiles of two different boreholes are compared, both boreholes recover to an absolute value of approximately 10% but one recovers in hours where the other recovers over days, indicating a very different risk.

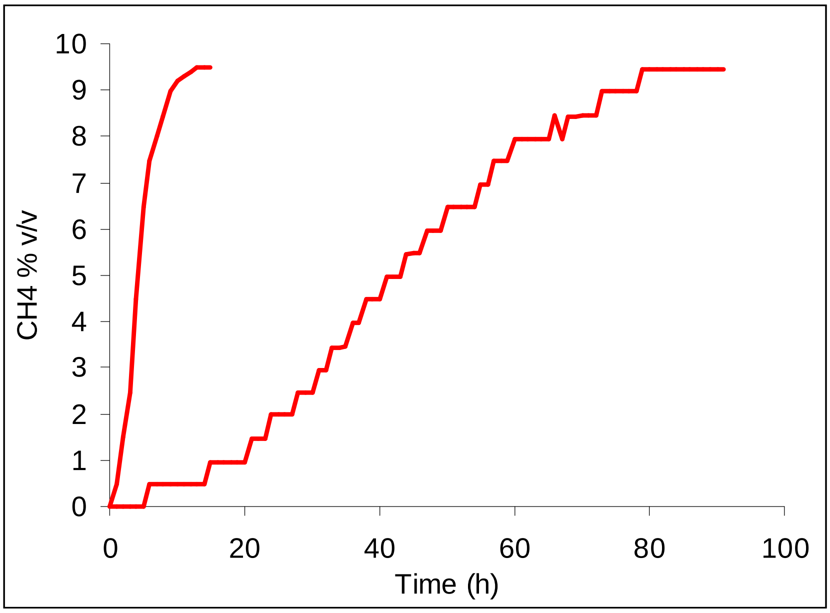


Figure 8. The recovery profiles from two boreholes both reach a maximum of 10% but the faster recovery poses more risk.

Conclusion

Continuous gas-monitoring data has revealed several potential flaws in the existing monitoring methodologies. The identification of ground-gas regimes that vary on a site-specific basis indicates the potential for a mismatch between the frequency of sampling and the variability of gas concentration, demonstrating the importance of selecting an appropriate sampling frequency to avoid missing valuable information. This can be clearly seen when comparing the concentration duration curves from the high frequency data and spot sample measurements.

The ability to monitor environmental parameters and concentration simultaneously will provide an understanding of the processes contributing to ground-gas production and migration. Initial results suggest that the relationship between environmental parameters and concentration are complex and currently poorly understood. The potential for further understanding of processes will allow for a more representative conceptual model. This has a further impact on risk assessment, which is currently based on inferences of worst-case conditions determined by limited periodic measurements of gas concentration.

Results of pump tests indicate that absolute concentration may not be the most important factor to consider when performing a risk assessment. Currently it is assumed that all boreholes to behave similarly but, it is now clear this is not the case and it is likely that pump tests will become standard practice in the future.

Thus it becomes apparent that a hierarchy of benefits arises from the ability to continuously monitor gas concentrations. The GasClam® can be used to collect data to fit into the current monitoring methodologies with the cost benefit of i) unmanned data collection and ii) improvement in data quality ensuring the monitoring program is executed correctly the first time.

For those incentivised to take a more proactive approach to gas migration risk they can take advantage of the improved data quality to remove the conservatism in the design of current gas mitigation measures and realise appropriate rather than over engineered solutions. In some instances it is likley that the option of permanent installation of telemetered gas monitoring will become a preferred option as its cost can be offset against what must otherwise be extremely cautious gas protection measures.

It is apparent from all of the above that to optimise the monitoring strategy, boreholes must undergo a degree of characterisation using a continuous monitoring device. This will have significant implications for the risk assessment framework and therefore, the availability of affordable continuous monitoring equipment will result in a new approach to risk prediction.

References:

Wilson, S; Oliver, S; Mallet, H; Hutchings, H & Card, G (2008) *Assessing Risks Posed by Hazardous Ground Gases to Buildings*, CIRIA Report C665.

About the Author

Dr Peter Morris has been working as a research associate at the University of Manchester for the past 5 years. His background is in studying environmental systems and identifying the dominant mechanisms and processes for aqueous and gaseous phase transport. Recently he has been liaising with the public and private sectors to improve ground-gas risk prediction.

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