The Monitoring of Landfill Gas

By Dr. Roger Riley

What is Landfill Gas?

Throughout Europe over 100 million tonnes of waste a year is deposited into Landfills. We may think we have seen the last of our rubbish when it is taken away each week, but the operators of the Landfill sites have to look after it for many years afterwards.

The waste within the landfill will consist of a wide variety of substances, but a large proportion will be biodegradable. This will include animal and vegetable matter, paper and wood.

These substances can be decomposed by micro-organisms within the landfill and this breakdown process produces gas. Landfill gas can be a complex mixture of gases, but a few gases predominate. Initially, carbon dioxide is the main gas, but there can also be significant quantities of hydrogen. Methane is produced during the major part of the decomposition process. Many other gases can be produced in trace amounts and the exact composition of the gas will vary between different landfill sites, different parts of the same site, and over time.

A typical landfill gas composition is shown in the table.

Component	% Volume
Methane	64
Carbon Dioxide	34
Oxygen	0.16
Nitrogen	2.4
Hydrogen	0.05
Carbon monoxide	0.001
Ethane	0.005
Unsaturated Hydrocarbons	0.009
Halogenated Compounds	0.00002
Hydrogen Sulphide	0.00002

Clearly this gas has to be monitored and controlled. A level of 5% of Methane in air is explosive. If uncontrolled it can find it's way into nearby buildings and underground chambers with obvious hazards. Methane is also a greenhouse gas second only to carbon dioxide so it's escape from a landfill site must be controlled. Landfill gas can also cause odour problems for those living near to sites. Some of the other constituents of landfill gas can also be dangerous to health if the concentration is allowed to build up.

There is therefore a legal requirement on landfill operators to monitor and control landfill gas on their sites. Indeed the licence for a site may well stipulate that the operator has to control the gas emissions for an indefinite period, even after the site is full and is no longer in active use. Methane can continue to be generated for 15 years or more after a site is completed.

Monitoring the gas

How do we monitor landfill gas?

The first problem is getting a sample of the gas. Usually, site operators sink boreholes down into the landfill itself. These boreholes serve as collection points for the gas, which can be extracted for analysis.

A number of techniques can be used to analyse the gas, but almost all on site analysis is carried out by portable, purpose designed, landfill gas monitors. Typically these monitors can analyse for methane, carbon dioxide, oxygen, carbon monoxide and hydrogen sulphide. The techniques used are mainly infra red absorption, and electrochemical cells.

Figure 1: Landfill site

Infra red absorption

Infra red absorption is usually the preferred method for measuring methane and carbon dioxide.

Most gases absorb radiation in the infra red region. The wavelength of radiation that is absorbed is determined by the natural vibration frequencies of the molecule. These natural frequencies will depend on the bond strengths, molecule size and shape, and mass of the atoms involved. Thus different gas molecules have different natural frequencies and will absorb infra red radiation of different wavelengths. Graph 1 shows the absorption bands of methane and carbon dioxide.

This property is used in infra red absorption to select a specific gas for analysis. By using IR radiation of the same wavelength as the absorption band the technique can be made specific to a particular gas - a useful property when analysing one gas within a mixture.

A typical IR gas cell is shown in diagram 1. IR radiation from a source is passed through the gas to be analysed. Several IR detectors are positioned to measure the amount of IR radiation that has passed through the gas. A filter that is tuned to the wavelength of interest is positioned in front of the IR detector. This then makes that particular detector sensitive to the gas of interest. By using several detectors with different filters a number of different gases can be detected at the same time.

The amount of radiation absorbed will be proportional to the path length through the gas and the concentration of the gas. Since the path length is fixed, the concentration of the gas can be calculated.

IR absorption can be made robust, accurate, and stable. It also requires little or no routine maintenance and an IR absorption cell has a lifetime of many years.

Figure 2: Landfill gas monitor and borehole

Electrochemical cells

Unfortunately not all gas molecules have a good IR absorption band. For oxygen, carbon monoxide, and hydrogen sulphide, electrochemical cells are used to measure the gases. These are based on chemical reactions and can be designed to give a voltage that is proportional to the concentration of the gas that they are designed to measure.

Electrochemical cells are simple to use. They do however have some problems with 'cross-sensitivity'. That is, they can respond to gases other than the one they were designed to detect, and this can on occasion lead to spurious results. They also have a limited lifetime, typically 2 years, and must be replaced.

Ease of use

Modern landfill gas monitors do much more than just measure gases. It is possible to load them with set measuring protocols and identification tags for the boreholes to be measured. They will record all measurements together with the time and date, and this data can be downloaded into a database for storage, retrieval and data manipulation. Many landfill operators have automatic processing and reporting of the data.

This functionality, together with the ability to measure temperature, pressure and gas flow makes the landfill gas analyser an important tool in the monitoring of a landfill site.

Fixed systems

Fixed systems are available that automatically monitor the gas from many boreholes, and can

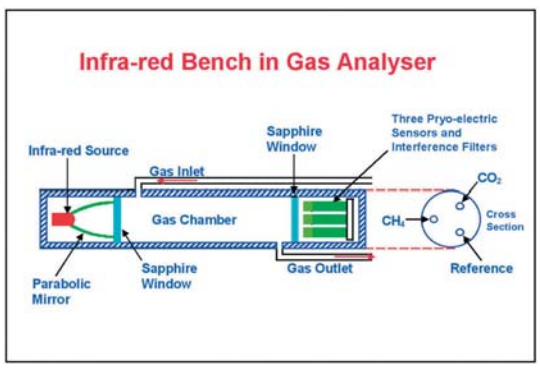
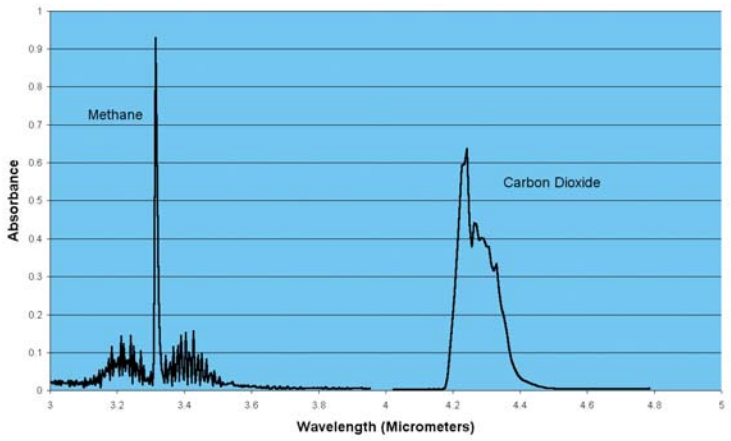
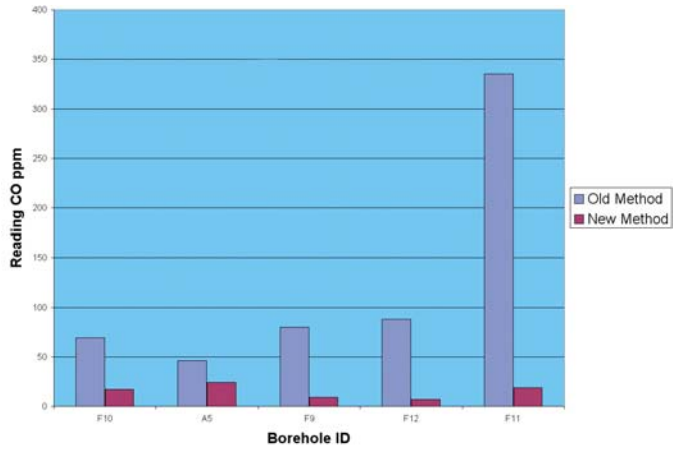


Diagram 1: Infra-Red cell



Graph 1: Absorption bands of Carbon Dioxide and Methane



Graph 2: Improvement in CO measurement in presence of Hydrogen

record, store, and transmit the data. However, these systems have not been installed on most landfill sites. The ever changing size and shape of landfill sites together with the high probability of cables and pipes being disturbed by earthmoving machinery can cause problems with these systems.

Surface emissions

Methane is a greenhouse gas second only in importance to carbon dioxide. Regulations are coming into place that put limits on the emission of methane from landfill sites.

Most completed landfill sites are 'capped'. That is, they are covered with a non-porous layer in order to stop the methane escaping into the atmosphere. However, fissures or defects in the cap can allow the methane to escape. The new regulations stipulate that landfill operators must monitor the emissions from the surface of their landfill sites.

With sites covering many acres this is not an easy task. Two main methods have been looked at.

The first is to carry out a walking survey of the site. A sensitive methane monitor is used with a probe at or near ground level. The operator walks a predetermined path across the site at a known rate. The monitor will indicate the positions of high methane emission and any problems with the landfill cap can then be investigated. The data can also be used to calculate a value for the total emissions from the site.

This survey technique requires a monitor that is much more sensitive than a normal landfill gas analyser. The only technique readily available if the flame ionisation detector. This has been used for many years in laboratory equipment and a number of portable instruments are now available. The portability is hampered somewhat by the need to have a source of hydrogen fuel for the FID, but clever design has largely overcome the main problems. The SEM500 is the only instrument to have been purpose designed for this application. Data download software is available that can plot maps of the site with the methane readings superimposed.

Figure 3: Surface emission monitor being used

The second method goes by the name of the fluxbox. Here a gas tight box with an open bottom is placed on the ground. Any methane escaping from the ground will be collected by the fluxbox, and the concentration within the box will increase with time. A sensitive methane monitor such as the SEM500 can be used to measure the rate of increase in concentration, and this gives a measure of the emission rate from the ground. Flux boxes are usually about the size of a normal plastic storage box - indeed such boxes can be adapted for use as a fluxbox.

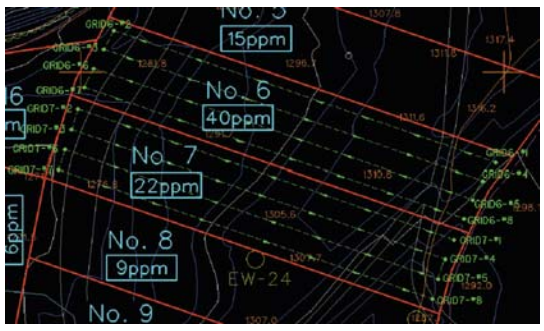


Figure 4: Surface emissions data plotted on a map of the site

The fluxbox technique is as yet not applied routinely to landfill sites, and its implementation needs care and expertise. It will probably be the case that a combination of the two techniques will be the best approach.

Gas for electricity generation

Landfill gas has a high percentage of methane. Clearly this methane can be used to generate electricity and earn the landfill site operator extra income. It is 'green' energy from recycled waste and as such a higher price can be obtained for any electricity generated from it. This is thus a growing area.

In order to run the electricity generation plant efficiently, the concentration of methane in the gas fed to the generators must be controlled. This can be done by adjusting the amount of gas taken from different parts of the site. To monitor the gas composition a variation of a landfill gas monitor is used. This has the additional ability to monitor the gas flow and can give a reading of the energy content of the gas passing through the pipe.

Fixed position monitors are also becoming important in this market. These continuously monitor the gas concentration and other parameters of interest and can feed back the data to a central control system.

Measurement of Carbon monoxide

Carbon monoxide is usually a trace gas. An increase in the concentration of carbon monoxide can be indicative of a fire in a landfill site. A fire in a landfill can be a major problem for the operator, thus carbon monoxide measurements are of great importance.

CO is usually measured by an electrochemical cell. These cells are sensitive to gases other than CO. In particular both H2S and H2 will give a reading on a CO cell and both of these gases can be present in landfill gas. This can cause spurious CO readings and wasted time and cost in trying to put out a fire that is not there.

An external filter has been developed that will absorb all of the H2S before it reaches the analyser. These filters are cheap and disposable, and their use will give an immediate improvement in the measurement of CO where H2S is also present.

The hydrogen problem has now been solved by a new technique that can measure the CO in the presence of hydrogen. Graph 2 shows results taken from actual boreholes with the old and new techniques. It can be seen that the old technique is giving much larger CO responses which are due in this case to the presence of H2. The new technique significantly reduces the interference from hydrogen.

These two new developments used together should give much improved and more reliable CO measurements and improve the prediction of fires.

This article has been provide by Dr Roger J Riley a member of CoGDEM (the Council of Gas Detection and Environmental Monitoring). CoGDEM represents over forty companies from around the world. The membership account for over 80% of the UK's domestic CO detection market and industrial gas detection, analysis and portable environmental monitoring market. CoGDEM aim is to serve its Membership by safeguarding the standards of and expanding the market for high quality, high specification gas detection, gas analysis and environmental monitoring equipment and services. For more details visit www.CoGDEM.org.uk .

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