Bio-oxidation of methane in landfill gas

By

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Environmental Sciences Association of Ireland
Overview of Odour Monitoring Ireland

Provide the following services:

- Established in 2002 providing an odour laboratory (only lab in Ireland to participate in inter-laboratory proficiency testing 2012), stack testing services and process engineering and design (air pollution control and waste management treatment technologies).
- Have been involved at design and implementation of many key technologies to include:
  - Biological air pollution control-biofilters and biotrickling filters
  - Dry and wet scrubbing
  - Regenerative thermal oxidisers / catalytic oxidation
  - Solvent pre-concentration technology
  - Carbon filtration
  - Non thermal plasma and plasma injection technology.
- Landfill gas infrastructure design, assessment and associated services, etc
- Dispersion and gas modelling, risk assessment and life cycle analysis
- Provide service to UK, mainland European countries and USA.
- Strong links with academia for R&D and commercialisation
Introduction

- Main constituents of landfill gas
- Overview of biofiltration systems
- Key design parameters for biofiltration systems
- Application of biofiltration systems for treating methane and design
Landfill gas constituents

Å Landfill gas predominately made up of Methane (45% : 60%) and Carbon dioxide (45% : 60%) with 0 to 2% mixed trace VOCs.

Å Trace VOCs include oxygenated organics, hydrocarbons, VFA's, nitrogen containing organics, sulphur containing organics and other inorganic based compounds such as Ammonia and Hydrogen sulphide, etc. Ammonia and Hydrogen sulphide can be restrictive to efficient operation of certain types of biofilters.

Å The older the gas gets in general the lower the mixed VOC content in terms of this presentation looking at facilities that have existing infrastructure but struggling to keep flare operational due to poor gas quality and low calorific value.
Quantities of landfill gas generation and quality dependent on infiltration rates, biodegradable content of the waste fill, age and landfill design and operation.

The collection efficiency of landfill gas depends on the landfill operation design and gas management systems utilised into the facility to abstract gas.

Most modern landfills have gas management systems installed, the difficulty arises when there is not enough energy content in the landfill gas to burn continuously especially with unlined sites where extraction is a necessity to minimise horizontal and lateral migration.
Biofiltration

- Fundamental research in academic environment has led to the advancement in understanding in key control criteria for bio-oxidation. Researchers such as Deshusses, Hamer, Devinny, Bohn etc have developed knowledge in the area and it is no longer a black box technology.

- Over 7,500 biofilters treating waste air installed throughout Europe. In Ireland alone there are between 500 and 700 units each with varying degrees of complexity (1st generation to 3rd generation systems). Units commercially available for odours and solvent abatement. Not familiar with any units available for landfill gas but its only a matter of time as academia publish and facts are combined into working knowledge for commercialisation of the technology.

What is a biofilter / biotrickling filter / bio-scrubber
What is a biofilter

- Involves the passing of contaminated air through a microbe rich medium (liquid, solid or both) whereby the mass and diffusion transfer of the contaminants (in this case methane and small concentrations of VOCs) occur onto the biofilter medium and into the biofilm results in cleaning of the influent air stream.
- The active microbial consortium feed on the contaminants in order to sustain growth.
- The bed medium acts as a means of increasing surface air just as in any scrubbing device and in this case the contaminant is methane which is broken down to Carbon dioxide and Water vapour.

Type of biofilters

- Passive biofilters allow contaminant air to radiate through the bed medium based on differential pressure. Operation on some landfill sites in Europe and Asia.
- Active biofilters use a fan to pump or suck the gas through the system. The existing gas management infrastructure and piping can be used.
  - Modular systems located in extraction area: smaller systems for localised control.
  - Open bed systems: similar visually to passive systems: large and low cost with less process control.
  - Enclosed systems (everything in a box) where greater control and performance is required and can be achieved.
Key design criteria for biofiltration systems

Process parameters such as:
- Volumetric airflow rate — amount of gas treated per unit volume of media,
- Surface velocity — speed of gas through bed (this can have a notable effect on mass transfer kinetics),
- True residence time (amount of time the gas remains in the bed),
- Elimination capacity — amount of gas removed per unit volume of bed per hr.
- Moisture content of media and the ability to control same,
- Nutrient content of media and sprinkling liquor,
- Buffering capacity and control
- Bed plenum pressure and air distribution
- Oxygen levels and Salt content of liquor and media — Methane oxidation performance affected by levels of Oxigen in feed inlet to biofilter, salt levels affect diffusion of Oxygen into the biofilm.
- pH — range for methane oxidation 4.5 to 9 ideally 6 to 8
- Temp — this has a notable affect of methane oxidation and therefore the size of the system and Capex expenditure
Engineering parameters such as:

- Dimensions of system
- Mixing box / oxygen control
- Consistent gas loading
- Air heating system and recirculation of waste gas
- Distribution of air within system / back pressure / homogenous
- Media type, depth and process flow
- Sprinkling and recirculating system ratios, control of biomass and nutrients
- SCADA controlled
- Media roughness / surface attachment
- Biomass plugging control
Types of media

- The media used in a biofilter depends on the specific application.
- Organic media and inorganic media.
- Both organic and inorganic media can be simple or engineered.
- Can be used together to complement each other in a system (pressure reduction, better air distribution).

Media characteristics

- Biofilter media should always be operated with sufficient moisture content to maintain biomass growth (40 to 60% w/w organic and 25% w/w for inorganic).
- Nutrients should always be added to the biofilter sprinkling liquor (these include essential micro and macro minerals and vitamins. For example - In the case of Methane oxidation, the addition of iron to a specific conc can assist in improving performance, the addition of ammonia and copper can reduce performance).
Key operational failures in design consideration.

- Media deterioration and acidification
- Poor inlet air distribution design
- Poor media selection
- Poor moisture control
- Poor nutrient addition and control (suck it and see approach)
- Lack of monitoring and SCADA control
- Lack of robustness

In the case of methane oxidation, Oxygen levels in the inlet gas, temperature of the inlet gas and nutrients will have a major affect on system design. For example, preheating the inlet premixing air for adding oxygen to the gas from 20 to 30 deg C will reduce the system size by half. Oxygen levels need to be at least 15% or higher %v/v basis, the addition of iron and the control of Ammonical nitrogen content within the media will also enhance performance.
Conclusions

• Methane bio-oxidation will play a major role in dealing with low quality landfill gas for landfill sites, lower opex cost to catylic, thermal and gas supplementation techniques.

• Typically treatment volumes from 10 to 500 m$^3$ landfill gas with methane levels up to 20%. Ideally suited for volumes from 50 to 150 m$^3$/hr landfill gas

• System design will play a major role in it performance and the implementation of control and monitoring systems will provide greater acceptance by regulator

• Enclosed systems likely to be preferred option as temperature, moisture, microbial content, nutrients, etc, can be controlled within the biofilter bed through the monitoring system.
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Question time?