Monitoring And Analysis of Landfill Gases

CoGDEM
The Council of Gas Detection and Environmental Monitoring

GAS DETECTION

"The Council of Gas Detection and Environmental Monitoring".
Telephone +44(0) 1462 434322 FAX +44(0) 1462 434488 Postal address Unit 11, Theobald Business Park, Knowl Piece, Wilbury Way, Hitchin, Herts, SG4 0TY, UK Email: CoGDEM@aol.com

CoGDEM is the trade association representing manufacturers and service providers who are active in the field of gas detection instrumentation and environmental monitoring apparatus. Crowcon Detection Instruments Ltd was one of the founding members of CoGDEM, and in this article their Product Manager of Fixed Systems, Andy Avenell, gives an update on Landfill Gas.

Landfill is by far the most common method of waste disposal in the United Kingdom. Despite the increase in recycling, data from the latest Defra* Municipal Management Survey (2003-2004) shows the amount of waste going into landfill still represents 72% of all waste and totals 20.9 million tonnes. In England and Wales, landfill is regulated under The Landfill (England and Wales) Regulations 2002. In Scotland, they are regulated through the Landfill (Scotland) Regulations 2003. These regulations set out a pollution control regime as part of their implementation of the EU Landfill Directive (Council Directive 1999/31/EC), which aims to prevent, or to reduce as far as possible, the negative environmental effects of landfill. Landfill site operators must carry out control and monitoring procedures during the life of the site and for a period after closing, as specified by the Environment Agency in England and Wales or SEPA in Scotland.

Hazards Associated with Landfill

There are two primary hazards associated with landfill. One is the production of leachate, which is formed when water passes through the waste in the landfill, picking up organic and inorganic compounds. This toxic liquid then collects at the base of the landfill cell. If not properly controlled, it can contaminate the surrounding soil, groundwater and nearby water courses.

The other main hazard is gas caused by the breakdown of organic materials, producing methane, carbon dioxide, hydrogen sulphide and other gases, depending on the landfill's content. This mixture is known as landfill gas. The majority of the gas is produced during the working life of a landfill and for about 20 years after a site has been sealed and capped. However low levels of residual generation will occur for much longer than the main period of gas production, possibly in excess of 100 years. Methane poses a severe explosion risk, is damaging to plant life and is also a greenhouse gas. Carbon dioxide, also a greenhouse gas, is toxic and an asphyxiant, as it depletes local oxygen levels. Hydrogen sulphide is highly toxic, even at very low concentrations.

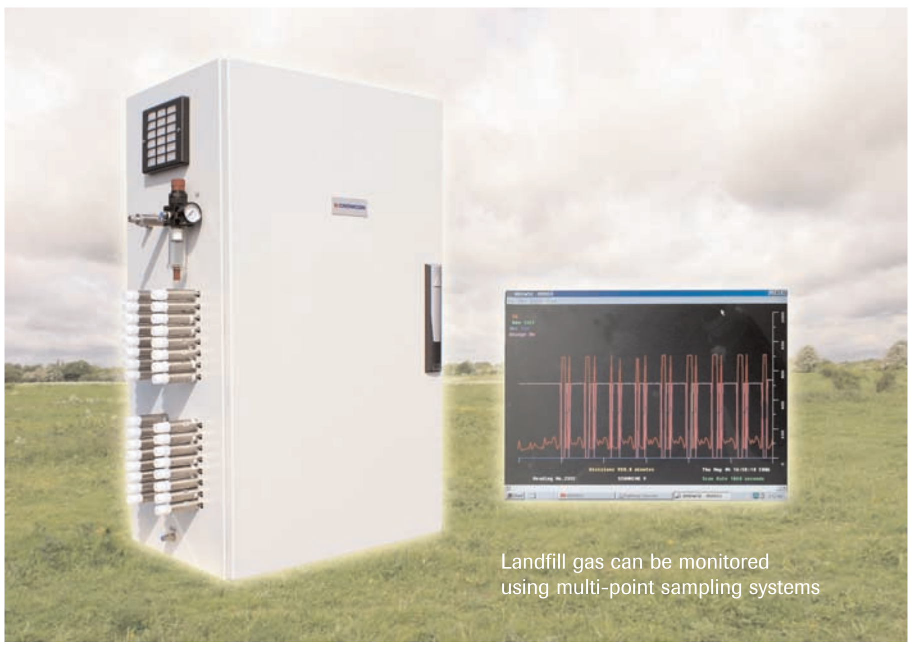
Schedule 2, paragraph (4) of The Landfill (England and Wales) Regulations 2002 requires the following gas control measures:

1. Appropriate measures must be taken in order to control the accumulation and migration of landfill gas
2. Landfill gas must be collected from all landfills receiving biodegradable waste and the land fill gas must be treated and, to the extent possible, used
3. The collection, treatment and use of landfill gas under sub-para graph (2) must be carried on in a manner which minimises damage to, or deterioration of, the environment and risk to human health
4. Landfill gas which cannot be used to produce energy must be flared

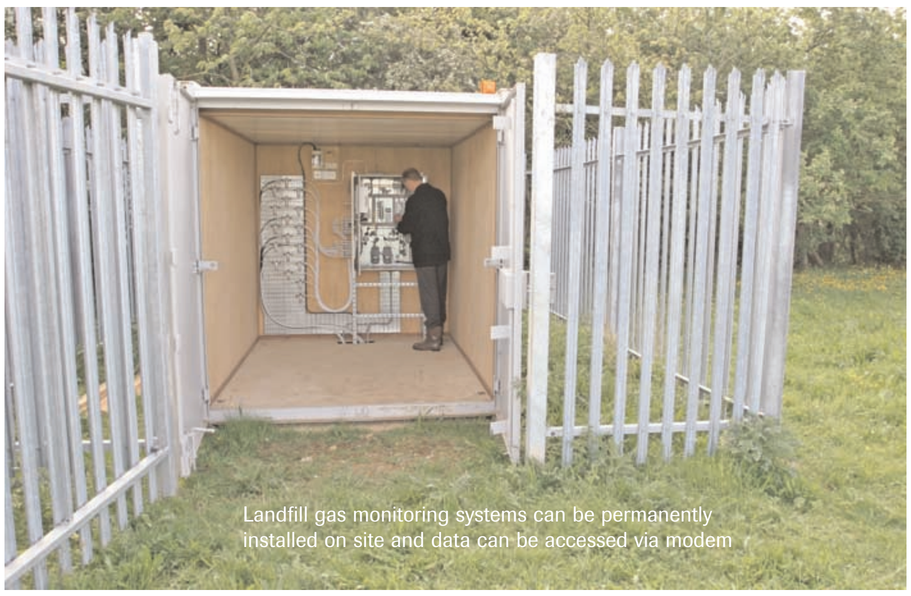
Monitoring and Analysis of Landfill Gases

Paper, vegetable matter, wood, textiles and plastic make up the majority of waste going into modern landfills, about 65% of which is biodegradable. When a landfill site is first set up there is a high proportion of oxygen present in the mass of waste. As this waste becomes damp from the seepage of rainfall, aerobic degradation takes place, producing carbon dioxide and sometimes other gases such as hydrogen. As the oxygen is used up, and under the right temperature and acidity conditions, anaerobic degradation begins to take place, producing methane, hydrogen sulphide and more carbon dioxide. All landfills therefore undergo physical, chemical and biological changes at a rate depending on the composition of the waste, the bacteria present, the acidity and the temperature.
It takes approximately two years for a landfill to start generating gases at a reasonably stable rate, and at this stage the main constituents are methane (70%) and carbon dioxide (30%) with small amounts of hydrogen, hydrogen sulphide and other trace gases, depending on conditions. Initially, between $5m^3$ to $10m^3$ of methane is produced per tonne of waste per year. After 20 years the quantity of gas produced will reduce by approximately 85%, with concentrations of methane and carbon dioxide becoming very variable across the site.

The minimum requirements for landfill gas monitoring as laid down by the Landfill Directive are set out in Table 1.



Landfill gas can be monitored using multi-point sampling systems



Landfill gas monitoring systems can be permanently installed on site and data can be accessed via modem

Table 1

	Operational Phase	After-care phase
Potential gas emissions and atmospheric pressure[1] (Methane, carbon dioxide, oxygen, hydrogen sulphide, etc)	Monthly [2,3]	Every six months [4]

1 These measurements are related mainly to the content of organic material in the waste
2 Longer intervals may be allowed if the evaluation of data indicates that they would be equally effective
3 Methane, carbon dioxide and oxygen regularly. Other gases as required, according to the composition of the waste deposited, with a view to reflecting its leaching properties.
4 Efficiency of the gas extraction system must be checked regularly.

According to the Environment Agency, a landfill gas monitoring and sampling plan should be prepared and set out as part of an overall Gas Management Plan. The plan should include the following:

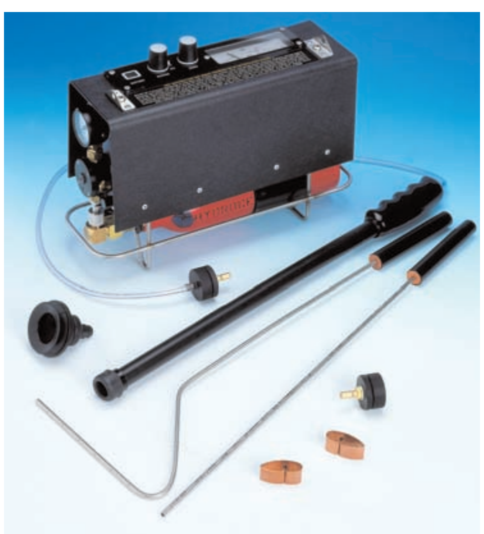
- The type of monitoring to be undertaken
- The methods of monitoring (including detection limits, accuracy, etc)
- Monitoring locations
- Frequency of monitoring
- Appropriate action/trigger levels necessitating action
- Appropriate action plans to be implemented should any levels greater than the trigger levels be recorded

Landfill gas samples can be extracted and analysed either using portable equipment or by installing a permanent monitoring system. The four main options are borehole monitoring, flux-box monitoring, perimeter monitoring and building monitoring.

A borehole monitoring point with gas sampling tubes and a pressure transducer

Borehole monitoring

The relative concentration of methane/carbon dioxide /oxygen in the head space of a borehole indicates the evolution of the decomposition process. Sampling equipment is used to monitor the site's gas evolution by regularly drawing samples from boreholes and measuring the concentrations of each gas. Fluctuations in atmospheric pressure affect gas evolution and concentration, so monitoring systems often also measure the pressure within each borehole. Gas concentrations and pressure readings can be taken manually using portable instruments, while fixed sampling systems provide an automated solution where by readings are regularly taken and logged for analysis purposes. Log files can then be uploaded from the sample system locally, or remotely via a modem link.



FID based instrument suitable for flux box or perimeter monitoring

Flux-box monitoring

This method is primarily used to locate methane emissions through breaches in the cap of a closed landfill and to demonstrate compliance with the Landfill Directive, particularly:

a) identify faults in the gas management system at a site and prioritise the remediation required;
b) quantify the total emissions of this important greenhouse gas from the site as a whole.

The flux of methane emitted through the intact cap is measured at a number of representative points using an array of flux boxes (an inverted 'bath tub' shaped hood designed to trap and collect gas emitted from the ground). From these measurements the average flux from the capped zones is determined. This identifies where methane flux exceeds the standard set by the Environment Agency. This is done in two stages:

First stage: The main characteristics of the cap are recorded and mapped in a desk study. A walkover survey is then conducted to identify where gas emissions are high. A sensitive, hand-held gas detector, such as a flame ionisation detector (FID), is used in the walkover to scan the air close to the surface of the cap and detect significant concentrations of methane. Monitoring will not normally proceed to the quantitative flux survey until a systematic walkover survey demonstrates that the concentration of methane in the air is:

a) less than 100 parts per million by volume (ppmv) immediately above the surface on the main zones of the cap;
b) less than 1,000 ppmv close to any discrete feature such as a leachate well or wellhead.

Second stage: A landfill's surface should be in a condition suitable for a quantitative flux box survey within one year of capping. Based on the walkover survey, the capped area should be divided into zones. Flux measurements should generally be subject to the following constraints:

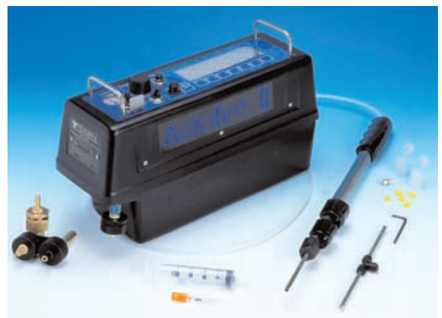
a) no measurements should be taken immediately after a prolonged period of heavy rainfall or where there are areas of standing surface water;
b) barometric pressure should not be very much higher or very much lower than the average for that area and, ideally, should not be rising quickly.

Flux boxes must be sealed on the surface (usually using earth) at a number of representative sampling locations within each zone and feature. The rate of change in methane concentration within each box is measured using an FID for up to an hour and the flux of methane from that part of the surface is calculated. An average flux of methane from the zone or feature is calculated from the rates measured by individual flux boxes.

The Environment Agency's standards for gas emission from a landfill surface are expressed as the average flux of methane from the surface of the cap in each zone. The emission standards are:

a) Permanently capped zone: 0.001 mg/m^2/second
b) Temporarily capped zone: 0.1 mg/m^2/second

The total emission rate of methane from a zone is calculated by multiplying the average flux by the area of the zone. The overall emission rate of methane for the site is the sum of emissions from the surface of each zone and feature. This value may be used in estimating the gas collection efficiency of the site. The annual emission rate may be used in computing the site's Pollution Inventory. (Source: Environment Agency document LFTGN 07 – Guidance on Monitoring Landfill Gas Surface Emissions).



FID based instrument with built-in gas chromatograph can identify methane, benzene etc in ppm levels

Perimeter monitoring

The air around the perimeter of an operating or closed landfill site is monitored to quantify the level of methane and other gases escaping into the surrounding environment. This is usually performed at night, when air conditions tend to be stiller and there is a thermal rise which takes gas from the ground upwards. In the UK the permitted limit for ambient methane escaping from a site is 10ppm. Samples may be taken at the site perimeter or up to 500 metres away. Sites are periodically checked using portable FID based instruments. Sites demonstrated to exceed limits will be subject to repeated tests. Very low levels of benzene, vinyl chloride and hydrogen sulphide are also monitored using different sensor technologies.

Building monitoring:

Once landfill sites are restored and the majority of gas generation is completed, some sites can be used for new constructions such as retail parks, or warehouses. Despite the gas management systems, there still remains a potential risk of methane and/or carbon dioxide gas breaching the landfill cap and causing a flammable/toxic risk. Methane presents a flammable risk at only 5% concentration in air, while the short-term and long-term exposure limits for carbon dioxide are 0.5/1.5% volume in air. Vulnerable areas that need to be monitored include toilets (possibility of gas ingress via sewage pipes), inspection pits, plant rooms (where cable ducts may run underground) and beneath false-floors.

Point-type gas detectors can be fitted and provide rapid detection of gas accumulation. They carry relatively high maintenance costs, however, as each point has to be regularly calibrated and the sensors need replacing every few years. Sample systems provide a lower cost alternative. A powerful pump is used to extract gas samples on a sequential basis from around the building; each gas sample is then passed across a set of gas sensors, which are monitored by a control system. Systems typically provide an indication of the gas level for each sample point, will trigger alarms and/or turn on ventilation systems if preset gas levels are exceeded, and also provide data-logging facilities. Datalog files are stored and be uploaded remotely using a modem for analysis if required. Maintenance costs are lower than point detectors due to one set of sensors being used to monitor all sample points.

Sensor Technologies

There are three main sensor technologies employed for monitoring landfill gas:

- Infrared (IR): is used for monitoring methane and carbon dioxide gases. Each gas type has a specific wavelength at which infrared light energy is absorbed due to molecular resonance. For methane the wavelength is 3.3μm, for carbon dioxide the wavelength is 4.26μm. The gas sample is exposed to light energy from an IR lamp, and the resultant reduction in IR energy due to absorption is measured using precisely filtered sensors to indicate the gas concentration.

- Electrochemical: this type of cell is used for monitoring oxygen. The cell contains a metal electrode, electrolyte and a diffusion barrier to allow air to enter. The oxygen in the air reacts with the electrolyte and a small current is produced proportional to the oxygen concentration. The signal current is amplified and used to indicate the oxygen level.

- Flame Ionisation (FID): the gas sample is ionised using a very hot hydrogen flame. Any hydrocarbon gas present in the sample is ionised and the charged particles are detected on an electrode. FID provides the ability to measure flammable gases in very low (parts per million) levels.

Landfill sites are, and will be for a long time, an integral part of any waste management strategy. Their ongoing use requires good operational practice, of which gas management is an integral part. With a Gas Management Plan in place, operators can be sure that any landfill under their jurisdiction will be safe for generations to come.

(* Department for Environment, Food and Rural Affairs)

Acknowledgements:

Our thanks go to the following for assistance in the production of this article:
Steve Wilson - Technical Director of The Environmental Protection Group Ltd.
Peter Stothers - Director of Gas Environmental Monitoring Specialists Ltd.