Continuous Landfill Gas Monitoring – Understanding the Risk

The risks posed by Landfill gas migration are not always well understood. This is usually a result of monitoring programmes failing to identify the true subsurface gas regime and producing conceptual site models that cannot reliably predict how it may change in the future. As a consequence of this frequent monitoring is often required but even costly investigations with many site visits still result in large uncertainty in estimations of ground-gas concentration. As the upper bound of the uncertainty must be used in risk assessment the uncertainty in measurement ultimately results in expensive mitigation measures.

Data is currently collected as 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(1) and are implicit in the continuing evolution of landfill gas management guidance notes(2). The underlying cause of flaws is that whilst accurate quantification of risk should require accurate measurement of landfill gas concentration and of fluxes, neither is directly measured, and both are likely to be temporally variable.

Measurement is indirect because soil-gas concentration is inferred from periodic sampling of gases that accumulate within a borehole; the flux is then inferred from these readings. The unit of flux is volume/time, therefore it cannot be directly measured without time series data.

Landfill industry regulators recognise the need for more representative data but cost has prevented the widespread collection of continuous records of landfill gas measurements. However, the availability of reliable miniature infra-red and photo-ionisation 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 provides an overview of the technology, demonstrates the benefits of time-series data over traditional methods and introduces new risk assessment tools.

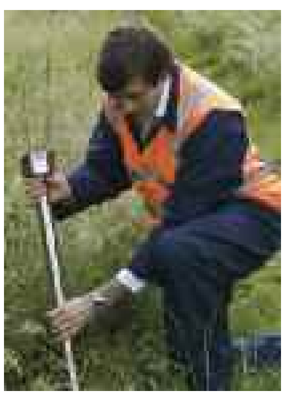

Figure 1

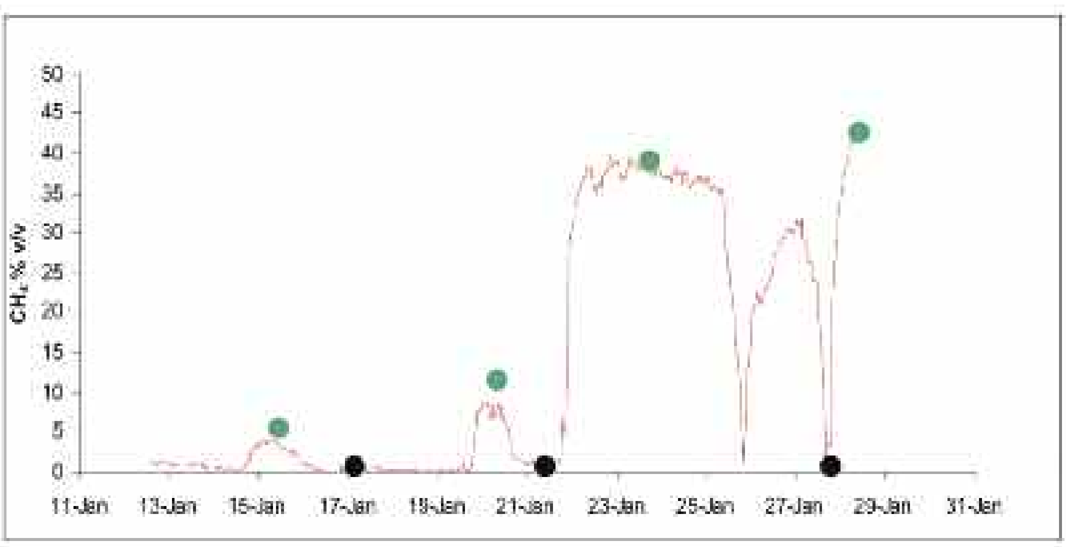

Figure 3: Continuous gas concentration data from "The Christmas Borehole", a landfill perimeter borehole thought to indicate gas migration problems only at Christmas time. A period of continuous data collection has overcome the artefact arising from the sampling frequency (monthly) mismatching with the variability of concentration. The continuous data clearly showed that, although the CH_4 concentration is variable, it is not only high at Christmas.

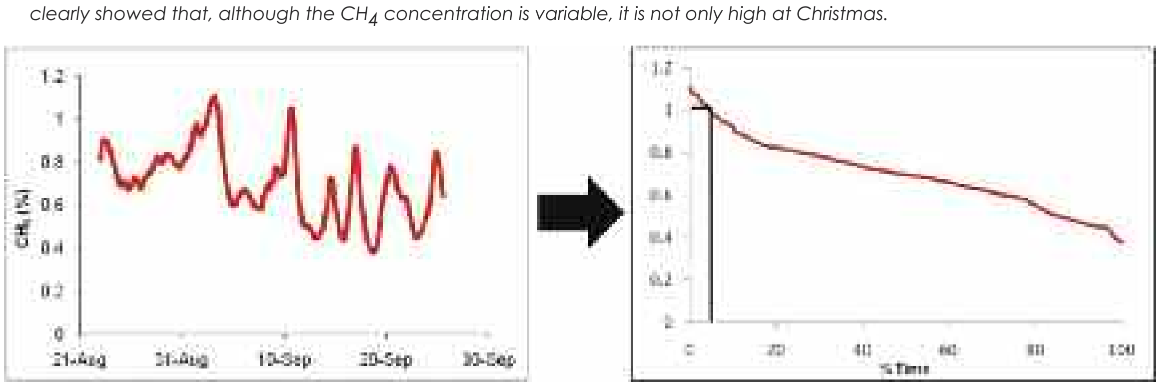

Figure 4: Continuous data (left hand side) can be converted into concentration duration curves. Now instead of only being able to say that 5% CH_4 had been recorded twice it is possible to make a more quantitative statement - the concentration is 5% or above only 2% of the time.

GasClam® Overview

The Gasclam®, see 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, hydrogen sulphide, carbon monoxide and VOC 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 whilst also allowing for controlled venting of the borehole.

Benefits of time-series data

Accounting for Temporal Variability

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. This is clearly demonstrated on a landfill where from traditional monthly spot sampling gas was only thought to migrate at Christmas. Continuous monitoring however, indicates the gas regime is highly variable, see figure 3. In this example if spot samples were taken on days represented by green dots the perceived risk would be very different to those taken on days represented by the black dots. With continuous data it is possible to overcome this mismatch in sampling frequency and variability in gas concentration revealing the true gas regime.

Summarising Time Series Data

Currently the only summary of borehole gas concentration data is if a trigger value has ever been recorded (e.g., 1 % v/v CH_4) and will determine if action is necessary. By collecting more highly resolved time-series data it is possible to re-plot the data as a concentration duration curve allowing more direct interpretation of risk. In figure 4 time series data has been transformed in to a concentration duration curve, in this example it is possible to see CH_4 concentrations only exceed 1 % v/v for 1% of the time, rather than the trigger level had ever been exceeded. With this information it is easier to determine if and what level of action is required to prevent or mitigate migration.

Identifying Correlations

In addition to higher temporal resolution of gas concentration, other temporally variable environmental parameters can also be measured, allowing 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 these parameters change.

Atmospheric pressure is considered to be a strong driving force for gas migration and in general it is assumed that concentrations are higher when pressure is low and vice versa(1), this can be seen in data collected from a perimeter borehole in figure 5. Current UK guidance recommends that the spot sampling programme should be stratified and samples should be taken when atmospheric pressure is 1000 mBar and falling, as this will increase the chances of observing worst case. However, we can see the arbitrary nature of this condition, as concentration continues to vary depending on changes in atmospheric pressure, rather than displaying a clear dependency on the absolute pressure.

However, the widely reported relationship between pressure and concentration does not always exist; the inverse relationship is observed at a neighbouring borehole, figure 6a. Also sometimes another parameter is responsible for migration, Figure 6b.

Understanding Processes

The above examples demonstrate the variability of gas concentrations and some of the factors that influence them. From this it is clear spot sampling will often fail to identify the true gas regime and the dominant processes occurring at a landfill site. This is highlighted by a site where data had been collected from perimeter boreholes over several years and highly variable gas concentrations and flows had been recorded but the reason could not be explained, see figure 7. As high concentrations and high flows were recorded gas generation was thought to be occurring and a there was a high perceived risk to the adjacent properties, consequently an expensive ongoing intense spot sampling programme was required by the regulator.

To improve the understanding of the processes occurring on the site, continuous monitoring in boreholes 10 and 11 was conducted. This also revealed variable gas concentrations however, a correlation with pressure is clear, see figure 8. When atmospheric pressure decreases borehole pressure lags behind it resulting in periods where the subsurface is positively pressurised allowing gas to migrate. As the pressure regime is identical in both boreholes even though gas regimes are different it indicates that changing atmospheric pressure not gas generation is responsible for the borehole pressure. Now instead of inferring high gas generation from spot sampling, continuous data reveals a pocket of gas migrating posses a much lower risk.

Improved Data Collection

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 it allows a more reasonable inter-borehole comparison to be made and 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.

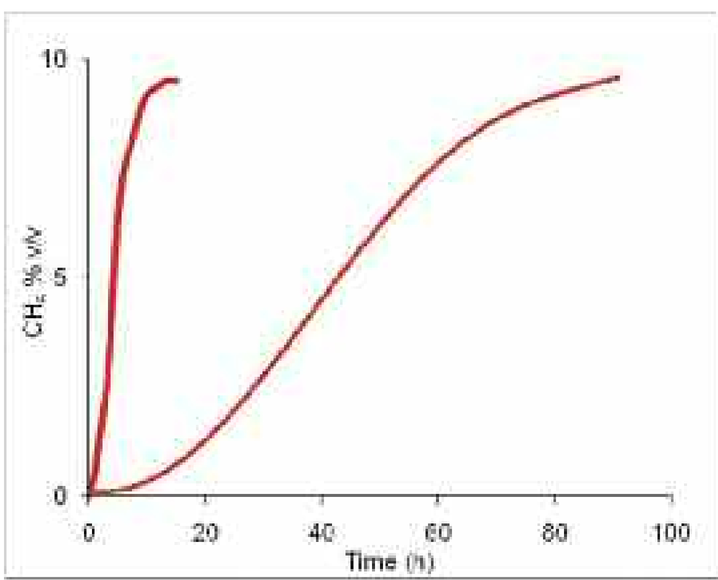

Figure 9: A purge test was conducted on two boreholes that spot sampling revealed a concentration of 10 %CH_4. The absolute concentration is the same but one recovers much faster indicating a very different risk. The recovery profile is related to the gas flux providing another vital line of evidence for risk assessment

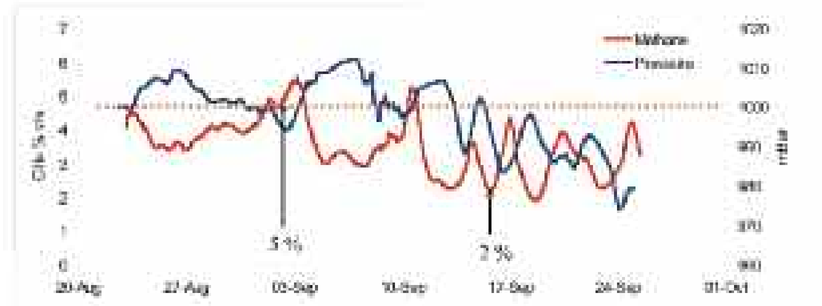

Figure 5: The expected relationship between atmospheric pressure and gas concentration is clear. Current guidance states a measurement should be taken at 1000 mbar and falling to observe worse case but this can produce significantly different results e.g. 2 or 5%

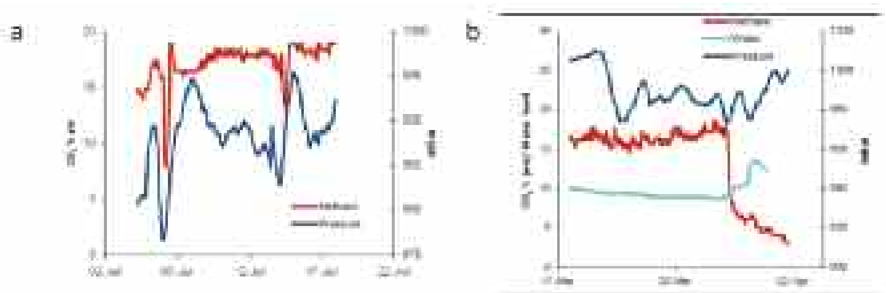

Figure 6: a The inverse relationship with pressure as expected, b atmospheric pressure has no affect on gas concentration however, when water level increase it triggers a change in concentration.

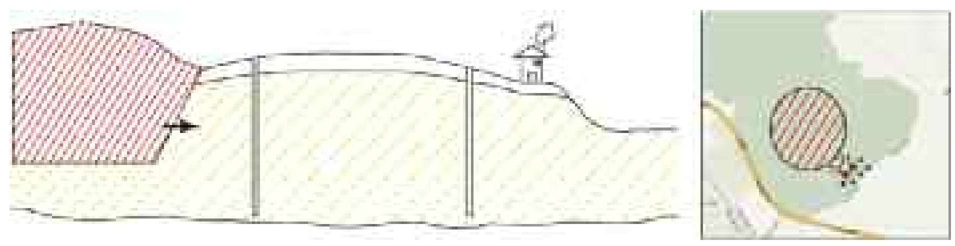

Figure 7: Schematic of landfill with gas migration issues. Spot sampling in BH 10 and 11 revealed highly variable concentrations and flows indicating gas generation.

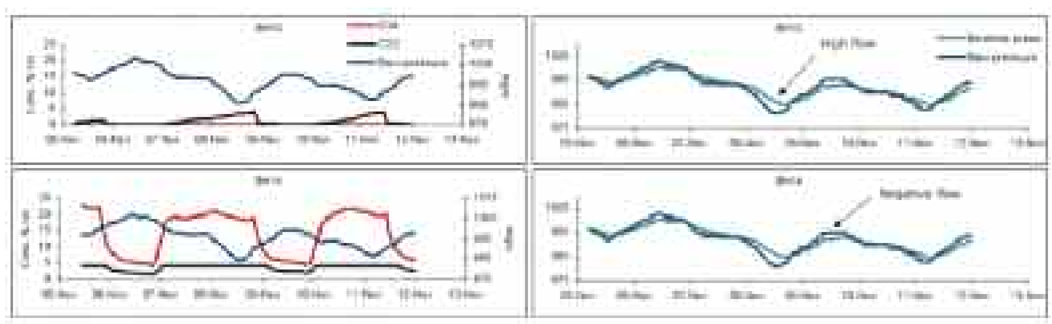

Figure 8: Highly variable gas concentrations are observed in BH15 and BH14 but the pressure regimes are identical. The semi-permeable geology means there is a lag between changing barometric pressure and the sub surface equilibrating, resulting in periods where flow would have been recorded and gas generation inferred

Conclusions

By collecting time series data of gas concentrations and environmental parameters that affect them it is possible to understand the dominant processes controlling gas migration/generation and gain a better understanding of flux. This information can then be feed into the conceptual site model and in turn used to design ongoing monitoring programmes. Following this iterative process a highly site-specific conceptual model can be generated that has a greater understanding of the processes at the site and thereby reduce uncertainty and produce more appropriate risk assessments. This will have to two fold effect of reducing the time and effort of monitoring programmes but also allow appropriate, cost effective, rather than over engineered solutions to migration problems.

References

1. Wilson, S., Oliver, S., Mallett, H., Hutchings, H. and Card, G, 2006. CIRIA Report 665 Assessing risks posed by hazardous ground gases in buildings. CIRIA
2. Environment Agency 2004. Guidance on the assessment of risk from landfill sites. External Consultation, Version 1.0

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