

Golder Associates (UK) Ltd

Attenborough House
Browns Lane Business Park
Stanton-on-the-Wolds
Nottinghamshire NG12 5BL
England

Tel: [44] (0)115 9371111
Fax: [44] (0)115 9371100
E-mail: nottingham@golder.com
<http://www.golder.com/uk>



REPORT ON

**LANDFILL GAS MANAGEMENT
TRECATTI LANDFILL SITE**

Submitted to:

Environment Agency Wales
Rivers House
St Mellons Business Park
Fortran Road
St Mellons
Cardiff
CF3 0LT

DISTRIBUTION:

2 copies (inc PDF) - Biffa Waste Services Ltd
2 copies (inc PDF) - Environment Agency Wales
1 copy - Golder Associates (UK) Ltd

July 2009

08514290139.500/A.0

REPORT ISSUE FORM

Version Code A.0 **Issue Date** 10 July 2009

Document Title
**Landfill Gas Management
Trecatti Landfill Site**


08514290139.500

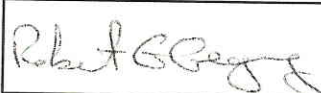
Comments Formatted by jt

List of Authors Stewart Davies

Client Environment Agency

Client Reference

Project Manager Approval Robert G Gregory (name)
 (signature)

Reviewer Robert G Gregory (name)
 (signature)

Report Distribution	Name	Hard Copies	PDF Copies
	Biffa Waste Services Ltd	1	1
	Environment Agency	1	1
	Golder Associates (UK) Ltd	1	0

Definition of Version Code:

- D. Applied during initial drafting of the report before it has been reviewed.
- C. Applied after the report has been reviewed but before it has been approved by the Project Manager.
- B. Applied after the Project Manager has approved the report ready for issue to the Client.
- A. Applied to reports after external/Client review.

The version number starts at '0' and is raised by '1' at each re-type.

TABLE OF CONTENTS

SECTION	PAGE
1.0 INTRODUCTION.....	1
2.0 MODEL PREDICTIONS OF BULK GAS GENERATION	2
2.1 Introduction	2
2.2 Zero Order Model	2
2.3 GasSim2 Model.....	3
2.4 USEPA LandGEM Model	4
2.5 IPCC Waste Model.....	6
2.6 Intercomparison of Models	7
2.7 Summary.....	10
3.0 SITE OPERATIONS AND INFRASTRUCTURE	11
3.1 Site Operational Practice.....	11
3.1.1 Waste Placement, Phasing and Capping.....	11
3.1.2 Gas Collection System	11
3.1.3 Gas Utilisation Plant	12
3.2 Landfill Gas Monitoring.....	12
3.2.1 Gas Composition	13
3.2.2 Gas Collection	14
3.3 Site Audit.....	15
3.3.1 Observations	16
3.3.2 Gas Flow Monitoring.....	17
3.3.3 Gas Composition Analysis	17
3.3.4 Differential Pressure	19
3.4 Summary.....	21
4.0 DETERMINATION OF GAS COLLECTION EFFICIENCY.....	22
4.1 Introduction	22
4.2 Site Gas Collection and Model Forecast Gas Generation.....	22
4.3 Summary.....	25
5.0 TRACE COMPONENT ASSAY	26
5.1 Background.....	26
5.2 Trace Component Monitoring Methodology	26
5.3 Trace Component Monitoring Results	27
5.3.1 Hydrogen Sulphide	28
5.3.2 Carbon Disulphide	29
5.3.3 1-Pentene.....	31
Dimethyl Disulphide	32
5.3.4 Dimethyl Sulphide.....	33
5.3.5 Ethanal	34
5.3.6 Ethyl Butanoate	35
5.4 Trace Gases as Potential Odour Sources	36
5.5 Trace Component Monitoring Trends	36

5.6	Summary.....	37
6.0	CONCLUSIONS.....	38
7.0	RECOMMENDATIONS.....	39
8.0	REFERENCES.....	40

LIST OF TABLES

Table 1	Comparison of Waste Degradation Rates Used within GasSim2 Models
Table 2	Degradation Rates Used in Different IPCC Waste Models
Table 3	Results of Gas Monitoring on 18 December 2008
Table 4	Monitoring Methodologies
Table 5	Detection limits, Maximum and Minimum Concentrations of Measured Odorous Trace Gas Components
Table 6	Relative Contribution of Identified Trace Gases to Landfill Gas Odour

LIST OF FIGURES

Figure 1	Bulk Landfill Gas Generation Model Comparison
Figure 2	Site Composite Bulk Landfill Gas Composition
Figure 3	Total Bulk Landfill Gas Collected at Site (excluding entrained air)
Figure 4	Results of Laboratory Bulk Gas Monitoring on 18 December 2008
Figure 5	Variation in Differential Pressure Along the Ring Main on 18 December 2008
Figure 6	Comparison of Model Gas Generation and Actual Gas Collection
Figure 7	Measured H ₂ S Concentrations and Comparison with GasSim2 Default Values
Figure 8	Measured CS ₂ Concentrations and Comparison with GasSim2 Default Values
Figure 9	Measured 1-Pentene Concentrations and Comparison with GasSim2 Default Values
Figure 10	Measured Dimethyl Disulphide Concentrations and Comparison with GasSim2 Default Values
Figure 11	Measured Dimethyl Sulphide Concentrations and Comparison With GasSim2 Default Values
Figure 12	Measured Ethanal Concentrations and Comparison with GasSim2 Default Values
Figure 13	Measured Ethyl Butanoate Concentrations and Comparison with GasSim2 Default Values

LIST OF APPENDICES

Appendix 1	Biffa 'Leanox' Policy
Appendix 2	CPL Trace Gas Monitoring Report

1.0 INTRODUCTION

Trecatti Landfill (the 'Site') has been the subject of numerous complaints since the 1990s, mostly linked to odours alleged to have come from the Site. The Site has been subject to a number of investigations to establish if controls at the Site are adequate to prevent odour events nearby. Following each of these investigations, changes have been made at the Site, giving rise to the current engineering design. The Site has a PPC Permit, RP3733PC, which gives the starting point for the levels of performance anticipated. The Agency, working with Biffa Waste Services Ltd (the Operator) wish to review whether this provides appropriate measures in respect of odour management and control.

Golder Associates (UK) Ltd ('Golder') has been commissioned to produce this report as a holistic review of the landfill gas management arrangements at Trecatti Landfill, near Merthyr Tydfil. This is intended to assess the current performance of the infrastructure, validate the models used, identify any issues that could give rise to releases or potential for releases, and make appropriate recommendations for any improvements.

2.0 MODEL PREDICTIONS OF BULK GAS GENERATION

2.1 Introduction

Biffa use the UK's default landfill gas generation and risk assessment model, GasSim2, for landfill gas management and Environmental Permitting purposes.

Four alternative models have been used to establish the theoretical range of landfill gas produced likely to be produced at Trecatti Landfill Site, a zero order spreadsheet model and three models based on first order decay: the Environment Agency-approved GasSim2 model; the Intergovernmental Panel on Climate Change (IPCC) model and United States of America Environmental Protection Agency (USEPA) LandGEM model. The reference year for inter-comparison of model gas generation was chosen to be 2008.

The simple zero order spreadsheet model is based on the assumption that each tonne of Municipal Solid Wastes (MSW) produces approximately 5 to 10 m³ landfill gas for the first 10 years after deposition and approximately 150 m³ landfill gas in total over its lifetime.

The GasSim2, LandGEM and IPCC models estimate waste degradation and landfill gas production using first order decay calculations. Key input parameters for these models include the assumed half life of waste decay and the amount of carbon within the waste mass that can ultimately be transformed into methane and carbon dioxide. Factors such as moisture content of the waste, temperature, climate and most importantly the waste material composition influence these parameters and the predicted landfill gas production.

GasSim2 is a resource and risk assessment tool for landfill gas. The latest version, GasSim2, was released in February 2006. LandGEM is an Microsoft Excel based tool for estimating emission rates from municipal solid waste (MSW) landfills. The IPCC model was developed to assist countries in estimating their greenhouse gas emissions from solid waste disposal sites.

2.2 Zero Order Model

The simple zero order spreadsheet model is based on two assumptions:

- Each tonne of MSW produces approximately 5-10 m³ landfill gas for the first 10 years after deposition. This approximate value is based on practical experience, is widely accepted within the waste industry and has been adopted by regulatory bodies such as the Irish EPA in their publication *Landfill Manuals: Landfill Site Design* (2000). A value of 10 m³ methane per tonne of biodegradable waste is provided by the Environment Agency in their *Guidance on the Management of Landfill Gas*, LFTGN03 (2002) which may overestimate landfill gas production. It is suspected that this is a typographic error, and the text should have said 10 m³ landfill gas per tonne of biodegradable waste; and

- Each tonne of MSW produces approximately 150 m³ landfill gas in total over 150 years (Gregory et al. 1991). Values often quoted of up to 450 m³ landfill gas generation are laboratory maxima which are never achieved in landfill conditions.

These two assumptions were applied to the Site's waste inputs from 1987 to 2020 as detailed in the GasSim2 model for Trecatti Landfill Site provided by Biffa. The inert waste stream was thereby excluded as it does not contain biodegradable matter.

The calculated bulk gas production assuming an initial landfill gas production of 5 m³ per tonne of biodegradable waste is 2,024 m³/h for 2008. The calculated bulk gas production assuming an initial landfill gas production of 10 m³ per tonne of biodegradable waste is 3,824 m³/h for 2008.

2.3 GasSim2 Model

GasSim is a resource and risk assessment tool for landfill gas which can be applied to a majority of landfill sites. GasSim was developed by Golder Associates for the Environment Agency and first released in 2002. The latest version, GasSim2, was released in February 2006. In GasSim2, the generation of landfill gas is determined by the mass of waste deposited and the composition of each waste stream. The waste composition is used to calculate the quantity of carbon that is available for slow, moderate and fast degradation and thus the quantity and rate of LFG production.

Waste degradation is modelled in a similar fashion for all the first order models compared here. Waste degradation, and hence gas generation, follows first order decay kinetics. The degradation rates for slow, moderate and rapidly degrading wastes are dependent on the waste moisture conditions. Default values, based on actual experience at UK landfills, are provided for 'dry', 'average', 'wet' and 'saturated' conditions within sites, however the degradation rates can also be adjusted manually. The theory behind GasSim2 bulk gas generation calculations as well as all default values for waste degradation are detailed in the GasSim2 User Manual (*GasSim Website: <http://www.gassim.co.uk>*).

Golder was provided by Biffa with a GasSim2 model for the Site (hereafter referred to as *GasSim2 Trecatti 2008 Biffa*). The total assumed waste input over 34 years (1978 to 2020) is 14 million tonnes. The main wastes streams include domestic, industrial and inert waste. In addition some civic amenity waste and sewage sludge has been modelled to be deposited on-site. Biffa has calibrated the model to the Site using their own waste degradation rates rather than using GasSim2 defaults (Table 1). The bulk gas generation for 2008 predicted by this model is 3,800 m³/h at the 50th percentile (%ile).

GasSim2 usually operates probabilistically, using probability density functions (PDFs) for parameters, to allow uncertainty to be modelled. Biffa's model is based mostly on single values for model parameters. Applying a 10% variation to the waste composition in the

Biffa model (giving *GasSim2 Trecatti 2008 Golder 1*) does not substantially change the bulk gas generation, yielding a forecast of 3,790 m³/h at the 50 %ile.

Applying GasSim2 default wet degradation rates in place of the Biffa degradation rates assumed in the *GasSim2 Trecatti 2008 Golder 1* model gives the *GasSim2 Trecatti 2008 Golder 2* model. The bulk gas generated *GasSim2 Trecatti 2008 Golder 2* model was predicted to be 3,300 m³/h at 50 %ile for 2008.

Applying GasSim2 default average degradation rates in place of the Biffa degradation rates assumed in the *GasSim2 Trecatti 2008 Golder 1* model gives the *GasSim2 Trecatti 2008 Golder 3* model. The bulk gas generated *GasSim2 Trecatti 2008 Golder 3* model was predicted to be 2,150 m³/h at 50 %ile for 2008.

Table 1: Comparison of Waste Half-Lives used within Gassim2 Models.

	GasSim2 Trecatti 2008 Biffa and GasSim2 Trecatti 2008 Golder 1	GasSim2 Trecatti 2008 Golder 2	GasSim2 Trecatti 2008 Golder 3
Waste Half-Lives (years)	Biffa	GasSim2 Default Wet Moisture Content	GasSim2 Default Average Moisture Content
Slowly Degrading Carbon	6	9	15
Moderately Degrading Carbon	4	6	9
Fast Degrading Carbon	2	1	6

A comparison of all model results including 5 %ile, 50 %ile and 95 %ile can be found in Figure 1.

2.4 USEPA LandGEM Model

LandGEM is an Microsoft Excel based tool for estimating emission rates from MSW landfills published by the USEPA. LandGEM was designed for the UK and allows landfill owners and operators to determine whether a landfill is subject to a variety of US control requirements such as the Federal Emission Guidelines for existing MSW landfill or the Federal New Source Performance Standards for new MSW landfills. Because of this, LandGEM is known to be very conservative in some situations, although LandGEM has become popular internationally because of its ready availability.

Like GasSim2, LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste. Model defaults for

LandGEM are based on empirical data from US landfills. A detailed description LandGEM and its underlying assumption can be found in the LandGEM User's Guide (USEPA 2005).

Waste inputs for the LandGEM models are based on the waste inputs as detailed in the original Biffa GasSim2 model (*GasSim2 Trecatti 2008 Biffa*). The inert waste stream was thereby excluded as it does not contain biodegradable matter and is therefore unlikely to produce significant amounts of LFG. This procedure is in line with the USEPA LandGEM guidance.

Critical model parameters that need to be determined to estimate bulk gas production in LandGEM are the potential methane generation capacity (L_0) and the methane generation rate (k).

L_0 describes the total amount of methane gas potentially produced by a metric ton of waste as it decays and depends on the type and composition of waste placed in the landfill. The L_0 of the deposited waste was derived from the original Biffa GasSim2 model which reports L_0 as part of the Global Impact Module.

k determines the rate of landfill gas generation and waste decomposition during the first order decay process. The definition of k in LandGEM is identical to the definition of the waste degradation rate in GasSim2.

Using Biffa's waste degradation rates (i.e. their k values) for moderately degradable waste (as *GasSim2 Trecatti 2008 Biffa*), LandGEM predicts a bulk gas production of 4,476 m³/h in 2008 (*LandGEM Trecatti 2008 Golder 1*).

Applying the GasSim2 wet default waste degradation rate for moderately degradable waste, LandGEM predicts a bulk gas production of 3,861 m³/h in 2008 (*LandGEM Trecatti Golder 2*).

Applying the GasSim2 average default waste degradation rate for moderately degradable waste, LandGEM predicts a bulk gas production of 3,124 m³/h in 2008 (*LandGEM Trecatti Golder 3*).

Applying LandGEM default values "CAA Conventional" for both L_0 and k to the GasSim2 Biffa based waste inputs results in a significantly higher bulk gas production estimate of 6,695 m³/h. CAA default values are based on requirements for MSW landfills in the United States laid out by the Clean Air Act (CAA), including the NSPS/EG (New Source Performance Standard and Emission guidelines) and NESHAP (National Emission Standards for Hazardous Air Pollutants). They yield conservative emission estimates (USEPA User's Guide, p.1) used to determine whether a landfill is subject to the control requirements of the NSPS/EG or NESHAP. Bulk gas production estimates based on CAA defaults therefore tend to significantly overestimate true bulk gas production.

A detailed comparison of all LandGEM model results can be found in Figure 1.

2.5 IPCC Waste Model

Methane produced at solid waste disposal sites (SWDS) contributes approximately 3 to 4% of annual global anthropogenic greenhouse gas emissions (IPCC, 2001). The Inter-Governmental Panel on Climate Change (IPCC) has therefore developed a methodology to estimate different countries' greenhouse gas emissions from SWDS which is based on the first order decay method (*IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste*, IPCC, 2006). To assist countries in implementation, a spreadsheet model has been generated by the IPCC, the *IPCC Spreadsheet for estimating Methane Emissions from Solid Waste Disposal Sites* (hereafter *IPCC Waste Model*). Developed to estimate a whole country's greenhouse gas emissions from SWDS, this model can be adapted to predict landfill gas bulk productions at single landfill sites. A detailed description the IPCC Waste Model and its underlying assumption can be found in IPCC, (2006).

A Methane Correction Factor (MCF) of 1.0 (i.e. 100%) was employed in the modelling as the Site is considered to be fully managed. The MCF accounts for the fact that unmanaged SWDS produce less methane from a given amount of waste than managed ones.

A Methane Recovery Factor (R) of 0.0 was used in the modelling. R describes the amount of methane recovered in the gas utilisation plant.

An Oxidation Factor (OX) of 0.0 was also used in the modelling. The OX reflects the amount of methane that is oxidised in the soil or cover material.

By setting both R and OX to 0.0, the calculated landfill gas emissions will equal the calculated bulk gas production. The approximate amount of food, garden, paper, wood, textile and inert waste, decomposable nappies and sludge deposited at the Site was derived on an annual basis from the waste composition and input data within the GasSim2 model provided by Biffa (*GasSim2 Trecatti 2008 Biffa*).

Key parameters used in the IPCC model to calculate bulk methane production include the methane generation rate, k (which is equivalent to the GasSim2 waste degradation rate); the degradable organic carbon (DOC) content of the waste; and the fraction of the DOC which decomposes (DOD_f).

Using IPCC default values for DOC, DOC_f and k for wet temperate climate, the IPCC model predicts a bulk gas production of 3707 m³/h (*IPCC Waste Model 1*).

Using IPCC default values for DOC and DOC_f and GasSim2 default k values for wet moisture content results in a bulk gas prediction of 4267 m³/h (*IPCC Waste Model 2*).

Using GasSim2 default k values for average moisture content results in a bulk gas prediction of 3,129 m³/h (*IPCC Waste Model 3*).

Using Biffa's GasSim2 k values the model predicts a bulk gas production of 4,969 m³/h (*IPCC Waste Model 4*).

Table 2 shows the different k values used within this three different models and a detailed comparison of all IPCC model results can be found in Figure 1.

Table 2: Waste Degradation Rates Used in Different IPCC Waste Models.

Methane Generation Rate Constant (k)	IPCC Waste Model 1	IPCC Waste Model 2	IPCC Waste Model 3	IPCC Waste Model 4
(years ⁻¹)	IPCC Default for Wet Temperate Climates	GasSim 2 Default Wet Moisture Content	GasSim 2 Default Average Moisture Content	GasSim 2 Biffa's Waste Degradation Rates
Food Waste	0.19	0.69	0.12	0.35
Garden	0.10	0.69	0.12	0.35
Paper	0.06	0.08	0.05	0.12
Wood and Straw	0.03	0.12	0.08	0.17
Textiles	0.06	0.08	0.05	0.12
Disposable Nappies	0.10	0.12	0.08	0.17
Sewage Sludge	0.19	0.69	0.12	0.35

2.6 Intercomparison of Models

Figure 1 shows the range of model bulk gas generation forecasts for the Site in 2008. The zero order spreadsheet assuming an initial landfill gas production of 5 m³/t/y predicts the lowest bulk gas production of 2024 m³/h. The IPCC model using k values based on Biffa's GasSim2 waste degradation rates predicts the highest bulk gas production of 4969 m³/h. The LandGEM CAA models have already been discounted as not representative.

The zero spreadsheet model assuming an initial landfill gas production of 10 m³/t/y, the GasSim2 models with 'wet' degradation rates, the LandGEM models and IPCC models all produced similar bulk gas production estimates.

Within each group of first-order models, the use of Biffa's waste degradation rates results in the highest and therefore most conservative bulk gas production estimates. The bulk gas production rate, 3,800 m³/h, forecast by Biffa's GasSim2 model (*GasSim2 Trecatti 2008 Biffa*) fits well within the range of different model prediction and appears to be a robust estimate of the gas generation potential of the Site.

The median gas generation rate of the 13 models included in the comparison is 3,707 m³/hr and the mean gas generation rate of these 13 models is 3,470 m³/hr. The Biffa-supplied

model is close to the median of the 13 model simulations, while the *GasSim2 Trecatti 2008 Golder 2* model, which includes the default GasSim2 wet degradation rates, is close to the mean of the 13 model simulations. Both models are therefore acceptable representations of the Site, but the more conservative Biffa model will yield lower estimates of gas collection efficiency than the GasSim2 model with the default wet degradation rates. The differences between the models should not be considered significant, given the wider variance in forecasts available from the other model simulations.

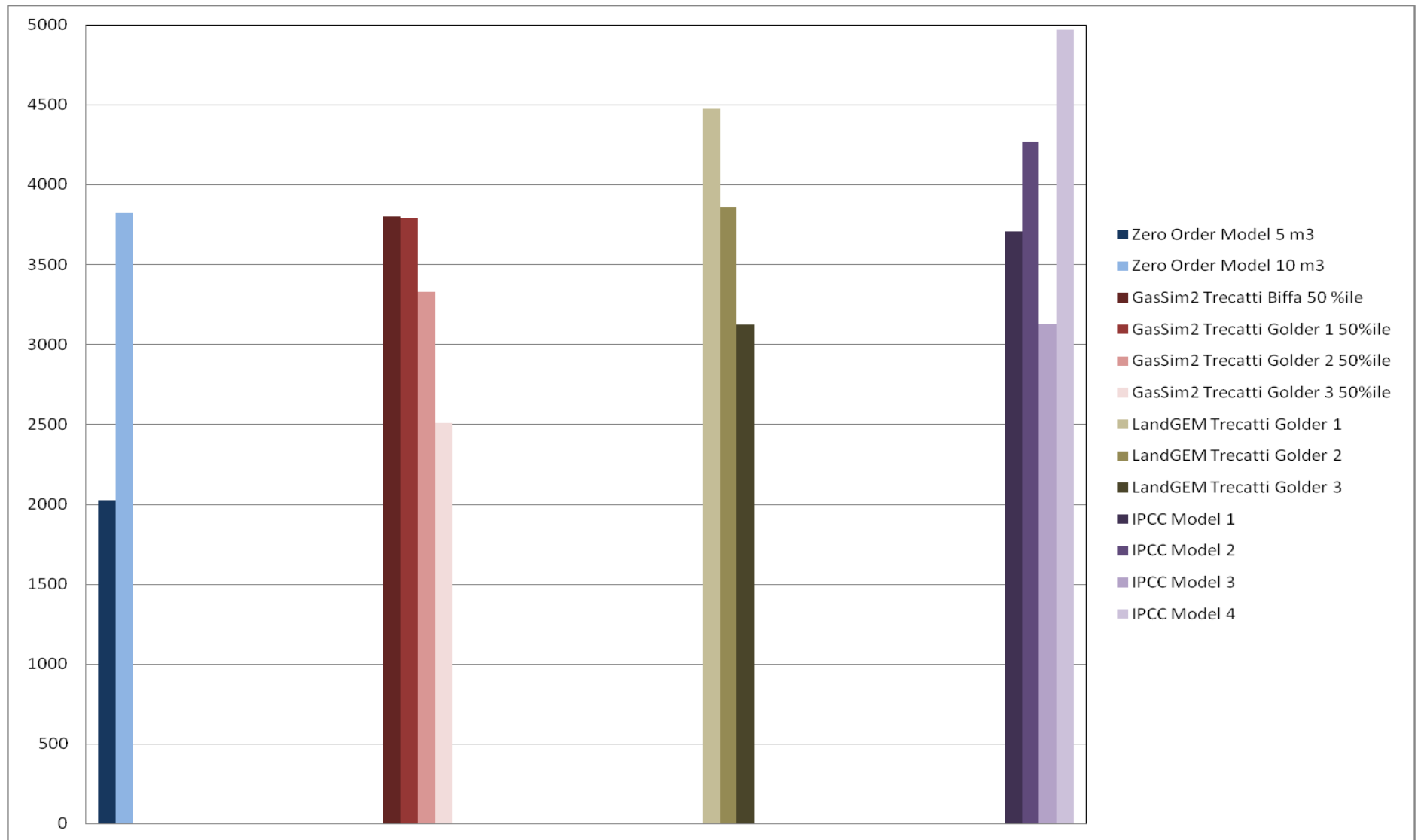


Figure 1: Bulk Landfill Gas Generation Model Comparison.

2.7 Summary

Golder has undertaken an assessment of the theoretical bulk gas generation at the Site. Four different gas generation models (zero-order spreadsheet, GasSim2, LandGEM and IPCC) have been used in the inter-comparison of bulk gas generation rates for 2008.

Each of the first-order models requires assumptions to be made about key waste composition and degradation parameters in order to generate a forecast gas generation rate. Biffa provided their GasSim2 gas generation model of the Site and this was used as the basis for the inter-comparison. These key parameters were varied as detailed in the text to examine the sensitivity of the models to changes in the key parameters.

The median gas generation rate of the 13 models included in the comparison is 3,707 m³/hr and the mean gas generation rate of these 13 models is 3,470 m³/hr.

The Biffa supplied GasSim2 model forecasts a bulk gas generation rate of 3,800 m³/h in 2008, close to the median value. The GasSim2 model with default wet degradation rates forecast a bulk gas generation rate of 3,300 m³/hr, close to the mean value. The limited variance between these two model forecasts fits well within the range of the different model predictions, and both appear to be reasonable forecasts of the gas generation potential of the Site.

3.0 SITE OPERATIONS AND INFRASTRUCTURE

3.1 Site Operational Practice

3.1.1 Waste Placement, Phasing and Capping

The physical layout of the Site, which can exceed 100 m depth at the centre of the landfill, means that waste placement occurs in sequential layers with temporary gas installation installed within each layer. These systems are usually buried with the next lift of waste emplaced on top of the temporary gas recovery systems. Once waste placement has ceased, the filled areas are temporarily capped with welded rigid plastic.

Waste placement at the Site is currently occurring in Phase 4, towards the centre of the Site. The operational area occupies an area of approximately 200 m x 100 m. Placement at this location re-commenced in late 2008 onto previously deposited and temporarily capped waste following completion of waste placement in Phase 3.

The western area of Phase 3 has been permanently capped with a welded HDPE cap. The remaining areas of the Site which have not yet reached final restoration levels are predominantly temporarily capped with a welded rigid plastic capping.

3.1.2 Gas Collection System

The Site gas collection pipework comprises a 355 mm diameter ring main with two entry points to the main gas utilisation compound, one feeding directly from the gas field, via the south of the Site, and the other via the north of the Site and the SES flare compound. The design of the system allows a degree of flexibility in managing the direction of flow of gas from the gas field. Control valves are located around the ring main to facilitate this process as necessary. The total bulk landfill gas collected at the Site is the aggregate of the flow via both legs of the ring main.

A manifold system is installed at the Site and currently comprises seven manifolds (numbered 1, 2, 3, 3A, 4, 5, 7). Manifold 3A was installed in mid-December into recently filled areas of Phase 3. Historically Manifold 8 was present but was removed in August 2008. Each manifold is connected to the ring main by a 180 mm pipe fitted with a control valve, a sampling port and a flow monitoring port. Manifolds are connected via a number of variable diameter gas transmission lines to a series of gas wells installed in the waste. Each gas line is fitted with a control valve and a gas sampling port. Both permanently drilled gas wells and temporary pin wells are used to collect landfill gas at the Site. Permanent gas wells are fitted with individual control valves.

Gas extraction is also undertaken from a number of side risers and leachate chambers at the Site. A few of these extraction points are connected directly to the gas main and not via

the seven manifolds. Side risers and leachate chambers connected directly to the gas main are fitted with a control valve, a gas sampling port and a flow monitoring point.

Condensate management is achieved by dewatering units located at low points around the gas main and in the gas utilisation compound.

3.1.3 Gas Utilisation Plant

The landfill gas utilisation compound houses six containerised Jenbacher J320 landfill gas engines located on the high ground to the east of the Site and above the area of waste placement. Engines 1 to 3 are nominally rated at 1,000 kW_e, Engines 4 and 5 are nominally rated at 1,065 kW_e and Engine 6 is nominally rated at 1,063 kW_e. Two high temperature enclosed flares (one 2,500 m³/hr capacity and one 500 m³/hr capacity, manufactured by Uniflare) are also located in the Gas utilisation compound. Landfill gas is fed to the gas utilisation compound by three blowers, each of 1,500 m³/hr capacity, providing a total of 4,500 m³/hr blower capacity. A second gas compound, containing a 2,000 m³/hr SES flare and an additional 1,500 m³/hr standby flare is located on the perimeter of the Site to the north. This gas compound is supplied by a pair of 1,000 m³/hr blowers for the SES flare, while the standby flare has its own blower.

Automated shut-down of the gas engines occurs at elevated O₂ concentrations (or low CH₄ concentrations) as measured by the *in situ* gas analyser or the engine management system, a situation termed 'leanox'. This shut-down condition is normally activated at 6% O₂ v/v. The flares at the Site are designed to operate automatically upon engine shut-down and will operate on a wider range of gas qualities than the gas engines. All flares at the Site are fitted with multiple safeguards to ensure safe operation. Appendix 1 details Biffa's approach to safe operation of landfill gas plant when variable gas qualities are encountered.

A Verdesis landfill gas pre-treatment unit for the removal of H₂S and siloxanes is also located in the gas utilisation compound and is installed for engine operational reasons and has no significance for this assessment of landfill gas management.

In the event of a power failure, the Site has a standby generator which provides power to the flares and blowers to enable the gas collection infrastructure to remain operable.

3.2 Landfill Gas Monitoring

Biffa undertake regular (weekly) monitoring of the gas composition and flow rates at strategic locations around the Site and at the Gas utilisation compound as part of their regular balancing of the gas field at the Site. Gas monitoring data at individual manifolds were provided by Biffa for the period 17 April 2008 to 21 January 2009. Biffa has also provided gas monitoring data at the gas utilisation compound and the SES flare for the period

28 August 2008 to 21 January 2009. The manifold monitoring data for the period 17 April 2008 to 28 August 2008 are broadly consistent with the later period. An exception is Manifold 2, which had no applied suction for approximately 1 month in July/August 2008. The results of detailed gas monitoring for the period 28 August 2008 to 21 January 2009 are discussed below. The recently installed Manifold 3A has only been monitored since 15 January 2009 and Manifold 8 was removed for operational reasons in August 2008.

3.2.1 Gas Composition

The bulk composition of the landfill gas collected at the Site is shown in Figure 2. This composition has been obtained by determining the flow-weighted mean of the gas analyses undertaken at the two gas lines (effectively the two ends of the ring main) entering the gas compound (termed *Main GUP* and *SES Flare* respectively).

The monitored CH₄ concentration was observed to lie within a relatively narrow range (40 to 45% v/v). Monitored concentrations of CO₂ were observed to lie within the range 32 to 36% v/v.

Monitored O₂ concentrations generally lie within the range 2 to 5% v/v. A single monitored concentration exceeding 5% v/v was observed on 18 December 2008 for the composite collected gas. Monitored balance gas (mostly N₂) concentrations were observed to lie within a slightly wider range 13 to 23% v/v. Entrained air (the sum of balance gas and O₂) therefore comprises approximately 25% of the volume of the gas collected at the Site.

The monitored gas concentrations in Figure 2 are relatively stable indicating frequent balancing of the gas system is undertaken and the gas field is operating efficiently. The relatively high O₂ and balance gas concentrations measured in the collected landfill gas together with the high suction pressures exerted on the gas field are indicative of a system which is operated in a manner designed to maximise the collection of landfill gas for the purposes of environmental control. The high (> 5% v/v) O₂ concentration observed on 18 December 2008 is discussed further in Section 3.3.

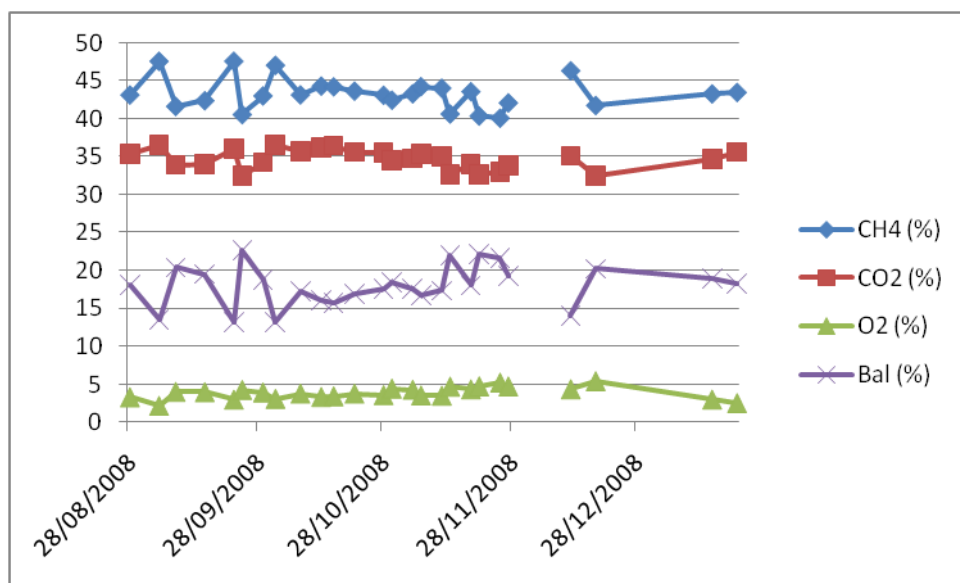


Figure 2: Site Composite Bulk Landfill Gas Composition

3.2.2 Gas Collection

3.2.2.1 Gas Volume

Collected landfill gas historically entered the gas utilisation compound through two separate gas lines: one via the SES flare and the other via the Main GUP. Biffa have provided detailed aggregated landfill gas flow data at these two monitoring points for the Site for the period 28 August 2008 to 21 January 2009.

Figure 3 shows the sum of the measured landfill gas flows to the gas compound from the SES flare and the Main GUP gas lines. The flow data presented here do not include the volume of entrained air (oxygen + balance gas) which is also collected along with the CH₄ and CO₂. The entrained air fraction has been mathematically removed to enable comparison of the gas volume collected at the Site with model predictions of the gas generation rate, which do not consider the entrained air fraction.

The mean volume of landfill gas (excluding entrained air) collected at the Site was 3,125 m³/hr with maximum and minimum flows of 2,713 m³/hr and 3,364 m³/hr respectively. The maximum and minimum monitored flows are a variation of approximately ± 10% from the mean collected volume which Golder considers to be reasonable for any large landfill gas collection system on an operational landfill site, as intermittent disruption to parts of the gas collection system with a consequent effect on both the volume and composition of the collected landfill gas would be expected.

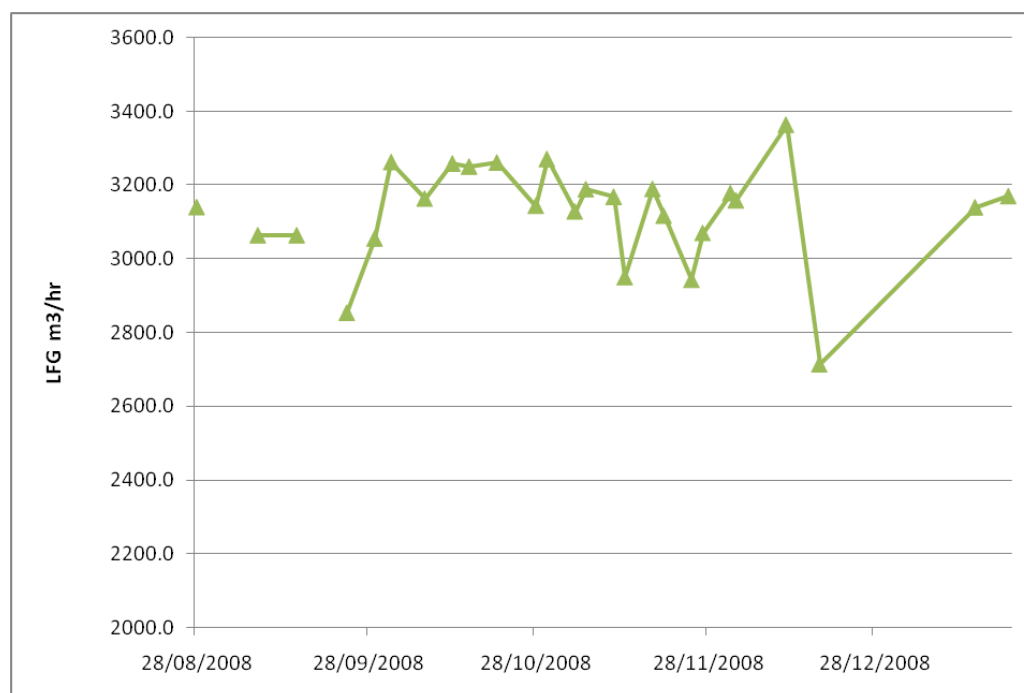


Figure 3: Total Bulk Landfill Gas Collected at Site (Excluding Entrained Air)

3.3 Site Audit

The aim of the audit was to provide validation of the long-term monitoring data provided by Biffa and to identify any potential gas management issues at the Site. The Site audit was undertaken on 18 December 2008 by Stewart Davies (Golder) accompanied by Steve Thayer (Biffa). Three of the six landfill gas engines were reported not to be operating on the day of the audit, with the residual gas being flared. Golder considers the non-operation of three engines not to materially affect the performance of the Site unduly as Site gas collection efficiency should not be significantly affected.

The audit consisted of an examination of the visible gas collection infrastructure installed at the Site (where it was safe to do so) together with gas composition and flow measurements at manifolds and the two main gas lines to the Gas utilisation compound.

Gas composition analysis was undertaken by Steve Thayer (Biffa) using a Geotechnical Instruments GA2000+. Flow rates were determined using a Testo 435 fitted with an 11 mm vane anemometer. The audit was undertaken in conjunction with the trace gas monitoring undertaken by CPL Laboratories (CPL), detailed in Section 4. Bulk gas samples were also collected at each manifold by CPL for laboratory analysis to provide independent verification of the results obtained from the portable GA2000+ gas monitor.

3.3.1 Observations

The gas collection system was observed to be in very good order. Gas extraction was observed to be efficiently applied at all manifolds indicating no significant blockages of the main gas collection pipework. No obvious sources of significant air ingress into the gas collection system were evident. There were no landfill gas odours present at the Site apart from an identifiable odour of landfill gas in the vicinity of the newly installed gas wells awaiting connection to Manifold 3A (discussed below). There was limited access to large areas of the Site for safety reasons and the burial of much of the gas collection infrastructure meant that inspection of the individual gas wells was not generally possible.

Manifold 1 is connected to four feeder lines which are attached mainly to pin wells in Phase 6. Only one of the four feeder lines was open on the day of the audit. Biffa confirmed that the wells are installed at depth into old waste and gas generation in this area of the Site is low. Relatively long runs of pipework were observed to be snaking across inaccessible areas of temporary cap with potential for condensate collection although the presence or absence of condensate could not be verified due to access restrictions.

Manifold 2 has three feeder lines, only one of which was operational on the day of the audit due to capping works. All of the lines are connected to buried pin wells within Phase 3.

Manifold 3 has a single active 180 mm feed line which is connected to a series of buried pin wells and side risers in the permanently capped area to the west of Phase 3 of the Site. The two remaining 180 mm feeder lines are intended for use with permanently drilled gas wells to be installed in Phase 3.

Manifold 3A was newly installed in the week of the audit and connected to approximately 12 permanent gas wells located in the western area of Phase 3 of the Site. A number of permanent gas wells were either in the process of being drilled or had been recently drilled into the cap in Phase 3 and were awaiting connection to the manifold. Cap welding was also underway in this area. Landfill gas was observed to be emanating from areas between the unwelded capping layers where the newly drilled wells were awaiting connection to the gas system. It is understood that this work has now been completed. The well installers (EGM) report that a number of the newly installed permanent wells exhibited suction prior to connection to the gas system, indicating that these wells were within the zone of influence of the remainder of the gas system.

Manifold 4 was connected to two feeder lines which are connected to pin wells located in Phase 1. Both were operational on the day of the audit.

Manifold 5 was connected to two operational feeder lines, one 90 mm and one 180 mm connected to pin wells and side risers located in Phase 2 of the Site.

Manifold 7 was located in the central region of the Site immediately to the west of the current haul road. Manifold 7 was connected via three 180 mm feeder lines, to a range of gas collection infrastructure comprising predominantly pin wells, and a leachate tower in Phase 3.

3.3.2 Gas Flow Monitoring

The results of the gas monitoring obtained during the audit are shown in Table 3. Approximately 55% of the gas collected at the Site is obtained from two manifolds: Manifolds 3 and 7. Approximately 80% of the total gas collected at the Site is obtained from four manifolds: Manifolds 3, 4, 5 and 7.

Manifolds 1 and 2 were observed to be collecting only small volumes of landfill gas (92 and 170 m³/hr respectively). Manifold 1 is connected primarily to buried pin wells in old waste in Phase 6. Of the three feeder lines connected to Manifold 2, only one of which was operational on the day of the audit due to capping works in Phase 3.

Two leachate chambers and two side risers were connected to the gas main directly. The measured flow from each of the leachate chambers was approximately 100 m³/hr with lower flows observed at the side risers. This is consistent with the measured discrepancy (~ 260 m³/hr) between the flows obtained at manifolds (3,759 m³/hr) and at the Gas Compound (4,020 m³/hr). Note all gas flows reported here include entrained air.

Table 3: Results of Gas Monitoring on 18 December 2008 Using the GA2000+.

Location	Phase ¹	CH ₄ % v/v	CO ₂ % v/v	O ₂ % v/v	Bal % v/v	Flow ² m ³ /h	Suction mb	H ₂ S ppmv
Manifold 1	1	33.6	27.2	6.1	33.1	92	-72	0
Manifold 2	1	43.7	35.9	3.6	16.8	170	-70	136
Manifold 3	1	45.9	34.4	3.7	16.0	1242	-67	131
Manifold 3A	1	49.3	38.7	3.6	8.4	200 ³	-67	586
Manifold 4	1	42.4	32.8	5.0	19.8	560	-66	143
Manifold 5	2	36.8	29.0	6.9	26.7	490	-89	13
Manifold 7	2	41.5	36.1	4.9	17.5	1005	-74	506
SES flare	1	44.8	34.6	4.3	16.3	1868	-88.8	144
Main GUP	2	42.2	32.7	5.4	19.7	2152	-102	227

Notes:

1. Flow may be diverted in either via SES flare (Phase 1) or direct to Main GUP (Phase 2).
2. Flow measurements using a vane anemometer are subject to significant error at low flows.
3. Flow estimated as no flow sampling port yet fitted to Manifold 3A.

3.3.3 Gas Composition Analysis

The results of the laboratory bulk gas composition at each manifold are shown in Figure 4. The monitoring results obtained during the Site audit on 18 December 2008 indicate that the Site was operating at lower gas extraction rates than normal as both the differential pressure and the volume of gas collected were below the long-term trend. Despite the performance of the gas collection system being below the 6 month historic performance of the Site,

Golder considers that the operational conditions observed at the Site on the day of the audit are a reasonable and conservative representation of the long-term gas management practice at the Site.

The laboratory bulk gas composition analyses are broadly consistent with the results obtained from composition monitoring using the portable GA2000+ in the case of CH₄ (Table 3). Laboratory measurements of CO₂ are systematically lower than those obtained using the portable GA2000+ by approximately 10% v/v. Laboratory measurements of O₂ are generally lower than those obtained using the portable GA2000+ by approximately 1 to 2% v/v.

According to the manufacturer, Geotechnical Instruments, the GA2000+ has a stated accuracy of $\pm 3.0\%$ for CH₄ and CO₂ when their concentrations exceed 15% v/v. The stated accuracy is $\pm 1\%$ for O₂, irrespective of concentration. In both cases the stated accuracies are dependent upon manufacturer's calibration and field calibration being undertaken. The GA2000+ undergoes factory calibration at 6 month intervals and involves performance assessment against a six gas supply containing a known and concentrations of CH₄ and CO₂ (normally in spanning the range 5% to 50%). The exact calibration undertaken will be stated on the Certificate of Calibration provided.

The bulk gas laboratory analyses were undertaken using Gresham tubes and gas chromatography fitted with a thermal conductivity detector (GC/TCD) following British Standard (BS) 3156. Laboratory analyses will have been performed on a dry sample, and so any water vapour in the gas sample will have been removed before analysis. This correction would have the effect of increasing the gas measurements obtained, rather than lowering them as observed. It is not possible to unambiguously determine which measurements are more accurate although laboratory analysis would normally be considered to be more accurate than portable instruments for stable bulk gases.

The high O₂ concentrations measured at the gas utilisation compound (5.4% v/v GA2000+, 7% v/v laboratory) and the SES Flare (4.3% v/v GA2000+, 6.6% v/v laboratory) is indicative of the requirement Biffa have to undertake balancing of the gas system to abstract as much landfill gas as is practicable while limiting oxygen and air ingress to safe limits. The O₂ content of the collected gas on the day of the audit (18 December 2008) was the highest recorded throughout the data record (28 August 2008 to 21 January 2009) as shown in Figure 2.

Gas composition analyses showed CH₄ concentrations at manifolds were 37 to 50% v/v (GA2000+) and 40 to 45% v/v (laboratory); CO₂ concentrations were 29 to 39% v/v (GA2000+) and 20 to 25% v/v (laboratory); and O₂ concentrations were 3.6 to 7% v/v (GA2000+) and 3.1 to 7.5% v/v (laboratory) in Manifolds 2 to 7.

High O₂ concentrations (6.1% v/v GA2000+; 7.75% v/v laboratory), together with low CH₄ and CO₂ concentrations, were observed in the gas sampled at Manifold 1. Low gas flow rates

were also recorded at Manifold 1, indicating that low gas generation rates within the zone of influence of the connected pin wells is the most plausible explanation. Biffa confirm that this accords with their experience of this area of the Site.

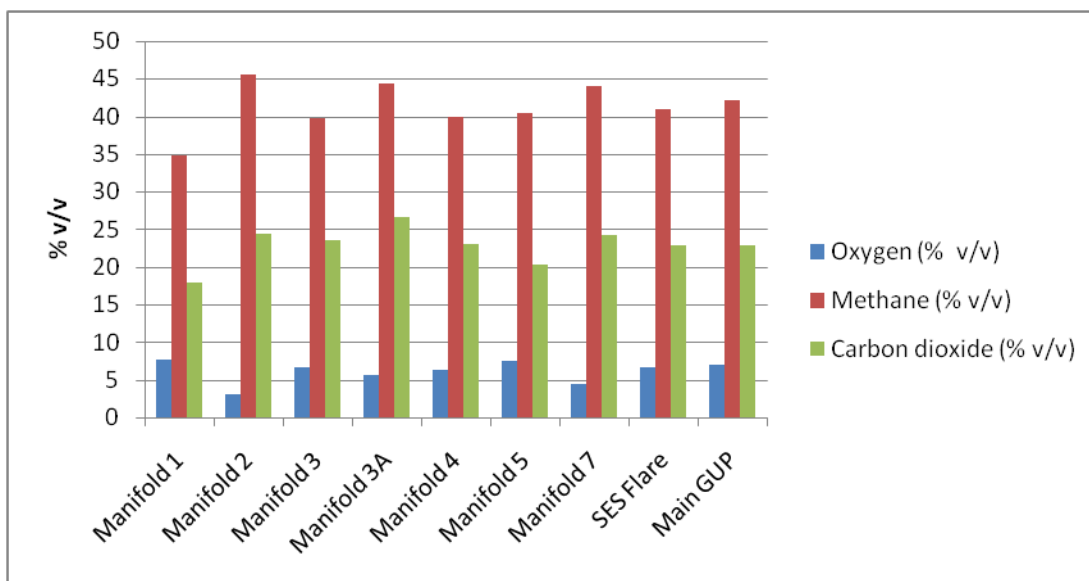


Figure 4: Results of Laboratory Bulk Gas Monitoring on 18 December 2008.

Indicative H₂S measurements made by the GA2000+ show H₂S concentrations in excess of 500 ppmv (~ 700 mg/m³) (the upper limit of detection of the portable instrument) to be present in the gas collected at Manifolds 3 and 7. These are the most productive in terms of landfill gas generation and collection. Laboratory trace gas analyses were undertaken and the results are discussed in detail in Section 5.

3.3.4 Differential Pressure

Differential pressure (suction) is applied to landfill sites in order to facilitate migration of generated landfill gas into the gas collection system. On the day of the audit, the differential pressure applied at the gas utilisation compound was approximately -100 mb. Differential pressures applied at the SES flare were lower than those at the gas utilisation compound at -89 mb. In both cases, the applied differential pressures are considered by Golder to be towards the upper range of practice at operational landfills and indicative of prioritisation of gas collection efficiency for environmental control purposes rather than optimal operation of combustion plant at the Site. The results obtained on the day of the audit indicate slightly less differential pressure being applied to the Site than was the case over the preceding 6 months. Golder considers the variation to be too small to significantly affect the representativeness of the Site audit.

There are two separate sources of differential pressure applied at either end of the gas ring main at the Site. The applied differential pressures measured at each individual manifold are

generally 15 – 40 mb less than those measured at the sources (gas utilisation compound or SES Flare) and were generally recorded in the range -60 to -100 mb. The measured differential pressures at manifolds are considered by Golder to be indicative of significant efforts to collect gas and that the gas collection system is operating without undue blockages or major sources of air ingress.

Figure 4 shows the change in differential pressure between the sources (gas utilisation compound or SES Flare) and the measuring location on the day of the audit (Table 3). The applied suction pressure generally decreases with increasing distance from the sources to a minimum approximately 1,000 to 1,200 m from either source in a manner which Golder considers to be normal. The reduction in pressure loss at distances above 1,200 m in Figure 4 is indicative of the monitoring point being under the influence of the other source of suction applied to the ring main.

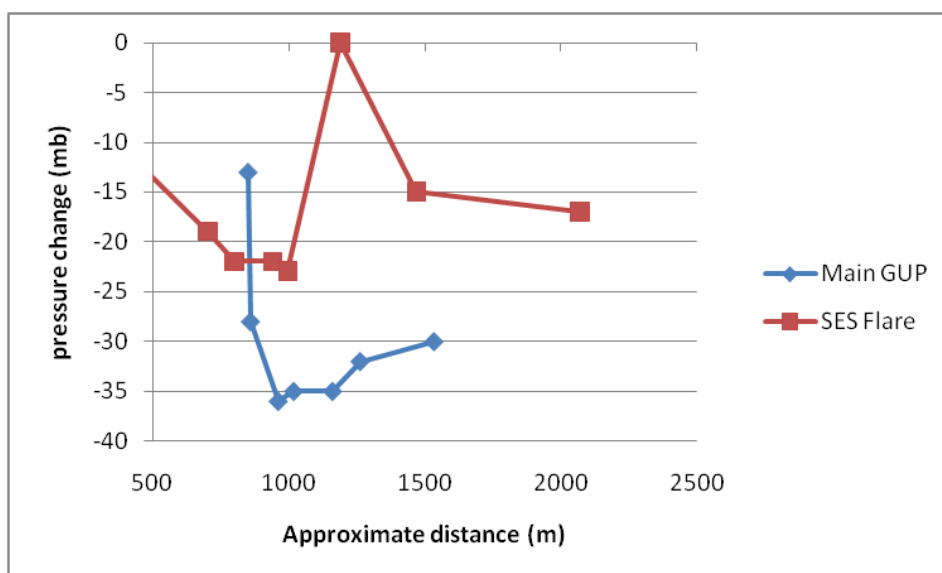


Figure 5: Variation in Differential Pressure along the Ring Main on 18 December 2008.

3.4 Summary

Waste placement is currently occurring in Phase 4 of the Site. An extensive temporary capping system comprising rigid welded plastic sheeting is in place over the areas of the Site which have yet to reach final levels. There is a 3 ha area of permanent capping to the west of Phase 3.

The Site gas collection infrastructure comprises six gas engines and two flares connected via a 355 mm gas ring main to seven manifolds and a combination of permanent and pin wells with some gas extraction at leachate towers and side risers. The majority of the gas collection infrastructure is buried.

The gas flow rate and composition across the Site is monitored frequently (approximately weekly). The mean volume of landfill gas (excluding entrained air) collected at the Site was 3,125 m³/hr (with an approximate \pm 10% variation) for the period 28 August 2008 to 21 January 2009.

Monitored gas compositions generally show relatively high oxygen concentrations (2 to 5% v/v) at the Gas utilisation compound. On the day of the gas audit, monitored oxygen concentrations were found to be above 5% at the Gas utilisation compound and several manifolds, indicating the need for gas balancing.

The differential pressure applied to the Site is generally high and there is no evidence of significant loss of extraction or clear points of air ingress across the system. The high applied differential pressures together with the high oxygen content of the collected gas are indicative of efforts to maximise collection of landfill gas.

4.0 DETERMINATION OF GAS COLLECTION EFFICIENCY

4.1 Introduction

The gas collection efficiency of a landfill site may be defined as the ratio of the quantity of landfill gas collected to the total quantity of landfill gas generated in the Site. The total quantity of gas collected may be determined from regular composition and flow measurements made at strategic locations within the Site gas collection infrastructure. The total quantity of landfill gas generated at a site is more difficult to determine and may be estimated in two separate ways. Firstly, all the fugitive emissions at a site could theoretically be measured and added to the gas collected to give a total gas generation rate. Alternatively, the total volume of gas generated may be derived from gas generation models. Golder has utilised the model forecasts of the total volume of gas generated at the Site to determine the gas collection efficiency at the Site as quantification of fugitive emissions is not a practical proposition on operational landfills.

When comparing model forecasts of landfill gas generation with gas composition and flow data obtained on-site it is essential to account for the entrained air collected along with the landfill gas. Landfill gas extraction systems operate by applying suction to the waste at discrete locations to provide a pathway for gases present in the waste to preferentially enter the gas collection system. Air is inevitably drawn into the waste and the collection system as a result of this process. Therefore all comparisons between model gas generation rates and Site operational gas data are made once the effects of entrained air are removed.

4.2 Site Gas Collection and Model Forecast Gas Generation

Figure 5 shows a summary of the model forecasts of landfill gas generation at the Site from Section 2, together with a histogram showing the volume of gas collected at the Site derived from approximately weekly monitoring for the period 28 August 2008 to 21 January 2009. In all cases the volume of entrained air has been removed. The shaded area represents the range bounded by the models Golder considers to be the most appropriate representations of the likely gas generation volume at the Site, bounded by the *GasSim2 Trecatti 2008 Golder 2* model which uses default wet degradation rates (3,300 m³/hr) and the *GasSim2 Trecatti 2008 Biffa* model (3,800 m³/hr).

Model forecasts of gas generation are annual averages and therefore the most appropriate comparison is with the mean volume of gas collected at the Site rather than individual spot measurements. The mean gas generation volume at the Site was 3,125 m³/hr for the period 28 August 2008 to 21 January 2009 (Section 3.2.2.1).

The gas collection efficiency for the Site is given by:

$$\text{Gas collection efficiency} = \frac{\text{Volume of gas collected}}{\text{Volume of gas generated}}$$

Therefore Golder considers that a reasonable estimate for gas collection efficiency is given in the range:

$$= \frac{3125}{3800} \quad \text{to} \quad \frac{3125}{3300} \quad \text{or} \quad 82.2\% \quad \text{to} \quad 94.7\%.$$

Biffa report that their estimate gas collection efficiency at the Site is 89%. The Biffa estimate is within the Golder forecast range and Golder therefore considers the Biffa estimate to be reasonable.

The reported gas collection efficiency achieved at the Site is therefore consistent the Environment Agency's target of 85% gas collection efficiency at landfill sites.

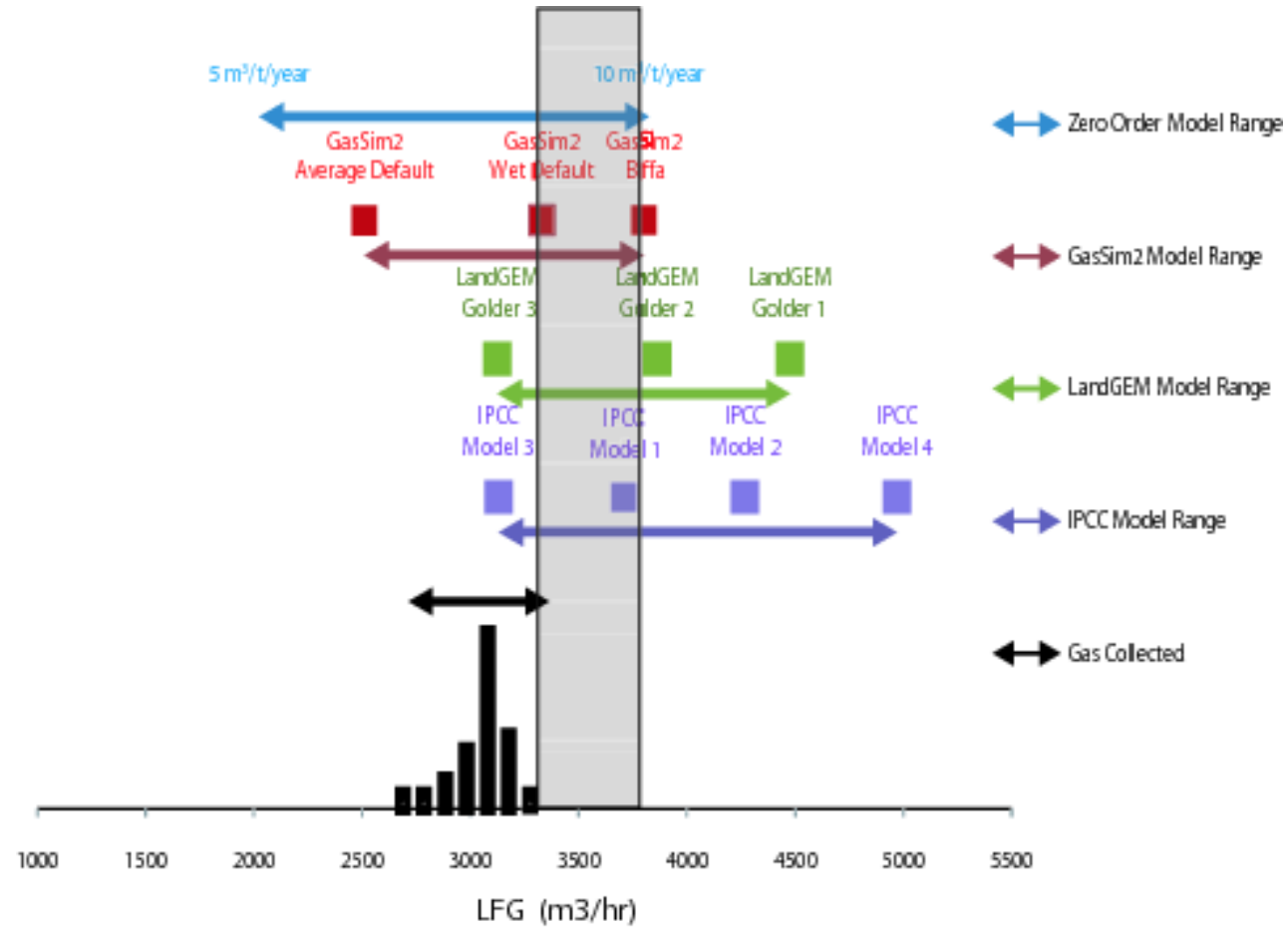


Figure 6: Comparison of Model Gas Generation and Actual Gas Collection.

In Golder's opinion, the gas collection efficiency achieved at the Site will generally be higher than would normally be achieved by a typical operational landfill for the following reasons:

- Extensive use of welded rigid temporary plastic capping to reduce fugitive surface emissions;
- Installation of gas extraction in layers as Site develops;
- Application of high differential pressures to attain maximum gas collection efficiencies across the Site; and
- Frequent balancing of the gas extraction system.

4.3 Summary

Golder has determined that the gas collection efficiency of the Site by comparing actual volumes of gas collected at the Site for the period 28 August 2008 to 21 January 2009 with model forecasts of gas generation at the Site in 2008.

The gas collection efficiency of the Site is considered by Golder to be in the range 82.2% to 94.7%. Biffa's forecast of 89% gas collection efficiency is consistent with the Golder forecast and therefore Golder considers Biffa's estimate to be reasonable.

The gas collection efficiency achieved at the Site is higher than would normally be achieved on an operational landfill and is consistent with the Environment Agency's target of 85%.

5.0 TRACE COMPONENT ASSAY

5.1 Background

The bulk constituents of landfill gas (CH_4 and CO_2 and H_2) are odourless. Therefore the odour of landfill gas is due to the presence of specific trace gas components, some of which have very low odour thresholds. Among the most important odorants of landfill gas is hydrogen sulphide (H_2S). Previous studies have indicated that historic odour complaints in the vicinity of the Site may be related to the high H_2S content of the landfill gas at the Site generated from the deposition of sulphur-containing industrial waste materials. The Site has not accepted such wastes for a number of years. This assessment therefore considers H_2S together with other odorous trace gases which are generally recognised to be potentially present in landfill gas: and known as the Environment Agency's Priority List (Table 1.1 of *Guidance for Monitoring Trace Components in Landfill Gas*, LFTGN04, September 2004). Such trace gases include organosulphur compounds such as dimethyl sulphide; carboxylic acids such as butanoic acid; aldehydes such as ethanol; and carbon disulphide.

5.2 Trace Component Monitoring Methodology

In order to determine the concentration of potentially odorous compounds in the landfill gas generated at the Site, gas samples were collected from strategic locations around the Site on 19 December 2008. Weather conditions on the day of sampling were wet and windy with an ambient temperature of approximately 6 °C. The gas sampling was undertaken by Steve Hatton and Oliver Warhurst from CPL, and accompanied by Stewart Davies (Golder) and Steve Thayer (Biffa). Nine strategic monitoring locations: Manifolds 1, 2, 3, 3a, 4, 5, 6 and 7, at the negative pressure side of the SES Flare and at the negative pressure side of the main GUP flare were sampled.

An initial analysis of the composition of the landfill gas at each monitoring location was undertaken and recorded by Steve Thayer (Biffa) using a Geotechnical Instruments GA2000+. The results of the GA2000+ composition monitoring (especially CH_4 and H_2S) were used to determine the optimum flow rate for the trace gas sampling. The results of the on-site monitoring undertaken are shown in Section 5.3. In addition, bulk gas samples (for subsequent laboratory analysis to determine concentrations of CH_4 , CO_2 , O_2 and H_2) were also collected at each monitoring location immediately following completion of trace gas sampling.

Sampling and subsequent analysis for trace components was undertaken according to the methodologies detailed in LFTGN04 using the MCERTS-accredited laboratory, CPL Laboratories (CPL). The sampled gases underwent laboratory analysis at the UKAS-accredited laboratories, CERAM and Scientifics, using the techniques shown in Table 4.

Table 4. Monitoring Methodologies

Determinand	Reference Method	UKAS No.	CPL Procedure No. ³	Summary of Procedure
Bulk Gases	BS 3156	1618	AM001	Gresham tubes, GC/TCD
Arsenic	BS EN 13649 (S) NIOSH 6001 (A)	1618 (S only)	ST13	Carbon tubes, AAS
Aldehydes ²	BS EN 13649 (S) NIOSH 2539 (A)	1618 and 1015	ST13	DNPH tubes, HPLC
Hydrogen Sulphide	BS 3156	1618	AM001	Iodimetry
VOCs ¹	BS EN 13649	1618 and 0013	ST13	ATD tubes, GC/MS

Notes:

1. VOCs analysis conducted at Ceram, Stoke;
2. Aldehydes analysis conducted at Scientifics, Harwell; and
3. CPL Procedure refers to internal CPL operational procedures and documentation.

5.3 Trace Component Monitoring Results

The full results of the trace component monitoring undertaken by CPL are shown in Appendix 2. This analysis focuses on those components in the Agency's Priority List which are considered to be odorous. Table 5 shows the EA recommended detection limits and the actual detection limits achieved and the maximum and minimum concentrations obtained during monitoring for the odorous trace gas components in the Agency's Priority List.

Table 5: Detection Limits, Maximum and Minimum Concentrations of Measured Odorous Trace Gas Components.

Trace Component	EA Recommended Detection Limit ($\mu\text{g}/\text{m}^3$)	Actual Detection Limit ($\mu\text{g}/\text{m}^3$)	Minimum ($\mu\text{g}/\text{m}^3$)	Maximum ($\mu\text{g}/\text{m}^3$)
1-butanethiol	300	60	ND	420
1-pentene	160	NA	140	450
1-propanethiol	200	60	ND	180
Butyric acid	400	100	ND	ND
Carbon disulphide	100	600	ND	5100
Dimethyl disulphide	100	60	ND	860
Dimethyl sulphide	110	60	ND	2,200
Ethanal	12	NA	52	6,300
Ethanethiol	300	180	ND	ND
Ethyl butyrate	90	60	ND	33,000
Hydrogen sulphide	150	NA	53,000	990,000
Methanethiol	1,000	600	ND	680

Notes:

- ND Not Detected
NA Not Applicable as all measured data above detection limit.

The monitored concentrations of five potentially odorous compounds (1-butanethiol, 1-propanethiol, ethanethiol, methanethiol and butyric acid) were found to be either close to or below to the Environment Agency's recommended detection limits at all monitored locations.

The results of monitoring for the remaining odorous trace gas compounds are discussed individually below.

Where appropriate, the range of GasSim2 default concentrations for each monitored trace gas are also included in order to provide a context for evaluating the results. The GasSim2 default concentrations are derived from historic monitoring of trace components at a large number of UK landfills and are considered representative of the typical range of concentrations of trace components normally encountered in landfill gas (Environment Agency R&D technical Report P1-491/TR, 2004). Trace gas concentrations are included in GasSim2 as probability distribution functions (PDFs). The maximum and minimum of the GasSim2 PDFs are referred to as 'High' and 'Low' respectively. Depending on the type of PDF used in GasSim2, a 'Medium' GasSim2 value is also included for comparison purposes where possible.

5.3.1 Hydrogen Sulphide

Hydrogen sulphide (H_2S) has an odour threshold of $0.76 \mu g/m^3$ according to *Draft Horizontal Guidance for Odour*, IPPC H4 Part 1, Environment Agency, 2002) and exhibits a characteristic smell of rotten eggs.

Figure 7 shows that the highest measured H_2S concentration ($990,000 \mu g/m^3$) occurred at the very recently installed Manifold 3A. The lowest measured concentration ($53,000 \mu g/m^3$) occurred at Manifold 5. H_2S concentrations at the manifolds (except Manifolds 3A and 7) are within the GasSim2 default range ($2,400$ to $580,000 \mu g/m^3$). H_2S concentrations in the two aggregated samples collected at the SES flare and the Main GUP (at $170,000$ and $410,000 \mu g/m^3$ respectively) are also within the default GasSim2 range and within the range of H_2S concentrations typically observed in gas utilised at UK landfills. The H_2S concentrations observed in the gas collected at Manifold 3A are higher than the default GasSim2 range but are not unrepresentative of H_2S concentrations observed in gas collected from newly placed wastes at UK landfills.

It should be noted that Manifold 3A abstracts gas from newly drilled gas wells to the west of Phase 3 of the Site. Waste placement has recently ceased in the area. Manifold 7 collects gas from wastes placed in Phase 3 of the Site. High concentrations of H_2S are considered by Golder to be not uncommon in landfill gas extracted from recently deposited municipal wastes and potentially a significant factor in the general increase in observed H_2S concentrations in landfill gas more generally (Parker and Pointer, 2008). Parker and Pointer (2008) report an average increase in H_2S concentrations in UK landfills from $85,000 \mu g/m^3$ in 2002 to $160,000 \mu g/m^3$ in 2007. It is not currently understood why an apparent increase in H_2S concentrations should occur in collected landfill gas and the Environment Agency has commissioned research into the issue. Possible suggestions for the increase in H_2S concentrations being observed in landfill gas collected at UK landfills include:

- Changes to the composition of wastes being placed in landfills in recent years due to waste diversion targets e.g. the removal of metals from the waste stream which may act as a sink for generated H₂S; and
- Changes to the timing of collection of landfill gas. Landfill gas collection is generally being undertaken more rapidly following the placement of wastes at sites and active gas extraction in operational areas is becoming more commonly undertaken. The most elevated concentrations of H₂S are generally observed in most recently placed wastes.

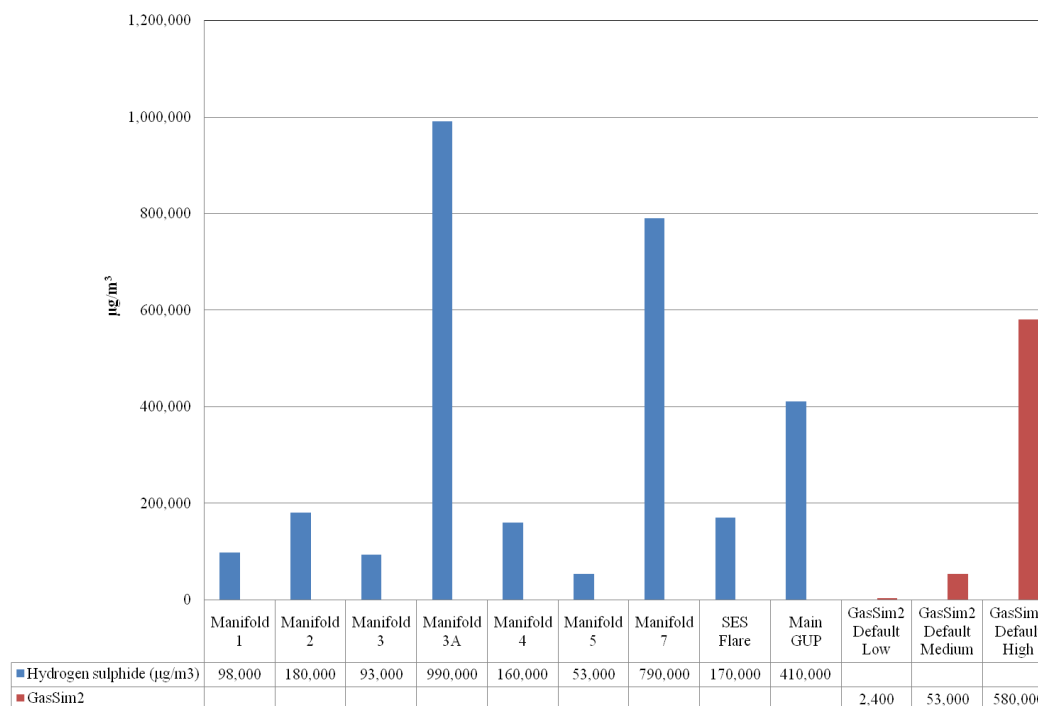


Figure 7: Measured H₂S Concentrations and Comparison with Gassim2 Default Value

5.3.2 Carbon Disulphide

Carbon disulphide (CS₂) has a reported odour threshold of 700 µg/m³ (Table A5.1 of *Environment Agency Guidance on Landfill Gas Flaring*, Version 2.1, 1999). Figure 8 shows that the highest measured CS₂ concentration (5,100 µg/m³) occurred at the very recently installed Manifold 3A. The lowest measured concentration (< 600 µg/m³) occurred at Manifold 1. CS₂ concentrations at the manifolds are within the GasSim2 default range (1,400 to 30,000 µg/m³). CS₂ concentrations in the two aggregated samples collected at the SES flare and the Main GUP (at 960 and 2,500 µg/m³ respectively) are also within the default GasSim2 range. The highest monitored concentrations of CS₂ occurred in Manifold 3A.

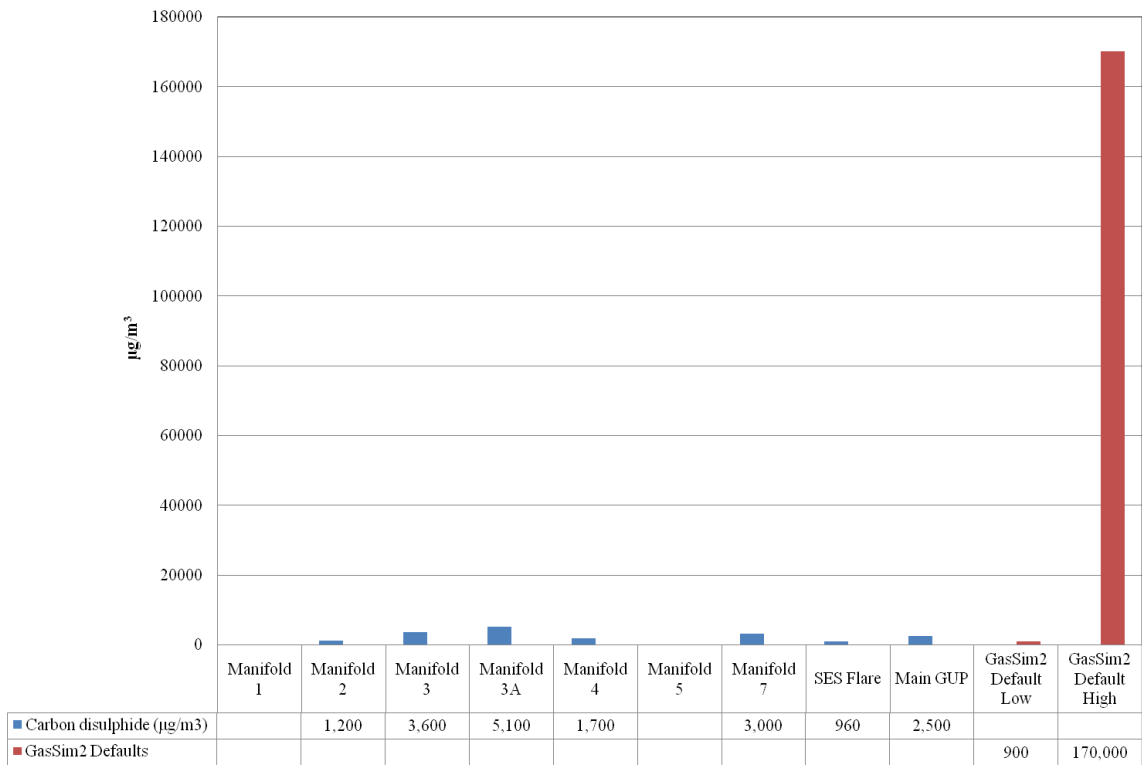


Figure 8: Measured CS₂ Concentrations and Comparison with Gassim2 Default Values.

5.3.3 1-Pentene

1-Pentene has a reported odour threshold of 600 µg/m³ (Table A5.1 of *Environment Agency Guidance on Landfill Gas Flaring*, Version 2.1, 1999). Figure 9 shows that the highest measured 1-pentene concentration (450 µg/m³ at Manifold 3A) is below the reported odour threshold. Therefore it is unlikely that the presence of 1-pentene at the monitored concentrations in the landfill gas generated at the Site could be a potential source of odour. The monitored 1-pentene concentrations are broadly comparable to the GasSim2 lower default value.

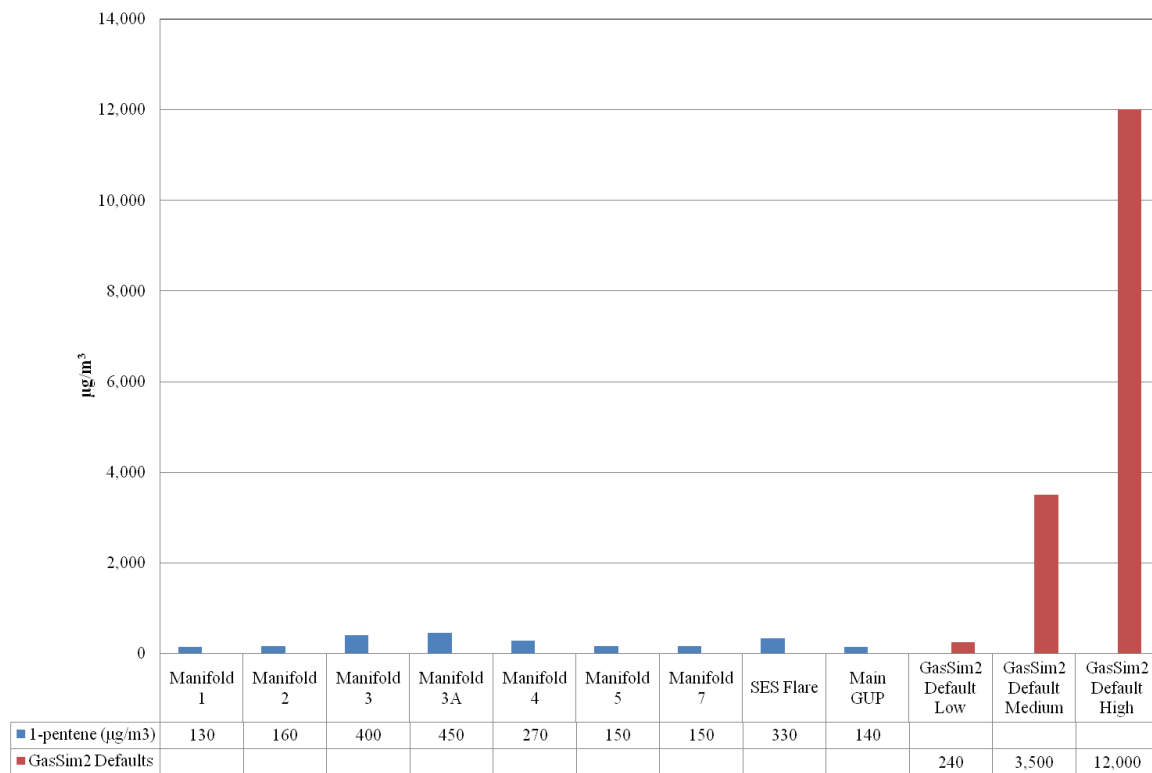


Figure 9: Measured 1-Pentene Concentrations and Comparison with GasSim2 Default Values

Dimethyl Disulphide

Dimethyl disulphide has a reported odour threshold of 4 µg/m³ (Table A5.1 of *Environment Agency Guidance on Landfill Gas Flaring*, Version 2.1, 1999). Figure 10 shows that the highest measured dimethyl disulphide concentration (860 µg/m³) was observed at Manifold 7. Monitored concentrations of dimethyl disulphide were below the detection limit (100 µg/m³) at Manifolds 1 and 5. Dimethyl disulphide concentrations in the two aggregated samples collected at the SES flare and the Main GUP (at 430 and 550 µg/m³ respectively) are also within the default GasSim2 range.

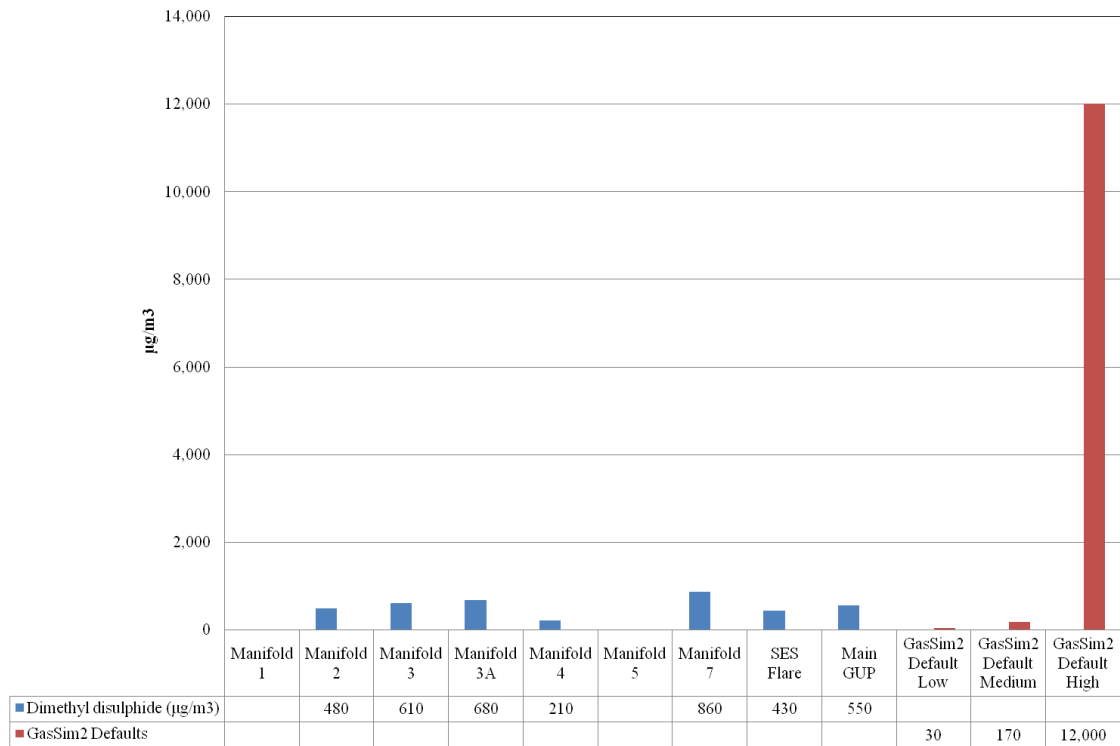


Figure 10: Measured Dimethyl Disulphide Concentrations and Comparison with GasSim2 Default Values.

5.3.4 Dimethyl Sulphide

Dimethyl sulphide has a reported odour threshold of 3.7 µg/m³ (Table A5.1 of *Environment Agency Guidance on Landfill Gas Flaring*, Version 2.1, 1999). Figure 11 shows that the highest measured dimethyl sulphide concentration (2,200 µg/m³) was observed at the Main GUP. Monitored concentrations of dimethyl sulphide were significantly lower at the Manifolds, ranging from below the detection limit (60 µg/m³) at Manifolds 1, 2 and 5 to 920 µg/m³ at Manifold 7.

Dimethyl sulphide concentrations in the two aggregated samples collected at the SES flare and the Main GUP (at 620 and 2,200 µg/m³ respectively) are also within the default GasSim2 range. It is not known why the concentration of dimethyl sulphide is significantly higher at the Main GUP than at the manifolds supplying it. Possible explanations include: significant dimethyl sulphide concentrations in the gas collected which was not collected via the gas manifolds e.g. from leachate towers and leachate side risers; or possibly from undetermined errors in the sample collection and laboratory analysis.

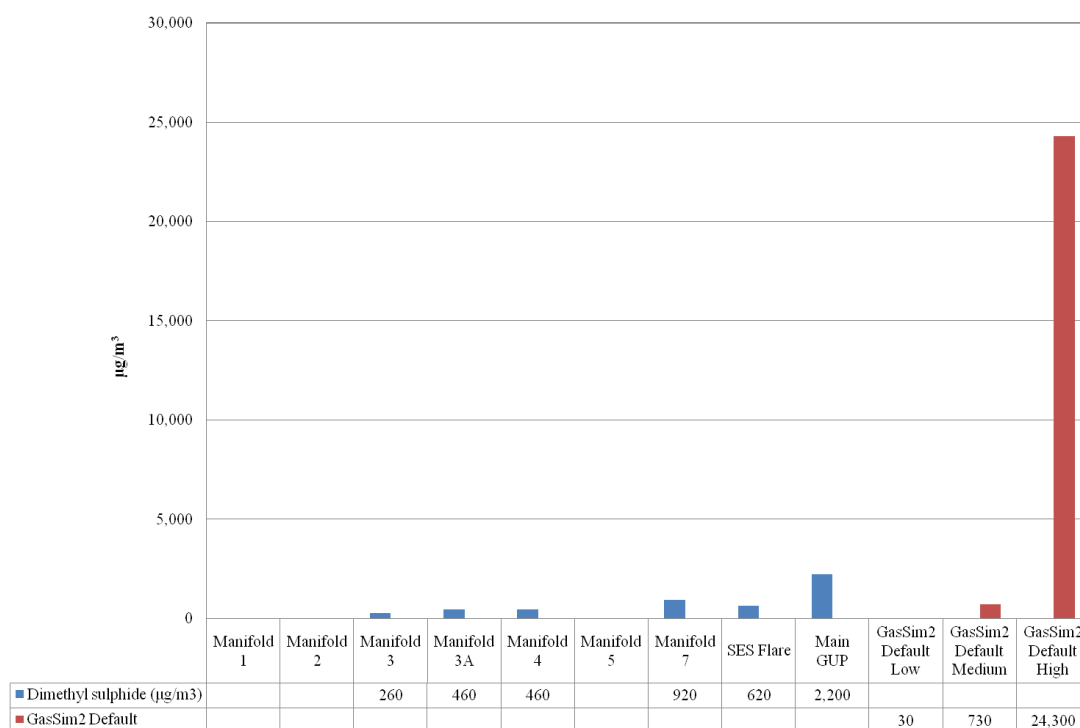


Figure 11: Measured Dimethyl Sulphide Concentrations and Comparison with Gassim2 Default Values.

5.3.5 Ethanal

Ethanal (acetaldehyde) has a reported odour threshold of 100 $\mu\text{g}/\text{m}^3$ (Table A5.1 of *Environment Agency Guidance on Landfill Gas Flaring*, Version 2.1, 1999). Figure 12 shows that the highest measured ethanal concentration (6,300 $\mu\text{g}/\text{m}^3$) occurred at Manifold 3. The lowest measured concentration (52 $\mu\text{g}/\text{m}^3$) occurred at Manifold 5. Ethanal concentrations at the manifolds (with the exception of Manifold 3) and the Main GUP are within the GasSim2 default range (750 to 2,546 $\mu\text{g}/\text{m}^3$). Ethanal concentrations in the two aggregated samples collected at the SES flare (4,400 $\mu\text{g}/\text{m}^3$) are higher than the default GasSim range.

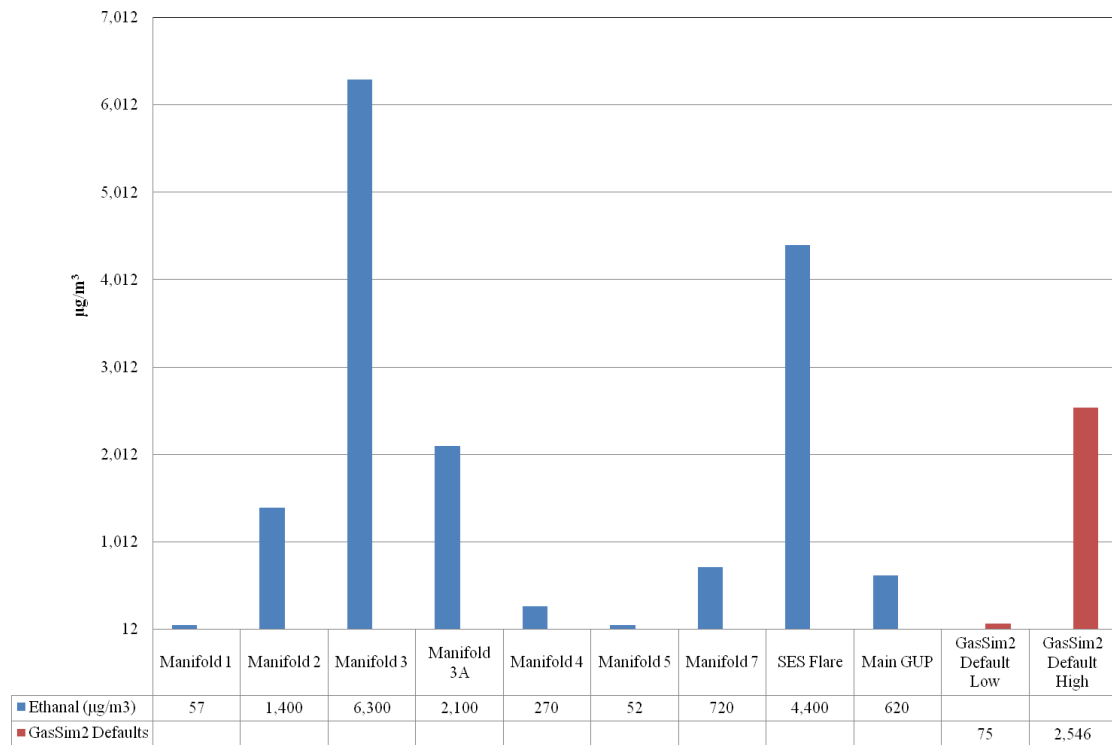


Figure 12: Measured Ethanal Concentrations and Comparison with GasSim2 Default Values.

5.3.6 Ethyl Butanoate

Ethyl butanoate (butyrate) has a reported odour threshold of 280 $\mu\text{g}/\text{m}^3$ (Table A5.1 of *Environment Agency Guidance on Landfill Gas Flaring*, Version 2.1, 1999). Figure 13 shows that the highest measured ethyl butanoate concentration (33,000 $\mu\text{g}/\text{m}^3$) occurred at the very recently installed Manifold 3A. The lowest measured concentration, below the detection limit of 60 $\mu\text{g}/\text{m}^3$, occurred at Manifold 5. All monitored concentrations of ethyl butanoate were within the GasSim2 default range (410 to 42,000 $\mu\text{g}/\text{m}^3$).

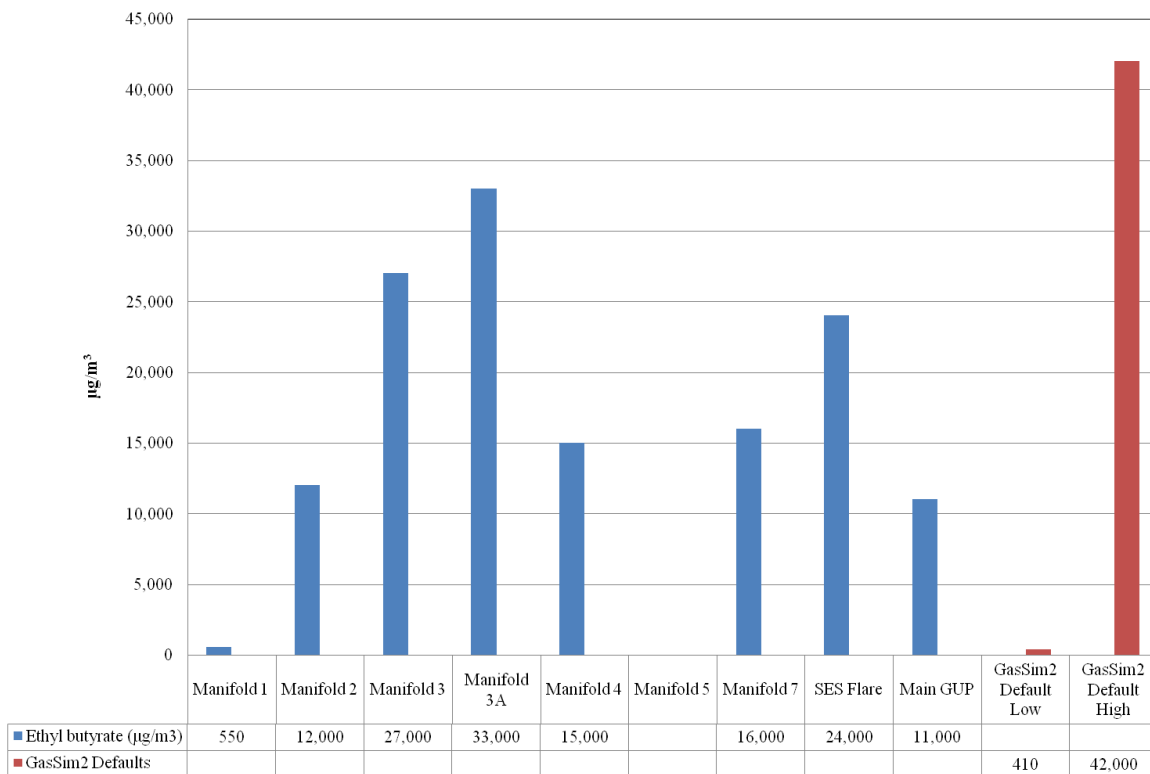


Figure 13: Measured Ethyl Butanoate Concentrations and Comparison with GasSim2 Default Values.

5.4 Trace Gases as Potential Odour Sources

The relative odour from a variety of potential sources may be conveniently assessed in terms of odour units. One odour unit may be defined as the odour threshold for a given compound. Table 6 shows the relative importance of the detected trace gases to the overall odour of the landfill gas collected at the Site. In each case the maximum monitored concentration of each trace gas together with the odour threshold is used to determine the number of odour units attributable to each. It should be noted that the determination of odour thresholds for highly odorous compounds is not straightforward and a wide range of values are quoted in the literature. The synergistic effects of multiple odorous sources has also not been considered in this assessment, but the dominant nature of the H₂S concentrations do confirm that H₂S is the dominant source of odour, accounting for over 99% of the identified potential sources of odour in the landfill gas generated at the Site.

Table 6: Relative contribution of Identified Trace Gases to Landfill Gas Odour.

Trace Component	Maximum Measured Concentration (µg/m ³)	Odour Threshold (µg/m ³)	Odour Units
H ₂ S	990,000	0.76	1,300,000
CS ₂	5,100	700	7.3
Pentene	450	600	0.75
Dimethyl Disulphide	860	4	215
Dimethyl Sulphide	2,200	3.7	595
Ethanal	6,300	100	63
Ethyl Butanoate	33,000	280	118

5.5 Trace Component Monitoring Trends

The results of the trace gas monitoring at the Site indicate that H₂S was identified as the dominant potentially odorous trace gas present in the collected landfill gas.

Historic gas monitoring data for ethyl butyrate, dimethyl sulphide, carbon disulphide, dimethyl disulphide, 1-pentene and ethanal monitoring data were available from 2006 onwards. Historic H₂S monitoring data was available from 2001. No historic trace gas monitoring has been undertaken at the individual gas manifolds.

A comparison of H₂S monitoring obtained in December 2008 at the Main GUP and the SES Flare are broadly consistent with the trace gas analyses undertaken by Biffa in 2007 and 2008. Concentrations of H₂S in the landfill gas appear to have generally increased since 2001, a feature which is occurring at a substantial number of non-hazardous UK landfills (Parker, 2008).

Monitored ethanal concentrations were also higher in December 2008 than in previous analyses. In contrast, the monitored concentrations of the remaining trace gases

(ethyl butyrate, dimethyl sulphide, carbon disulphide, dimethyl disulphide, and 1-pentene) were found to be generally lower in December 2008 than in previous analyses.

5.6 Summary

Sampling for and subsequent laboratory analysis of the species listed in the Environment Agency's Priority List of trace constituents of the landfill gas were undertaken in conjunction with the landfill gas audit. Sampling was undertaken by MCERTS accredited technicians and the collected samples analysed at UKAS-accredited laboratories. Gas samples were collected at seven manifold locations: Manifolds 1, 2, 3, 3a, 4, 5 and 7. Two aggregated samples were also collected at the SES flare and at the main GUP.

The monitored concentrations of five potentially odorous compounds (1-butanethiol, 1-propanethiol, ethanethiol, methanethiol and butyric acid) were found to be either close to or below to the Environment Agency's recommended detection limits at all monitored locations.

Six potentially odorous trace gases were identified at concentrations significantly above the detection limit: H₂S, CS₂, 1-pentene, dimethyl disulphide, dimethyl sulphide, ethanal and ethyl butanoate. Monitored concentrations of four of these trace components were present at concentrations within the GasSim2 default range, the exceptions being H₂S and ethanal. The maximum monitored concentrations of H₂S and ethanal at individual gas manifolds exceeded the maximum GasSim2 default concentration by approximately a factor of 2. In the case of H₂S, the aggregated samples collected at the Main GUP and the SES flare contained H₂S at concentrations within the GasSim2 default concentration range, because of integration of the various individual gas samples from each gas manifold.

Hydrogen sulphide was found to dominate the odorous trace components in the landfill gas at the Site.

In general, the highest trace component concentrations were observed in Manifold 3A and Manifold 7. These manifolds collect gas from areas of relatively recent waste placement and trace gas concentrations are frequently higher in recently placed wastes.

6.0 CONCLUSIONS

Golder has undertaken an assessment of the theoretical bulk gas generation at the Site. Four different gas generation models (zero-order spreadsheet, GasSim2, LandGEM and IPCC) have been used in the inter-comparison for 2008. The median gas generation rate of the 13 models included in the comparison was 3,707 m³/hr and the mean was 3,470 m³/hr. The Biffa supplied GasSim2 model forecasts a bulk gas generation rate of 3,800 m³/h in 2008. The range of model forecasts varied from fits well within the range of different model predictions and appears to be a reasonable forecast of the gas generation potential of the Site.

Monitored gas compositions generally show relatively high oxygen concentrations (2 to 5% v/v) at the gas utilisation compound. The differential pressure applied to the Site is generally high and there is no evidence of significant loss of extraction or clear points of air ingress across the system. The high applied differential pressures together with the high oxygen content of the collected gas are indicative of efforts to maximise collection of landfill gas.

Golder has determined that the gas collection efficiency of the Site by comparing actual volumes of gas collected with model forecasts for 2008. The gas collection efficiency of the Site was determined to be in the range 82.2% to 94.7%. Biffa's forecast of 89% gas collection efficiency is therefore considered by Golder to be reasonable. The gas collection efficiency achieved at the Site is higher than would normally be achieved on an operational landfill and is consistent with the Environment Agency's target of 85%.

Sampling for the species listed in the Environment Agency's Priority List was undertaken by MCERTS accredited staff with subsequent analysis at UKAS-accredited laboratories. Gas samples were collected at nine locations: seven manifolds and the two gas lines. Monitored concentrations of five potentially odorous compounds (1-butanethiol, 1-propanethiol, ethanethiol, methanethiol and butyric acid) were found to be either close to or below to the Environment Agency's recommended detection limits at all monitored locations.

Six potentially odorous trace gases were identified at concentrations significantly above the detection limit (H₂S, CS₂, 1-pentene, dimethyl disulphide, dimethyl sulphide, ethanal and ethyl butanoate). Hydrogen sulphide was found to dominate the odorous trace components in the landfill gas at the Site.

7.0 RECOMMENDATIONS

The gas collection efficiency is calculated to be higher than the Environment Agency's target of 85%, and this needs to be maintained using the current gas management techniques employed at the Site to manage the particularly challenging atmospheric drainage meteorological conditions which may occur at the Site.

The high applied differential pressures together with the high oxygen content of the collected gas are indicative of efforts to maximise collection of landfill gas. Biffa exceed the Agency's recommended oxygen limit on abstracted landfill gas (5% O₂ v/v) but this is managed effectively, and no change to this practice is recommended.

Of all the trace gas species present in varying concentrations across the Site, the dominant odorous trace component identified was H₂S. The highest monitored H₂S concentrations were observed to be present in the landfill gas collected from recently placed wastes. Therefore, in order to most effectively manage potential fugitive emissions of landfill gas which may lead to odour complaints, Biffa should continue to place particular emphasis on the collection of the gas generated from recently placed wastes at the Site.

Biffa currently undertake the following activities at the Site to maintain a high overall gas collection efficiency and management of recently placed wastes:

- Frequent (weekly) gas balancing at the Site to maintain a suction pressure on gas collection infrastructure in areas of recently placed waste which provides the maximum collection efficiency without unduly compromising the safety of operation of the gas system from excessive ingress of air;
- Installation of rigid plastic capping and associated gas collection infrastructure (whether sacrificial or permanent as appropriate) into areas of placed waste as soon as it is practicable to do so;
- Use a combination of active and engineered passive gas management technologies, in the form of sacrificial gas extraction techniques combined with application of daily cover in areas of recent waste placement where it is not considered practical to install rigid plastic capping;
- Maintain an operational area which is as small as is practicable to minimise fugitive emissions from newly placed waste; and
- Use sacrificial gas extraction in operational areas where there is considered to be no significant influence of the existing gas collection infrastructure on the gas generated where it is safe to do so.

Biffa should continue the current operational practices detailed above to ensure that fugitive emissions of landfill gas are minimised.

8.0 REFERENCES

1. Environmental Protection Agency, Ireland. *Landfill Manuals: Landfill Site Design*, Environmental Protection Agency, 2000. ISBN 1 84095 026 9.
2. IPCC, 2001: *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp. . ISBN 0521 80767 0.
3. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. , Volume 5: Waste.
4. GasSim2 User Manual: GasSim website. [http:// www.gassim.co.uk](http://www.gassim.co.uk)
5. Gregory, R. G., Manley, B. J. W. and Garner, N., Evaluation of National Assessment of Landfill Gas Production. ETSU contractors Report. ETSU, Oxfordshire, UK, 1991.
6. Environment Agency, *Guidance on Landfill Gas Flaring*, Version 2.1, 1999.
7. Environment Agency, *Guidance on the Management of Landfill Gas*, LFTGN03 Bristol, September 2004.
8. Guidance for monitoring trace components in landfill gas, LFTGN04, Bristol, September 2004.
9. Environment Agency, Draft Horizontal Guidance for Odour , IPPC H4 Part 1, Bristol, October 2002.
10. Environment Agency, Quantification of Trace Components in landfill Gas. R&D Technical Report P1-491/TR, 2004.
11. Parker, T. and Pointer, P., Trends and Assessment of Priority Trace Components, Proceedings of Waste 2008, 437, 16 – 17 September 2008.

APPENDICES

APPENDIX 1
BIFFA 'LEANOX' POLICY

Although it is highly unlikely but in the event of a catastrophic failure of the gas utilisation plant, Biffa Waste Services Ltd operate their gas utilisation plants to ensure that both the safety of the operation and the environment are paramount at all times. With this in mind, the gas utilisations plants have a series of protection levels installed and are summarised below.

Historical data has shown that during normal operation, the oxygen concentration value by volume of the gas being extracted from the landfill has been less than 5% v/v. When concentration levels have exceeded this threshold it is generally due to a component failure on site. An example being an electro fusion joint failure and the gas pipe being detached from the gas well or where mobile plant or vehicles have accidentally driven into a gas collection pipe.

PROTECTION LEVELS

Gas Generators - Leanox Control

1. Landfill gas generators are designed not to operate in LEL or HEL environments.
2. Landfill gas generators will trip on "leanox control" due to high levels of O₂% or low levels of CH₄% and cause the generator to automatically shut down.
3. All gas technicians operating the plants are part of a call out system.
4. Respective gas technician of the gas utilisation plant will be notified by a telephone and text message giving details of the trip.
5. Gas technician is also equipped with means of monitoring the gas plant remotely and will undertake his first investigation to determine the reason as to why the generator has tripped.
6. If the gas generator has tripped on leanox control, the landfill gas flares will automatically operate, as they are set up based on the volume of gas previously being extracted from site.
7. Call out technician attends to site and subject to day light hours being present, will attend to the gas manifolds to check gas qualities and pressures and check all condensate knock out pots are operating correctly.
8. Should a gas component failure be identified, the gas technician will either repair the failed component or isolate the gas well and/or gas line to prevent release to the environment and air being entrained into the gas system. If they are not able to carry out the repair they will notify a gas contractor to mobilise to site.
9. Gas technician will check gas quality, pressures and flow back at the gas utilisation compound and providing all is within its parameters will restart the gas generators.

Landfill Gas Flare Failure

There are a number of safety features that are built into all the flare plants to ensure safe operation when operating variable gas concentrations. On the basis of the above scenario and whereby the gas generators are unable to restart due to high levels of O₂% or low levels of CH₄% the flares will be in operation to ensure that the control of landfill gas from site is still being maintained in accordance with the site permit and relevant guidance.

In the event of a flare failure the following safety features are in place:

1. Flares are designed to re-ignite three times before it shuts down completely. NB: *On a complete "shut down" the slam shut valve will operate and close the gas inlet line to prevent any landfill gas from site flowing through the header pipe to release within the gas compound.*

2. If the flare fails to ignite, the gas technician will be notified by telephone and text message.
3. The following failure features are generally all incorporated within the flares, these being high temperature failure, blower failure, ignition/flame fail sensor failure and high level condensate failure.
4. Gas technicians on site will be able to carry out further investigations on the understanding that the flare has failed on one or more of the above.
5. If high levels of oxygen have been identified on the static gas analysers within the gas compound the gas technician will attend to site as per item 8 above.
6. Post repair; the gas technician will operate and run the flare and will check gas qualities, pressures and flows in addition to the set points on the flare, such as temperature, flame fail/ignition sensors and blower signals.
7. To prevent any possibilities of a "flash back" in the gas header lines, the flares are all equipped with "flame arresters". These arresters prevent any ignition of gas igniting and travelling through the gas header lines back towards the blowers.
8. The slam shut valve that is fitted will remain closed until such a point when the flame sensor unit has established a strong signal confirming that the pilot light has lit. After a period of time and providing a strong signal is still being received, the "slam shut" valve will open confirming that the flare is in operation.
9. Gas technicians will continue to monitor delivery and suction pressures, gas qualities, and temperatures and gas flow until it all stabilises at their respective set points.
10. On some circumstances, non-ignition of flares has occurred to which either the gas volumes and qualities are extremely low or an electrical/mechanical component has failed. Biffa have flare engineers on standby at all times who stock key components and in addition, they have a flare contractor available on call out at short notice.

APPENDIX 2
CPL TRACE GAS MONITORING REPORT

TEST REPORT




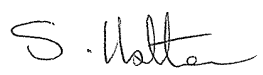
CONFIDENTIAL

Client Organisation: Golder Associates (UK) Ltd.
Address: Attenborough House
Browns Lane Business Park
Stanton – on – the Wolds
Nottinghamshire
NG12 5BL

Monitoring Organisation: CPL Laboratories
Address: Mill Lane
Wingerworth
Chesterfield
S42 6NG

Date of Report: 23rd January 2009

Report Author: 
.....
O. Warhurst
Environmental Scientist

Report Approved by: 
.....
S.Hatton
Team Leader (Landfill)

THIS PAGE IS INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Mr. S. Davies, Golder Associates, commissioned CPL Laboratories to monitor the levels of bulk gases and selected trace inorganic and organic compounds at a number of locations on Trecatti Landfill Site, South Wales.

This monitoring was carried out at 9 strategic locations as directed by Mr. Davies, Golder Associates, during the monitoring campaign.

S. Hatton and O. Warhurst carried out the monitoring on the 18th December 2008. Monitoring comprised the determination of bulk gases and priority trace components priority detailed in current Environment Agency Guidance Document LFTGN04.

The investigation yielded the following salient information:-

A wide variety of trace species was found to be present across the site.

THIS PAGE IS INTENTIONALLY LEFT BLANK

1 INTRODUCTION

- 1.1 Mr. S. Davies, Golder Associates, commissioned CPL Laboratories to monitor the levels of bulk gases and selected trace inorganic and organic compounds at a number of locations on Trecatti Landfill Site, South Wales.
- 1.2 This monitoring was carried out at 9 strategic locations as directed by Mr. Davies, Golder Associates, during the monitoring campaign.
- 1.3 S. Hatton and O. Warhurst carried out the monitoring on the 18th December 2008. Monitoring comprised the determination of bulk gases and priority trace components priority detailed in current Environment Agency Guidance Document LFTGN04.

2 SAMPLING PROCEDURE

- 2.1 Table 10 summarises the techniques used during this campaign.

3 RESULTS

- 3.1 The results of the monitoring and analysis are summarised in the Tables 1 to 9.

4 DISCUSSION OF RESULTS

- 4.1 Manifolds 1 and 5 were demonstrated to contain the lowest amount of trace compounds in general (Tables 1 to 9).
- 4.2 Manifold 3 was demonstrated to contain the highest amount trace compounds in general (Tables 1 to 9).
- 4.3 There was an increase in the limit of detection of 1,3-butadiene during the analysis. This was due to uncharacteristic spectral occurrences, which essentially prevented unequivocal identification.

5 CONCLUSIONS

- 5.1 A wide variety of trace species was found to be present across the site.

6 DISCLAIMERS

- 6.1 Any interpretations and opinions expressed herein are outside of CPL Laboratories UKAS accreditation under ISO 17025.
- 6.2 Any subcontract laboratories used in this study will be clearly identified.
- 6.3 Any non-accredited tests will be marked with an asterisk.

TABLE 1 MONITORING RESULTS AND SITE INFORMATION

Site: Trecatti Landfill
Monitoring location: Manifold 1
Date: 18/12/08
Time: 11:05 to 11:38
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 – dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	7.71	N/A	7.71
Methane	%	34.84	N/A	34.84
Carbon dioxide	%	17.98	N/A	17.98
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	180	N/A	180
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	65	N/A	65
1-pentene	$\mu\text{g}/\text{m}^3$	130	N/A	130
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	0.56	N/A	0.56
Benzene	$\mu\text{g}/\text{m}^3$	2,700	N/A	2,700
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Chloroethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Chloroethene	$\mu\text{g}/\text{m}^3$	460	N/A	460
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Ethanal	$\mu\text{g}/\text{m}^3$	57	N/A	57
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	550	N/A	550
Furan	$\mu\text{g}/\text{m}^3$	180	N/A	180
Hydrogen sulphide	mg/m^3	98	N/A	98
Methanal	$\mu\text{g}/\text{m}^3$	65	N/A	65
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	180	N/A	180

TABLE 2

MONITORING RESULTS AND SITE INFORMATION

Site: Trecatti Landfill
Monitoring location: Manifold 2
Date: 18/12/08
Time: 11:40 to 12:15
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 – dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	3.1	N/A	3.1
Methane	%	45.5	N/A	45.5
Carbon dioxide	%	24.4	N/A	24.4
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	180	N/A	180
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	62	N/A	62
1-pentene	$\mu\text{g}/\text{m}^3$	160	N/A	160
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	0.74	N/A	0.74
Benzene	$\mu\text{g}/\text{m}^3$	1,300	N/A	1,300
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	1,200	N/A	1,200
Chloroethane	$\mu\text{g}/\text{m}^3$	100	N/A	100
Chloroethene	$\mu\text{g}/\text{m}^3$	280	N/A	280
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	480	N/A	480
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Ethanal	$\mu\text{g}/\text{m}^3$	1,400	N/A	1,400
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	12,000	N/A	12,000
Furan	$\mu\text{g}/\text{m}^3$	190	N/A	190
Hydrogen sulphide	mg/m^3	180	N/A	180
Methanal	$\mu\text{g}/\text{m}^3$	92	N/A	92
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	330	N/A	330

TABLE 3**MONITORING RESULTS AND SITE INFORMATION**

Site: Trecatti Landfill
Monitoring location: Manifold 3
Date: 18/12/08
Time: 12:18 to 12:46
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 – dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	6.7	N/A	6.7
Methane	%	39.8	N/A	39.8
Carbon dioxide	%	23.6	N/A	23.6
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	160	N/A	160
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	950	N/A	950
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1-pentene	$\mu\text{g}/\text{m}^3$	400	N/A	400
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	0.46	N/A	0.46
Benzene	$\mu\text{g}/\text{m}^3$	5,500	N/A	5,500
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	3,600	N/A	3,600
Chloroethane	$\mu\text{g}/\text{m}^3$	280	N/A	280
Chloroethene	$\mu\text{g}/\text{m}^3$	950	N/A	950
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	610	N/A	610
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	260	N/A	260
Ethanal	$\mu\text{g}/\text{m}^3$	6,300	N/A	6,300
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	27,000	N/A	27,000
Furan	$\mu\text{g}/\text{m}^3$	2,100	N/A	2,100
Hydrogen sulphide	mg/m^3	93	N/A	93
Methanal	$\mu\text{g}/\text{m}^3$	140	N/A	140
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	890	N/A	890

TABLE 4**MONITORING RESULTS AND SITE INFORMATION**

Site: Trecatti Landfill
Monitoring location: Manifold 3A
Date: 18/12/08
Time: 12:47 to 13:11
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 – dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	5.7	N/A	5.7
Methane	%	44.3	N/A	44.3
Carbon dioxide	%	26.6	N/A	26.6
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	380	N/A	380
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	75	N/A	75
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	1,200	N/A	1,200
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	81	N/A	81
1-pentene	$\mu\text{g}/\text{m}^3$	450	N/A	450
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	1.0	N/A	1.0
Benzene	$\mu\text{g}/\text{m}^3$	2,500	N/A	2,500
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Carbon disulphide	$\mu\text{g}/\text{m}^3$	5,100	N/A	5,100
Chloroethane	$\mu\text{g}/\text{m}^3$	1,100	N/A	1,100
Chloroethene	$\mu\text{g}/\text{m}^3$	1,100	N/A	1,100
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	680	N/A	680
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	460	N/A	460
Ethanal	$\mu\text{g}/\text{m}^3$	2,100	N/A	2,100
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	33,000	N/A	33,000
Furan	$\mu\text{g}/\text{m}^3$	220	N/A	220
Hydrogen sulphide	mg/m^3	990	N/A	990
Methanal	$\mu\text{g}/\text{m}^3$	250	N/A	250
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	9,500	N/A	9,500

TABLE 5

MONITORING RESULTS AND SITE INFORMATION

Site: Trecatti Landfill
Monitoring location: Manifold 4
Date: 18/12/08
Time: 13:12 to 13:30
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 - dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	6.3	N/A	6.3
Methane	%	40.0	N/A	40.0
Carbon dioxide	%	23.0	N/A	23.0
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	360	N/A	360
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	1,900	N/A	1,900
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1-pentene	$\mu\text{g}/\text{m}^3$	270	N/A	270
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	0.56	N/A	0.56
Benzene	$\mu\text{g}/\text{m}^3$	1,900	N/A	1,900
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	1,700	N/A	1,700
Chloroethane	$\mu\text{g}/\text{m}^3$	1,000	N/A	1,000
Chloroethene	$\mu\text{g}/\text{m}^3$	2,100	N/A	2,100
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	210	N/A	210
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	460	N/A	460
Ethanal	$\mu\text{g}/\text{m}^3$	270	N/A	270
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	15,000	N/A	15,000
Furan	$\mu\text{g}/\text{m}^3$	200	N/A	200
Hydrogen sulphide	mg/m^3	160	N/A	160
Methanal	$\mu\text{g}/\text{m}^3$	290	N/A	290
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	3,900	N/A	3,900

TABLE 6**MONITORING RESULTS AND SITE INFORMATION**

Site: Trecatti Landfill
Monitoring location: Manifold 5
Date: 18/12/08
Time: 09:40 to 10:18
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 – dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	7.5	N/A	7.5
Methane	%	40.4	N/A	40.4
Carbon dioxide	%	20.3	N/A	20.3
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	170	N/A	170
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1-pentene	$\mu\text{g}/\text{m}^3$	150	N/A	150
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	0.56	N/A	0.56
Benzene	$\mu\text{g}/\text{m}^3$	4,100	N/A	4,100
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Chloroethane	$\mu\text{g}/\text{m}^3$	150	N/A	150
Chloroethene	$\mu\text{g}/\text{m}^3$	520	N/A	520
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Ethanal	$\mu\text{g}/\text{m}^3$	52	N/A	52
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Furan	$\mu\text{g}/\text{m}^3$	170	N/A	170
Hydrogen sulphide	mg/m^3	53	N/A	53
Methanal	$\mu\text{g}/\text{m}^3$	72	N/A	72
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	180	N/A	180

TABLE 7

MONITORING RESULTS AND SITE INFORMATION

Site: Trecatti Landfill
Monitoring location: Manifold 7
Date: 18/12/08
Time: 10:30 to 11:00
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 - dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	0.1	N/A	0.1
Oxygen	%	4.4	N/A	4.4
Methane	%	44.1	N/A	44.1
Carbon dioxide	%	24.2	N/A	24.2
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	84	N/A	84
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	540	N/A	540
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1-pentene	$\mu\text{g}/\text{m}^3$	150	N/A	150
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	10	N/A	10
Benzene	$\mu\text{g}/\text{m}^3$	2,800	N/A	2,800
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Carbon disulphide	$\mu\text{g}/\text{m}^3$	3,000	N/A	3,000
Chloroethane	$\mu\text{g}/\text{m}^3$	260	N/A	260
Chloroethene	$\mu\text{g}/\text{m}^3$	330	N/A	330
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	860	N/A	860
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	920	N/A	920
Ethanal	$\mu\text{g}/\text{m}^3$	720	N/A	720
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	16,000	N/A	16,000
Furan	$\mu\text{g}/\text{m}^3$	290	N/A	290
Hydrogen sulphide	mg/m^3	790	N/A	790
Methanal	$\mu\text{g}/\text{m}^3$	75	N/A	75
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	4,200	N/A	4,200

TABLE 8**MONITORING RESULTS AND SITE INFORMATION**

Site: Trecatti Landfill
Monitoring location: SES Flare Inlet
Date: 18/12/08
Time: 13:44 to 14:08
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 - dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	6.6	N/A	6.6
Methane	%	41.0	N/A	41.0
Carbon dioxide	%	22.9	N/A	22.9
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	100	N/A	100
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	1,200	N/A	1,200
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	420	N/A	420
1-pentene	$\mu\text{g}/\text{m}^3$	330	N/A	330
1-propanethiol	$\mu\text{g}/\text{m}^3$	180	N/A	180
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	< 0.001	N/A	< 0.001
Benzene	$\mu\text{g}/\text{m}^3$	4,200	N/A	4,200
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	960	N/A	960
Chloroethane	$\mu\text{g}/\text{m}^3$	100	N/A	100
Chloroethene	$\mu\text{g}/\text{m}^3$	420	N/A	420
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	430	N/A	430
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	620	N/A	620
Ethanal	$\mu\text{g}/\text{m}^3$	4,400	N/A	4,400
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	24,000	N/A	24,000
Furan	$\mu\text{g}/\text{m}^3$	430	N/A	430
Hydrogen sulphide	mg/m^3	170	N/A	170
Methanal	$\mu\text{g}/\text{m}^3$	190	N/A	190
Methanethiol	$\mu\text{g}/\text{m}^3$	< 600	N/A	< 600
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	160	N/A	160
Trichloroethene	$\mu\text{g}/\text{m}^3$	2,500	N/A	2,500

TABLE 9**MONITORING RESULTS AND SITE INFORMATION**

Site: Trecatti Landfill
Monitoring location: Engine Compound Inlet
Date: 18/12/08
Time: 14:30 to 15:03
Barometric Pressure: 97.6 kPa
Ambient temperature: 8 °C
Reference conditions: $\mu\text{g}/\text{m}^3$ - 273K, 101.3 kPa, without moisture correction; % and mg/m^3 - dry

Determinand		Test 1	Test 2	Mean
Hydrogen	%	< 0.1	N/A	< 0.1
Oxygen	%	7.0	N/A	7.0
Methane	%	42.2	N/A	42.2
Carbon dioxide	%	22.8	N/A	22.8
1,1-dichloroethane	$\mu\text{g}/\text{m}^3$	110	N/A	110
1,1-dichloroethene	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1,2-dichloroethene	$\mu\text{g}/\text{m}^3$	1,200	N/A	1,200
1,3-butadiene	$\mu\text{g}/\text{m}^3$	< 400	N/A	< 400
1-butanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
1-pentene	$\mu\text{g}/\text{m}^3$	140	N/A	140
1-propanethiol	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
2-butoxy ethanol	$\mu\text{g}/\text{m}^3$	< 120	N/A	< 120
Arsenic *	$\mu\text{g}/\text{m}^3$	10	N/A	10
Benzene	$\mu\text{g}/\text{m}^3$	6,800	N/A	6,800
Butyric acid *	$\mu\text{g}/\text{m}^3$	< 100	N/A	< 100
Carbon disulphide	$\mu\text{g}/\text{m}^3$	2,500	N/A	2,500
Chloroethane	$\mu\text{g}/\text{m}^3$	200	N/A	200
Chloroethene	$\mu\text{g}/\text{m}^3$	580	N/A	580
Dimethyl disulphide	$\mu\text{g}/\text{m}^3$	550	N/A	550
Dimethyl sulphide	$\mu\text{g}/\text{m}^3$	2,200	N/A	2,200
Ethanal	$\mu\text{g}/\text{m}^3$	620	N/A	620
Ethanethiol	$\mu\text{g}/\text{m}^3$	< 180	N/A	< 180
Ethyl butyrate	$\mu\text{g}/\text{m}^3$	11,000	N/A	11,000
Furan	$\mu\text{g}/\text{m}^3$	500	N/A	500
Hydrogen sulphide	mg/m^3	410	N/A	410
Methanal	$\mu\text{g}/\text{m}^3$	120	N/A	120
Methanethiol	$\mu\text{g}/\text{m}^3$	680	N/A	680
Tetrachloromethane	$\mu\text{g}/\text{m}^3$	< 60	N/A	< 60
Trichloroethene	$\mu\text{g}/\text{m}^3$	2,700	N/A	2,700

TABLE 10 MONITORING METHODS

Determinand	Reference Method	UKAS No.	CPL Procedure No.	Summary of Procedure
Bulk Gases	BS 3156	1618	AM001	Gresham tubes, GC/TCD
Arsenic	BS EN 13649 (S) NIOSH 6001 (A)	1618 (S only)	ST13	Carbon tubes, AAS
Aldehydes	BS EN 13649 (S) NIOSH 2539 (A)	1618 and 1015	ST13	DNPH tubes, HPLC
Hydrogen Sulphide	BS 3156	1618	AM001	Iodimetry
VOCs	BS EN 13649	1618 and 0013	ST13	ATD tubes, GC/MS

COMMENTS

VOCs analysis conducted at Ceram, Stoke

Aldehydes analysis conducted at Scientifics, Harwell

X END OF REPORT X