

www.environment-agency.gov.uk

Quantification of trace components in landfill gas



**ENVIRONMENT
AGENCY**

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:

Environment Agency, Rio House, Waterside Drive, Aztec West,
Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

ISBN: 184432 397 8

© Environment Agency

March 2005

All rights reserved. This document may be reproduced with prior permission of the Environment Agency.

The views expressed in this document are not necessarily those of the Environment Agency.

This report is printed on Cyclus Print, a 100% recycled stock, which is 100% post consumer waste and is totally chlorine free. Water used is treated and in most cases returned to source in better condition than removed.

Further copies of this report are available from:
The Environment Agency's National Customer Contact Centre by emailing enquiries@environment-agency.gov.uk or by telephoning 08708 506506.

Author(s):

T. Parker, J. Hillier, S. Kelly and S. O'Leary

Dissemination Status:

Publicly available

Keywords:

Landfill gas, trace components, analytical techniques and sampling techniques

Research Contractor:

Komex and Harwell Scientifics

Environment Agency's Project Manager:

Alan Rosevear, Science Group, Head Office
e-mail: alan.rosevear@environment-agency.gov.uk

Environment Agency Project Board:

Jan Gronow, Science Group, Head Office
Peter Braithwaite, Science Group, Head Office
Chris Deed, Waste Policy, Head Office

Science Project Number:

P1-491

Product Code:

SCHO0305BIUR-E-P

Executive Summary

This project continued the work initiated in R&D Project P1-438 on developing and using suitable monitoring methods for priority trace components of landfill gas. The gas at six typical UK landfills was sampled on two occasions. The sites were designated according to the significant waste stream:

- codisposal
- mainly domestic (with leachate)
- mainly domestic (little leachate)
- substantial ash
- substantial fragmentiser waste
- commercial & industrial (non hazardous)

Gas was sampled from the main gas collection system at each site. In addition, at three sites, gas from cells containing relatively recent and relatively old waste was also sampled and gas from a leachate well was sampled.

The analytical results have been added to the UK database of trace component concentrations. Method refinements made during this monitoring programme were included in the latest *Guidance for monitoring trace components in landfill gas* and the results have been compiled into a datafile suitable for use in the GasSim risk assessment modelling tool.

One hundred and fifty-five samples were taken from 15 sampling locations at 6 different landfill sites, primarily targeting the 25 priority compounds of interest identified in R&D Project P1-438. Monitoring programmes took place in 2002 and 2003.

Monitoring methodology

- The basic techniques recommended in R&D Project P1-438 were used successfully. An important refinement in analysis during the 2003 monitoring was the use of a dry nitrogen purge to reduce the effect of moisture on the Automated Thermal Desorption (ATD) tubes. Another important change was the use of lower sampling volumes to avoid overloading of the sorption tubes. These factors improved the recovery of less strongly bound substances such as chloroethene. The ATD columns were found to give adequate quantification of butyric acid and so the specialist column proposed for this acid was not needed. The importance of using sorbents with a low background level for mercury was emphasised.
- During the 2003 monitoring, Tedlar bag samples were analysed for the purposes of assessing screening tests. The quantification of priority organo-chlorine and sulphonated compounds from Tedlar bag samples is poor compared with the ATD method, generally under reporting concentrations.
- The concentration of hydrogen sulphide is often outside the measurable range of accurate field instruments. Where this occurs it is recommended that a Tedlar bag sample should be sent to a laboratory for analysis of the hydrogen sulphide concentration.
- Field instruments give inconsistent results for the concentration of carbon monoxide in raw landfill gas and may over-report this trace component significantly. If an accurate quantification of carbon monoxide is necessary, then Tedlar bag samples need to be taken and analysed at a laboratory by means other than electrochemical cells.

Concentration of priority trace components

The data obtained in 2003 with the improved monitoring methodology are regarded as most representative, with the exception of the mercury measurements where the low background tubes used in 2002 were more reliable. Data on the concentration of the priority trace components in the gas at the six landfills, using the preferred methodologies, is summarised in the table below.

Priority Compound	Method	(mg/m ³)				
		Detection Limit	Min	Max	Mean	Change in conc ⁿ from P1-438 data mean to P1-491 mean
1,1-dichloroethane	ATD	0.02	<0.02	3.90	0.57	-477
1,1-dichloroethene	ATD	0.03	<0.03	19.00	2.24	+2.1
1,2-dichloroethene [#]	ATD	0.07	0.13	46.00	5.71	-10.5
1,3-butadiene	ATD	0.02	<0.02	<0.02	<0.02	-0.11
1-butanethiol	ATD	0.08	<0.08	<0.08	<0.08	->0.09
1-pentene	ATD	0.16	0.24	21.00	5.49	+3.8
1-propanethiol	ATD	0.04	<0.04	0.09	<0.05	-0.43
2-butoxy ethanol	ATD	0.04	<0.04	<0.05	<0.05	No change / -
Arsenic	Arsenic Tube	0.00004	0.0006	0.4300	0.0511	+0.047
Benzene	ATD	0.03	3.1	73.0	18.4	+13.5
Butyric acid	ATD	0.08	<0.08	17.50	1.85	-7
Carbon disulphide	ATD	0.1	0.9	170.0	34.0	+34
Chloroethane	ATD	0.02	<0.02	5.30	0.49	-76.4
Chloroethene	ATD	0.3	1.1	730.0	102.1	+35.7
Dimethyl disulphide	ATD	0.03	<0.03	12.00	1.02	+1.0
Dimethyl sulphide	ATD	0.03	<0.03	24.30	3.69	->0.37
Ethanal	DNPH	0.012	0.075	2.546	0.431	-2.6
Ethanethiol	ATD	0.08	<0.08	<0.08	<0.08	No change
Ethyl butyrate	ATD	0.09	0.41	42.00	7.22	-25.7
Furan	ATD	0.07	0.02	6.20	1.23	+0.5
Hydrogen sulphide	Lab GC	0.15	2.4	580.0	111.1	No change
Mercury *	Mercury tube	0.0005	0.00017	0.00133	0.00058	-0.0035
Methanal	DNPH	0.012	0.026	0.188	0.070	-2.9
Methanethiol	ATD	0.3	<0.3	<0.3	<0.3	->6
Tetrachloromethane	ATD	0.02	<0.02	<0.02	<0.02	->5.2
Trichloroethene	ATD	0.04	0.25	88.00	8.59	-6.4

[#] *cis* and *trans* isomers combined

* all data were obtained in 2003 except mercury, which was from 2002 with low background tube

No definitive temporal or spatial effects could be inferred from the data, particularly since there were changes in methodology between 2002 and 2003. Nor were there obvious patterns that might be used as fingerprints for gas from particular waste types. However, a number of trends were noted and are summarised below.

- **Arsenic** - Recent waste appears to be the main source of gas containing arsenic. There were differences of up to an order of magnitude in concentration between the two sampling periods.
- **Halogenated volatile organic compounds (HVOCs)** - Concentrations in the 'typical' landfill sites were below the average concentrations in the database produced during R&D Project P1-438. The exception was chloroethene (vinyl chloride), which was detected at higher concentrations using the analytical method refinements implemented in 2003. Tetrachloromethane was not detected in any of the samples, suggesting that data within the database may be biased towards sites where halogenated VOCs are more common.
- **Oxygenated VOCs** - Butoxy ethanol was found in higher concentrations in recent waste samples in 2002, but was not detected at any sampling location in 2003. Ethyl butyrate was

detected in all samples. Butyric acid is difficult to quantify and although the ATD method was adequate there was only a marginal improvement in quantification.

- *Sulphonated VOCs* - There are relatively few differences in sulphonated VOC composition between the waste types. Older waste has higher carbon disulphide and methanethiol concentrations. Methanethiol and ethanethiol were not detected at any sampling location during the 2003 monitoring and 1-propanethiol was not detected as frequently in 2003 monitoring.
- *Hydrogen Sulphide* - This was found in similar concentrations in both 2002 and 2003 at most sample locations. It is tentatively concluded that hydrogen sulphide concentration in the source raw gas does not in general show temporal variation over the period of a year. Hydrogen sulphide was detected at the highest concentrations in recent waste.
- *1-pentene* - The main gas samples universally exhibited the highest concentrations and the mature waste generally contained the lowest concentrations, with the exception of the substantial-ash waste.
- *Benzene* - There were no apparent trends between different waste types. Higher concentrations of benzene were detected during the 2003 monitoring event. This is probably a consequence of the improved analytical technique rather than temporal variation.
- *Poly-Chlorinated-Dibenzo-Dioxins and -Furans (PCDDs and PCDFs)* - No reliable detection's of the toxic PCDDs or PCDFs were made in either the 2002 or 2003 monitoring event. Some trace detection's of non-toxic PCDDs and PCDFs were recorded.

Relative priorities

- Using the current data, the prioritisation exercise undertaken in Project P1-438 was repeated. From a toxicological viewpoint, the existing priority list remains the same, except for mercury.
- There are now sufficient data to demonstrate that mercury is not present in significant amounts and does not warrant inclusion on the main priority list. The data confirmed the earlier conclusion that PCDDs and PCDFs are not present in significant amounts and do not warrant inclusion on the main priority list of trace components in landfill gas.
- Although chloroethene, benzene, furan and carbon disulphide were detected in higher concentrations than the existing database average, the majority of compounds on the toxicological list were at lower concentration. Where higher concentrations were found this is thought to result from the improved monitoring methodology used in this project. Most of the priority compounds found at a lower concentration than in the database are chlorinated compounds. This may be because this project sampled 'typical' landfill gas, whereas many previous studies were concerned with landfill gas at sites with particular problems.
- From an odour perspective, the existing priority list remains the same. Although there has been some rearrangement of the order of priority, in general, measured concentrations in this R&D Project P1-491 were close to the previous P1-438 database averages.

Contents

1	Introduction	8
1.1	Background to the project	8
1.2	Objectives	8
1.3	Issues associated with trace components in landfill gas	8
1.4	Potential sources of trace components	8
1.5	Report contents	9
2	Review of priority substances and sampling/analytical methodology	10
2.1	Determination of sites and individual sampling locations	10
2.2	Sampling and analytical methodologies	10
2.3	Sampling method	11
2.3.1	Sampling	11
2.3.2	Equipment	12
2.3.3	Sampling adsorbent choice	12
2.4	Sampling matrix	13
2.4.1	Type A sampling	14
2.4.2	Type B sampling	14
2.5	Analytical methods	14
2.5.1	Total mercury method	14
2.5.2	Total inorganic arsenic method	15
2.5.3	VOC method	15
2.5.4	Aldehyde (methanal & ethanal) method	16
2.5.5	Butyric acid method	16
2.5.6	Hydrogen sulphide and carbon monoxide	16
2.5.7	Polychlorinated dibenzo – dioxin and furan method	16
3	Results of 2002 monitoring	17
3.1	Field results and discussion	17
3.1.1	Field variations to sampling method	18
3.2	Inorganic laboratory results and discussion	18
3.2.1	Mercury results	18
3.2.2	Arsenic results	19
3.3	Organic laboratory results and discussion	21
3.3.1	Aldehyde compound results	21
3.3.2	VOC compound results	22
3.3.3	Oxygenated VOCs	27
3.3.4	Sulphonated VOCs and hydrogen sulphide	28
3.3.5	Aliphatic VOCs	29
3.3.6	Aromatic VOCs	29
3.3.7	PCDD/PCDF results	30
3.4	Summary of 2002 monitoring programme	30
4	Results of 2003 monitoring	31
4.1	Sampling and analytical methods	31
4.1.1	Variations to sampling methodology in 2003	31
4.1.2	Variation of bulk gas sampling methodology	31
4.1.3	Variations in equipment	32
4.1.4	Variations in sampling adsorbent and total mercury analytical method	32
4.1.5	Variations in VOC sampling and analytical method	32
4.2	Field results and discussion	32
4.3	Inorganic laboratory results and discussion	34
4.3.1	Mercury results	35
4.3.2	Arsenic results	36
4.4	Organic laboratory results and discussion	38
4.4.1	Carbonyl compound results	38

4.4.2	VOC results	40
4.4.3	Halogenated VOCs (HVOCs)	40
4.4.4	Oxygenated VOCs	43
4.4.5	Sulphonated VOCs and hydrogen sulphide	44
4.4.6	Aliphatic VOCs	46
4.4.7	Aromatic VOCs	46
4.4.8	Assessment of optimum sample volumes for the bulk analysis of VOCs	47
4.4.9	Assessment of PCDD/PCDF results in context of sampling/analytical methods	48
4.5	Summary of 2003 monitoring programme	49
4.6	Comparison of 2003 and 2002 data	50
5	Reassessment of trace component prioritisation using new data	51
5.1	Revised toxicology list	51
5.2	Revised odour list	52
5.3	Summary	53
6	Database and GasSim input	54
6.1	Distribution of priority trace components	54
6.1.1	Selection of data	54
6.1.2	Units and limitations	54
6.1.3	Probability Density Functions	55
6.2	Distribution of priority trace components for different waste types	55
6.3	Distribution of priority trace components in a 'typical' UK landfill	56
7	Potential screening methods	58
7.1	Potential screening tests	58
7.2	Potential sampling methods	58
7.2.1	Bulk gas samples	58
7.2.2	Adsorption methods	59
7.3	Potential analytical methods	59
7.3.1	Laboratory analysis	59
7.3.2	Portable analytical equipment	60
7.4	Comparison of screening data	60
7.4.1	Comparison of results from dual sorbent ATD-GC-MS and Tedlar bag PT-GC-MS sampling methods	60
7.4.2	Comparison of results from ATD tube and direct injection GC-MS	62
7.5	Summary of screening test comparisons	64
8	Conclusions	66
9	References	68
	Appendix 1: 2002 monitoring field data	69
	Appendix 2: 2002 monitoring laboratory data	71
	Appendix 3: 2003 monitoring data	96
	Appendix 4: Statistical distribution of priority trace components for different waste types	127
	Appendix 5: Screen test comparison	128

1 Introduction

1.1 Background to the project

Much previous research into landfill gas emissions has focussed on the bulk constituents such as methane and carbon dioxide. A previous project, R&D Project P1-438, investigated the variability of the trace component composition of the source term in landfill gas (Environment Agency, 2002a). A review of publicly available data on trace components of landfill gas concluded that most of the published UK data had been gathered at 'problem' sites likely to generate gas with relatively high concentrations of a wide range of trace components. This subsequently skewed the available dataset towards worst case conditions. It was also concluded that earlier studies had focused on particular groups of compounds and generally had not assessed the full spectrum of trace components that may be present in an individual sample.

In the previous research project, a method of assessing the potential toxicological and odour importance of trace components in landfill gas was also derived. The potential odour and toxicological importance ranking scores were combined with a range of measured landfill gas component concentrations taken from the database to derive a potential significance 'score'. This score was used to prioritise the landfill gas components relative to one another and led to the selection of a relatively small suite of sampling and analytical methods that could be used to quantify these priority components from a single monitoring event. The previous study highlighted a question regarding the consistency and reliability of existing trace landfill gas studies for the purpose of understanding "typical" trace landfill gas. The present project was proposed to provide a rigorous dataset across a variety of different landfills.

1.2 Objectives

The overall aim of this project was to produce a consistent dataset on priority trace components of gas measured at typical UK landfill sites. The project builds on a previous R&D Project P1-438 adding to the Microsoft AccessTM database on trace components. The same landfill sites were sampled twice to assess the variability of trace gas composition over a discrete time interval. These data are linked to the associated information needed to assign appropriate trace component characteristics to particular classes of landfill. The project has informed R&D Project P1-396 '*Exposure assessment of landfill sites*'.

A secondary objective was to assess screening methods for monitoring trace components of landfill gas. Sampling landfill gas using Tedlar Bags is the screening method assessed.

1.3 Issues associated with trace components in landfill gas

Trace components have chemical or physical properties that differ significantly from the bulk gases (Environment Agency, 2004a). Furthermore, some trace components have particular physiological effects that give them a potential impact far greater than the major components in landfill gas. For this reason, monitoring of trace components is important in understanding the source term in any site-specific risk assessment (Environment Agency, 2004b).

1.4 Potential sources of trace components

The trace components of concern are mixed within the bulk gas phase. Organic substances constitute the greatest variety of trace components but some organo-metallic compounds may be significant and several inorganic compounds, notably hydrogen sulphide and water, are common trace components. The trace components originate from a number of sources.

Direct sources include:

- out-gassing of waste
- vaporisation of low boiling point liquids in the waste
- anaerobic respiration by micro-organisms

- corrosion of metals
- chemical reactions between organic or inorganic substances, and
- microbial degradation of organic substances.

Indirect sources include:

- equilibration of substances from the aqueous phase into the gas phase
- gas stripping of substances from leachate as a result of forced flow through the liquid
- aerosols carrying liquid phase, and
- dusts carrying material adsorbed on the solid.

Knowledge about the waste and the conditions within a landfill may help to assign the presence or concentration of individual trace components to particular circumstances.

1.5 Report contents

The report is divided into the following sections:

- Section 2 introduces the sampling and analytical methodology used for the 2002 monitoring event and rationale for sampling the particular sites.
- Section 3 details the results of 2002 monitoring and discusses areas for possible improvement.
- Section 4 discusses the refinements to the sampling and analytical methods introduced before the 2003 monitoring and the resultant improvement in quantification results.
- Section 5 discusses the input of the data collected into the database and the rationale behind deriving inputs into the GasSim model database.
- Section 6 documents the comparison of the recommended method with potential screening methods.
- Section 7 briefly discusses the changes to UK trace component guidance.
- Section 8 provides the conclusions.

2 Review of priority substances and sampling/analytical methodology

The first specific objective was to establish the sites and sampling locations, and to finalise the sampling and analytical methodologies to be used on the project.

2.1 Determination of sites and individual sampling locations

A range of factors affects the trace gas composition in landfills. To give a range of 'typical' landfill gas results, six English landfills representative of the main classes of site taking biodegradable wastes were selected. The chosen sites had each taken either a proportion of a certain type of waste that may affect the trace component composition or represented different waste management regimes. To get a representative sample of typical landfill gas, different locations within certain of the sites were also sampled. The six different waste types or scenarios sampled were:

- codisposal
- mainly domestic (with leachate)
- mainly domestic (little leachate)
- substantial ash
- substantial fragmentiser waste
- commercial & industrial (non hazardous)

The chosen sites were not associated with any known 'problems' and were regarded as 'typical' UK landfills. Main gas samples were taken from the gas collection system at all sites. Additional samples taken at a recent waste monitoring well, a leachate well and a mature waste monitoring well at three of the sites. These three additional sampling locations were at the sites categorised as *mainly domestic*, *substantial-ash* and *commercial & industrial*.

2.2 Sampling and analytical methodologies

Sampling and analytical methodologies have been developed to gather data of highest practicable quality. Target compounds for analysis have been selected from the results of P1-438 (Environment Agency, 2002a). The chemicals with the potential to contribute significantly to the impact of landfill gas are listed below.

Table 2.1 Priority chemicals of interest

Substance	Priority Category	Substance	Priority Category
1,1-dichloroethane	Toxicology	1-butanethiol	Odour
1,1-dichloroethene	Toxicology	1-pentene	Odour
1,2-dichloroethene	Toxicology	1-propanethiol	Odour
1,3-butadiene	Toxicology	Butyric acid	Odour
2-butoxy ethanol	Toxicology	Carbon disulphide	Odour
Arsenic (total)	Toxicology	Dimethyl disulphide	Odour
Benzene	Toxicology	Dimethyl sulphide	Odour
Chloroethane	Toxicology	Ethanal (acetaldehyde)	Odour
Chloroethene	Toxicology	Ethanethiol	Odour
Furan	Toxicology	Ethyl butyrate	Odour
Methanal (formaldehyde)	Toxicology	Methanethiol	Odour
Tetrachloromethane	Toxicology	Carbon Monoxide	Insufficient data
Trichloroethene	Toxicology	Mercury (total)	Insufficient data
Hydrogen sulphide	Toxicology & Odour	PCDDs and PCDFs	Insufficient data

Based on the simple ranking methodology adopted in Project P1-438, these compounds represent 90% of the contribution to the potential toxicological score from average concentrations of trace components in the database and 95% of the corresponding potential total for odour. A small suite of analytical methods has been compiled to detect these highest priority compounds (Environment Agency, 2004b). The suite will also detect many other compounds concurrently but these are not reported in this project.

2.3 Sampling method

The overall sampling method was that developed during project P1-438 and has formed the basis of Agency Draft Guidance for monitoring trace components. Minor refinements have been introduced as a result of further method development in 2002. The sampling and analytical methods in Section 2 relate to monitoring carried out in 2002. The minor refinements instigated prior to the 2003 monitoring are detailed in Section 4.

2.3.1 Sampling

The sampling methodology is as follows.

1. A pressure measurement is taken at the sampling location, taking care to allow no gas leakage around the pressure gauge.
2. Provided the pressure is within 0.25 bar of atmospheric, the bulk gas analyser is connected and readings taken every minute until readings stabilise.
3. If methane concentrations are less than 25%, the well is not sampled because the gas has been diluted by atmospheric gas. If more than one possible sampling well exists, they are all tested for methane concentrations (following steps one to three) and the one with the highest methane concentration is sampled.
4. The sample apparatus is set up with the appropriate adsorbents, pumps, splitters and tubing, and connected to the sample point. If the pressure is outside the acceptable range, alternative sampling arrangements need to be made.
5. The pumps are started and the master valve is opened.
6. If all flows are within 30% of expected values, the flows are tuned and sampling commences. If flows are greater than 30% of expected values, the master valve is shut, and the valves adjusted. This is repeated as required.
7. At the end of the sampling sequence, the master valve is shut and the pumps shut off. Samples are placed in appropriate containers for transportation to the laboratory. These containers will typically be metal cans containing ~1/3 volume of scavenging charcoal.
8. A two litre Tedlar bag is filled using a vacuum extraction box and the landfill gas analysed using the Jerome H₂S analyser.
9. The bulk gas analyser is again connected to the sample point, and the closing bulk gas concentrations are measured. This verifies that large variations in gas composition did not occur during the sampling period. If variation occurs, the data quality is downgraded.

The typical sampling assembly is shown in Figure 2.1 below.

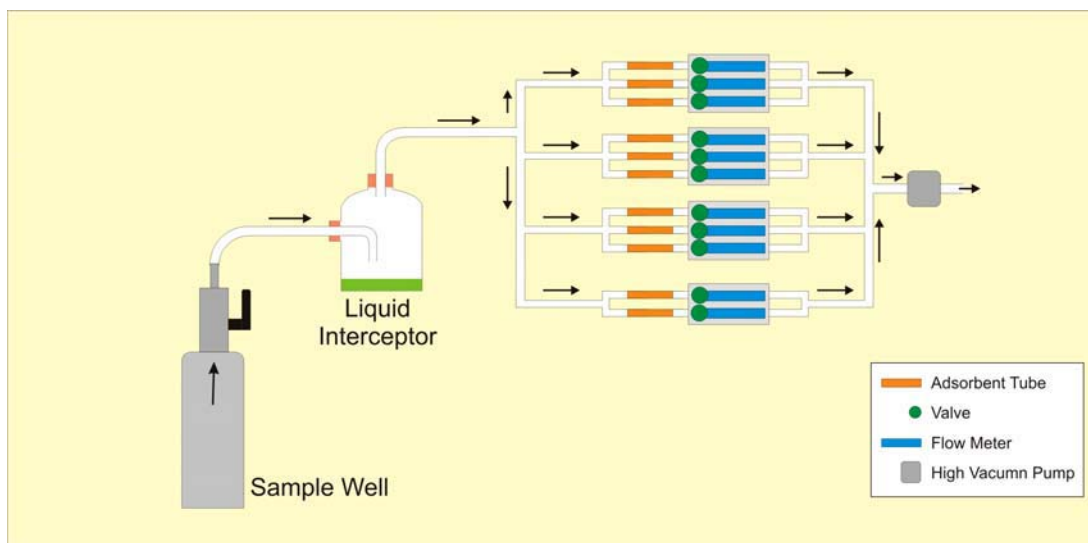


Figure 2.1 Typical sampling set up

At locations where Tedlar bags were sampled for the purposes of assessing possible screening methods, the samples (2 litre and 5 litre bags) were taken immediately following the hydrogen sulphide sampling.

2.3.2 Equipment

The following equipment was used.

- Pump: SKC Universal constant flow pumps. Intrinsic Safety and CE approval for EMC shielding. For overcoming higher vacuums, ADI low flow, high vacuum sampling pump;
- Rotameters: Influx Direct Reading variable area flowmeter (calibrated glass tube and float, stainless steel needle valve) 20 – 250 ml min⁻¹, and KI GR series flowmeter 0 – 5 l min⁻¹;
- Tubing: Tygon 2275 high purity tubing, plasticiser free;
- Tube Holders: SKC sorbent tube holders with individual adjustable flows for three tubes.
- Analyte specific sample tubes;
- SKC Tedlar Bags
- VES Vacuum Box;
- Bulk Gas Analyser: Gas Data LMSxi Portable Landfill Gas Analyser; and,
- H₂S Monitor: Jerome 631-X hydrogen sulphide analyser.

2.3.3 Sampling adsorbent choice

The following is a description of sorbents for specific analyte sampling.

- Arsenic: Standard activated coconut charcoal.
- Mercury: Modified activated coconut charcoal (Frontier Mercury Solid Sorbent Traps). These sample tubes were purchased from a specialist source, which guaranteed a background level of mercury of 1-2 ng.
- VOCs: This is a large and chemically variable list of compounds present in a gas with a high background concentration of hydrocarbon and requires a 'universal' sorbent tube. A dual-bed sorbent packed in an inert ATD tube was selected as the most appropriate.
- Aldehydes (methanal & ethanal): The propensity for methanal to polymerise when heated, as well as the highly polar nature of both these compounds, means that the ATD method is unsuitable. Dinitrophenylhydrazine coated silica gel tubes were used to collect this analytes through *in-situ* derivatisation.
- Dioxins and furans: A custom made trap packed with about 30g of Amberlite XAD-2 resin was used to sample for dioxins and furans. It allowed the sampling at high flow rates and capacitated large sample volumes.

2.4 Sampling matrix

A sampling point on the main gas collection system was monitored at all the chosen sites. In addition, three other locations were sampled at three of the landfills, in order to provide information on gas from individual areas of the site. These were designated Type A samples and Type B samples.

Type A samples for the 2002 monitoring consisted of the following regime

- dual-bed adsorbent in triplicate (VOCs) – low volume (0.5 L sample);
- dual-bed adsorbent in triplicate (VOCs) – high volume (2 L sample);
- DNPH derivatisation (methanal) (10 L sample);
- dioxin (SVOC) sample (single) (100 L sample);
- arsenic in triplicate (5 L sample);
- mercury in triplicate (20 L sample);
- at-well carbon monoxide (CO) and hydrogen sulphide (H₂S) monitoring

Type B samples consisted of the following:

- dual-bed adsorbent in triplicate (VOCs) – low volume (0.5 L sample);
- dual-bed adsorbent in triplicate (VOCs) – high volume (2 L sample);
- DNPH derivatisation (methanal) (10 L sample);
- triplicate samples consisting of two Tenax TA adsorbent tubes in series (VOCs) (0.5 L sample);
- triplicate samples consisting of two Spherocarb adsorbent tubes in series (VOCs) (0.5 L sample);
- triplicate samples consisting of two Silica Gel adsorbent tubes in series (butyric acid) (18 L sample);
- dioxin (SVOC) sample (single) (100 L sample);
- arsenic in triplicate (5 L sample);
- mercury in triplicate (20 L sample);
- at-well carbon monoxide (CO) and hydrogen sulphide (H₂S) monitoring.

The monitoring regime is summarised in Table 2.2, below.

Table 2.2 Sampling matrix

Site	Main Gas	Monitoring Well (Recent Waste)	Leachate Well	Monitoring well (Mature Waste)
Codisposal	A			
Domestic-with-leachate	B	A	B	A
Domestic-with-little-leachate)	A			
Substantial-ash	B	A	B	A
Substantial-fragmentiser	A			
Commercial & Industrial	B	A	B	A

In order to evaluate available screening technologies, Laboratory L1 analysed for CO by IR, VOC by GC-MS and total elements (chlorine, phosphorous, sulphur and silica) by ICP through direct injection of samples collected in Tedlar bags. These samples were taken at all sampling locations at the two *domestic* waste sites and the *commercial & industrial* waste site.

2.4.1 Type A sampling

In order to allow sufficient time to control the gas flow, the Type A sampling was divided into two runs as follows.

- The first sample run involved single sampling for SVOCs and triplicate sampling for aldehydes (methanal), mercury and arsenic.
- The second sampling run involved triplicate sampling using dual sorbent ATD tubes at both high and low volume.

2.4.2 Type B sampling

In order to allow sufficient time to control the gas flow, the Type B sampling at the three chosen sites was divided into the three following runs.

- The first sample run involved triplicate sampling for aldehydes (methanal), mercury, arsenic and single sampling for SVOCs.
- The second run involved triplicate sampling using 2 single adsorbent ATD tubes in series for both Tenax TA and Spherocarb, the Silica Gel butyric acid method, and the high volume dual adsorbent sampling.
- The third sampling run involved a triplicate low volume dual sorbent sampling run.

Care was taken to minimise variation over the sampling period. This was primarily done by pumping and monitoring bulk gas concentrations until they were stable, prior to commencing more detailed sampling. The bulk gas concentrations were analysed again following completion of all sampling so as to verify reasonably constant vapour conditions over the sampling period.

To provide adequate QA/QC, the following blanks were run.

1. To ensure the tubes were not contaminated and had not been impacted by environmental factors during the journey, one trip blank per method per site was transported from the beginning to the end of the sampling programme and subsequently analysed. 39 trip blanks were analysed – 8 per site for sites with type B sampling (3 sites), 5 per site for sites with only Type A sampling (3 sites).
2. Before the start of the sampling programme, the sampling rig including tubing was assembled to collect analytical grade nitrogen at typical conditions. This “verified” tubing type was used in the sampling campaign. Fresh tubing from the batch tested was used at each sampling location to prevent contamination being carried over from location to location.
3. Additionally, to ensure the validity of the dual bed method, a series of triplicate analyses was carried out at three sites, using each adsorbent on its own with a second tube in series to check for breakthrough. These samples were run in parallel with a method targeted for butyric acid, to assess the quality of the dual tube method for butyric acid.
4. Because the gas concentrations were quite variable and unknown, two sets of the dual tube adsorbents were taken at each location with different sample volumes. One sample was taken with 2 l of sample, the other with 0.5 l of sample. This strategy increased the likelihood of clean chromatography and minimised the chance that target compounds were masked by high concentrations of non-target compounds, should concentrations be unexpectedly high.

2.5 Analytical methods

To quantify the chemicals of interest described in Table 2.1, the samples were analysed using similar methodology to that developed during the previous project, P1-438. The overall methods and detailed changes made during the present project are described in the sections below.

2.5.1 Total mercury method

The methodology to detect total mercury is based on National Institute of Occupational Safety and Health (NIOSH) method 6009 issue 2 (NIOSH, 1994). The determination of total gaseous mercury is performed by Inductively Coupled Plasma – Mass spectroscopy (ICP-MS). The samples are

taken by pre-concentrating mercury onto treated charcoal adsorbent in glass tubes (Frontier Mercury Solid Sorbent Traps).

The modified charcoal extraction adsorbent is acid digested using a Microwave Digestion System to ensure complete analyte dissolution and minimise the losses through volatilisation. This is achieved by first placing the contents of the tube into a microwave vessel. A mixture of sulphuric acid, hydrogen peroxide and nitric acid is then added and the samples extracted under high temperature and pressure in a microwave system. The resulting solutions are measured for Hg using ICP-MS, calibrated using the method of standard additions. Internal standards are added to monitor and correct for instrumental drift.

Full elemental analysis in solution by ICP-MS analysis is covered by the laboratory's UKAS accreditation, but the overall method for mercury is not UKAS accredited.

Results from the measurement are expressed as total ng Hg per tube and then converted to µg/cubic metre of gas as sampled, based on flow rates and duration of sampling.

2.5.2 Total inorganic arsenic method

The principal method to sample trace inorganic arsenic compounds is to pre-concentrate them onto coconut shell carbon in glass tubes. The determination of total inorganic arsenic is by NIOSH method 6001 issue 2 using ICP-MS for measurement.

The contents of the tube are extracted using 0.01M nitric acid in an ultrasonic bath for 1 hour. The resulting solutions are measured for arsenic using ICP-MS, calibrated using the method of standard additions. Internal standards are added to monitor and correct for instrumental drift. The relatively weak extraction conditions are aimed at dissolving only the arsenic in the inorganic form, this being the most toxic.

Full elemental analysis in solution by ICP-MS analysis is covered by the laboratory's UKAS accreditation, but the overall method for arsenic is not UKAS accredited.

Results from the measurement are expressed as total ng As per tube and then converted to µg/cubic metre of gas as sampled, based on sampling flow rates and duration of sampling.

2.5.3 VOC method

The principal method to sample trace VOC substances is to pre-concentrate them onto dual adsorbent ATD tubes containing equal weights of Tenax TA and Spherocharb. The Sulfinert ATD tubes were chosen to improve the recovery of labile organo-sulphur compounds. These compounds tend to react with exposed ferrous metals. These tubes were thermally desorbed and analysed by GC-MS.

Additional VOC samples were taken at some locations using each adsorbent separately in parallel sampling runs as an additional check. These samples were taken in series to determine if breakthrough was occurring at significant levels at high flow, 2 litre sampling volumes.

Previous studies have shown that the very high background levels of other trace components present in landfill gas may have a serious effect on extraction and desorption efficiencies of ATD tubes. Thus samples were taken at both a 2 l and 0.5 l volume at each location to improve the likelihood of getting high quality quantification, regardless of variations in trace compound concentrations.

The ATD-GC-MS method is covered by the laboratory's UKAS accreditation for benzene, toluene, ethylbenzene, xylenes and chlorinated butadienes, but is not accredited specifically for the priority component list.

2.5.4 Aldehyde (methanal & ethanal) method

Methanal polymerises when heated and is not therefore suited to gas chromatography. A sampling method involving *in-situ* derivatisation with dinitrophenylhydrazine (DNPH) has therefore been chosen to target methanal and ethanal.

The derivatised analytes are desorbed with acetonitrile and analysed by High Pressure Liquid Chromatography (HPLC) with ultraviolet detection, based on US EPA TO-5. This is an established method that has been validated in the field of environmental monitoring, though not UKAS accredited.

2.5.5 Butyric acid method

A specialised Silica Gel adsorbent was used to measure butyric acid separately since its polarity makes it more difficult to quantify through the standard ATD-GC-MS method. The butyric acid specific method follows the Occupational Safety & Health Administration (U.S. Department of Labor) (OSHA) CSI method.

Silica gel is used to collect the sample. The analyte is then desorbed from the silica with a formic acid solution and the sample extract analysed by GC fitted with a flame ionisation detector (FID). The separation is achieved using a 'WAX' phase column. These results have also been used to evaluate the performance of the dual bed tube with respect to butyric acid.

2.5.6 Hydrogen sulphide and carbon monoxide

Hydrogen sulphide and carbon monoxide were analysed on site using hand held analysers. The portable Jerome-631-X gold film sensor instrument is able to detect hydrogen sulphide at levels from 2 ppbv to 50 ppmv. Its selectivity eliminates interference from sulphur dioxide (SO₂), carbon dioxide (CO₂), carbon monoxide (CO) and water vapour. A real time carbon monoxide and hydrogen sulphide analyser that monitors concentrations down to the parts per million range by electrochemical cell was also used.

2.5.7 Polychlorinated dibenzo – dioxin and furan method

The method chosen to quantify semi volatile substances uses Amberlite XAD-2 resin as the sorbent. This method (NIOSH, 1994) was developed specifically for PAHs (NIOSH method 5515 issue 2) and but is also recommended by the US EPA for dioxin sampling. The method was modified by using a customised, high-capacity collecting trap. This trap, containing approximately 30 g of resin, enabled sampling at high (2 l/min) flow rates.

Sample preparation and measurement was carried in accordance with BS EN1948. This method is aimed at the analysis of XAD-2 for dioxins at levels of 0.1 mg/m³ ITEQ.

The sorbent undergoes Soxhlet/accelerated Soxhlet extraction using toluene followed by extract clean up using column chromatography. The concentrated extracts are then analysed by GC-HRMS

This method is UKAS approved.

3 Results of 2002 monitoring

The 2002 monitoring results have been reported in three sections, dealing with field measured parameters, inorganic laboratory results and organic laboratory results.

3.1 Field results and discussion

Field data have been collected from a number of sources. Some data have been correlated by laboratory measurements. Field measurements of the bulk gases were taken using an LMSxi portable gas monitor and a Jerome Hydrogen sulphide analyser. The field data are presented in Appendix 1 – Table 1 and the summary results are provided in Table 3.1, below.

From Appendix 1 – Table 1, it can be seen that there was good agreement between the results from analysis at Laboratory L1 and field measurements of oxygen, carbon dioxide and methane. The field data from the main gas supply sampled from each landfill is shown in Table 3.1, below.

Table 3.1 Field Bulk Gas Measurements 2002

Parameter	Unit	Com/Ind	Dom/Leach	Dom/No Leach	Codisposal	Ash
Bulk gases						
Methane	%	44.8	53.5	51.0	49.8	29.0
Carbon Dioxide	%	33.0	34.5	37.0	34.5	23.0
Oxygen	%	2.1	0.0	0.2	0.0	6.7
Nitrogen (difference)	%	20.1	12.0	11.8	15.7	41.3
Minor gases						
Hydrogen Sulphide	ppm _v	93.9	10.2	26.9	29.2	37.9

There are no obvious trends to these data. The consistency of methane and carbon dioxide readings at all landfills except the *ash waste* site may be due to similar levels of gas management at those sites that have on-site engines. There is considerable air infiltration into the gas from the ash site and the methane concentration is on the limit of what is considered acceptable as representative gas, however, no alternative sampling locations with better quality gas could be found at the site.

The *commercial & industrial waste* site contained noticeably more hydrogen sulphide (up to approx. 100ppmv), which possibly reflects the relatively high input of wastes containing sulphate (e.g. plaster board).

Field carbon monoxide results were universally higher than laboratory carbon monoxide readings (many hundreds of ppmv compared with close to or below the detection limit of 20ppmv in the laboratory, see Appendix 1 – Table 1). There are two possible reasons for this:

- carbon monoxide, being a small molecular gas, is lost from Tedlar bag in transport. This is unlikely because carbon dioxide results in the field and the laboratory were similar; or
- the field measurement device co-responds to hydrogen gas and possibly other trace gas components. From three hydrogen readings, it can be seen that when hydrogen is present (laboratory analysis) in large concentrations, this correlates with high field carbon monoxide readings. However, carbon monoxide was detected in the field even when laboratory hydrogen was much lower.

As a check, two samples were analysed at a third party laboratory (Laboratory L2). The carbon monoxide results verified the results from Laboratory L1 while improving on the detection limit (i.e. a result of < 20ppm from Laboratory L1 was measured at 2ppm by Laboratory L2.)

A concentration of 20 ppmv carbon monoxide in landfill gas is a 'rule of thumb' indication that there may be thermal oxidation processes (e.g. a deep-seated fire) in the waste and so high readings may be viewed with concern. The field meter can 'prove the negative' i.e., if the meter reads below 20 ppmv, carbon monoxide concentrations are likely to be lower than the threshold. If the meter reads above 20 ppmv, the cause of this reading may or may not be carbon monoxide and laboratory verification is required before conclusions are drawn. This is likely to be true for meters that use an electrochemical cell for carbon monoxide detection.

Hydrogen cyanide results were not thought to be representative because of co-response of the field detector with hydrogen sulphide.

3.1.1 Field variations to sampling method

It was impractical to pre-set the sampling flow rates to within 30% of the final flow. Instead the flow control valves were closed prior to flow start and adjusted as rapidly as practical to the required flow once the control valve was open. The preferred flows were sometimes not achievable due to back-pressure at the sampling location. In these cases the maximum achievable flow rate was used.

3.2 Inorganic laboratory results and discussion

The analytical detection methods report a mass of trace component present on the sampling tube. To provide a landfill gas concentration, the mass of trace component collected is divided by the volume of landfill gas drawn through the tube. See Appendix 2 for the volumes of air used in each calculation.

The results have been divided into two sections. The first section reports the laboratory data and discusses consistencies and anomalies within the dataset with respect to methods of sampling and analysis. The second section discusses the results in the context of the different landfill sites.

3.2.1 Mercury results

The results of the total mercury analysis are presented in Appendix 2 and summarised in Table 3.2, below.

Table 3.2 Mercury measurements 2002

	Dom/Dry	Com & Ind	Codisposal	Ash site	Dom/Leach
Units	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
Main Gas	0.49	0.30	0.58	<0.39	<0.33
Main Gas	0.30	0.82	0.54	0.21	1.33
Main Gas	0.50	0.29	0.41	<0.30	<0.81
Recent Waste		0.40		<1.8	0.17
Recent Waste		0.32		No value	<0.13
Recent Waste		0.27		10.09	0.14
Older Waste		0.80		0.31	<0.35
Older Waste		0.14		0.64	<0.33
Older Waste		0.20		0.99	<0.36
Leachate					<0.27
Leachate					<0.25
Leachate					<0.24

Assessment of mercury results in context of sampling/analytical methods

The use of specialist, high purity, sorbent tubes enabled the analytical method to reach a detection limit of 1-5 ng and consequently an overall detection limit approximately $0.5 \mu\text{g}/\text{m}^3$ assuming a sampling volume of 10l. Drift in the instrument over the period of analysis caused the detection limit

to vary. The tubes came in two sections; the front, primary adsorbent, and the rear, secondary adsorbent. The secondary adsorbent was used to detect breakthrough, that is, to confirm that insignificant amounts of mercury passed through the primary adsorbent.

The complete digestion of the sorbent within a sealed vessel enabled full recovery of mercury without the problems of losses through volatility or from incoming contamination.

All positive mercury results were near the detection limit of the method. These detections were well enough resolved to conclude that mercury was present, although quantification was difficult. There were no detections of mercury above trace levels on the secondary adsorbent. The results were cross-checked by comparing the results with results from tubes spiked with 5 to 10 ng of mercury (the range of the positive detections) in the laboratory. These spiked tubes showed very good agreement with the positive results.

Assessment of mercury results in context of different waste types

Identifiable detections of mercury occurred at all sites. Gas from the *domestic-with-little-leachate*, *codisposal*, *commercial & industrial sites* and the recent waste at the *substantial-ash* site showed quantities at or near the detection limit in all tubes sampled. Two domestic/leachate locations showed quantities below the detection limit in all samples. The other two *substantial-ash* site locations and the recent waste and main gas at the *domestic-with-leachate* site showed quantities below detections in at least one of the three triplicate tubes analysed. These detections were below reliable quantification limits, but appear to be less than $1 \mu\text{g}/\text{m}^3$ with most results below $0.5 \mu\text{g}/\text{m}^3$. One of the *domestic-with-leachate* main gas samples showed a concentration of $1.33 \mu\text{g}/\text{m}^3$ (10 ng), but the analysis of the other two of the triplicate tubes taken at this location show quantities below the detection limit.

The ideal detection limit from Task 1 was less than $0.01 \mu\text{g}/\text{m}^3$. A concentration above this threshold would produce a toxicity-concentration score of over 50. Limits imposed by the maximum safe sampling volumes mean that the lowest practical detection limit with these tubes is $0.04 \mu\text{g}/\text{m}^3$, with that limit achieved in only one analysis during this investigation. Adjustments have been made to the laboratory method and it is believed that this detection limit will be achievable in most instances in the future, if 'Frontier Geoscience' or equivalent low background tubes are used.

Results indicate that mercury exists in landfill gas at concentrations in the range of 0.2 to $1 \mu\text{g}/\text{m}^3$. Because reliable detections can be made at most sites with this detection limit, a lower detection limit is not required. However, routine availability of the low background mercury tubes is not assured. Nevertheless, assuming these five sites represent 'typical landfill sites, a practical detection limit of $0.5 \mu\text{g}/\text{m}^3$ would be adequate to discern whether mercury concentrations were elevated above 'typical' concentrations.

3.2.2 Arsenic results

The arsenic laboratory data are presented in Appendix 2 and are summarised in Table 3.3, below.

Table 3.3 Summary of arsenic measurements 2002

	All units $\mu\text{g}/\text{m}^3$				
	Dom/Dry	Com & Ind	Codisposal	Ash site	Dom/Leach
Main Gas	0.87	36	0.35	3.2	< 0.08
Main Gas	0.92	28	0.45	4.2	< 0.08
Main Gas	0.89	60	0.41	3.8	< 0.08
Recent Waste		12		16.7	1.8
Recent Waste		12		19	2.0
Recent Waste		7.2		19	1.5
Older Waste		0.77		3.3	0.30
Older Waste		0.76		0.24	0.33
Older Waste		2.2		0.83	0.20
Leachate					0.51
Leachate					0.11
Leachate					0.11

Assessment of arsenic results in context of sampling/analytical methods

Through careful sample preparation, the potential interference from the polyatomic ion $^{40}\text{Ar}^{35}\text{Cl}$ with ^{75}As was shown not to be present. Consequently, an analytical detection limit of 6 ng was achieved, resulting in an overall detection limit of approximately $0.08 \mu\text{g}/\text{m}^3$. The tubes came in two sections; the front, primary adsorbent, and the rear, secondary adsorbent. The secondary adsorbent is used to detect breakthrough, that is, to confirm that insignificant amounts of arsenic passed through the primary adsorbent.

Levels of inorganic arsenic were quantified significantly above the limit of detection in the sample batch. Only trace amounts of arsenic were detected in the secondary adsorbent in the tubes, verifying that breakthrough is not significant.

Assessment of arsenic results in context of different waste types

The total arsenic concentrations from the main gas supply at the *commercial & industrial* site were between 28 and $60 \mu\text{g}/\text{m}^3$. The concentration in gas from old waste at this site was approximately $1 \mu\text{g}/\text{m}^3$, whereas gas from the recent waste contained between 7 and $12 \mu\text{g}/\text{m}^3$ total arsenic. From limited data at this site, it would appear that the recently deposited waste was the main source of arsenic in the gas. However, the landfill cell generating the gas that must be contributing most to the high concentration of arsenic in the main gas was not sampled.

The total arsenic from the main gas supply at the *codisposal* site was below $0.5 \mu\text{g}/\text{m}^3$ total arsenic.

At the *domestic-with-leachate* site, the lowest readings at any of the sites (approximately $0.1 \mu\text{g}/\text{m}^3$) were detected at the leachate well. Old waste at the same site contained approximately $0.3 \mu\text{g}/\text{m}^3$. As at the *commercial & industrial* site, gas from the recent waste contained the highest total arsenic concentration at this landfill at almost $2 \mu\text{g}/\text{m}^3$. The main gas supply showed the same concentration as the leachate well at approximately $0.1 \mu\text{g}/\text{m}^3$. One possible explanation for the low total arsenic concentration at the main gas well is that the high moisture content at this landfill scrubs out arsenic compounds from the vapour phase.

The main gas at the *Domestic-with-little-leachate* site consistently contained $0.9 \mu\text{g}/\text{m}^3$ of total arsenic.

At the *ash waste* site, recent waste gas contained nearly $20 \mu\text{g}/\text{m}^3$ total arsenic, while old waste contained between 0.2 and $3.3 \mu\text{g}/\text{m}^3$. Total arsenic readings of the main gas were approximately $4 \mu\text{g}/\text{m}^3$. At these concentrations, small amounts of breakthrough appeared to occur on the secondary adsorbent. The breakthrough concentrations of approximately $0.04 - 0.2 \mu\text{g}/\text{m}^3$ were one to two orders of magnitude below the concentrations found on the primary adsorbent. Any

result under 10% on the secondary adsorbent is generally considered acceptable, so these small amounts were not indicative of significant breakthrough.

In the context of the toxicology assessment in P1-438, arsenic theoretically requires a detection limit of $0.00001 \mu\text{gm}^{-3}$ because a concentration above this threshold would produce a toxicity-concentration score of over 50. However, the lowest mass in the primary adsorbent is 0.4 ng, corresponding to a concentration of $0.05 \mu\text{g}/\text{m}^3$ with an 8 litre sampling volume. If these sites are typical, then total arsenic will always be detected above this 'experience' threshold. Since arsenic appears to be present in all the samples at these 'typical' landfill gases and can be measured using a reasonable volume of sample, lower detection limits are not necessary for routine sampling. Present methodologies provide a means to establish whether total arsenic content of the landfill gas is elevated above 'typical' concentrations and allow confirmation of the place of arsenic in the priority trace component list.

3.3 Organic laboratory results and discussion

The laboratory results are presented in the Appendix 2 and the results summarised in Table 3.4 are discussed in sections below.

Table 3.4 Priority aldehydes in gas from different landfills 2002

	<i>Database Average</i>	Com & Ind	Dom/Dry	Dom/Leach	Codisp.	Ash
UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
Methanal (formaldehyde)	2900	10	14	287	252	176
Ethanal (acetaldehyde)	2900	20	54	494	852	5946
RECENT WASTE						
Methanal (formaldehyde)	2900	140	No Sample	334	No Sample	13
Ethanal (acetaldehyde)	2900	410	No Sample	2570	No Sample	89
OLD WASTE						
Methanal (formaldehyde)	2900	64	No Sample	14	No Sample	25
Ethanal (acetaldehyde)	2900	147	No Sample	63	No Sample	3442

3.3.1 Aldehyde compound results

The aldehyde laboratory data sheets are presented in Appendix 2 Tables 4A to 4C.

Assessment of aldehyde results in context of sampling/analytical methods

Within the sample batch, the secondary adsorbent consistently contained half the mass of analyte of the primary adsorbent. Because the secondary adsorbent contains only half the amount of DNPH impregnated silica gel, the indication is that the derivative has been completely saturated in both adsorbent sections during sampling. The concentrations of methanal and ethanal were not particularly high and the saturation was attributed to other aldehydes and ketones such as butanal.

The analytes were consistently found above the limit of detection throughout the sample batch, which was typically $0.01 \mu\text{g}.\text{m}^{-3}$.

Acetone was also determined by this method. It was also determined through the ATD-GC-MS method so the values obtained by both the DNPH and the dual sorbent method have been compared in Figure 3.1 below.

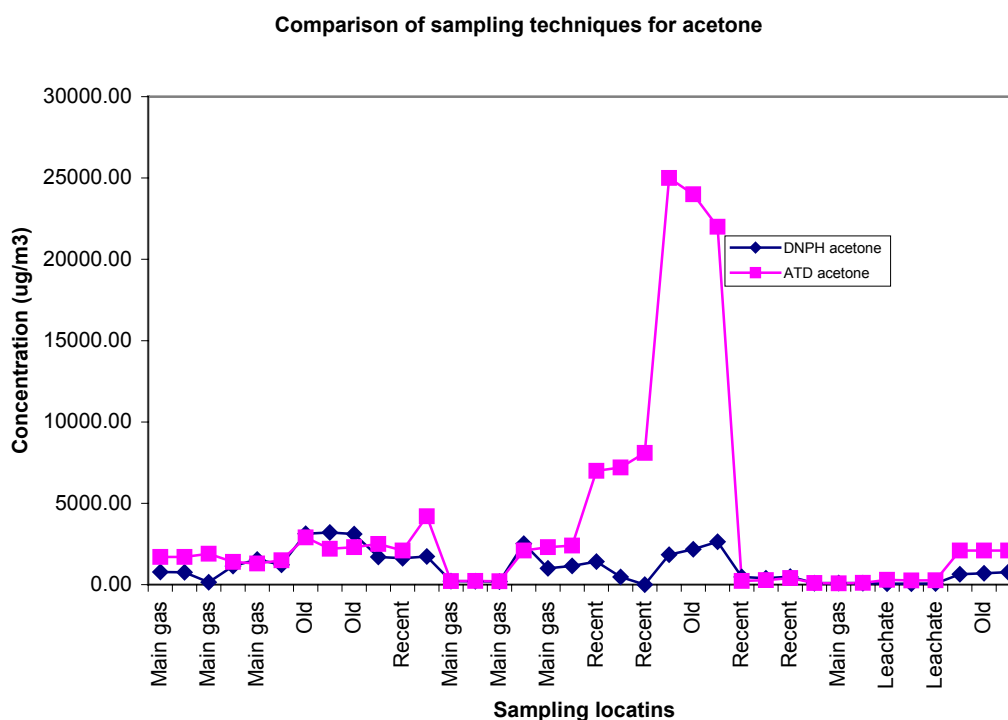


Figure 3.1 Comparison of sampling techniques for acetone

The comparison shows reasonable agreement where low concentrations were determined by the ATD method. When higher levels were found by this method the DNP method did not show a similar rise, again suggesting saturation of the derivative. To reduce saturation, either the sampling volume can be reduced (increasing the detection limit), or more DNP silica gel is needed in the tubes.

Assessment of aldehyde results in context of different waste types

Methanal is a priority compound based on its toxicity significance score, while ethanal is on the odour priority list. Other than observing that concentrations of ethanal are generally higher than methanal, it is thought unwise to draw major conclusions from this comparison because the concentrations measured in this sampling set are almost certainly significantly under reported.

3.3.2 VOC compound results

The results are shown in Appendix 2, Table 5.

Assessment of VOC results in context of sampling/analytical methods

Standards were prepared for 60 target compounds. All but the 1,3-butadiene standard were diluted in methanol. The methanol/standard mix was then spiked onto blank ATD tubes under a stream of helium for 30 sec. This is enough time to allow the bulk of the methanol to pass through the tube without losing significant amounts of any of the standards. These tubes were then analysed in the same manner as the samples.

The calibration range for most compounds was from 50 ng to 1000 ng on the tube and was calculated from a four-point calibration. Good linearity was achieved for the vast majority of compounds over this calibration range. For some well-detected compounds e.g. benzene, a five-point calibration was made with a calibration range from 25 ng to 1000 ng on the tube. There were also a number of less well-detected compounds (both very volatile and with poor detector response) where only a three level calibration was carried out. These compounds were chloroethane, 1-pentene, trans-1,2-dichloroethene and dichlorofluoromethane. The calibration

range for these compounds was also 50 ng to 1000 ng, but due to the difficulty in handling the standards, only three levels were used.

It was anticipated that the highly polar (butyric acid and butoxy ethanol) and the organosulphur compounds would cause difficulties. The former produced poor chromatographs with tailing present, and the latter gave comparatively poor response. However, both sets of compounds fell within the criteria briefly outlined above.

As in previous studies, the very high concentrations of non-target VOCs present and the wide variation in concentration of the target compounds made analysis difficult. Use of the target ion facility on the mass spectrometer enabled the analyst to identify and quantify most of the target analytes, even when there was co-elution with a considerably more abundant peak. This method is less discriminatory at lower masses and thus the analyst was required to carry out some data interpretation.

All sampling onto sorbents was carried out in triplicate (see Table 5). It can be seen from the data that over the whole sample batch the triplicate values were reasonably consistent at one location. This is demonstrated by the similar totals for the target compounds for each triplicate analysis.

Both type A and type B sample regimes included low and high volume dual adsorbent samples. Although the flows were variable through the sampling programme, the high volume tubes (HF in graph below) were typically collected at 100 to 150 ml/min while the low volume tubes (LF in graph below) were typically collected at 20 to 50 ml/min. The total volume for the low volume sample was typically 0.2 litre with 2.5 litres for the high volume sample. It can be seen from Table 5 and from the example of data for chloroethane in Figure 3.2, that the concentration value calculated for each analyte was generally higher in the low flow (LF) samples (varying from parity to more than four times greater).

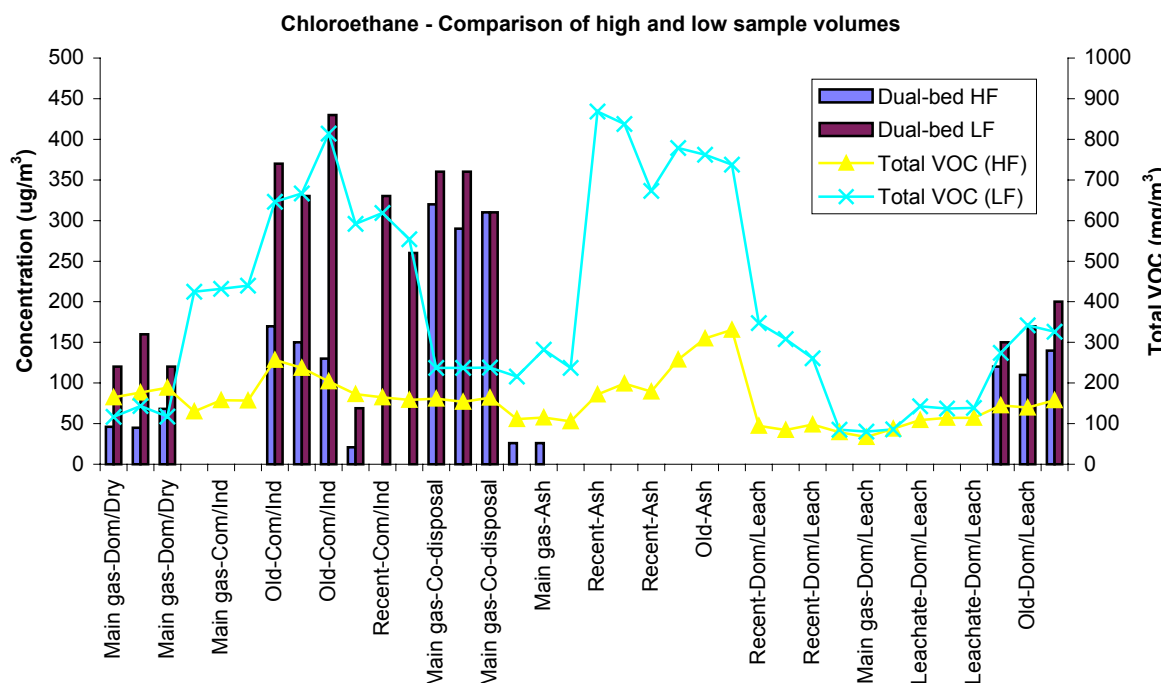


Figure 3.2 Chloroethane results – comparison of high and low sampling volumes

Two possible causes of this under-recovery from the high volume tubes are either irreversible adsorption or breakthrough. However, neither of these potential causes provides a complete explanation, because in the cases where a significant difference existed, the concentrations on the high volume tubes were universally and similarly lower throughout the entire target list.

If irreversible adsorption were the problem, the higher boiling point compounds would be lost in greater amounts than the lower boiling point compounds, because of generally high adsorption affinities with increasing boiling point (the safe sampling volume under experimental conditions for decane on Tenax alone is 2,100l, whereas chloroethene shows no significant adsorption on Tenax). If breakthrough were the problem, one would expect the lower boiling point compounds to exhibit a greater loss than the higher boiling point compounds, because of generally lower adsorption affinities for the lower boiling point compounds.

Additionally, single adsorbent ATD tubes were prepared and sampled alongside the dual bed tubes to ascertain the recovery efficiency of each (see examples Figure 3.3 & 3.4 below). Run conditions were similar to the high volume sample tubes. The Spherocharb tube results gave further evidence that neither breakthrough nor irreversible adsorption was the main cause of the discrepancy in results. The Spherocharb tubes showed minimal breakthrough to the rear tube, and even on low boiling point compounds, the concentrations were universally and similarly lower than the low flow dual bed tube throughout most of the analytical range. The signs of irreversible adsorption were expected (and evident) only on the heaviest compounds (such as decane), which would be trapped on the Tenax and never reach the Spherocharb in the dual bed set-up.

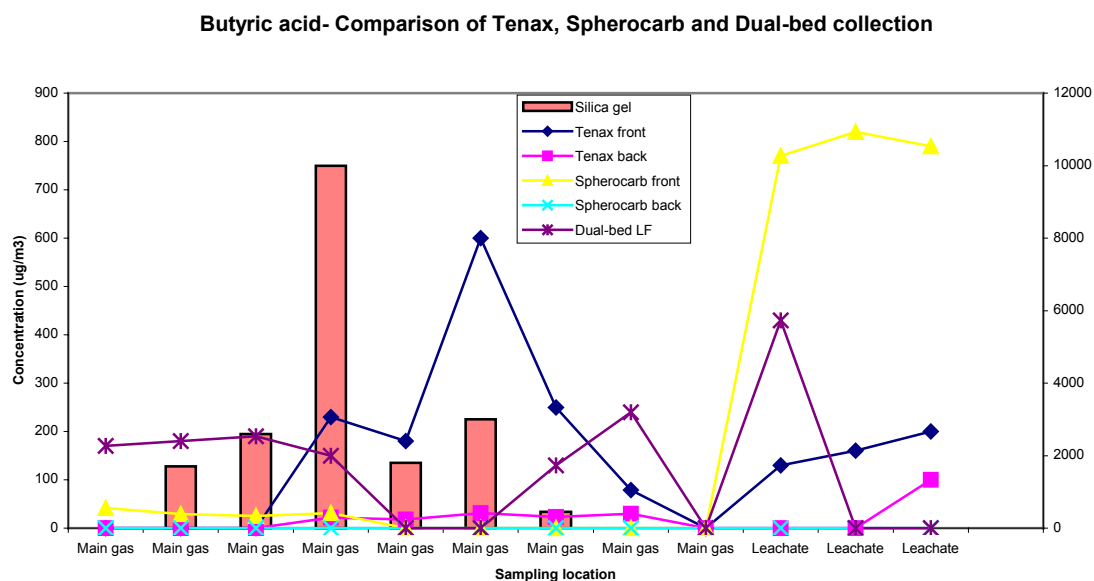


Figure 3.3 Decane results – comparison of Tenax, Spherocharb and dual bed collection

As expected, Tenax showed a very poor retention of analytes especially for low boiling point compounds (see chromatograph below). The rear tube gave values similar to the front tubes indicating chronic breakthrough. The purpose of the Tenax in the dual-bed sorbent is to act as a filter to capture high boiling point compounds and prevent them from reaching and irreversibly bonding onto the Spherocharb.

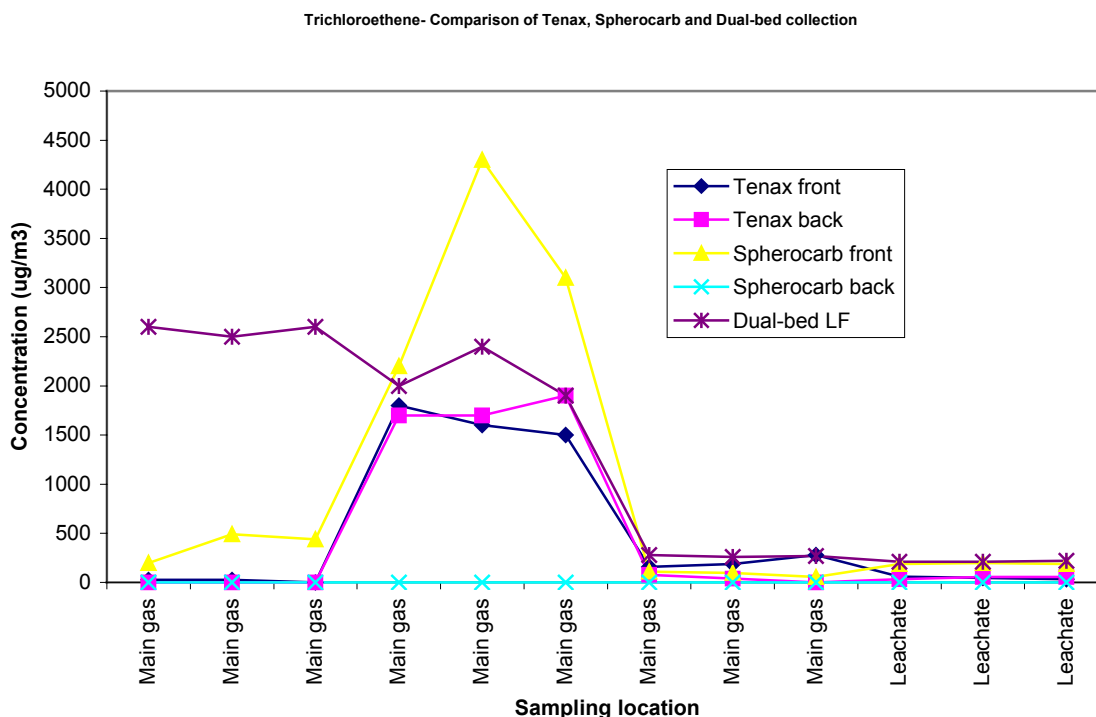


Figure 3.4 Trichloroethene results – comparison of Tenax, Spherocarb and dual bed collection

It was hypothesised that the cause of the lower reporting on the high volume samples might be linked to the high moisture content in the sampled vapour. Very high levels of moisture can cause the MS to lose sensitivity. This results in the associated analysis giving concentrations that are universally lower than dry samples. Because the calibrations are run on dry samples, the associated quantification is lower than it should be. This problem expresses itself less in the low volume tubes because the total sample volume is much less than in the higher volume samples, and therefore the amount of moisture adsorbed on the tubes is reduced. Further investigation was deemed necessary to determine how to overcome this problem. Limiting the sample volume and increasing the temperature of the internal trap in the MS itself were possibilities that were considered.

From analysing the current dataset, it was assumed the most accurate data came from the dual-bed low volume ATD tubes for all the target compounds, since these data should be less affected by moisture. For this method, the detection limit was typically $50 \mu\text{gm}^{-3}$ per analyte or for a few favourable compounds $25 \mu\text{gm}^{-3}$.

Assessment of VOC results in context of different waste types

The following sub-sections describe the consistencies and differences between priority VOC results with respect to the type of waste that may have generated them. The results from the different sampling mechanisms (dual sorbent high volume, low volume, single sorbent etc.) have been compared and the maximum concentration determined at any one location has been chosen for comparison with other site data. This follows the principle that most problems in sampling/analysis result in the loss of material and therefore a lower reported concentration.

It should be noted that the differences in concentrations found with the various sampling regimes indicate that all results obtained in this phase of the project may be underreported. Based on the typical variation between the high and low flow samples, the concentrations are expected to be correct within an order of magnitude (and probably much less than an order of magnitude). It is not anticipated that the relative concentrations within an analysis set are affected by the moisture problems in the analytical results.

Halogenated Volatile Organic Compounds (HVOCs)

Comparison between landfills has focussed on five halogenated compounds that are present in the priority list (Table 2.1). Table 3.5 shows the five priority halogenated compounds from the main gas supply at the five sites.

Table 3.5 Priority Halogenated VOCs in main gas supply 2002

	<i>Database Average</i>	Com & Ind	Dom/Dry	Dom/Leach	Codisp.	Ash
UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
Chloroethene	80000	1600	4900	46	17000	2100
Chloroethane	70000	<10	160	<10	360	26
Tetrachloromethane	5000	<10	<10	<10	<10	<8
1,1-Dichloroethene	11000	200	62	<10	410	200
Trichloroethene	15000	2600	1600	280	1200	2400

A number of possible trends are apparent within these data.

- Chloroethane concentrations are universally lower than chloroethene concentrations.
- 1,1-dichloroethene concentrations are universally lower than trichloroethene concentrations.
- Tetrachloromethane was below detection limits in all main gas wells, and considerably below the average concentration in the database. The average concentrations in the database are universally higher than those measured from main gas from five 'typical' landfills. The database may contain a predominance of halogenated data from 'problem' sites.
- The domestic waste with significant leachate has the lowest priority halogenated VOC content. This could potentially be due to the HVOCs dissolving in the aqueous phase.

Data was obtained on the priority halogenated VOCs in gas from old and new cells at three of the landfills (Table 3.6). This has been assessed to determine whether there are trends that may be relevant to degradation pathways.

Table 3.6 Compounds associated with priority Halogenated VOC degradation pathways in recent and old waste samples 2002

	<i>Database Average</i>	Com & Ind	Dom/Dry	Dom/Leach	Co-disp.	Ash
UNITS	μgm^{-3}	μgm^{-3}		μgm^{-3}		μgm^{-3}
RECENT WASTE						
Chloroethene	80000	1300	No Sample	3800	No Sample	1600
Chloroethane	70000	330	No Sample	<10	No Sample	<10
Tetrachloromethane	5000	<10	No Sample	<10	No Sample	<10
1,1-Dichloroethene	11000	270	No Sample	<10	No Sample	750
Trichloroethene	15000	3900	No Sample	3400	No Sample	18000
OLD WASTE						
Chloroethene	80000	4900	No Sample	6500	No Sample	3900
Chloroethane	70000	430	No Sample	200	No Sample	<10
Tetrachloromethane	5000	<10	No Sample	<9	No Sample	<10
1,1-Dichloroethene	11000	350	No Sample	420	No Sample	680
Trichloroethene	15000	7800	No Sample	700	No Sample	11000

Observable trends comparing recent and old waste in the same landfill include:

- Chloroethene was detected at higher concentrations in the older waste than in the recent waste. Because there is no discernible trend in the chloroethene precursor compounds (tetrachloroethene, trichloroethene and cis-1,2-dichloroethene), this difference may not be related to biodegradation.
- 1,1-dichloroethene also showed higher concentrations in the older waste than in the recent waste on two of the three sites. The 1,1-dichloroethene is likely to arise from hydrolysis of 1,1,1-trichloroethane, but the latter is not one of the priority substances and has not been quantified.
- An absence of tetrachloromethane was again noted in all samples.
- The concentrations of HVOCs were much higher in both recent and old waste samples than in the main gas sample from the *domestic-with-leachate* landfill.

3.3.3 Oxygenated VOCs

There are three oxygenated VOC compounds on the priority list in terms of toxicity and odour potential. The data from various sampling and analytical methods have been sorted to determine the maximum concentration for comparison between landfills. These data are shown in Table 3.7.

Table 3.7 Priority Oxygenated VOCs in landfills 2002

	<i>Database Average</i>	Com & Ind	Dom/Dry	Dom/Leach	Codisposal	Ash
UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
2-butoxy ethanol	200	10000	3200	300	280	95
Butyric Acid*	9000	190	550	240	71	600
Ethyl Butyrate	20000	2800	4100	3800	2500	6500
RECENT WASTE						
2-butoxy ethanol	200	12000	No Sample	2300	No Sample	<10
Butyric Acid*	9000	240	No Sample	1100	No Sample	<10
Ethyl Butyrate	20000	1300	No Sample	28000	No Sample	24000
OLD WASTE						
2-butoxy ethanol	200	730	No Sample	<9	No Sample	<10
Butyric Acid*	9000	970	No Sample	2800	No Sample	<10
Ethyl Butyrate	20000	19000	No Sample	14000	No Sample	22000

* butyric acid by ATD tube-quantification uncertain

The results from collection of butyric acid on silica gel are shown in Appendix 2, Table 7. Although chromatographic peak shape was much poorer using the ATD method, when these ATD derived data were compared to the silica gel method the former was shown to have greater sensitivity (lower detection limit). The silica gel tube had to be desorbed with 5 ml of solvent of which only 2 μl were injected on the gas chromatograph and thus the detection limit was typically 500 $\mu\text{g.m}^{-3}$. Sensitivity could not be improved by using MS detection because the solvent used consisted largely of water.

Significant problems were encountered in the butyric acid by silica gel analyses. Under field conditions the silica gel method showed extremely poor precision, and quantification was suspect because the triplicate variation covers orders of magnitude. The data were therefore not of sufficient quality to use in this assessment. It appears that the high moisture contents and potentially acid conditions of the vapour may have caused the adsorbent to function erratically. When detections were made however, the concentrations were generally much higher than those on the ATD tubes. Nevertheless, the ATD tube detected butyric acid in more samples. Butyric acid was expected to have poor quantification on the ATD tubes due to its high polarity. However, it appears that the ATD tube may have been more sensitive to butyric acid, even though it may have been less good for quantifying concentrations.

2-butoxyethanol is on the toxicity priority list and appeared in highest concentrations in gas from the *commercial & industrial* waste. In two of the three sampled landfills, the concentration was highest in gas from recent waste and lower in older waste, as would be expected for a compound most likely to be formed in fermentative conditions. At the third landfill, concentrations were below the detection limit so no trend could be discerned. Unexpectedly, this trend of higher recent waste concentrations did not hold for ethyl butyrate, implying other mechanisms were active, most likely involving air ingress into the landfill caused by gas collection extraction. This apparent symptom of air ingress is consistent with there being detectable concentrations of oxygen in the gas at several sampling locations (Appendix I).

Butyric acid and ethyl butyrate are on the odour priority list. Ethyl butyrate was found in all samples at concentrations above 1000 μgm^{-3} and the ester was consistently at a higher concentration than the free acid.

3.3.4 Sulphonated VOCs and hydrogen sulphide

There are five sulphonated trace VOC compounds on the odour priority list. Hydrogen sulphide is on both lists. In Table 3.8 below, the hydrogen sulphide readings are from field measurements.

Table 3.8 Priority sulphonated VOCs in landfills 2002

	<i>Database Average</i>	<i>Com & Ind</i>	<i>Dom/Dry</i>	<i>Dom/Leach</i>	<i>Codisposal</i>	<i>Ash</i>
UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
Hydrogen sulphide	100,000	133000	38000	14500	41000	54000
Methanethiol	7000	6900	10000	25	<10	4000
Carbon disulphide	80	4900	2200	130	1700	2600
1-Propanethiol	400	340	74	<10	93	72
Dimethyl disulphide	200	200	59	110	18	1000
Ethanethiol	100	1800	860	<10	2100	470
RECENT WASTE						
Hydrogen sulphide	100,000	163000	No Sample	227000	No Sample	>280000
Methanethiol	7000	36000	No Sample	200	No Sample	2000
Carbon disulphide	80	12000	No Sample	720	No Sample	31000
1-Propanethiol	400	610	No Sample	<10	No Sample	<10
Dimethyl disulphide	200	3500	No Sample	340	No Sample	<10
Ethanethiol	100	4000	No Sample	<10	No Sample	3000
OLD WASTE						
Hydrogen sulphide	100,000	106000	No Sample	25000	No Sample	14500
Methanethiol	7000	76000	No Sample	8700	No Sample	150
Carbon disulphide	80	14000	No Sample	1400	No Sample	1100
1-Propanethiol	400	230	No Sample	<10	No Sample	18
Dimethyl disulphide	200	280	No Sample	5200	No Sample	51
Ethanethiol	100	460	No Sample	<10	No Sample	530

The main gas sample with the lowest sulphonated content came from the landfill with significant leachate. This may be a reflection of the solubility of the sulphur compounds. However, this landfill site also produced one of the highest hydrogen sulphide readings from a sample of gas taken from a monitoring well in its recent waste, and there were concentrations of sulphonated VOCs in gas from a well in the older waste.

There appears to be as great a variation in sulphonated compound concentrations within the landfills as between them, and those variations do not show a consistent pattern. The generation of sulphonated compound appears to be a mechanism common to all landfill types and may be due to a ubiquitous waste stream such as municipal waste (all the sampled landfills take a dominant proportion of municipal waste).

The recent waste samples typically had higher hydrogen sulphide concentrations than the older waste.

Carbon disulphide was found in all samples at a concentration higher than that in the current database, suggesting that it had been under-reported in many earlier studies.

3.3.5 Aliphatic VOCs

1-Pentene is a priority compound because of its odour properties.

Table 3.9 Priority Aliphatic VOCs in landfills 2002

	<i>Database Average</i>	Com & Ind	Dom/Dry	Dom/Leach	Codisposal	Ash
UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
1-pentene	1700	7400	7900	110	37000	32000
RECENT WASTE						
1-pentene	1700	18000	No Sample	1600	No Sample	18000
OLD WASTE						
1-pentene	1700	36000	No Sample	30000	No Sample	88000

A trend from all landfills suggests that 1-pentene production may increase in older waste.

3.3.6 Aromatic VOCs

Benzene is the priority aromatic VOC in landfill gas due to its toxicity.

Table 3.10 Priority Aromatic VOCs in landfills 2002

	<i>Database Average</i>	Com & Ind	Dom/Dry	Dom/Leach	Codisposal	Ash
UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
Benzene	4900	19000	1600	1100	4500	10000
RECENT WASTE						
Benzene	4900	40000	No Sample	2900	No Sample	7200
OLD WASTE						
Benzene	4900	17000	No Sample	2300	No Sample	35000

Gas from the *commercial & industrial* site contained the largest concentrations of benzene with the *substantial-ash* site also containing elevated concentrations. The *domestic* waste sites produced gas containing the lowest concentrations of benzene.

3.3.7 PCDD/PCDF results

Results on the quantities of dioxins and furans found in the gas samples are shown in Appendix 2, Table 6. Extraction and sampling spike recoveries (of selected ^{13}C labelled analogues) for all the samples were within the limits defined by Method BS EN1948, with the exception of sample LF-A-100 (*ash* site). In this case there was almost a complete loss of both spikes indicating a problem with the extraction and/or clean up process. It is likely that the chromatographic column used to clean up the sample was degraded by an excess of non-PCDD/PCDF compounds. This would consequently lead to the loss of both native and labelled dioxins and furans.

Limits of detection were significantly better than the previous analyses. Most samples had some results above the LOD, but not significantly. Three blanks were run with the samples, and the total ITEQ values were very similar to the samples.

The total PCDD and PCDF results for some samples were higher than the blanks, which may indicate underlying PCDD and PCDF emissions. It should be noted that the 'total' results were made up of mostly non-toxic PCDDs and PCDFs, which were more abundant than the toxic species (193 non-toxic species compared with 17 toxic ones).

There were no reliable detections of the toxic PCDDs or PCDFs so no comparison can be done. It should be noted that PCDD/PCDF analysis was not completed on gas from the *substantial-ash* site due to problems with the extraction.

3.4 Summary of 2002 monitoring programme

Over three hundred analyses were performed at the five sites that were sampled. In general the approach of using a small number of monitoring methods was successful but results from some of the key methods did not give results of the quality thought achievable for certain determinands. The summary position on the method acceptability after assessment of the 2002 data is discussed below.

Acceptable Methods: The sampling and analytical methods for total mercury, total inorganic arsenic and PCDDs & PCDFs were shown to have worked well with acceptable detection limits obtained.

Methods requiring further refinement:

DNPH Derivatisation - The aldehyde sample tube was found to contain an inadequate amount of derivatising agent for the volume of gas being sampled. The analytical method was shown to work well. Further sampling with this method should include large derivative masses, lower flow volumes or both.

Butyric Acid - the silica gel method was found to lack sensitivity at the sampling volumes used. Additionally, the precision of the measured concentrations was poor. The ATD method already used for other VOCs appeared as satisfactory as the dedicated method.

VOCs - There appeared to be a loss of sensitivity in the mass spectrometer associated with increasing sample volume. This is thought to be caused by moisture in the samples interfering with the operation of the MS. These problems should be surmountable but would require more method development before re-sampling.

4 Results of 2003 monitoring

The objective of 2003 monitoring was to assess the variability of trace gas composition over a discrete time interval by sampling the same landfill sites on a second occasion.

In the period between the 2002 and 2003 monitoring programmes, the analytical methods were refined and stronger sampling pumps tested. The method improvements were undertaken independently on gas samples from a landfill that was not included in the main programme but is close to the laboratory. Although the results are not recorded here, the methods used for the 2003 monitoring are the culmination of that method development.

4.1 Sampling and analytical methods

The general principles of the sampling and analytical methods used in 2003 were the same as those employed in 2002 (Section 2), but a few minor modifications of the methodology were introduced as a result of the independent method development. These modifications are discussed below.

4.1.1 Variations to sampling methodology in 2003

In the first monitoring event in 2002, the rotameters were set prior to sampling and if the flows were within 30% of the expected values, the rotameters were tuned and the sampling commenced. If the flows were greater than the 30% range of the expected values, then the master valves would be shut and the rotameter valves adjusted. During the second monitoring event in 2003, the rotameters were initially closed and then rapidly adjusted to the specified flowrate on opening the master valve and switching on the pump.

4.1.2 Variation of bulk gas sampling methodology

The suggested sampling method involves connecting the bulk gas analyser directly to the sampling port when taking readings. During this monitoring event for the purpose of comparison, the bulk gas analyser was used to take samples by means of 3 different techniques:

1. direct connection to the sampling port;
2. analysis of landfill gas first collected in a Tedlar bag; and
3. connection to the sampling port via a flow regulator.

Although connecting the bulk gas analyser directly to the sampling port is the most practical method and generally gives consistent readings over time, there are problems with this technique. Firstly, the flow through the instrument must be at a specified rate in order for the cells in the instrument to calculate the correct concentration. This flow cannot be predicted consistently and this introduces an unknown degree of error to the readings. Secondly, a high pressure differential, either negative or positive, may damage the instrument.

Bulk gas readings from the three methods demonstrate that sampling from a Tedlar bag produces the least consistent results between samples at the same location over time. The results are often a few percent different from corresponding readings taken directly from the sampling port. It is suggested that the transfer of gas from the sampling port to the Tedlar bag and the subsequent connection of the bulk gas analyser to the Tedlar bag via may lead to the dilution of the sample with atmospheric gases.

The addition of a flow regulator between the bulk gas analyser and the sampling port can ensure that the flow rate of the gas sample is limited to that required by the gas analyser. The flow regulator will also prevent damage to the instrument. The readings taken using this method compare favourably with those from the Tedlar bag samples and show greater consistency. One sampling location (*domestic-with-little-leachate*: Main gas) was sampled using all three techniques. Most readings for the bulk gases were similar, except for the methane readings. The percentage volume of methane taken using the direct connection to the sampling port was 4% higher than the corresponding readings using the other techniques. It is interpreted that this extra 4% may be an

artefact of non-optimal pressure / flow conditions in the meter. Although the evidence is limited, it is suggested that a flow regulator be considered when taking bulk gas readings from a sampling port. If one is not available, the use of Tedlar bags is suggested as the alternative method for bulk gas sampling.

4.1.3 Variations in equipment

In place of the SKC low flow pumps used in 2002, an ADI low flow/high vacuum sampling pump was used. This proved successful in maintaining a constant flow rate even when overcoming a considerable back-pressure (i.e. vacuum) at the gas sampling point.

4.1.4 Variations in sampling adsorbent and total mercury analytical method

The original sampling tubes with a low background level of mercury had been sourced from the Frontier Geosciences Inc., USA. However, these could not be obtained for this round of sampling and SKC Anasorb 300 mercury tubes were used as an alternative. These are claimed to have a low background mercury and are designed for occupational health monitoring. The samples were taken by pre-concentrating mercury onto treated charcoal adsorbent in glass tubes. The preferred sampling volume was approximately 20 litres (NIOSH 6009).

The analysis of the 2002 samples had been undertaken using ICP-MS. The analysis of the mercury tubes for the 2003 monitoring was by the determination of total gaseous mercury using Cold Vapour Atomic Fluorescence Spectrometry (CV-AFS) at Laboratory L3; this method is covered by UKAS accreditation.

The modified charcoal extraction adsorbent was digested with acidic reagents, using a Microwave Digestion System to ensure complete analyte dissolution and minimise the losses through volatilisation. The contents of the sorbent tube were placed in a microwaveable vessel. A mixture of sulphuric acid, hydrogen peroxide and nitric acid were then added and the samples extracted under high temperature and pressure in a microwave system. The conversion of all forms of mercury into inorganic mercury was achieved by treating the acidified sample with a solution containing potassium bromate and bromide. Excess bromine is removed by the addition of hydroxyl ammonium chloride. The inorganic mercury was then determined by reacting the sample with acidic stannous chloride (tin II chloride solution) to release elemental mercury. The mercury vapour was carried along in a stream of argon and detected by Atomic Fluorescence Spectrometry.

Results from the measurement are expressed as a concentration of total Hg in the extract (mg.l^{-1}) and then converted to $\mu\text{g m}^{-3}$ of gas as sampled, based on flow rates and duration of sampling.

4.1.5 Variations in VOC sampling and analytical method

Both the high and low sample volumes were typically collected at 50 ml.min^{-1} . In 2003, the total volume for the low volume sample was typically 100 ml and the high volume sample was 400 ml.

In order to reduce the adverse effect of moisture on the detection of the least strongly bound VOCs, an important refinement of the analytical method was introduced. After sampling but before the initial desorption stage, the ATD tubes were flushed with 2 litres of pure (dry) nitrogen. During the independent development work this had been shown to remove sufficient moisture to prevent interference or loss of sensitivity, without any significant loss of the sorbed VOCs present on the tube.

4.2 Field results and discussion

Field measurements were taken of the bulk gases using an LMSxi portable gas analyser and a Jerome-631-X hydrogen sulphide analyser. The field readings are presented in Appendix 3 - Table 1. The summary results for the field data from the main gas supply sampled from each landfill in both 2002 and 2003 are shown in Table 4.1, below.

Table 4.1 Field Bulk Gas Measurements

Parameter	Unit	Com & Ind		Dom with Leach		Dom little Leach		Co-disposal		Frag.		Ash	
Monitoring event		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Bulk gases													
Methane	%	44.8	40.0	53.5	*	51.0	48.7	49.8	53.0	44.0	42.0	29.0	36.0
Carbon Dioxide	%	33.0	27.0	34.5	19.9	37.0	34.7	34.5	31.7	34.0	30.0	23.0	23.0
Oxygen	%	2.1	2.2	0.0	1.2	0.2	0.7	0.0	1.7	0.0	1.5	6.7	2.9
Nitrogen by difference	%	20.1	30.8	12		11.8	15.9	15.7	13.6	22	26.5	41.3	38.1
Minor gases													
Hydrogen Sulphide	ppm _v	93.9	>50	10.2	22.7	26.9	35.6	29.2	37.0	21.0	>50	37.9	39.9

* denotes instrument out of range error

Observations

- The two monitoring events showed that little temporal variation in landfill gas composition existed within each waste type. The exception to this is gas from the *domestic-with-leachate* waste site.
- The consistency of methane and carbon dioxide readings for different waste types, except the *ash* site, is interpreted to be due to the management of gas from the substantial amounts of domestic waste that is present in all these sites to provide an input gas for the on-site engines.
- The gas from the *substantial-ash* waste site exhibited relatively low carbon dioxide and methane readings and relatively high oxygen readings. This is a surprising result because the two samples taken from recent wells at this site (Table 1, Appendix 3) displayed the highest concentrations of methane sampled during the second monitoring event. The elevated oxygen may be due to open pathways to the atmosphere or a function of the proportion of mature waste contributing gas to the engine.
- The gas from the *commercial & industrial* waste site contained noticeably more hydrogen sulphide, which possibly reflects a relatively higher proportion of sulphate rich streams in *commercial & industrial* waste.
- The gas from the *substantial-fragmentiser* waste site contained concentrations of hydrogen sulphide elevated above those from the previous sampling event.

From Table 1 – Appendix 3, it can be seen that there is generally good agreement between oxygen and methane readings taken in the field and those analysed in a laboratory. The main exception to this is the monitoring of gas from the mature waste at the *domestic-with-leachate* site where the field results for oxygen and methane were both significantly below the results analysed by Laboratory L1.

The carbon dioxide concentrations reported from the field instrument were generally lower than the analyses conducted in the laboratory. This is a variation from the first sampling programme when the carbon dioxide results from both the field and laboratory analysis were generally consistent. It can be observed from Table 1 (Appendix 3) that field measured carbon dioxide readings in the second monitoring event were generally below those from the first monitoring event and sometimes significantly so, whereas the laboratory analyses show greater consistency. This may indicate calibration drift on the field instrument and so, in circumstances where carbon dioxide concentration quantification is important, it appears that the laboratory analyses produce consistent, higher results.

Tedlar bag samples were collected at every sample location and sent to Laboratory L2 for analysis of carbon monoxide. This third party laboratory data were typically at least one order of magnitude lower than the field readings. Only one sample exhibited a concentration in excess of 20 ppmv (38 ppmv). The corresponding field reading for carbon monoxide was 715 ppmv.

There are two possible reasons for the field readings of carbon monoxide being universally higher than laboratory results for carbon monoxide.

- Carbon monoxide, being a small molecular gas, is lost from Tedlar bag in transport. This is unlikely because carbon dioxide results in the field and the laboratory were relatively similar.
- The field measurement device also responds to other trace components of the landfill gas. Figure 4.1 shows the carbon monoxide field and laboratory readings in relation to laboratory analysed hydrogen concentrations. From this chart, it can be seen that field carbon monoxide readings using electrochemical cells were significantly greater than concentrations determined by laboratory analysis. It can also be seen that as the hydrogen concentration increased, an increase was also observed in the field carbon monoxide readings. However, carbon monoxide was detected in the field even when hydrogen concentrations were low. This may be due to the co-response to hydrogen or another compound generated with hydrogen. In addition to this, the carbon monoxide electrochemical cell was fitted with a chemical filter to remove cross-interference from compounds such as SO_x , NO_x and H_2S . Depending on the frequency of use of the instrument and the concentrations of these compounds in the sample gas, break-through of the filter could have occurred at any time during the sampling periods resulting in elevated readings.

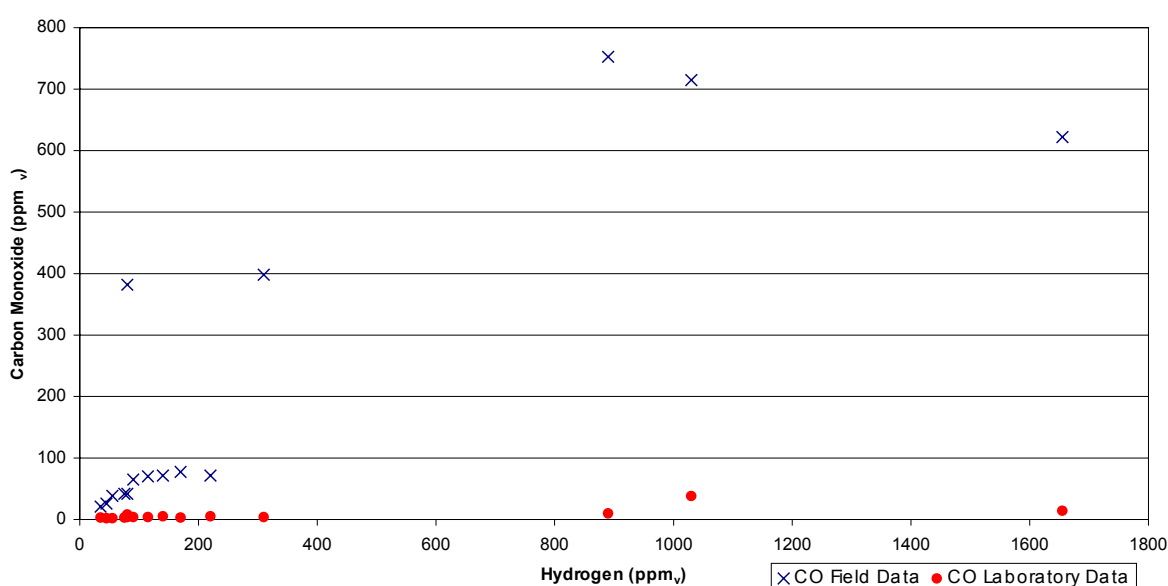


Figure 4.1 The co-response of hydrogen with carbon monoxide

Since 20 ppm_v carbon monoxide is an approximate 'rule of thumb' for possible indication of thermal oxidation processes, the field meter appears to be useful to 'prove the negative' i.e., if the meter reads below 20 ppm_v, carbon monoxide concentrations are likely to be lower. If the meter reads above 20 ppm_v, laboratory verification is required before conclusions are drawn on whether the carbon monoxide levels are elevated. This interference is likely to have an affect on all meters that use an electrochemical cell for carbon monoxide detection.

The field instrument results for concentration of hydrogen cyanide are thought to be unrepresentative due to the co-response of the field detector with hydrogen sulphide. During the second sampling period the hydrogen cyanide detector displayed erratic readings and usually stabilised towards zero.

4.3 Inorganic laboratory results and discussion

The analytical detection methods report the data as a mass of trace component present on the sampling tube. To provide a concentration of that component in the original landfill gas sample, the mass of trace component collected is divided by the volume of air drawn through the tube. Sampling volumes are included with the analytical results in Appendix 3.

The results for each individual compound have been divided into three sections. The first section reports the laboratory data from the second monitoring event and discusses consistencies and anomalies within the dataset with respect to methods of sampling and analysis. The second section compares the results from the different sampling periods and the third section discusses the results in context of the different landfill sites.

4.3.1 Mercury results

The results of the total mercury analysis are presented in Table 2 (Appendix 3).

Assessment of mercury results in context of sampling/analytical methods

Sorbent tubes could not be sourced from the supplier used in 2002 and so low background mercury sorbent tubes from SKC were used in 2003. Two tubes from the sample batch were analysed by ICP-MS prior to the sampling programme to ensure that the background mercury levels were minimal. Both tubes were reported to contain concentrations of mercury below the analytical detection limit of 0.4 ng. This would give an overall detection limit of approximately 0.04 $\mu\text{g m}^{-3}$ for a 10 litre sampling volume, which is an improvement upon the previous monitoring event.

The samples were taken in accordance with the methodology detailed in Section 2.4.1 and sent to the laboratory for analysis. The mercury was extracted and made up to a volume of 15 ml. Upon digestion of the mercury adsorbent tubes sampled at the landfills, a blue colouration appeared to be extracted from the binder in this specific tube type. It was also noticed that after analysing four samples, the sensitivity of the instrument had fallen to approximately one third of the starting sensitivity. This is thought to be due to the binding material blocking the orifice of the cones in the ICP-MS and consequently this method was abandoned. The remaining samples were sent to an alternative laboratory for analyses via Cold Vapour Atomic Fluorescence Spectrometry (CV-AFS).

The results were reported as concentrations of the extract solutions (mg l^{-1}) and were subsequently converted into a mass of mercury on each tube (ng) and finally a concentration per cubic metre of gas ($\mu\text{g m}^{-3}$). These are presented in Table 2 (Appendix 3). The limit of detection for this method is 0.9 ng or 0.09 $\mu\text{g m}^{-3}$, assuming a sample volume of 10 litres.

From Table 2 (Appendix 3), it can be observed that the concentrations of mercury ranged between 3.6 and 22.5 $\mu\text{g m}^{-3}$. This concentration is comparable to the emissions from a coal-fired power plant and not consistent with results reported in UK landfill gas elsewhere (ESART 2003). During the 2002 sampling programme at these same landfills the gas had mercury content $<1 \mu\text{g m}^{-3}$. Only one result during that sampling event was marginally elevated (1.33 $\mu\text{g m}^{-3}$). The blanks all contain concentrations in excess of 0.04 $\mu\text{g m}^{-3}$ (the background concentration on tubes prior to the sampling event analysed via ICP-MS) with a minimum concentration of 3.6 $\mu\text{g m}^{-3}$. However, a spiked sample was sent with the landfill samples containing a concentration of 0.033 mg L^{-1} of mercury and the laboratory reported a concentration of 0.031 mg L^{-1} , verifying the reported concentrations. Similar sorbent tubes from SKC were used during the P1-438 R & D project producing similar results to those obtained during this monitoring event.

Samples were taken in series as well as in duplicate (parallel) to determine whether any break-through was occurring. From the 8 samples taken in series, one sample exhibited a higher concentration on the back tube in comparison to the front tube and six other samples were either of the same concentration or negligibly different (within 20%). Only one sample location exhibited significantly different concentrations between the two tubes in series, with the rear tube containing approximately 40% of the front tube. Under normal circumstances, this would demonstrate that break-through is occurring. The fact that apparent breakthrough occurs at variable rates when the flow rate and sampling volume remain constant suggest that there is a large difference between tubes or analyses. This makes the dataset unreliable.

The mercury concentrations from this monitoring event were significantly different to concentrations of mercury determined during the previous sampling programme. Potential reasons for this difference are as follows:

1. conversion calculations associated with dilution and/or extract volumes are incorrect, are missing, or including an extra factor;

2. the SKC mercury tubes have high and variable background concentrations of mercury;
3. the reagents or extraction glassware/equipment have high and variable background concentrations of mercury carried over from previous sample runs;
4. July 2002 analytical technique using ICP-MS did not accurately report the concentrations of mercury;
5. August 2003 analytical technique using CV-AFS did not accurately report the concentrations of mercury;
6. the August 2003 limit of detection could be higher than reported and hence baseline noise may have been reported which could give rise to higher concentrations after dilution correction; and
7. the samples had been cross-contaminated.

In project P1-438 it had been concluded that the erratic results when using the SKC tubes could be explained by the second point, i.e. high and variable background concentrations of mercury. This had been the reason for choosing the Frontier Scientifics tubes for the 2002 monitoring. Although the initial measurement of blanks in 2003 had suggested that the performance of the SKC tubes had improved, it is now concluded that high and erratic background concentrations of mercury are the most logical explanation for 2003 monitoring results. It is concluded that only tubes with a consistent and demonstrable low background of mercury can be used to measure the very low concentrations of mercury in landfill gas.

Assessment of mercury results in context of different waste types

Concentrations of mercury determined during the 2003 monitoring event appear significantly elevated above 'typical' concentrations and are not considered representative. Comparison between waste types is not therefore possible.

Assessment of mercury results from different sampling periods

The two monitoring events cannot be compared because the 2003 dataset appears unrepresentative.

4.3.2 Arsenic results

The arsenic results are presented in Table 3 (Appendix 3), and are summarised in Table 4.2, below.

Table 4.2 Summary of arsenic measurements 2003

	Dom/Dry	Commercial	Codisposal	Ash site	Dom/Leach	Frag.
Units	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
Main Gas	4.2	34.3	3.1	31.5	28.7	6.8
Recent Waste		5.5		409.5	3.7	
Older Waste		0.6		1.6	43.9	
Leachate		11.0		117.2	4.9	

Assessment of arsenic results in context of sampling/analytical methods

Through careful sample preparation, the potential interference from the polyatomic ion $^{40}\text{Ar}^{35}\text{Cl}$ with ^{75}As was shown not to be present. Consequently an analytical detection limit of 0.4 ng was achieved resulting in an overall detection limit of approximately $0.04 \mu\text{g/m}^3$.

Levels of inorganic arsenic were quantified significantly above the limit of detection in the 2003 monitoring programme. Only trace amounts of arsenic were detected in the secondary adsorbent in the tubes, verifying that breakthrough is not significant.

The reproducibility of the arsenic results from samples taken in duplicate in 2003 was good, with the analytical results from 11 out of the 15 sample locations (>70%) showing a relative percentage difference (RPD) of less than 20%. The maximum absolute RPD calculated was 69%. The relative percentage difference is calculated by taking the difference between two samples, dividing by the mean and multiplying by 100.

Assessment of arsenic results in context of different waste types

The total arsenic concentrations from the main gas supply at the *commercial & industrial* site were between 28 and 42 $\mu\text{g m}^{-3}$. The gas from the mature waste at this site contained concentrations between 0.5 and 0.6 $\mu\text{g m}^{-3}$, the recent waste contained concentrations between 4.7 and 6.4 $\mu\text{g m}^{-3}$. Gas from the leachate well at the *commercial & industrial* site contained a duplicated concentration of 11 $\mu\text{g m}^{-3}$ total arsenic. The relative concentrations of arsenic produced from each sampling location are consistent with the 2002 sampling results and are of comparable concentrations. From limited data at this site, it would appear that the total gaseous arsenic component is being generated in conjunction with leachate.

The total arsenic from the main gas supply at the *codisposal* site contained a reproducible concentration of 3.1 $\mu\text{g m}^{-3}$. This result is almost an order of magnitude above the concentration obtained during the first sampling event.

The main gas samples from the *domestic-with-leachate* site contained concentrations of total arsenic between 20 and 41 $\mu\text{g m}^{-3}$, the mature waste contained concentrations of between 40 and 48 $\mu\text{g m}^{-3}$, the recent waste between 3.4 and 4.1 $\mu\text{g m}^{-3}$, and sample associated with leachate contained concentrations between 4.0 and 5.9 $\mu\text{g m}^{-3}$. From these results, it can be seen that the mature waste appears to contain the highest concentrations of arsenic, conflicting with the result from the *commercial & industrial* site. These results are significantly greater than the results obtained during the 2002 sampling event.

The main gas at the *domestic-with-little-leachate* site contained concentrations between 3.8 and 4.6 $\mu\text{g m}^{-3}$ of total arsenic. These concentrations are greater than the previous (2002) monitoring event (0.9 $\mu\text{g m}^{-3}$).

At the *substantial-ash* waste site, the main gas contained concentrations of total arsenic between 30 and 33 $\mu\text{g m}^{-3}$ and the mature waste contained between 1.5 and 1.7 $\mu\text{g m}^{-3}$. The sample from recent waste and from the leachate point contained relatively high concentrations of between 390 and 430 $\mu\text{g m}^{-3}$ and 108 and 128 $\mu\text{g m}^{-3}$, respectively. The *substantial-ash* waste site mainly accepts Commercial & Industrial waste in conjunction to the ash that was generated by the incinerator plant, formerly located on site. The relatively high arsenic concentrations found in the recent waste are consistent with the results from the recent waste in the *commercial & industrial* waste site, suggesting that arsenic generation mainly occurs in the recent waste.

The main gas at the *substantial-fragmentiser* waste site, sampled during the second monitoring event, contained concentrations between 6.2 and 7.4 $\mu\text{g m}^{-3}$ of total arsenic. In the 2002 monitoring event, the main gas contained concentrations of arsenic below the reporting limit of 0.8 $\mu\text{g m}^{-3}$. The leachate sample from the 2002 monitoring event contained concentrations of total arsenic between 22.8 and 33.0 $\mu\text{g m}^{-3}$.

Assessment of arsenic results from different sampling periods

Table 4 Appendix 3 compares the maximum concentrations from both monitoring events for different waste types. This demonstrates that samples taken during different sampling periods display a large degree of variation, sometimes greater than an order of magnitude. The RPDs calculated between different sampling periods for different waste types vary between -199% and 115%, with a mean of -89%. The geometric mean of the absolute RPDs for all waste types is 117%. These results indicate that the 2003 monitoring event generally exhibited higher concentrations of arsenic and the average difference between sampling periods for each waste type was up to an order of magnitude. Since the sampling methodology, analytical technique and sampling adsorbent (tube type and manufacturer) remained constant for both sampling periods; the variation in concentration between the sampling periods would appear to be due to changing conditions in the landfill. The fact that this occurred consistently across all sites suggests that this temporal change may be the result of a universal factor such as the weather.

In the context of the toxicology assessment in P1-438, arsenic theoretically requires a detection limit of 0.00001 $\mu\text{g m}^{-3}$ because a concentration above this threshold would produce a toxicity-concentration score of over 50. However, the lowest mass found on the adsorbent during the 2003 monitoring event was 5.4 ng and 0.4 ng during the 2002 monitoring event, with corresponding

concentrations of 0.54 and 0.05 $\mu\text{g m}^{-3}$, respectively. The blank tubes contained a mass of arsenic between 2 and 3 ng, corresponding to a concentration of between 0.2 and 0.3 $\mu\text{g m}^{-3}$ with a 10 litre sampling volume. The P1-438 database only contains 3 records of total arsenic, with a mean concentration of 1.88 $\mu\text{g m}^{-3}$. If these six sites coupled with the 3 database records are typical, then total arsenic will always be detected above the 'experience' threshold of 0.05 $\mu\text{g m}^{-3}$. Because total arsenic has been found in all 'typical' landfill gas and can be measured if a reasonable volume is sampled, lower detection limits are not necessary. Present methodologies provide a means to establish whether total arsenic content of the landfill gas is elevated above 'typical' concentrations.

4.4 Organic laboratory results and discussion

The laboratory results are presented in the Appendix 3 and discussed in sections below.

4.4.1 Carbonyl compound results

The carbonyl compound laboratory data sheets are presented in Tables 5A and 5B (Appendix 3).

Assessment of aldehyde results in context of sampling/analytical methods

The DNPH tubes have two sections, a primary and secondary sorbent to monitor for potential break-through. Within the sample batch, the secondary adsorbent typically contained concentrations above the limit of detection. In most cases the concentration was close to the limit of detection. However, some samples contained concentrations of methanal and ethanal approaching half of that contained in the primary adsorbent. Because the secondary adsorbent contains only half the amount of DNPH impregnated silica the indication is that both sections of the derivatised adsorbent had been completely saturated during sampling and these results must therefore be under-reporting the aldehydes.

Throughout the sample batch, the analytes were consistently found above the limit of detection, which was typically 12 $\mu\text{g m}^{-3}$. The limit of detection is greater than in the previous results (5 $\mu\text{g m}^{-3}$).

The reproducibility of the methanal results was reasonably good. The absolute relative percentage difference between duplicate samples varied between 3 and 78%, with a geometric average of 23%. The ethanal duplicates displayed better reproducibility than the methanal results, with the absolute relative percentage difference ranging from 0 to 76% and a geometric average of 12%.

Assessment of aldehyde results in context of different waste types

Methanal is a priority compound based on its toxicity significance score whereas ethanal is on the odour priority list. The methanal results are presented in Table 5A (Appendix 3) and the ethanal results are presented in Table 5B (Appendix 3).

The methanal (formaldehyde) measured concentrations varied between 21 and 188 $\mu\text{g m}^{-3}$ for all waste types, whereas the ethanal (acetaldehyde) concentrations were between 43 and 2546 $\mu\text{g m}^{-3}$. The geometric mean concentrations of methanal and ethanal are 53 and 193 $\mu\text{g m}^{-3}$, respectively. The P1-438 database contains 24 records of methanal and 22 records of ethanal. Of these, only 3 methanal and 2 ethanal records are discrete concentrations and do not contain qualifiers, i.e., less than (<) signs. Using only the discrete values from the database, the mean concentrations of methanal and ethanal are 150 and 1605 $\mu\text{g m}^{-3}$, respectively. These concentrations are of the same range as the concentrations analysed at the six sites during this sampling event, verifying these data.

Table 4.3 presents the maximum concentrations of methanal and ethanal contained at each sampling location for different waste types. The maximum concentration is chosen as representative because most problems in sampling and analysis result in the loss of material and therefore a lower reported concentration.

Table 4.3 Summary of priority aldehydes in gas from different landfills 2003

	Com & Ind.	Dom. little leachate	Dom. with leachate	Co-disposal	Frag.	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
Methanal	72	26	188	56	68	89
Ethanal	266	84	2546	249	225	1458
RECENT						
Methanal	32	-	99	-	-	49
Ethanal	92	-	508	-	-	84
RECENT LEACH						
Methanal	68	-	72	-	-	97
Ethanal	105	-	238	-	-	301
MATURE						
Methanal	36	-	61	-	-	43
Ethanal	75	-	136	-	-	97

Although the concentration of ethanal is generally higher than that of methanal in all cases, there are no clear trends between different waste types. The main gas from *the domestic-with-leachate* site contained the highest concentrations of both methanal and ethanal, whereas the main gas from the *domestic-with-little-leachate* contained the lowest. For the sites with different ages of waste, ethanal concentrations were typically highest at the main gas location, suggesting that the source cell of elevated ethanal was not sampled. The sites with the greatest evidence of air infiltration, the *commercial & industrial* and the *substantial-ash* wastes, did not show significantly elevated concentrations of aldehydes.

Assessment of aldehyde results from different sampling periods

Table 4.4 compares the maximum concentrations of samples taken at the main gas sampling locations for different waste types from both monitoring events.

Table 4.4 Comparison of main gas priority aldehydes from different sampling periods

Waste Type	Methanal (Formaldehyde)			Ethanal (Acetaldehyde)		
	2002 ($\mu\text{g m}^{-3}$)	2003 ($\mu\text{g m}^{-3}$)	RPD (%)	2002 ($\mu\text{g m}^{-3}$)	2003 ($\mu\text{g m}^{-3}$)	RPD (%)
Substantial-ash	66	89	-30	2279	1458	44
Codisposal	118	56	72	1174	249	130
Commercial & Industrial	106	72	39	295	266	10
Domestic-with-leachate	60	188	-103	298	2546	-158
Domestic-with-little-leachate	14	26	-59	107	84	24
Substantial-fragmentiser	251	68	115	723	225	105

The methanal results were almost all within the same order of magnitude, although they showed small variation between both waste types and monitoring events. On average, the results compare well; the geometric average of methanal concentrations from the first monitoring event was $75 \mu\text{gm}^{-3}$, whereas the geometric average of the second monitoring event concentrations was a comparable $70 \mu\text{gm}^{-3}$. The main gas concentrations of methanal vary between 14 and $251 \mu\text{gm}^{-3}$.

The ethanal concentrations were generally higher than the methanal concentrations and for each individual sampling location the ethanal concentration was always greater than the corresponding methanal concentration. The ethanal concentrations showed a higher degree of variation than the methanal concentrations. Although there was no significant consistency at individual sampling locations over time, the range of concentrations between sampling periods was very similar (i.e.,

the range of ethanal concentrations was 107 – 2279 μgm^{-3} during the 2002 monitoring event and 84 – 2546 μgm^{-3} during the 2003 event).

No trends are apparent within the temporal dataset.

4.4.2 VOC results

The VOC laboratory data are presented in Table 6 (Appendix 3). The priority VOCs are summarised and discussed in subsequent sections. The analytical method has quantified many other VOCs. These others have not been discussed, but are reported in Table 6 Appendix 3.

Assessment of VOC results in context of sampling/analytical methods

Standards were prepared for 60 target compounds. All but the 1,3-butadiene standard was diluted in methanol. The methanol/standard mix was then spiked onto blank ATD tubes under a stream of helium for 90 sec. This is enough time to allow the bulk of the methanol to pass through the tube without losing significant amounts of any of the standards. These tubes were then analysed in the same manner as the samples.

The calibration range for most compounds was from 50 ng to 1000 ng on the tube and was calculated from a five-point calibration. Good linearity was achieved for the vast majority of compounds over this calibration range. It was anticipated that the highly polar (butyric acid and butoxy ethanol) and the organosulphur compounds would cause difficulties. The former produced poor chromatographs with tailing present and could not be detected in the lowest standards, and the latter gave comparatively poor responses. Because of this, the detection limits of these compounds were relatively high.

As in previous studies, the very high levels of non-target VOCs present and wide variation in concentration of the target compounds made this analysis difficult and time consuming. Using the target ion facility on the mass spectrometer enabled the analyst to identify and quantify most of the target analytes even when there was co-elution with a considerably more abundant peak. This method is less discriminatory at lower masses and thus the analyst was required to carry out some data interpretation.

Because of the extremely complex nature of the analysis all sampling was carried out in duplicate, see Table 6 (Appendix 3). It can be seen from the data that the duplicate values were consistent to within an order of magnitude. This is demonstrated by the similar totals for the target compounds for each duplicate analysis.

Assessment of VOC results in context of different waste types over different sampling periods

The following sub-sections describe the consistencies and differences between the concentrations of priority VOC found in the gas samples with respect to the type of waste over the two sampling periods. This combines comparisons within each dataset with comparisons between the two datasets from the two monitoring events.

The results from the different sampling volumes (100 ml and 400 ml) have been compared and the maximum concentration determined at any one location has been chosen for comparison with other site data. This follows the principle that most problems in sampling/analysis result in the loss of material and therefore a lower reported concentration.

Based on the typical variation between the high and low volume samples, the concentrations are expected to be correct within an order of magnitude (and probably much less than an order of magnitude).

4.4.3 Halogenated VOCs (HVOCs)

Five halogenated compounds that are present in the priority list (Table 2.1) have been considered in detail for comparison between landfills. Table 4.5 reports the results on the five priority halogenated compounds from the main gas supply at the six sites.

Table 4.5 Priority halogenated VOCs in main gas supply 2003

SITE	Com & Ind.	Dom. little leachate	Dom. with leachate	Co-disposal	Frag.	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
Chloroethene	22000 ⁽¹⁰⁰⁾	180000 ⁽¹⁰⁰⁾	730000 ⁽¹⁰⁰⁾	271000 ⁽¹³³⁾	46000 ⁽¹⁰⁰⁾	22600 ⁽¹⁰⁰⁾
Chloroethane	<30 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾	5300 ⁽³⁰⁰⁾	1610 ⁽⁴¹⁷⁾	<30 ⁽⁴⁰⁰⁾	<20 ⁽⁵⁰²⁾
Tetrachloromethane	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴¹⁷⁾	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁵⁰²⁾
1,1-Dichloroethene	1400 ⁽¹⁰⁰⁾	2800 ⁽¹⁰⁰⁾	19000 ⁽¹⁰⁰⁾	40 ⁽⁴¹⁷⁾	140 ⁽¹⁰⁰⁾	160 ⁽⁵⁰²⁾
Trichloroethene	6700 ⁽¹⁰⁰⁾	7100 ⁽¹⁰⁰⁾	88000 ⁽¹⁰⁰⁾	1650 ⁽¹³³⁾	540 ⁽¹⁰⁰⁾	1140 ⁽⁵⁰²⁾

Actual sample volumes are shown in brackets (ml)

It should be noted in this table that where the compound of interest is not detected, the higher sample volume would always give a lower reporting limit. For chloroethane, the corresponding reporting limit for 100 ml volume samples is $100 \mu\text{gm}^{-3}$ (reporting limits have been calculated to one significant figure). The corresponding reporting limit for tetrachloromethane from the 100 ml sample volume is $70 \mu\text{gm}^{-3}$.

A number of possible trends are apparent within these data.

- Chloroethane concentrations were universally lower than chloroethene concentrations and were only detected in the *codisposal* and *domestic-with-leachate* main gas samples. Chloroethane was also detected using the 100 ml sample volume in both of these sites but was of lower concentration. Chloroethane was rarely detected during the first monitoring event. However, in the P1-438 database the average for this compound is $77,300 \mu\text{gm}^{-3}$ from 1,408 records with 415 qualifiers and a median of $5,210 \mu\text{gm}^{-3}$. It is therefore surprising that this compound was not detected in more locations and suggests that the database is biased towards problem sites.
- 1,1-dichloroethene concentrations were universally lower than trichloroethene concentrations and generally significantly lower than the P1-438 database average concentration of $476,000 \mu\text{gm}^{-3}$ (median of $13,400 \mu\text{gm}^{-3}$).
- Tetrachloromethane was below detection limits in all main gas wells, and well below the average concentration of $5,300 \mu\text{gm}^{-3}$ in the P1-438 database, suggesting that the database may be biased.
- Trichloroethene concentrations are universally lower than chloroethene concentrations and compare well with the P1-438 database median concentration of $3,300 \mu\text{gm}^{-3}$.
- Gas from the *domestic-with-leachate* landfill had the highest priority HVOC content. This is in disagreement with the first sampling event because the *domestic-with-leachate* site during the first monitoring event contained the lowest HVOC concentrations (however it should be noted that moisture had a significant impact on sampling during the 2002 event and so the HVOCs at sites with wetter gases may have been under-reported to a greater degree).
- For all priority HVOCs, excluding chloroethane, the second sampling event and modified methodology reported a marked increase in concentrations.

In comparison to the previous monitoring event, the concentrations of chloroethene increased by up to several orders of magnitude for all waste types. This increase is almost certainly the result of the improved methodology of purging the ATD tubes with dry nitrogen prior to analysis in order to mitigate moisture effects.

Table 4.6 compares the five priority HVOC compounds and possible age of waste pathways for different waste types. Only main gas samples were taken at the sites designated *domestic-with-little-leachate*, *codisposal* and *substantial-fragmentiser* waste and are not included in this analysis.

Table 4.6 Comparison of priority HVOCs in landfill gas with respect to age of waste sources for different waste types

	Com & Ind.	Dom. with leachate	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}
RECENT			
Chloroethene	17600 ⁽¹⁰⁰⁾	7700 ⁽⁴⁰⁰⁾	2300 ⁽⁴⁰⁰⁾
Chloroethane	<30 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾
Tetrachloromethane	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾
1,1-Dichloroethene	280 ⁽⁴⁰⁰⁾	2800 ⁽¹⁰⁰⁾	80 ⁽⁴⁰⁰⁾
Trichloroethene	900 ⁽⁴⁰⁰⁾	7300 ⁽¹⁰⁰⁾	400 ⁽⁴⁰⁰⁾
RECENT LEACH.			
Chloroethene	9000 ⁽⁴⁰⁰⁾	55000 ⁽⁴⁰⁰⁾	17000 ⁽¹⁰⁰⁾
Chloroethane	<30 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾
Tetrachloromethane	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾
1,1-Dichloroethene	1980 ⁽⁴⁰⁰⁾	2800 ⁽⁴⁰⁰⁾	140 ⁽¹⁰⁰⁾
Trichloroethene	2450 ⁽⁴⁰⁰⁾	8000 ⁽⁴⁰⁰⁾	550 ⁽⁴⁰⁰⁾
MATURE			
Chloroethene	1100 ⁽¹⁰⁰⁾	100000 ⁽⁴⁰⁰⁾	31000 ⁽¹⁰⁰⁾
Chloroethane	<30 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾
Tetrachloromethane	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾	<20 ⁽⁴⁰⁰⁾
1,1-Dichloroethene	<30 ⁽⁴⁰⁰⁾	1880 ⁽⁴⁰⁰⁾	<30 ⁽⁴⁰⁰⁾
Trichloroethene	250 ⁽¹⁰⁰⁾	3500 ⁽⁴⁰⁰⁾	330 ⁽⁴⁰⁰⁾

Actual sample volumes are shown in brackets (ml)

Observable trends comparing recent and old waste in the same landfill include the following.

- Chloroethene was present in higher concentrations than the other HVOCs. This could potentially be used as a screening technique: if chloroethene is not detected, or is detected in very low concentrations, then the other priority HVOCs are unlikely to be detected in significant concentrations.
- Chloroethene displayed no trend with regards to waste type. However, at the *domestic-with-leachate and ash* site, the chloroethene concentrations increased with the age of the waste. In conjunction with this, the concentrations of chloroethene precursor compounds, trichloroethene and 1,1-dichloroethene, decreased with age of waste. The limited data are consistent with the hypothesis that the poly-chlorinated ethenes are degrading with age to yield chloroethene. The oldest waste was sampled from the *commercial & industrial* site (approximately a 9 year difference in age between the recent and mature waste): this may be reflected in the low concentrations at the mature waste sampling location.
- Trichloroethene and 1,1-dichloroethene showed no trends with regard to waste type.
- Tetrachloromethane was not detected at any sampling location. This is also true for the entire 2002 and 2003 datasets.
- Gas from the *domestic-with-leachate* waste type exhibited the highest concentrations of all HVOCs, in comparison to the other waste types.

It can be seen from Table 4.6 and Table 4.7 that greater concentrations of HVOCs per sampling location were generally obtained using the higher volume samples (400 ml). Chloroethene, which is the priority HVOC present at highest concentration, was the exception to this rule, with 10 out of 15 samples exhibiting greater concentrations using the low sample volume (100 ml). Trichloroethene and 1,1-dichloroethene, which are present at lower concentrations, were both borderline, with 8 out of 15 trichloroethene and 7 out of 13 1,1-dichloroethene samples exhibiting greater concentrations using the higher volume. Chloroethane was only detected twice by the high sample volume and was not detected with the low sample volume.

In general, HVOCs showed higher concentrations in the second monitoring event than those obtained during the first. However, the methodology for measuring the HVOCs had changed, particularly the purging of ATD tubes with dry nitrogen prior to mitigate moisture effects. Hence, it is uncertain whether this increased response is an effect of changing conditions in the landfill or due to the change in the analytical methodology. The latter is the favoured explanation.

4.4.4 Oxygenated VOCs

There are three oxygenated VOC compounds on the priority list. Butyric acid and ethyl butyrate are priority compounds because of odour, and 2-butoxy ethanol is a priority compound because of toxicity. The maximum concentration per sampling location for each compound has been selected and is compared for each waste type in Table 4.7, below.

Table 4.7 Priority Oxygenated VOCs in landfill gas 2003

	Com & Ind.	Dom. little leachate	Dom. with leachate	Co-disposal	Frag.	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
2-butoxy ethanol	<50 ⁽⁴⁰⁰⁾	<50 ⁽⁴⁰⁰⁾	<50 ⁽⁴⁰¹⁾	<50 ⁽⁴⁰⁰⁾	<50 ⁽⁴⁰⁰⁾	<40 ⁽⁴⁰⁰⁾
Butyric Acid*	8300 ⁽¹⁰⁰⁾	17500 ⁽⁴⁰⁰⁾	<100 ⁽⁴⁰¹⁾	<100 ⁽⁴⁰⁰⁾	<100 ⁽⁴⁰⁰⁾	<80 ⁽⁴⁰⁰⁾
Ethyl Butyrate	5900 ⁽¹⁰⁰⁾	11000 ⁽¹⁰⁰⁾	42000 ⁽¹⁰⁰⁾	4800 ⁽⁴⁰⁰⁾	700 ⁽⁴⁰⁰⁾	1290 ⁽⁴⁰⁰⁾
RECENT						
2-butoxy ethanol	<50 ⁽⁴⁰⁰⁾	-	<50 ⁽⁴⁰⁰⁾	-	-	<50 ⁽⁴⁰⁰⁾
Butyric Acid*	<100 ⁽⁴⁰⁰⁾	-	<100 ⁽⁴⁰⁰⁾	-	-	<100 ⁽⁴⁰⁰⁾
Ethyl Butyrate	1940 ⁽¹⁰⁰⁾	-	20000 ⁽¹⁰⁰⁾	-	-	480 ⁽⁴⁰⁰⁾
RECENT LEACH						
2-butoxy ethanol	<50 ⁽⁴⁰⁰⁾	-	<50 ⁽⁴⁰⁰⁾	-	-	<50 ⁽⁴⁰⁰⁾
Butyric Acid*	<100 ⁽⁴⁰⁰⁾	-	<100 ⁽⁴⁰⁰⁾	-	-	<100 ⁽⁴⁰⁰⁾
Ethyl Butyrate	3800 ⁽⁴⁰⁰⁾	-	11000 ⁽¹⁰⁰⁾	-	-	830 ⁽⁴⁰⁰⁾
MATURE						
2-butoxy ethanol	<50 ⁽⁴⁰⁰⁾	-	<50 ⁽⁴⁰⁰⁾	-	-	<50 ⁽⁴⁰⁰⁾
Butyric Acid*	700 ⁽¹⁰⁰⁾	-	<100 ⁽⁴⁰⁰⁾	-	-	<100 ⁽⁴⁰⁰⁾
Ethyl Butyrate	410 ⁽¹⁰⁰⁾	-	3500 ⁽⁴⁰⁰⁾	-	-	630 ⁽⁴⁰⁰⁾

Actual sample volumes are shown in brackets (ml)

* butyric acid by ATD tube-quantification uncertain

A number of observations are apparent from these data:

- 2-butoxy ethanol was not detected at any of the sampling locations;
- butyric acid was only detected in samples from the *commercial & industrial* and *domestic-with-little-leachate* sites;
- ethyl butyrate was detected at all sample locations, with the highest concentrations at the *domestic-with-leachate site*;
- the main gas samples contained the highest concentrations of oxygenated VOCs for all waste types; and,
- when butyric acid is detected, it is of higher concentration than ethyl butyrate.

These data vary significantly from the 2002 monitoring event. In 2002, 2-butoxy ethanol was detected in a number of the sampling locations at concentrations up to 12,000 μgm^{-3} , whereas it was not detected during the later monitoring event. Similarly, butyric acid was detected at more locations during the 2002 monitoring event and was typically of low concentration. Detections of butyric acid during 2003 were less frequent but were of a significantly higher magnitude, with the main gas sample for the *commercial & industrial* site of similar concentration to the P1-438 database average of 9000 μgm^{-3} . The two main gas samples for butyric acid at the *commercial &*

industrial and *domestic-with-little-leachate* sites were a few orders of magnitude greater than their corresponding concentrations during the first monitoring event.

From Table 4.7 it can be observed that a majority of the compound detections are from the low sample volume (100 ml). The butyric acid detections were of greater concentration using the low volume samples on 2 out of 3 samples, whereas concentrations of ethyl butyrate were greater on 8 out of 15 samples using the low sample volume. It is therefore unclear whether a 400 or 100 ml sample volume should be used when analysing for these compounds.

4.4.5 Sulphonated VOCs and hydrogen sulphide

There are five sulphonated trace VOC compounds on the odour priority list. Hydrogen sulphide is also on the toxicity priority list. In Table 4.8 below, the reported concentrations of hydrogen sulphide are either from the field readings using the Jerome 631-X hydrogen sulphide analyser or from laboratory analysis of Tedlar bag samples. The latter are used when the field concentrations were out of range of the Jerome instrument ($>50 \text{ ppm}_v$) or when no reading was taken (due to a saturated sensor). The field readings for hydrogen sulphide have been converted from ppm_v to μgm^{-3} .

The main gas sample with the highest sulphonated content came from the *domestic-with-leachate* site. This contradicts the observation made during the 2002 monitoring event when this sample location displayed the lowest sulphonated VOC content. The carbon disulphide concentrations from the main gas samples for the *codisposal* and *substantial-ash* waste types are the same concentration for both monitoring events whereas the main gas samples for the other waste types vary from 1 to 3 orders of magnitude greater than the 2002 monitoring event.

1-propanethiol was only detected in the leachate sample from the *substantial-ash* site and this concentration was well below the P1-438 database average of $400 \mu\text{gm}^{-3}$. In the 2002 monitoring event, 1-propanethiol was more regularly detected. Coupled to this, methanethiol and ethanethiol were not detected at any location. This is a surprising result because during the 2002 monitoring event, methanethiol was detected at every location and was found at concentrations up to $76,000 \mu\text{gm}^{-3}$. Similarly, during the first sampling event, ethanethiol was detected at most locations.

Table 4.8 Priority Sulphonated VOCs in landfill gas 2003

SITE	Com & Ind.	Dom. little leachate	Dom. with leachate	Co-disposal	Frag.	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
Hydrogen sulphide	110000*	49000	31000	52000	>67000	53000
Methanethiol	<300 ⁽⁴⁰⁰⁾	<300 ⁽⁴⁰⁰⁾	<300 ⁽⁴⁰¹⁾	<300 ⁽⁴¹⁷⁾	<300 ⁽⁴⁰⁰⁾	<200 ⁽⁵⁰²⁾
Carbon disulphide	59000 ⁽¹⁰⁰⁾	32000 ⁽¹⁰⁰⁾	170000 ⁽¹⁰⁰⁾	1650 ⁽¹³³⁾	1400 ⁽¹⁰⁰⁾	2600 ⁽⁵⁰²⁾
1-propanethiol	<50 ⁽⁴⁰⁰⁾	<50 ⁽⁴⁰⁰⁾	<50 ⁽⁴⁰¹⁾	<50 ⁽⁴¹⁷⁾	<50 ⁽⁴⁰⁰⁾	<40 ⁽⁵⁰²⁾
Dimethyl disulphide	170 ⁽¹⁰⁰⁾	170 ⁽¹⁰⁰⁾	70 ⁽⁴⁰¹⁾	150 ⁽¹³³⁾	<30 ⁽⁴⁰⁰⁾	480 ⁽⁵⁰²⁾
Ethanethiol	<80 ⁽⁴⁰⁰⁾	<80 ⁽⁴⁰⁰⁾	<80 ⁽⁴⁰⁰⁾	<70 ⁽⁴³³⁾	<80 ⁽⁴⁰⁰⁾	<60 ⁽⁵⁰²⁾
RECENT						
Hydrogen sulphide	200000*	-	300000*	-	-	>69000
Methanethiol	<300 ⁽⁴⁰⁰⁾	-	<300 ⁽⁴⁰⁰⁾	-	-	<300 ⁽⁴⁰⁰⁾
Carbon disulphide	18000 ⁽⁴⁰⁰⁾	-	87000 ⁽¹⁰⁰⁾	-	-	35000 ⁽¹⁰⁰⁾
1-propanethiol	<50 ⁽⁴⁰⁰⁾	-	<50 ⁽⁴⁰⁰⁾	-	-	<50 ⁽⁴⁰⁰⁾
Dimethyl disulphide	30 ⁽⁴⁰⁰⁾	-	790 ⁽¹⁰⁰⁾	-	-	12000 ⁽¹⁰⁰⁾
Ethanethiol	<80 ⁽⁴⁰⁰⁾	-	<80 ⁽⁴⁰⁰⁾	-	-	<80 ⁽⁴⁰⁰⁾
RECENT LEACH						
Hydrogen sulphide	53000	-	580000*	-	-	>68000
Methanethiol	<300 ⁽⁴⁰⁰⁾	-	<300 ⁽⁴⁰⁰⁾	-	-	<300 ⁽⁴⁰⁰⁾
Carbon disulphide	7000 ⁽¹⁰⁰⁾	-	68000 ⁽⁴⁰⁰⁾	-	-	13000 ⁽¹⁰⁰⁾
1-propanethiol	<50 ⁽⁴⁰⁰⁾	-	<50 ⁽⁴⁰⁰⁾	-	-	90 ⁽⁴⁰⁰⁾
Dimethyl disulphide	60 ⁽⁴⁰⁰⁾	-	180 ⁽⁴⁰⁰⁾	-	-	960 ⁽¹⁰⁰⁾
Ethanethiol	<80 ⁽⁴⁰⁰⁾	-	<80 ⁽⁴⁰⁰⁾	-	-	<80 ⁽⁴⁰⁰⁾
MATURE						
Hydrogen sulphide	2400	-	25000	-	-	7000
Methanethiol	<300 ⁽⁴⁰⁰⁾	-	<300 ⁽⁴⁰⁰⁾	-	-	<300 ⁽⁴⁰⁰⁾
Carbon disulphide	1400 ⁽¹⁰⁰⁾	-	12800 ⁽⁴⁰⁰⁾	-	-	900 ⁽¹⁰⁰⁾
1-propanethiol	<50 ⁽⁴⁰⁰⁾	-	<50 ⁽⁴⁰⁰⁾	-	-	<50 ⁽⁴⁰⁰⁾
Dimethyl disulphide	<30 ⁽⁴⁰⁰⁾	-	70 ⁽⁴⁰⁰⁾	-	-	170 ⁽¹⁰⁰⁾
Ethanethiol	<80 ⁽⁴⁰⁰⁾	-	<80 ⁽⁴⁰⁰⁾	-	-	<80 ⁽⁴⁰⁰⁾

Actual sample volumes are shown in brackets (ml)

* Results from laboratory analysis.

Dimethyl disulphide was detected at every main gas sampling location except at the *substantial-fragmentiser* waste site. The highest concentrations of dimethyl disulphide were typically sampled from the recent waste type, with lower concentrations at the mature waste sampling locations.

Hydrogen sulphide concentrations were always found to be highest in the recent waste and lowest in the mature waste for all waste types. The *domestic-with-leachate* site appeared to generate gas with the highest concentrations of hydrogen sulphide. The gas from *substantial-fragmentiser* and *substantial-ash* waste types were not accurately quantified, but had concentrations of hydrogen sulphide in excess of 67,000 $\mu\text{g}/\text{m}^3$.

For the compounds detected, sulphonated VOCs were generally found in greater concentrations using the low sample volume (100 ml). Dimethyl disulphide exhibited higher concentrations at 8 out of 13 sample locations and carbon disulphide was detected in higher concentrations at 10 out of 15 locations using the low sample volume. 1-propanethiol was detected only once and this was with the high sample volume. It appears that in the case of dimethyl disulphide, if the concentration in the sampled media is low then the higher sample volume yields greater concentrations. Conversely, when higher concentrations exist then the low sample volume is more appropriate.

4.4.6 Aliphatic VOCs

1-Pentene is a priority compound because of its odour properties. Table 4.9 presents the maximum concentration of 1-pentene for each waste type.

Table 4.9 Priority Aliphatic VOCs in landfill gas 2003

	Com & Ind.	Dom. little leachate	Dom. with leachate	Co-disposal	Frag.	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
1-pentene	5200 ⁽¹⁰⁰⁾	8800 ⁽¹⁰⁰⁾	21000 ⁽¹⁰⁰⁾	3680 ⁽¹⁰⁰⁾	2700 ⁽¹⁰⁰⁾	14300 ⁽¹⁰⁰⁾
RECENT						
1-pentene	2870 ⁽¹⁰⁰⁾	-	6000 ⁽¹⁰⁰⁾	-	-	700 ⁽⁴⁰⁰⁾
RECENT LEACH						
1-pentene	3500 ⁽⁴⁰⁰⁾	-	5300 ⁽⁴⁰⁰⁾	-	-	2100 ⁽¹⁰⁰⁾
MATURE						
1-pentene	240 ⁽¹⁰⁰⁾	-	3500 ⁽⁴⁰⁰⁾	-	-	2400 ⁽¹⁰⁰⁾

Actual sample volumes are shown in brackets (ml)

The *domestic-with-leachate* site exhibited the highest concentrations of 1-pentene. In the previous sampling event, it was suggested that 1-pentene production might increase in older waste. The results above do not verify this hypothesis, with the exception of gas from the *substantial-ash* site. The concentrations of 1-pentene were generally lower in 2003 than in the 2002 sampling event, especially in the mature waste, which exhibited concentrations up to two orders of magnitude greater in 2002 compared with the 2003 monitoring event.

From a comparison of the main gas samples over the two sampling periods, the *commercial & industrial* and *domestic-with-little-leachate* waste types exhibited similar concentrations of 1-pentene. The *domestic-with-leachate* site was over 2.5 times the concentration during the 2002 round and the ash site was half the concentration. The main gas concentration at the *codisposal* site in 2003 was an order of magnitude below the concentration determined in the 2002 monitoring event.

The P1-438 database contains 23 records of 1-pentene with 12 qualifiers, giving a mean of 1650 μgm^{-3} and a median of 200 μgm^{-3} . The qualifiers distort this information. If only the discrete concentrations are used to calculate a mean and a median, then the recently measured concentrations are in agreement with the database. The mean and median of the discrete concentrations were 3,300 and 2,900 μgm^{-3} respectively, with a geometric mean concentration of 2,100 μgm^{-3} . The mean, median and geometric concentrations of the recently sampled data were 5,500, 3,500 and 3,500 μgm^{-3} , respectively. The median and geometric mean are exactly the same indicating that the concentration is representative. This concentration is also similar to the database mean and median.

The low sampling volume (100ml) appears best suited to sampling for 1-pentene with 11 out of 15 samples exhibiting higher concentrations using this volume.

4.4.7 Aromatic VOCs

Benzene is the priority aromatic VOC in landfill gas due to its toxicity. Table 4.10 presents the maximum concentration from each sampling location for different waste types.

Table 4.10 Priority Aromatic VOCs in landfill gas 2003

	Com & Ind.	Dom. little leachate	Dom. with leachate	Co-disposal	Frag.	Ash
ANALYTE / UNITS	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
MAIN GAS						
Benzene	60000 ⁽¹⁰⁰⁾	15000 ⁽¹⁰⁰⁾	73000 ⁽¹⁰⁰⁾	5640 ⁽¹⁰⁰⁾	3500 ⁽¹⁰⁰⁾	24800 ⁽¹⁰⁰⁾
RECENT						
Benzene	7800 ⁽⁴⁰⁰⁾	-	15000 ⁽¹⁰⁰⁾	-	-	3100 ⁽¹⁰⁰⁾
RECENT LEACH						
Benzene	15500 ⁽⁴⁰⁰⁾	-	17000 ⁽¹⁰⁰⁾	-	-	3400 ⁽¹⁰⁰⁾
MATURE						
Benzene	7900 ⁽¹⁰⁰⁾	-	19000 ⁽¹⁰⁰⁾	-	-	5000 ⁽¹⁰⁰⁾

Actual sample volumes are shown in brackets (ml)

The *domestic-with-leachate* site contained the highest concentrations of benzene for all ages of waste. This contradicts the results from the 2002 monitoring event. The *substantial-fragmentiser* waste site contained the lowest main gas concentration in 2003. The benzene concentrations were frequently elevated above the P1-438 database average of 4,900 μgm^{-3} , with some concentrations orders of magnitude higher. The mean, median and geometric average of this dataset were 18,000, 15,000 and 12,000 μgm^{-3} , respectively. There appeared to be no trend between different ages of waste, but some consistency of concentration was shown between sampling locations for the same waste type.

There was no consistency between concentrations of benzene obtained during the 2003 monitoring event and those obtained during the 2002 monitoring event.

The highest concentrations of benzene were best obtained using the low sample volume (100 ml) with 13 out of 15 samples verifying this.

4.4.8 Assessment of optimum sample volumes for the bulk analysis of VOCs

Table 7 Appendix 3 summarises the VOC analytical results, including all the priority substances as well as some lower priority substances, in the following ways.

- It compares the median, mean and geometric mean of the maximum concentration for each analyte from each sampling location. As a further comparison, the geometric mean of the mean concentration of duplicate samples for both 100 ml and 400 ml volumes for each analyte from each sampling location is also calculated. The comparison of these means gives an indication of the 'typical' concentration of each compound in landfill gas in the UK;
- The geometric mean of the relative percentage differences calculated between duplicates for each compound at each sampling location. This mean represents the average reproducibility of samples and is calculated for 100 and 400 ml sampling volumes. The geometric average of the relative percentage difference between the mean of duplicates for each analyte and sampling location has also been calculated to give an indication of the average difference between the mean concentrations of the 100 and 400 ml sampling volumes; and,
- For each compound at each sampling location, the maximum concentration from both the 100 and 400 ml sampling volumes has been identified and labelled in terms of the sampling volume. The number of 'maximums' using the 100 and 400 ml sampling volumes has been counted for each compound, identifying which sampling volume gives the best response for each compound.

From 15 sample locations, analysing for 61 different compounds, with 4 samples taken from each location (duplicates analyses of 100 and 400 ml sampling volume), a total of 3,660 results were determined for VOCs (not including blanks). For each compound at each location, the maximum concentration from the 4 samples was selected as the representative concentration. From these

915 results, 450 were from the low sample volume (100 ml) and 212 were from the high volume (400 ml) samples, with 253 samples below the detection limit.

In conjunction to this, the last column in Table 7 (Appendix 3), labelled 'best volume', selects the best sample volume determined by the dominant sample volume for each compound (i.e., the sample volume with the highest concentration the greatest number of times for each compound). From this analysis, it can be seen that the low volume sample (100 ml) is dominant for 42 out of 61 compounds. The high sample volume (400 ml) is only dominant for 9 compounds, which is less than the number of compounds (10) that were not detected. With most of the compounds for which the high sample volume is dominant, they are typically borderline cases. For example, 1,1-dichloroethene shows a better response using the high sample volume 7 times and the low sample volume 6 times. Similarly, the concentrations of trichloroethene using the high sample volume are greater 8 times, with the low sample volume being dominant 7 times. The only compounds that show a significant dominance by the high sampling volume are 1,2-dichlorobenzene and 1,2-dichloroethane, which are not priority compounds according to the P1-438 priority chemicals of interest.

In terms of reproducibility of sample concentrations, the low sampling volume shows a more favourable comparison. The maximum geometric mean RPD for both low and high volume samples are 173% and 128%, respectively. The low volume figure is associated with butyric acid, which is suspect in terms of ATD-GC-MS quantification. A high value of 121% is also recorded for the high sampling volume of butyric acid. Ignoring these results, the maximum geometric mean RPD for the low sampling volume reduces to 58%. The mean and median geometric mean RPD for the low sampling volume is 14% and 9%, respectively. The corresponding mean and median for the high sampling volume are 28% and 30%, respectively. It can be seen from these values that the reproducibility of the low sampling volume is typically better than the high sampling volume.

This evidence suggests that the low sample volume (100 ml) typically produces the best results. However, it may be necessary to use the higher sampling volume if low concentrations of the compound of interest are suspected, as with dimethyl disulphide.

4.4.9 Assessment of PCDD/PCDF results in context of sampling/analytical methods

The extraction recoveries for all samples, except LF-E-69, were within the limits required by method EN1948, Table 8 (Appendix 3). The extraction recoveries for LF-E-69 were in the order of 25-30% for all congeners. The reason for the low recoveries is unclear, but it is possible that high levels of non-dioxin/furan compounds were collected by the XAD-2 resin and overloaded the chromatographic columns used for cleanup. Despite the losses of the extraction standard, the recoveries for the sampling standard are acceptable, indicating adequate correction within the standard scheme. It is probable that similar correction has occurred for the native congeners present in the sample.

The sampling recoveries for all samples were within the limits required by EN1948.

Legal emission limits for incinerators are set at 0.1 ngm^{-3} ITEQ and all samples were within this limit except LF-E-15. The sampling volume for LF-E-15 was 25 litres, resulting in higher limits of detection than the rest of the samples. It can be seen that the majority of the ITEQ contribution for this sample is made up from non-detects. If the ITEQ contribution from results less than the limit of detection is assumed to be zero, then this sample also falls below 0.1 ngm^{-3} . Correspondingly the rest of the results fall significantly below this figure. The overall uncertainty attached to these results, based on the results of QC materials and reference materials is estimated to be 25%.

Limits of detection are similar to the previous monitoring event. Most samples have some results above the LOD, but not significantly. Two blanks were run with the samples and all concentrations of the major toxic constituents are below or within 2 times the detection limits.

The total PCDD and PCDF results for some samples were higher than the blanks, which may indicate underlying PCDD and PCDF emissions. It should be noted that the 'total' results are made up of mostly non-toxic PCDDs and PCDFs, which are more abundant than the toxic species (193 non-toxic species vs. 17 toxic ones).

None of the samples in both monitoring events had reliable detections of the toxic PCDDs or PCDFs. It appears that these compounds were not found above trace concentrations within landfill gas in any of the waste types.

4.5 Summary of 2003 monitoring programme

During the 2003 monitoring event, tetrachloromethane, 2-butoxy ethanol, methanethiol and ethanethiol were not detected and chloroethane and 1-propanethiol were rarely detected. The chromatographs were re-analysed for these compounds, confirming the reported concentrations and reaffirming the results.

The analysis of mercury during this monitoring event produced unsatisfactory results. The SKC tubes appear to have an erratic background concentration of mercury and are not suitable for analysis using ICP-MS. Hence, the data from 2003 should be disregarded.

Total arsenic has been detected in concentrations from 0.6 - 410 $\mu\text{g m}^{-3}$, with 50% of concentrations below 10 $\mu\text{g m}^{-3}$. Recent waste appears to be the main generator of inorganic arsenic in the vapour phase. A high degree of variation exists between sampling periods with differences of up to an order of magnitude. This difference occurred at all the sites and is likely associated with a common factor such as changing conditions in the landfill related to weather.

The halogenated VOC chromatographs showed a better response and peak shape during the 2003 monitoring event in comparison to the 2002 event. This was probably a consequence of the improvement in analytical methodology that had been adopted to mitigate the effects of moisture on the chromatography. Temporal variation in concentrations of halogenated VOCs between the 2003 and 2002 monitoring event is difficult to quantify because of this change.

The concentrations of oxygenated species determined during the 2003 monitoring event varied significantly from the 2002 monitoring event. Concentrations of 2-butoxy ethanol were not detected at any sampling location. Butyric acid was detected at fewer locations than in the first monitoring event and ethyl butyrate was detected over a greater range of concentrations.

Difficulty in quantifying butyric acid was expected because of the polar charge affecting the retention time in the GC column. The chromatograph displayed a better response than the previous monitoring event but showed only a marginal improvement in quantification.

The chromatographs for detected sulphonated VOCs showed a marked improvement in response in 2003. However, methanethiol and ethanethiol were not detected at any sampling location during this monitoring event, whereas detections were reported during the first monitoring event. Similarly, 1-propanethiol was not detected as frequently during the 2003 monitoring event.

Hydrogen sulphide was found in comparable concentrations to the 2002 monitoring event at all sample locations except in the mature waste from the *commercial & industrial* waste type. From these observations it can be concluded that hydrogen sulphide does not show temporal variation over the timescales investigated. Hydrogen sulphide was detected at the highest concentrations in recent waste.

Temporal variations in concentrations of detected sulphonated VOCs are difficult to assess because of the increased response on the chromatographs due to the purging of samples with nitrogen to remove water.

Concentrations of 1-pentene were detected at every sample location, although concentrations were generally lower than the 2002 monitoring event. The main gas samples universally exhibited the highest concentrations and gas from the mature waste generally contained the lowest concentrations, with the exception of the *substantial-ash* waste.

Concentrations of benzene varied significantly between the two monitoring events with no apparent trends between different waste types. Higher concentrations of benzene were detected during the 2003 monitoring event, which is likely to arise from the improved VOC analytical technique.

No reliable detections of the toxic PCDDs or PCDFs were made. Some trace detections of non-toxic PCDDs and PCDFs were recorded.

From a comparison between the two monitoring events, it is apparent that concentrations of priority compounds contained within gas from the *domestic-with-leachate* site had significantly changed relative to other waste types. In the first monitoring event, the *domestic-with-leachate* site generally produced gas with the lowest concentrations of most priority compounds. During the second monitoring event, gas from the *domestic-with-leachate* site was observed to contain the highest concentrations of most priority compounds. This may reflect an improved recovery from gas with a very high moisture content through the introduction of the dry nitrogen purge of the ATD tubes.

4.6 Comparison of 2003 and 2002 data

The data obtained in 2003 with the improved monitoring methodology are regarded as most representative, with the exception of the mercury measurements where the low background tubes used in 2002 were more reliable. The 2003 mercury data have been disregarded.

5 Reassessment of trace component prioritisation using new data

The priority list of trace components was derived in R&D project P1-438 by giving each substance a score assigned by multiplying its toxicity or odour rating with the log of the average concentration of the component in the UK landfill database. The data-worth of the historic data on trace components, which made up most of the database, was generally ranked as poor for the purposes of that report. Using the good quality, more comprehensive dataset from this current project it is now possible to re-compute the prioritisation score to give what may be regarded as a more up to date priority list that is representative of landfill gas typically found at current UK sites. At the same time the weighting given to the priority compounds during R&D Project P1-438 was reviewed in the light of current opinion. On the precautionary principle, butadiene was reassessed with a higher toxicity score of 25, reflecting its potential carcinogenicity, whereas the previous score for chloroethane was judged over cautious and was reduced to 5.

Since many compounds other than those on the priority list had been tentatively identified and quantified by the suite of monitoring methods there was sufficient reliable data to reassess compounds that were up to 20 places behind the selected priority components based on toxicity score and 10 based on odour score. Using the earlier toxicity and odour data and the concentrations found in the 2003 monitoring event, these components were reviewed to see whether any were present at sufficiently high concentrations, above the database average, to promote them into the priority list.

In the assessment of trace components in P1-438, 16 chemicals were prioritised in terms of toxicity and 12 in terms of odour. The top 36 components on the toxicity list have been reassessed in light of the new data and the top 22 on the odour list. Some compounds were not detected during the P1-491 monitoring and it is not clear what the limit of detection of those not on the priority list would be. Hence these cannot be assessed but are assumed to be low priority based on concentration. Results on the more ubiquitous trace components that have been reported are shown in Table 9 – Appendix 3 for toxicity and Table 10 – Appendix 3 for odour.

5.1 Revised toxicology list

After reviewing the priority scores with the 2003 data, all of the compounds on the original list remain in the top 16 of toxicity scores, although there is some re-ordering within the sixteen. Table 5.1 below, compares the original ranking with the ranking based upon P1-491 concentrations.

Table 5.1 Comparison of top 16 toxicity scores using database and P1-491 concentrations

Chemical Name	Average Database Concentration	Priority Toxicity Score (P1-438 - database)	Chemical Name	Average P1-491 Concentration	Priority Toxicity Score (P1-491)
	picogm ⁻³			picogm ⁻³	
chloroethane	7.68E+10	500	chloroethene	1.02E+11	550
chloroethene	6.63E+10	500	benzene	1.84E+10	500
benzene	4.86E+09	450	chloroethane	4.61E+08	400
2-butoxy ethanol	2.00E+08	200	2-butoxy ethanol	ND (2.0E+08)	200
arsenic	3.65E+06	150	arsenic	5.11E+07	175
1,1-dichloroethane	4.77E+11	110	trichloroethene	8.59E+09	90
trichloroethene	1.50E+10	100	1,1-dichloroethene	2.23E+09	90
tetrachloromethane	5.26E+09	90	furan	1.43E+09	90
methanal	2.93E+09	90	hydrogen sulphide	1.33E+11	88
hydrogen sulphide	1.34E+11	88	1,1-dichloroethane	5.64E+08	80
1,2-dichloroethene	1.65E+10	80	carbon disulphide	3.40E+10	80
1,1-dichloroethene *	1.00E+08	80	1,2-dichloroethene	6.15E+09	72
Furan	9.75E+08	80	tetrachloromethane	ND (7.0E+07)	70
1,3-butadiene	1.82E+08	80	methanal	5.90E+07	70
mercury	4.09E+06	60	1,3-butadiene	ND (7.0E+07)	70
Carbon disulphide	7.66E+07	56	mercury	**5.00E+05	50

*1,1-dichloroethene from database used median concentration

** mercury average excludes wet sample. Including wet sample, the average would be 1.45E+06 picogm⁻³.

The detection limit used in brackets after the ND is based on a 100 ml sample. 400 ml sample data have also been used in P1-491 calculated averages

Chloroethene and benzene are now higher in the priority list than chloroethane. Furan and carbon disulphide have increased in significance. Tetrachloromethane and methanal have become less of a priority. Mercury has a lower priority now, having a score twenty points below the next priority compound and only 2 above those classed as non-priority compounds. Note that butadiene and 2-butoxy ethanol are ranked highly on the basis of analytical detection limits rather than the measurement of quantifiable amounts of these substances in the current study.

Of the previously determined non-priority compounds detected, none warrants inclusion in the priority list based on P1-491 data. All have the same or a lower toxicity score and roughly follow the existing priority order. The highest non-priority toxicity score is for chloromethane, which based on a detection limit estimate, is now 48, only just below the mercury score.

5.2 Revised odour list

All of the established priority odour compounds remain on the priority list, although again, some reordering has taken place as shown in Table 5.2, below.

Carbon disulphide was found in concentrations three orders of magnitude higher than those in the database, and the dimethyl disulphide average concentration also increased by an order of magnitude. The thiols (mercaptans) were either not detected, or detected in much lower concentrations than in the database and are consequently less of a priority.

Table 5.2 Comparison of 12 odour scores using database and P1-491 concentrations

Chemical Name	Average Database Concentration picogm^{-3}	Priority Odour Score (database)	Chemical Name	Average P1-491 Concentration picogm^{-3}	Priority Odour Score (P1-491)
hydrogen sulphide	1.34E+11	110	hydrogen sulphide	1.33E+11	110
methanethiol	7.26E+09	90	Methanethiol	ND(1.0E+09)	90
butyric acid	8.96E+09	45	carbon disulphide	3.40E+10	60
Ethanal	2.93E+09	45	butyric acid	1.75E+09	45
carbon disulphide	7.66E+07	42	dimethyl disulphide	1.19E+09	45
1-propanethiol	4.33E+08	40	Ethanal	3.91E+08	40
dimethyl disulphide	2.15E+08	40	Ethanethiol	ND(3.0E+08)	40
ethanethiol	1.45E+08	40	1-pentene	5.49E+09	36
1-pentene	1.72E+09	36	ethyl butyrate	7.24E+09	36
ethyl butyrate *	3.29E+10	32	dimethyl sulphide	ND(1.1E+08)	32
dimethyl sulphide	4.80E+08	32	1-butanethiol	ND(1.1E+08)	32
1-butanethiol	2.00E+08	32	1-propanethiol	6.00E+06	30

*ethyl butyrate from database used median concentration

The detection limit used in brackets after the ND is based on a 100 ml sample. 400 ml sample data have also been used in P1-491 calculated averages

Of the extra 10 non-priority compounds assessed, only a few were detected. The compounds that were not on the priority list but were quantified in P1-491 were reported because there was a distinct peak on the chromatograms. Therefore, although compounds not reported are not likely to be present in large concentrations, analytical analysis was not done to confirm this. Of the compounds detected, the odour score of butyl acetate increased to 27, whereas the score for chlorobenzene odour dropped to 16 as a result of lower concentrations detected in P1-491. The increase in butyl acetate concentration is not enough to elevate it above propanethiol in the odour priority list.

5.3 Summary

The existing priority list remains the same for those substances that may have a toxicological significance in typical landfill gas. The caveat placed on the significance of the absolute scores in Project P1-491 remains; that the system is only a simple ranking to determine which substances need to be quantified on a site-specific basis. Previously mercury had been included on the list since there was little data on which to base a score. The datasets now available in this and other projects (ESART, 2003) suggest that mercury no longer warrants inclusion on the priority list. Although in this study of gas from typical sites a few priority compounds have been detected in higher concentrations than the database average (chloroethene, benzene, furan and carbon disulphide), the majority of compounds on the toxicological list had a lower score than determined using the database average. The increase in concentrations of certain compounds is interpreted to result from better recovery of these compounds during the improved sampling and analysis methods used here. Of the compounds that show a decrease relative to the database, the chlorinated compounds are predominant. This is interpreted to be because 'typical' landfill gas has been sampled as opposed to landfill gas sampled to address nuisance issues (problem sites are over-represented in the database).

From an odour perspective, the existing priority list remains the same. Although there has been some rearrangement of the order of priority, in general, measured concentrations in P1-491 were relatively close to the database averages.

6 Database and GasSim input

In the assessment of trace components in R&D project P1-438, a database was constructed containing 45,841 records of trace component data collected from 79 sites across the UK. A data-worth analysis of these data rated 17% as excellent quality and 83% as poor quality. Subsequent research during this project has optimised the sampling methodology and analytical techniques for the collection of trace component data.

The data collected from six 'typical' landfills during the 2002 and 2003 monitoring events have been added to this database, extending the database by 1,940 records. The updated MS Access 2000 Landfill Gas Trace Component Database (version 1.4) is available on CD from the Environment Agency on request.

6.1 Distribution of priority trace components

This section assesses the distribution of priority trace components in different waste types and for a 'typical' UK landfill, providing a source term dataset. The dataset is provided in a form compatible with GasSim (2002b); software developed by Golder Associates on behalf of the Environment Agency to model landfill gas emissions for the purposes of risk assessment.

6.1.1 Selection of data

During this project six landfills containing predominantly different waste types were monitored to act as a representative sample population of 'typical' UK landfills. Gases at these six landfills were sampled during 2002 and 2003.

The improved sampling methodology and analytical techniques developed during this project have allowed the simultaneous collection of a consistent set of high quality data on the priority trace components in landfill gas. In particular, data collected during the 2003 monitoring event displayed much improved chromatograph peak shape and response for volatile organic carbon species. The data collected during 2003 are considered of highest quality and will form the basis of the source term dataset for all but one of the priority components. The only exception to this is the mercury data. Mercury data collected during 2003 monitoring event were of poor quality due to high background concentrations of mercury contained within the sampling media (SKC sorption tube). Mercury data collected during the 2002 monitoring event used low background mercury sampling media sourced from Frontier Geosciences Ltd. The 2002 data are considered of better overall quality and so are likely to be representative of concentrations of mercury contained within 'typical' landfill sites in the UK. Hence the 2002 data have been used in preference to the 2003 mercury data.

During the 2003 monitoring event, up to four samples for each compound were taken from every sample location. In each case, only the maximum concentration for each compound from each location was selected as the most representative concentration. This follows the principle that most problems in sampling/analysis result in the loss of material and therefore a lower reported concentration. Based on the typical variation between samples, the concentrations are estimated to be correct within an order of magnitude (and probably much less than an order of magnitude).

6.1.2 Units and limitations

GasSim requires the entry of trace component data in mgm^{-3} and so all the data on trace gas components was converted to these units for use in the source term dataset. GasSim also includes the option to enter trace gas component data as Probability Density Functions (PDFs). The limited quantity of high quality data available to compile the source term dataset reduces the potential for the application of this function to different waste types. Probability Density Functions have been determined for a 'typical' UK landfill and are included in Section 6.3. It should be noted that where these statistical data are included, they are based on a limited quantity of trace component data. Although they represent the best available default values for landfill gas from "typical" UK sites, site-specific data may be outside these ranges. Much more representative data will become available as site operators undertake annual monitoring of trace components when following the

guidance, which is based on this project. It is recommended that this dataset be used to update the PDFs at a future date.

6.1.3 Probability Density Functions

Probability Density Functions are used within GasSim to allow for the uncertainty in the quality and quantity of available data. GasSim contains PDFs describing the range and distribution of concentrations that a priority trace component may have in a 'typical' UK landfill. The PDF for each priority trace component is used within GasSim for probabilistic modelling of the most likely quantity of each compound in the source term gas at the landfill.

The data from this project have been used to generate a PDF for each priority trace component. A combination of a statistical and subjective approach has been adopted. For each compound, descriptive statistical data were calculated and used to define a histogram. Histograms were plotted with varying number of Bins (intervals) and Bin widths, and superimposed with the cumulative frequency curve to describe the distribution of the data. Since the data for each compound consisted of a limited number of concentrations, the histograms were subjectively interpreted with direct visual interrogation of both the dataset and the corresponding logarithmic dataset to define the most appropriate PDF. The existing GasSim trace component PDFs, based upon the greater quantity of data contained within the P1-438 Landfill Gas Trace Component Database, were also consulted to verify that the distributions of the newly derived PDFs were acceptable.

As a general rule, when determining PDFs, if the range of the dataset is greater than an order of magnitude, then a logarithmic distribution will best represent the dataset. It is also necessary to adopt a consistent convention to deal with concentrations less than or equal to the limit of detection. If a priority trace component has been quantified at concentrations in excess of the limit of detection in the bulk of the dataset, then the limit of detection has been used as the minimum concentration within the PDF. This is consistent with the convention used in the P1-491 Landfill Gas Trace Component Database. If the bulk of concentrations contained within a trace component dataset are below the limit of detection, then a minimum concentration of zero has been assumed (GasSim requires the input of 1E-30 for logarithmic distributions). A maximum concentration equal to the limit of detection is assumed if the compound was not detected in the entire dataset. When determining a logarithmic triangular distribution, the most likely concentration is also required as well as the maximum and minimum concentrations. Generally, the most likely concentration is based upon the mode, however, in certain circumstances when the mode cannot be defined, or does not visually fit the dataset, then either the median or mean has been used.

It should be noted that defining PDFs is mathematically subjective especially when the dataset contains limited data. Therefore, when site-specific data are available for a site, this should always be used in preference to the default PDFs, whether derived from current or historic data.

6.2 Distribution of priority trace components for different waste types

Priority trace component landfill gas data collected during the 2003 monitoring event and mercury data collected during the 2002 monitoring event have been compiled to produce a dataset of 'typical' concentrations of priority trace components in the landfill gas at the sites studied. It should be noted that the data cannot be assigned to a waste type, only to the specific site monitored. This dataset from the present study is presented in Table 6.1, below. The minimum, maximum, mean and the range statistics are included in Table 1 (Appendix 4).

Table 6.1 Summary of data on priority trace components in gas at sites in this study
(Note that header titles relate to site designation for this study, not the source of the gas)

Priority Chemicals of Interest	Codisposal mg m ⁻³	Commercial & Industrial mg m ⁻³	Domestic with Leachate mg m ⁻³	Domestic with little Leachate mg m ⁻³	Substantial Ash mg m ⁻³	Substantial Fragmentiser mg m ⁻³
1,1-dichloroethane	0.43	0.22	1.44	0.59	0.14	0.28
1,1-dichloroethene	0.04	0.92	6.62	2.80	0.10	0.14
1,3-butadiene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
1-butanethiol	<0.07	<0.08	<0.08	<0.08	<0.08	<0.08
1-pentene	3.68	2.95	8.95	8.80	4.88	2.70
1-propanethiol	<0.05	<0.05	<0.05	<0.05	0.06	<0.05
2-butoxy ethanol	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
arsenic	0.003	0.015	0.025	0.005	0.148	0.007
benzene	6	23	31	15	9	4
butyric acid	<0.1	2.3	<0.1	17.5	<0.1	<0.1
carbon disulphide	1.7	21.4	84.5	32.0	12.9	1.4
chloroethane	1.61	<0.03	1.35	<0.03	<0.03	<0.03
chloroethene	271	17	223	180	18	46
cis-1,2-dichloroethene	4.0	1.5	16.0	5.0	1.5	1.0
dimethyl disulphide	0.15	0.07	0.28	0.17	3.40	<0.03
dimethyl sulphide	0.44	0.24	5.58	0.73	7.70	0.19
ethanal	0.25	0.13	0.86	0.08	0.49	0.23
ethanethiol	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
ethyl butyrate	4.80	3.01	19.13	11.00	0.81	0.70
furan	0.23	0.50	2.62	1.20	1.06	0.34
hydrogen sulphide	52	91	234	49	>49	>67
mercury	0.0006	0.0007	0.0005	0.0005	0.0006	-
methanal	0.056	0.052	0.105	0.026	0.070	0.068
methanethiol	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
tetrachloromethane	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
trans-1,2-dichloroethene	0.50	0.16	1.02	0.35	0.19	0.23
trichloroethene	1.65	2.58	26.70	7.10	0.61	0.54

6.3 Distribution of priority trace components in a 'typical' UK landfill

In Table 6.2, the priority trace component data collected during the 2003 monitoring event and the mercury data collected during the 2002 monitoring event have been collated into a single dataset, to produce a statistical distribution of trace component data from a 'typical' UK landfill site. The minimum, maximum, range, mode, median and mean have been calculated from 15 sample locations from 6 different landfill sites, with the exception of the mercury data which has been calculated from 11 sample locations from 5 different landfill sites. The GasSim PDF has also been determined for each compound. This single PDF incorporates data from gas at all the sites studied in this project and can provide default values for use in GasSim when no site-specific data is available.

Table 6.2 Distribution of priority trace components in a 'typical' UK landfill

Priority Chemicals of Interest	Concentration at 'typical' UK Landfill (mg m ⁻³)						
	min	max	range	mode	median	mean	GasSim PDF
1,1-dichloroethane	<0.02	3.90	3.88	0.28	0.28	0.57	LogT(0.02,0.28,3.9)
1,1-dichloroethene	<0.03	19.00	18.97	2.80	0.28	2.24	LogT(0.03,2.8,19)
1,3-butadiene	<0.02	<0.02	>0.00	<0.02	<0.02	<0.02	LogU(1E-30,0.02)
1-butanethiol	<0.06	<0.08	>0.02	<0.08	<0.08	<0.08	LogU(1E-30,0.08)
1-pentene	0.24	21.00	20.76	3.50	3.50	5.49	LogT(0.24,3.5,12)
1-propanethiol	<0.04	0.09	>0.05	<0.05	<0.05	<0.05	LogU(1E-30,0.09)
2-butoxy ethanol	<0.04	<0.05	>0.01	<0.05	<0.05	<0.05	LogU(1E-30,0.05)
Arsenic	0.0006	0.4300	0.4294	-	0.0074	0.0511	LogT(1E-4,0.0074,0.43)
Benzene	3.1	73.0	69.9	15.0	15.0	18.4	LogT(3.1,15,73)
butyric acid	<0.08	17.50	17.42	<0.10	<0.10	1.85	LogT(1E-30,0.1,17.5)
carbon disulphide	0.9	170.0	169.1	1.4	13.0	34.0	LogU(0.9,170)
Chloroethane	<0.02	5.30	5.28	0.03	0.03	0.49	LogU(1E-30,5.3)
Chloroethene	1.1	730.0	728.9	-	31.0	102.1	LogT(1.1,31,730)
cis-1,2-dichloroethene	0.13	46.00	45.87	3.90	2.20	5.71	LogT(0.13,3.9,46)
dimethyl disulphide	<0.03	12.00	11.97	0.17	0.17	1.02	LogT(0.03,0.17,12)
dimethyl sulphide	<0.03	24.30	24.27	-	0.73	3.69	LogT(0.03,0.73,24.3)
Ethanal	0.075	2.546	2.471	0.084	0.225	0.431	LogU(0.075,2.546)
Ethanethiol	<0.08	<0.08	>0.00	<0.08	<0.08	<0.08	LogU(1E-30,0.08)
ethyl butyrate	0.41	42.00	41.59	11.00	3.50	7.22	LogU(0.41,42)
Furan	0.02	6.20	6.18	-	0.82	1.23	LogT(0.02,0.82,6.2)
hydrogen sulphide	2.4	580.0	577.6	53.0	53.0	111.1	LogT(2.4,53,580)
Mercury	0.00017	0.00133	0.00116	-	0.00050	0.00058	LogU(0.00017,0.00133)
Methanal	0.026	0.188	0.162	0.072	0.068	0.070	LogT(0.026,0.068,0.188)
Methanethiol	<0.3	<0.3	>0.0	<0.3	<0.3	<0.3	LogU(1E-30,0.3)
tetrachloromethane	<0.02	<0.02	>0.00	<0.02	<0.02	<0.02	LogU(1E-30,0.02)
trans-1,2-dichloroethene	<0.02	2.60	2.58	-	0.26	0.44	LogT(0.02,0.24,2.6)
Trichloroethene	0.25	88.00	87.75	-	1.65	8.59	LogT(0.25,1.65,88)

Notes: LogU denotes LOGUNIFORM

LogT denotes LOGTRIANGULAR

Great care has been taken with the fitting of distributions (PDFs) to the datasets. However, this process is mathematically subjective and is based upon limited data. Therefore, the PDFs may not be fully representative of the distribution of concentrations at 'typical' UK landfill sites

7 Potential screening methods

The proposed sampling methodology and analytical techniques developed for the sampling of trace landfill gases use sophisticated techniques to distinguish individual components and so are relatively expensive. The detailed results of this monitoring will be used for the Pollution Inventory and site-specific risk assessments. Screening methodologies could potentially be used more frequently than sophisticated sampling to decrease the uncertainty in the overall data. Hence, consideration has been given here to possible screening methods. However, screening techniques are not an alternative for the more robust sampling/analytical methodologies necessary for quantifying concentrations of compounds for use in the Pollution Inventory and for site-specific risk assessments.

7.1 Potential screening tests

Screening tests can be used in conjunction with regular quantitative sampling to:

- inform the selection of sample points and the analytical suite on a site-specific basis;
- identify problematic areas prior to sampling with protocol methodologies; and
- monitor fluctuations in trace landfill gases between annual surveys. This includes checks after operational changes in the gas management system or waste composition.

Operators frequently use a screening method to estimate the concentration of substances that may affect the life of components used in gas collection systems and power generation engines. These data can potentially be used as screening data with little or no extra cost.

The required detection limit of a screening test is dependent upon the concentrations of compounds being quantified and the objective of the screening test. If a trace component is routinely detected in all landfill gas samples at high concentrations, there is no requirement for a low detection limit to achieve good quantification of that compound. Typically, a detection limit an order of magnitude below the detected concentration permits reliable quantification. However, if the objective of the screening test is to determine trace gas composition, then it may be necessary to identify compounds at low concentrations, requiring a low detection limit. Screening techniques are therefore more applicable to proving the positive, i.e. to quantify a compound that is present, rather than to determine whether a compound is absent.

7.2 Potential sampling methods

There are two types of sampling that may be appropriate for screening analysis.

7.2.1 Bulk gas samples

A common methodology used in vapour sampling involves collection of bulk gas samples. This is followed by direct injection into an analytical device (discussed in the following section). Gas collection is usually done into an evacuated cylinder (Gresham Tube or Summa Canister) or an inert polymer bag (Tedlar Bag).

These devices share two main problems:

- 1) there is a limitation on achievable detection limit in direct gas injection; and
- 2) the gases may react during transportation from the sample location to the laboratory.

The detection limit is governed by the gas capacity of the analytical device. Usually samples are limited to low (ml) volumes without pre-concentration. Pre-concentration can be achieved using adsorbent media or by gas injection into purge and trap units.

Due to the heterogeneous nature of the landfill matrix, gases sampled from the subsurface may not be in equilibrium. The mixing induced by the gas flow may result in a thermodynamically unstable

mixture that will degrade over time. It is best to analyse the gases as soon as possible to reduce the effect of any reactions between gases.

Tedlar bags have an additional problem. Due to the reducing nature of typical landfill gas, even small amounts of oxygen entering into the bag may induce reactions. Certain compounds are also known to adsorb to the bag, fittings and valves.

There are additional problems with evacuated cylinders. These cylinders are made of metal, offering active sites for reactions to take place (i.e. sulphur reactions on steel). The cylinders can be coated in glass and salt washed to reduce the reactivity of the canister surface and care taken in the selection of gas fittings so that exposure of reactive surfaces is reduced. Due to the cost of these cylinders, they are usually washed and reused. It can be quite difficult to achieve thorough cleansing, and the need for repeated blank analytical runs to ensure that the vessels are free from trace components prior to sampling can be time consuming and expensive.

7.2.2 Adsorption methods

Some of these methods have been thoroughly described in the review of candidate methodologies (Environment Agency, 2002a). Modifications to the sorbent or sample volumes may permit screening samples to be taken at a lower cost or thoroughness than those taken for the comprehensive screening of priority substances undertaken in this present project.

7.3 Potential analytical methods

In general, for reliable quantification, the screening methodology should be able to achieve detection limits an order of magnitude below the concentration of the compound being determined on a sample-specific basis. In some cases, where prior knowledge of typical concentrations from the selected sampling point is not available, screening tests can be conducted to determine any positive identification of priority compounds.

It is important that method verification of any screening takes account of the problems associated with landfill gas. The development of the methods used in the 2002-2003 monitoring have highlighted that methods derived for a different use (such as occupational hygiene methods) may need to be modified. Any method used should be proven to work on landfill gases (e.g. by comparison with a reference method).

There are two types of analysis that may be appropriate for screening methods. Laboratory analysis and field analysis may both be suitable under certain conditions.

7.3.1 Laboratory analysis

In screening by both bulk gas sampling and adsorption methods a sample is taken to a laboratory for analysis. For general VOCs, common methods of analysis include IR (Infrared Absorbance), GC-MS (Gas Chromatography-Mass Spectrometry), GC-FID (Flame Ionisation Detector), GC-PID (Photo Ionisation Detector) and GC-ECD (Electron Capture Device). For hydrogen sulphide (H_2S) IR may be appropriate.

Some of these methods are selective only to certain groups of VOCs, but may give an indication of whether a site has elevated concentrations of priority components. For instance, ECD is very sensitive to halogenated species but will not significantly detect most other species. Photo Ionisation Detector response is related to the power of the ionising lamp. If the energy of the lamp exceeds the ionisation potential of the targeted species then detection is good. If the energy of the lamp is too low, the response to target species is low. Generally, a PID usefully detects only unsaturated compounds. FID gives a fairly even response to hydrocarbons, compared to most other methods, but is less sensitive. Mass Spectroscopy allows additional confirmation of the separated component. Most of these screening methods rely on chromatography to separate components before any identification. Although the optimum methodology to quantify all the priority species was selected for the site work reported here, quantification of individual species or screening of those classes present at high concentration could use one of these options. However,

any method, or group of methods, must achieve the required detection limits and must be verified to work on landfill gas samples.

7.3.2 Portable analytical equipment

There is a variety of portable sampling equipment that can achieve reliable analysis for certain components in the field. The most common of these are field monitors for H₂S, carbon monoxide (CO) and the bulk gases. More complex instrumentation is available up to and including field portable GC-MS.

Using field portable equipment may simplify the sampling step, or at least reduce some of the problems associated with it. If the sample is taken directly into the instrument, no additional sampling step is required but problems with pressure control may prohibit direct sampling. As an alternative, a sample could be pulled into a Tedlar bag and then introduced in a controlled manner into the field instrument. Because the sample would only be in the Tedlar bag for a short period, reactivity and permeation would not have time to significantly degrade the sample quality. Evacuated cylinders would not easily lend themselves to this use, given the need to pump samples against the vacuum on the gas line.

In general, due to the limited control of the operating environment, the quality of analysis with field equipment may be lower (both in precision and accuracy) compared with laboratory analysis. However, this may be offset by a higher quality in the sample as a result of reducing transportation and time to analysis.

7.4 Comparison of screening data

Whenever two different analytical methods are used on trace components, it is likely that the variation in the detected concentrations will be much greater between the methods than within the methods. Although significant work has been done to determine the best method for a given sample, the huge number of variables involved in sampling and analysis often lead to considerable disparity between the results from two apparently, very good methods. As such, although the sampling error may be typical of general gas sampling at approximately 20%, variation between methods may be much greater and could be closer to 100%.

In order to assess one alternative method that may be used for screenings during the 2003 monitoring event, Tedlar bag samples were taken at every sampling location and analysed using Purge and Trap Gas Chromatography Mass Spectrometry (PT-GC-MS) by a third party (Laboratory L4). This was in parallel with the main VOC sampling programme involving the sampling of all 15 locations using dual sorbent ATD tubes analysed by GC-MS. The Tedlar bag samples were analysed for VOCs and Tentatively Identified Compounds (TICS). Ten priority compounds and a further twenty non-priority compounds were found on the dual sorbent samples, allowing partial comparison of the results. A further set of Tedlar bag samples were taken at six locations and sent to Laboratory B for analysis using direct injection GC-MS. This method analysed for thirty-six compounds of which fourteen were priority compounds and a further eight coincided with compounds present in the ATD-GC-MS method target compound suite. These results will be discussed in two separate sections below.

7.4.1 Comparison of results from dual sorbent ATD-GC-MS and Tedlar bag PT-GC-MS sampling methods

As discussed above, Tedlar bag samples were taken from all 15 sampling locations during the 2003 monitoring event in conjunction with the ATD tube samples. The limit of detection achieved for the Tedlar bag PT-GC-MS method was 200 µg m⁻³.

A comparison between priority compounds for both sampling/analytical methodologies are presented in Table 7.1, below and the non-priority compounds are presented in Table 1 (Appendix 5). Relative Percentage Differences (RPDs) were calculated by determining the difference, dividing by the average and then multiplying by 100. These percentages were used to compare the analyses.

Table 7.1 Comparison of results from dual sorbent ATD-GC-MS and Tedlar bag PT-GC-MS sampling / analytical methods

Waste Type	Sample Location	Sample Collection Media	PRIORITY COMPOUNDS									
			Chloroethene $\mu\text{g m}^{-3}$	Chloroethane $\mu\text{g m}^{-3}$	Furan $\mu\text{g m}^{-3}$	1,1-Dichloroethane $\mu\text{g m}^{-3}$	Tetrachloromethane $\mu\text{g m}^{-3}$	Benzene $\mu\text{g m}^{-3}$	Trichloroethene $\mu\text{g m}^{-3}$	Ethyl Butyrate $\mu\text{g m}^{-3}$	trans-1,2-Dichloroethene $\mu\text{g m}^{-3}$	cis-1,2-Dichloroethene $\mu\text{g m}^{-3}$
Domestic with Leachate	Main Gas	ATD	730000	5300	6200	3900	<20	73000	88000	42000	2600	46000
		Tedlar	5800	<200	<200	500	<200	5700	4400	15550	<200	8700
	Mature	ATD	100000	<30	1130	360	<20	19000	3500	3500	310	3900
		Tedlar	1100	<200	<200	<200	<200	1400	<200	<200	<200	1000
Domestic with little Leachate	Recent	ATD	7700	<30	1600	1100	<20	15000	7300	20000	470	5700
		Tedlar	3000	<200	<200	1300	<200	6300	3100	<200	<200	13900
	Leachate	ATD	55000	<30	1530	380	<20	17000	8000	11000	700	8300
		Tedlar	2500	<200	<200	<200	<200	3900	1900	<200	<200	6500
Commercial and Industrial	Main Gas	ATD	180000	<30	1200	590	<20	15000	7100	11000	350	5000
		Tedlar	1000	<200	<200	<200	<200	500	300	<200	<200	700
	Leachate	ATD	41000	<30	1300	560	<20	60000	6700	5900	420	3900
		Tedlar	700	<200	<200	<200	<200	4700	700	<200	<200	800
Fragmentiser	Recent	ATD	9000	<30	530	150	<20	15500	2450	3800	120	1450
		Tedlar	<200	<200	<200	<200	<200	3100	<200	<200	<200	1000
	Mature	ATD	17600	<30	150	140	<20	7800	900	1940	60	450
		Tedlar	900	<200	<200	<200	<200	2000	400	<200	<200	300
Substantial Ash	Main Gas	ATD	1100	<30	20	<20	<20	7900	250	700	<20	130
		Tedlar	<200	<200	<200	<200	<200	2000	<200	<200	<200	<200
	Leachate	ATD	46000	<30	340	280	<20	3500	540	730	230	1000
		Tedlar	500	<200	<200	<200	<200	<200	<200	<200	<200	200
Codisposal	Main Gas	ATD	22600	<20	5560	170	<20	24800	1140	1290	260	2200
		Tedlar	900	<200	<200	600	<200	3000	<200	14030	<200	7000
	Recent	ATD	2300	<30	700	50	<20	3100	400	480	220	1400
		Tedlar	12300	1400	<200	400	<200	2700	1300	<200	<200	4300
Substantial Ash	Mature	ATD	31000	<30	130	70	<20	5000	330	630	70	580
		Tedlar	2100	<200	<200	200	<200	1800	<200	<200	<200	1000
	Leachate	ATD	17000	<30	820	280	<20	3400	550	830	210	1700
		Tedlar	1500	<200	<200	<200	<200	39400	<200	9010	<200	3800
Fragmentiser	Main Gas	ATD	271000	1610	230	430	<20	5640	1650	4800	500	3980
		Tedlar	400	<200	<200	<200	<200	1200	<200	<200	<200	3600

Notes:

white
blue
green
Orange
yellow
red

denotes compounds not in a comparable range (i.e. detected ATD concentrations are lower than the Tedlar bag detection limit)

denotes good to excellent comparison (RPD \leq 150%) when one methodology is out of range

denotes excellent comparison (RPD \leq 100%)

Denotes good comparison (100% < RPD < 150%)

denotes poor comparison of an undetermined magnitude

denotes very poor comparison (greater than an order of magnitude)

From Table 7.1, the following observations are apparent.

- Only 9 out of 25 priority compounds were detected using the Tedlar bag sampling media coupled with PT-GC-MS. It is recognised that PT-GC-MS is not suitable for the analysis of arsenic, mercury, methanal and ethanal. However, this still does not account for the non-detection of 12 priority compounds.
- Concentrations of chloroethene determined from Tedlar bag samples are generally an order of magnitude below concentrations reported in the ATD tubes, demonstrating poor comparison. In only one instance (gas from recent waste at the *substantial-ash* site) is the concentration of chloroethene greater in the Tedlar bag sample.
- Chloroethane was rarely detected in both sampling media. It is interesting to note that chloroethane was detected twice in the Tedlar bag samples and twice in the ATD tubes but none of these detections were from corresponding sampling locations.
- Furan was not detected in any Tedlar bag samples even though furan was detected in concentrations greater than the PT-GC-MS detection limit in every ATD tube sample.
- 1,1-dichloroethane was detected in 5 Tedlar bag samples and 10 ATD tube samples. From these detections, 2 comparative samples were rated as an excellent comparison and a further sample was rated as good. In 4 out of the 5 cases, where 1,1-dichloroethane was detected in the Tedlar bag samples, the Tedlar bag samples exhibited greater concentrations.
- Tetrachloromethane was not detected using either sampling media and analytical methodology.
- Concentrations of benzene were detected in nearly every sample for both sampling media. In all but one sample, the ATD tubes exhibited greater concentrations of benzene than the Tedlar bag samples. This one Tedlar bag sample was an order of magnitude greater than the corresponding ATD sample and was sampled from the *substantial-ash* site (leachate). Of these samples, 3 showed an excellent comparison, 4 were of good comparison and 7 showed a poor comparison with 6 being greater than an order of magnitude different.
- Trichloroethene was detected in every ATD sample but only in 7 Tedlar bag samples. Of these detections, 2 were of excellent comparison, 2 were of good comparison and 3 samples were poor to very poor. The recent waste from the *substantial-ash* site exhibited higher concentrations in the Tedlar bag sample than in the corresponding ATD tube sample.
- Ethyl butyrate was rarely detected in the Tedlar bag samples (3 out of 15 samples) although it was detected in every ATD tube. Where ethyl butyrate was detected in the Tedlar bag samples, 2 out of 3 of these samples exhibited concentrations greater than the corresponding ATD tube samples. Both of these samples came from the *substantial-ash* site and showed a very poor comparison with the ATD tube concentrations.
- Trans-1,2-dichloroethene was not detected in any Tedlar bag sample. Concentrations of trans-1,2-dichloroethene determined from ATD tubes were above the limit of detection for PT-GC-MS analysis in 11 out of 15 samples.
- Concentrations of cis-1,2-dichloroethene were detected in all but one Tedlar bag sample. The concentrations detected in both sampling media demonstrated a very good comparison with 7 samples of excellent and 6 samples of good comparison rating.

From Table 1 (Appendix 5), incorporating non-priority compounds into the discussion, it can be seen that the lighter, more volatile compounds (several of which are priority compounds) show poor quantification using Tedlar bags and PT-GC-MS, whereas the heavier compounds (which tend not to be priority compounds), especially the aromatic hydrocarbons, show better quantification. In summary, the Tedlar bag sampling media coupled with PT-GC-MS analytical techniques generally under reports, and frequently does not detect, priority compounds.

7.4.2 Comparison of results from ATD tube and direct injection GC-MS

In addition to the Tedlar bag samples mentioned above, a further 6 Tedlar bag samples were taken from select locations and submitted to Laboratory L5 for analysis by GC-MS. It should be noted that this methodology is designed for determining concentrations of chlorinated compounds in high concentrations ($>100 \text{ mg m}^{-3}$) to monitor and prevent damage to the power generation plants. The limit of detection achieved for this method was $1,000 \text{ } \mu\text{g m}^{-3}$, except for dichlorodifluoromethane, which has a detection limit of $5,000 \text{ } \mu\text{g m}^{-3}$. The detection limit of dichlorodifluoromethane is $5,000 \text{ } \mu\text{g m}^{-3}$ because of false positive readings associated with water vapour below this concentration.

Laboratory L5 analysed for 14 priority compounds and 12 non-priority compounds. The results were compared with ATD-GC-MS derived concentrations and the priority compounds are presented in Table 7.2, below. Non-priority compounds are presented in Table 2 (Appendix 5). Relative Percentage Differences were used to compare the analyses. Chloroethane, ethanethiol, methanethiol, 1-propanethiol, 1-butanethiol and dimethyl disulphide have been excluded from this table because they were not detected by either analytical technique at any sample location.

Table 7.2 Comparison of results from ATD-GC-MS and direct injection GC-MS sampling methods

Waste Type	Sample Location	Sample Collection Media	Priority Compounds ($\mu\text{g}/\text{m}^3$)							
			Chloroethene	1,1-Dichloroethene	Dimethyl Sulphide	Carbon Disulfide	1,1-Dichloroethane	Trichloroethene	cis-1,2-Dichloroethene	Hydrogen Sulphide
Domestic-with-Leachate	Mature	ATD	100000	1880	140	12800	360	3500	3900	25000
		Lab B	4580	<1000	<1000	<1000	<1000	<1000	5370	89610
	Recent	ATD	7700	2800	4700	87000	1100	7300	5700	>67000
		Lab B	4050	<1000	NC	NC	<1000	4430	11760	295510
	Leachate	ATD	55000	2800	1480	68000	380	8000	8300	-
		Lab B	3430	<1000	<1000	NC	<1000	1400	12220	577080
Domestic-with-little-Leachate	Main Gas	ATD	180000	2800	730	32000	590	7100	5000	46800
		Lab B	2700	<1000	<1000	<1000	<1000	1750	<1000	66220
Commercial & Industrial	Main Gas	ATD	41000	1400	590	59000	560	6700	3900	>70000
		Lab B	1590	<1000	<1000	NC	<1000	1260	2360	110510
	Recent	ATD	17600	280	240	18000	140	900	450	>67000
		Lab B	990	<1000	<1000	NC	<1000	<1000	<1000	200450

Notes:

White	denotes compounds not in a comparable range (i.e. detected ATD concentrations are lower than the Tedlar bag detection limit)
Blue	denotes good to excellent comparison ($\text{RPD} \leq 150\%$) when one methodology is out of range
Green	denotes excellent comparison ($\text{RPD} \leq 100\%$)
Yellow	denotes poor comparison of an undetermined magnitude
Red	denotes very poor comparison (greater than an order of magnitude)
NC	denotes no calibration factor for this compound. A response was observed.
-	denotes no reading

From Table 7.2, the following observations are apparent.

- As noted above, chloroethane, ethanethiol, methanethiol, 1-propanethiol, 1-butanethiol and dimethyl disulphide were not detected by either analytical technique. The detection limits for the two analytical methods were greater than an order of magnitude apart.
- Chloroethene was detected in all samples but was under reported by an order of magnitude in 5 out of 6 Tedlar bag samples. One Tedlar bag sample exhibited concentrations of chloroethene with an excellent comparison rating with an absolute RPD of 62%.
- Concentrations of 1,1-dichloroethene were detected in all ATD samples but not detected in any Tedlar bag samples. The detection limit for the Tedlar bag method was similar to the concentrations determined by ATD-GC-MS and therefore the comparison appears to be of

excellent rating. However, the Tedlar bag method has not been demonstrated to be suitable for the quantification of this compound.

- Methyl sulphide was universally detected in the ATD samples. Most of the ATD concentrations were below the GC-MS detection limits. Methyl sulphide was detected in the Tedlar bag sample from the *domestic-with-leachate* site (recent waste), although no calibration coefficient has been determined to quantify the response.
- Carbon disulphide was universally detected in the ATD samples. Four Tedlar bag samples displayed a response in the GC-MS chromatograph but no calibration factor has been determined preventing these responses from being quantified. Two Tedlar bag samples did not detect carbon disulphide even though lower concentrations showed a response.
- Concentrations of 1,1-dichloroethane determined by ATD-GC-MS were generally below the detection limit of the Tedlar bag method. One sample was quantified by ATD-GC-MS to be marginally above the Tedlar bag method detection limit but was not detected in the Tedlar bag.
- The Tedlar bag method detected trichloroethene in 3 out of 5 samples. The ATD-GC-MS method detected concentrations of trichloroethene in all samples, although one concentration was below the Tedlar bag detection limit. The four samples that were detected by both methods showed a good to excellent comparison rating.
- Hydrogen sulphide was detected in all Tedlar bag samples. The ATD-GC-MS method did not analyse for hydrogen sulphide and therefore the results are compared to field readings taken by a Jerome 631-X H₂S Portable Analyser. The Jerome 631-X H₂S Portable Analyser has a limited measurement range, with a maximum measurable concentration of 50 parts per million by volume (~70,000 µg/m³ depending on pressure and temperature). Two concentrations were not out of range of the portable analyser and showed a good to excellent comparison with the Tedlar bag method. Three other samples were above the maximum concentration of the portable analyser.

The Tedlar bag sampling media coupled with GC-MS generally under-reports or does not detect concentrations of priority compounds. The detection limit is generally too close to typical concentrations of some priority compounds, consequently leading to non-detection of these compounds. Only cis-1,2-dichloroethene was detected in concentrations greater than the ATD-GC-MS method in 3 out of 5 samples. This method may be fit for its original screening function, to determine all the chlorinated compounds that may be at a concentrations sufficient to damage components associated with power generation. However, in its present form it does not appear to have the power to discriminate between the priority substances of concern here.

Hydrogen sulphide concentrations could be measured over a much wider range using the Tedlar bag method than with the Jerome 631-X H₂S Portable Analyser.

7.5 Summary of screening test comparisons

Screening methods can be used in conjunction to protocol sampling methodology to indicate whether a site has elevated concentrations of the priority components and aid in the identification of problematic areas. Different compounds displayed different comparisons between the methodologies. Based on the available data, the following conclusions can be drawn.

Halogenated VOCs

The Tedlar bag methods showed poor detection frequency and poor quantification. Only cis-1,2-dichloroethene displayed good comparison with ATD-GC-MS derived concentrations, often reporting greater concentrations.

Oxygenated VOCs

The ATD-GC-MS concentrations were generally near the Tedlar bag method limit of detection. Because of this, the Tedlar bag method rarely detected concentrations of oxygenated VOCs. There was poor detection of the concentrations of ethyl butyrate in the Tedlar bag method, although concentrations were found to be greater (by an order of magnitude) than in the ATD tube samples on two occasions.

<i>Sulphonated VOCs</i>	Sulphonated VOCs were not detected in Tedlar bag samples sent to Laboratory A and generally not detected in Tedlar bag samples sent to Laboratory B. However, the method used by Laboratory B did show a response for most priority sulphonated VOCs in the recent waste at the <i>domestic-with-leachate</i> site although the response could not be quantified. This is because there were no instrument calibration coefficients for these compounds.
<i>Aliphatic VOCs</i>	1-pentene was not detected in any Tedlar bag sample.
<i>Aromatic VOCs</i>	Benzene was detected in nearly all Tedlar bag samples sent to Laboratory A. Laboratory B did not analyse for benzene. The Tedlar bag samples displayed good detection and good quantification at low concentrations ($<15000 \mu\text{g}/\text{m}^3$). In greater concentrations, the Tedlar bag method showed poor quantification.
<i>Hydrogen Sulphide</i>	From the data available, hydrogen sulphide is best determined and more accurately quantified using Tedlar bag samples and GC-MS. The Jerome 631-X Portable H_2S Analyser, although providing good quantification within the measurable range of the instrument (2 ppb _v – 50 ppm _v) was often not suitable for quantifying the concentrations of Hydrogen Sulphide at 'typical' concentrations.

In summary, Tedlar bag samples coupled with GC-MS analytical methodology showed poor comparison to the protocol method for priority compounds, generally under reporting concentrations. Some non-priority compounds display a better comparison. It may be possible in the future to calibrate the response of Tedlar bag analysis to more accurately reflect concentrations derived from the protocol methodology, but detection limits will always be constrained by a lack of on-site sample pre-concentration.

8 Conclusions

The gas at six typical UK landfills has been sampled on two occasions and the analytical results have been added to the UK national database of trace component concentrations. Method refinements made during this monitoring programme have been included in the latest Guidance for Monitoring Trace Components in Landfill Gas (Environment Agency, 2004b) and the results have been compiled into a datafile suitable for use in the GasSim risk assessment modelling tool.

One hundred and fifty-five samples were taken from 15 sampling locations at 6 different landfill sites, primarily targeting the 25 priority compounds of interest identified during the previous P1-438 project. Monitoring programmes took place in 2002 and 2003, providing the following conclusions.

Monitoring Methodology

- The basic techniques recommended in R&D Project P1-438 were used successfully. An important refinement during the 2003 monitoring was the use of a dry nitrogen purge to reduce the effect of moisture on the Automated Thermal Desorption (ATD) tubes. In addition, lower sampling volumes were used to avoid overloading. These factors improved the recovery of less strongly bound substances such as chloroethene. The ATD columns were found to give adequate quantification of butyric acid and so the specialist column proposed for this acid was not needed. The importance of using sorbents with a low background level for mercury was emphasised.
- The limit of detection for mercury has effectively been reduced to $0.04 \mu\text{g m}^{-3}$ if sampling conditions are ideal. Commercially available techniques would need to have a minimum detection limit of $0.5 \mu\text{g m}^{-3}$ to ascertain whether mercury within a particular landfill is elevated. Low mercury sampling tubes sourced from Frontier Geosciences are the only tubes found to provide reliable results to date. Data gained using this method suggests that the inclusion of mercury on the priority trace component list may not be warranted.
- During the 2003 monitoring, Tedlar bag samples were taken at every sampling location and analysed for the purposes of assessing screening tests. The quantification of priority organo-chlorine and sulphonated compounds from Tedlar bag samples was poor compared with the ATD method, generally under reporting concentrations. Priority compounds were frequently not detected in samples carried to the laboratory in Tedlar bags. The detection limit of the Tedlar bag method was generally too close to 'typical' concentrations of some priority compounds, preventing quantification. Some non-priority compounds, especially the aromatic hydrocarbons, showed good comparison with the protocol methodology. It may be possible in the future to calibrate the response of Tedlar bag analysis to more accurately reflect protocol methodology derived concentrations, but detection limits will always be constrained by a lack of on-site sample pre-concentration.
- The concentration of hydrogen sulphide is often outside the measurable range of accurate field instruments. Where this occurs it is recommended that a Tedlar bag samples should be sent to a laboratory for analysis of the hydrogen sulphide concentration.
- Carbon monoxide is over-reported by field instruments sampling landfill gas. If an accurate quantification of carbon monoxide is necessary, then Tedlar bag samples need to be taken and analysed at a laboratory by means other than electrochemical cells.

Concentration of Priority Trace Components

- Mercury was detected in concentrations less than $1 \mu\text{g m}^{-3}$ in typical landfill sites. Most positive identifications were at concentrations less than $0.5 \mu\text{g m}^{-3}$.
- Total arsenic has been reliably detected in concentrations from $0.6 - 410 \mu\text{g m}^{-3}$, with 50% of concentrations below $10 \mu\text{g m}^{-3}$ and most concentrations in the $1 \mu\text{g m}^{-3}$ range. Recent waste appears to be the main source of gas containing arsenic. A high degree of variation exists between sampling periods with differences of up to an order of magnitude. This difference is likely to be associated with changing conditions in the landfill. Tentative trends suggest that moisture may reduce the concentration of arsenic in the vapour phase.
- Halogenated volatile organic compound (VOC) concentrations in the 'typical' landfill sites were below the average concentrations in the database produced during R&D Project P1-438. The

exception to this was chloroethene (vinyl chloride), which was detected at higher concentrations using the analytical method refinements implemented in 2003. Tetrachloromethane was not detected in any of the samples suggesting that data within the database may be biased towards sites where halogenated VOCs are more common.

- Oxygenated VOCs. Butoxy ethanol was found in higher concentrations in recent waste samples compared with older waste samples in 2002, but was not detected at any sampling location in 2003. Ethyl butyrate was detected in all samples. Butyric acid is difficult to quantify because the polar charge affects the retention time in the GC column. The chromatograph displayed a better response in 2003 than in 2002, but only a marginal improvement in quantification.
- There are relatively few differences in sulphonated VOC composition between the waste types, although waste with significant leachate appears to have lower concentrations. Older waste has higher carbon disulphide and methanethiol concentrations. Methanethiol and ethanethiol were not detected at any sampling location during the 2003 monitoring event and 1-propanethiol was not detected as frequently during the 2003 monitoring.
- In 2003, hydrogen sulphide was found in comparable concentrations to the 2002 monitoring event at all sample locations except in the mature waste from the commercial & industrial waste type. From these observations it can be concluded that hydrogen sulphide does not in general show temporal variation over the timescales used. Hydrogen sulphide was detected at the highest concentrations in recent waste.
- Concentrations of 1-pentene were detected at every sample location. The main gas samples universally exhibited the highest concentrations and the mature waste generally contained the lowest concentrations, with the exception of the *substantial-ash* waste.
- In 2002, benzene concentrations were highest in the commercial/industrial landfill. Concentrations of benzene varied significantly between the two monitoring events with no apparent trends between different waste types in 2003. Higher concentrations of benzene were detected during the 2003 monitoring event. This is likely to be the product of the improved analytical technique rather than being a reflection of temporal variation.
- Poly-Chlorinated-Dibenzo-Dioxins and -Furans (PCDDs and PCDFs). No reliable detections of the toxic PCDDs or PCDFs were made in either the 2002 or 2003 monitoring event. Some trace detections of non-toxic PCDDs and PCDFs were recorded.
- From a comparison between the two monitoring events it is apparent that concentrations of priority compounds, contained within the gas from the *domestic-with-leachate* site for example, have significantly changed with time. The conclusion from this is that there may be large temporal variations in trace component composition.

Relative Priorities

- Using the current data, the prioritisation exercise undertaken in Project P1-438 was repeated. From a toxicological viewpoint, the existing priority list remains the same, except for mercury. There is now sufficient data to demonstrate that this does not warrant inclusion on the main priority list. The data confirmed the earlier conclusion that PCDDs and PCDFs do not warrant inclusion on the main priority list.
- Although chloroethene, benzene, furan and carbon disulphide were detected in higher concentrations than the existing database average, the majority of compounds on the toxicological list were at a lower concentration. Where higher concentrations were found these appear to result from the improved monitoring methodology used in this project. Most of the priority compounds found at a lower concentration than in the database are chlorinated compounds. This may be because this project sampled 'typical' landfill gas, whereas many previous studies were concerned with landfill gas at sites with particular problems.
- From an odour perspective, the existing priority list remains the same. Although there has been some rearrangement of the order of priority, in general, measured concentrations in R&D Project P1-491 were close to the previous database averages.

9 References

- Environment Agency (2002a) Investigation of the composition, emissions and effects of trace components in landfill gas. R&D Technical Report P1-438/TR, Environment Agency, Bristol.
- Environment Agency (2002b) GasSim - landfill gas risk assessment tool. R&D Project P1-295, GasSim Model (Version 1) and User Manual, Environment Agency, Bristol. A free demonstration version is available at <http://www.gassim.co.uk>
- Environment Agency (2004a) *Guidance on the management of landfill gas*. Environment Agency, Bristol.
- Environment Agency (2004b) *Guidance for monitoring trace components in landfill gas*. Environment Agency, Bristol.
- ESART (Environmental Services Association Research Trust) (2003) Monitoring and speciating mercury in landfill gas: A short status study on emissions from UK landfills prepared for ESART. ESART Research Report D/009.
- NIOSH (National Institute of Occupational Safety and Health) (1994) NIOSH Manual of Analytical Methods (NMAM®), 4th ed. DHHS (NIOSH) Publication 94-113 (August, 1994), www.cdc.gov/NIOSH/nmam/nmmenu.html
- Occupational Safety and Health Administration (OSHA) (online). *OSHA sampling and analytical methods*. www.osha-slc.gov/dts/sltc/methods/index.html
- US EPA methods. www.epa.gov/ttn/amtic/airtox.html
- US EPA (1997) Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air (2nd Ed), Jan 1997, US EPA, OH45268, Washington, USA.
- Winegar, E.D. and Schmidt, C.E. (1988) Analyzing using a Jerome 631-X portable hydrogen sulfide sensor: laboratory and field evaluation. Report to Arizona Instruments, Corp. Applied Measurement Science. Fair Oaks, CA.

Appendix 1: 2002 monitoring field data

Sampling Location	Waste	Age if known years	Data Source	Oxygen % v/v	Carbon Dioxide % v/v	Methane % v/v	Nitrogen % v/v	Carbon Monoxide ppmv	Hydrogen ppmv	Helium ppmv	Hydrogen Sulphide ppmv	Hydrogen Cyanide ppmv
Main gas	Com & Ind		Lab 1	4.4	31.6	43.2	20.9	<20	<50	<50	-	-
Main gas	Com & Ind		Field	2.1	33.0	44.8	-	45	-	-	93.9	*****
Recent	Com & Ind		Lab 1	0.3	42.1	57.1	0.5	<20	337	<50	-	-
Recent	Com & Ind		Field	0.0	39.5	58.5	-	155	-	-	115	*****
Old	Com & Ind	9	Field	0.0	47.5	50.8	-	132	-	-	74.6	*****
Main gas	Dom/Leach		Field	0.0	34.5	53.5	-	76	-	-	10.2	34.2
Old	Dom/Leach		Lab 1	0.3	38.1	61.0	0.6	<20	-	-	-	-
Old	Dom/Leach		Field	0.0	39.5	60.5	-	115	-	-	10.2	30.7
Old	Dom/Leach		LAB 2	-	-	-	-	4	-	-	-	-
Leachate	Dom/Leach		Lab 1	0.5	29.6	68.6	1.3	<20	-	-	-	-
Leachate	Dom/Leach		Field	0.0	25.0	70.5	-	17	-	-	16.6	43.0
Leachate	Dom/Leach		LAB 2	-	-	-	-	2	-	-	-	-
Recent	Dom/Leach		Lab 1	0.5	43.2	54.3	2.1	20	-	-	-	-
Recent	Dom/Leach		Field	0.0	42.5	54.0	-	942	-	-	160	*****
Main gas	Dom/Dry		Lab 1	1.2	38.1	50.7	10.1	<20	69	<50	-	-
Main gas	Dom/Dry		Field	0.2	37.0	51.0	-	42	-	-	26.9	>100
Main gas	Codisposal		Field	0.0	34.5	49.8	-	38	-	-	29.2	>100
Main gas	Ash		Field	6.7	23.0	29.0	-	225	-	-	37.9	>100
Recent	Ash		Field	0.0	37.5	60.5	-	407	-	-	>200	-
Old	Ash		Field	0.0	26.5	27.5	-	>1000	-	-	17.6	42.8

NOTES

- Not analysed

% v/v Percentage composition by volume

ppmv parts per million in vapour

Lab 1

Field Laboratory analysis from Tedlar bag

Lab 2 Field portable instrument at wellhead. Last reading before sample taken has been reported

***** 3rd party laboratory analysis from Tedlar bag

Meter off-scale

Appendix 2: 2002 monitoring laboratory data

TABLE 1 2002 SAMPLING VOLUMES

Sample ID	Time on	Time off	Time	Flow rate 1	Flow rate 2	Flow rate 3	Average flow rate	Total volume
			(mins)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(L)
LF-A-001	13:10	14:51	101	110	100	95	102	10.3
LF-A-002	13:10	14:51	101	100	100	100	100	10.1
LF-A-003	13:10	14:51	101	110	110	80	100	10.1
LF-A-004	13:10	14:51	101	120	120	100	113	11.4
LF-A-005	13:10	14:51	101	120	120	115	118	12.0
LF-A-006	13:10	14:51	101	110	130	95	112	11.3
LF-A-007	13:10	14:51	101	160	150	110	140	14.1
LF-A-008	13:10	14:51	101	130	120		125	12.6
LF-A-009	13:10	14:51	101	155	130	105	130	13.1
LF-A-010	12:32	15:27	175	2000	2000		2000	350.0
LF-A-011	15:07	15:27	20	105	120		113	2.3
LF-A-012	15:07	15:27	20	100	110		105	2.1
LF-A-013	15:07	15:27	20	90	85		88	1.8
LF-A-014	15:07	15:27	20	20	25		23	0.5
LF-A-015	15:07	15:27	20	25	20		23	0.5
LF-A-016	15:07	15:27	20	20	20		20	0.4
LF-A-017	12:01	13:43	102	140	120		130	13.3
LF-A-018	12:01	13:43	102	120	120		120	12.2
LF-A-019	12:01	13:43	102	160	180		170	17.3
LF-A-020	12:01	13:43	102	90	90		90	9.2
LF-A-021	12:01	13:43	102	90	105		98	9.9
LF-A-022	12:01	13:43	102	60	75		68	6.9
LF-A-023	12:01	13:43	102	145	175		160	16.3
LF-A-024	12:01	13:43	102	130	125		128	13.0
LF-A-025	12:01	13:43	102	140	165		153	15.6
LF-A-026								
LF-A-027	11:32	15:30	238	2000			2000	476.0
LF-A-028	14:19	15:10	51	40	35		38	1.9
LF-A-029	14:19	15:10	51	40	35		38	1.9
LF-A-030	14:19	15:10	51	30	25		28	1.4
LF-A-031	14:19	15:10	51	30	25		28	1.4
LF-A-032								
LF-A-033								
LF-A-034	14:19	15:10	51	35	35		35	1.8
LF-A-035	14:19	15:10	51	35	35		35	1.8
LF-A-036	14:19	15:10	51	35	30		33	1.7
LF-A-037	14:19	15:10	51	35	30		33	1.7
LF-A-038	14:19	15:10	51	35	30		33	1.7
LF-A-039	14:19	15:10	51	35	30		33	1.7
LF-A-040	14:19	15:10	41	55	60		58	2.4
LF-A-041	14:19	15:10	41	55	60		58	2.4
LF-A-042	14:19	15:10	41	110	110		110	4.5
LF-A-043	14:19	15:10	41	110	110		110	4.5
LF-A-044	14:19	15:10	41	115	105		110	4.5
LF-A-045	14:19	15:10	41	115	105		110	4.5

TABLE 1 2002 SAMPLING VOLUMES (CONTINUED)

Sample ID	Time on	Time off	Time	Flow rate 1	Flow rate 2	Flow rate 3	Average flow rate	Total volume
			(mins)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(L)
LF-A-046	14:19	15:10	51	40	40		40	2.0
LF-A-047	14:19	15:10	51	45	40		43	2.2
LF-A-048	14:19	15:10	51	35	35		35	1.8
LF-A-049	15:25	15:30	5	80	85		83	0.4
LF-A-050	15:25	15:30	5	75	75		75	0.4
LF-A-051	15:25	15:30	5	80	80		80	0.4
LF-A-052	16:18	17:35	77	90	105		98	7.5
LF-A-053	16:18	17:35	77	105	85		95	7.3
LF-A-054	16:18	17:35	77	70	60		65	5.0
LF-A-055	15:57	17:45	108	2000			2000	216.0
LF-A-056	16:18	17:18	60	95	95		95	5.7
LF-A-057	16:18	17:18	60	85	90		88	5.3
LF-A-058	16:18	17:18	60	95	85		90	5.4
LF-A-059	16:18	17:18	60	85	80		83	5.0
LF-A-060	16:18	17:18	60	85	80		83	5.0
LF-A-061	16:18	17:18	60	85	80		83	5.0
LF-A-062	17:23	17:40	17	80	80		80	1.4
LF-A-063	17:23	17:40	17	90	80		85	1.4
LF-A-064	17:23	17:40	17	110	130		120	2.0
LF-A-065	17:23	17:40	17	25	30		28	0.5
LF-A-066	17:23	17:40	17	30	30		30	0.5
LF-A-067	17:23	17:40	17	25	25		25	0.4
LF-A-068	10:35	12:17	102	240	245		243	24.7
LF-A-069	10:35	12:17	102	240	250		245	25.0
LF-A-070	10:35	12:17	102	250	250		250	25.5
LF-A-071	10:35	12:17	102	100	110		105	10.7
LF-A-072	10:35	12:17	102	100	120		110	11.2
LF-A-073	10:35	12:17	102	90	100		95	9.7
LF-A-074	10:35	12:17	102	140	140		140	14.3
LF-A-075	10:35	12:17	102	130	140		135	13.8
LF-A-076	10:35	12:17	102	130	150		140	14.3
LF-A-077	10:33	12:44	131	2000	2000		2000	262.0
LF-A-078	12:25	12:42	17	120	120		120	2.0
LF-A-079	12:25	12:42	17	120	120		120	2.0
LF-A-080	12:25	12:42	17	140	140		140	2.4
LF-A-081	12:25	12:42	17	25	25		25	0.4
LF-A-082	12:25	12:42	17	30	20		25	0.4
LF-A-083	12:25	12:42	17	25	25		25	0.4
LF-A-084	10:20	12:33	133	2000	2000		2000	266.0
LF-A-085	10:28	12:08	100	135	115	115	122	12.2
LF-A-086	10:28	12:08	100	200	180	180	187	18.7
LF-A-087	10:28	12:08	100	205	190	185	193	19.3
LF-A-088	10:28	12:08	100	105	100	95	100	10.0
LF-A-089	10:28	12:08	100	105	100	100	102	10.2
LF-A-090	10:28	12:08	100	105	70	80	85	8.5
LF-A-091	10:28	12:08	100	125	150	145	140	14.0
LF-A-092	10:28	12:08	100	145	155	150	150	15.0
LF-A-093	10:28	12:08	100	140	165	165	157	15.7
LF-A-094	12:15	12:32	17	120	120		120	2.0
LF-A-095	12:15	12:32	17	130	120		125	2.1

TABLE 1 2002 SAMPLING VOLUMES (CONTINUED)

Sample ID	Time on	Time off	Time	Flow rate 1	Flow rate 2	Flow rate 3	Average flow rate	Total volume
			(mins)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(L)
LF-A-096	12:15	12:32	17	125	120		123	2.1
LF-A-097	12:15	12:32	17	35	35		35	0.6
LF-A-098	12:15	12:32	17	35	35		35	0.6
LF-A-099	12:15	12:32	17	35	35		35	0.6
LF-A-100	09:18	12:43	205	2000	1900		1950	399.8
LF-A-101	09:26	11:06	100	140	120	120	127	12.7
LF-A-102	09:26	11:06	100	140	140	140	140	14.0
LF-A-103	09:26	11:06	100	170	165	170	168	16.8
LF-A-104	09:26	11:06	100	110	110	85	102	10.2
LF-A-105	09:26	11:06	100	115	110	115	113	11.3
LF-A-106	09:26	11:06	100	115	110	110	112	11.2
LF-A-107	09:26	11:06	100	70	65	70	68	6.8
LF-A-108	09:26	11:06	100	150	150	160	153	15.3
LF-A-109	09:26	11:06	100	135	130	140	135	13.5
LF-A-110	11:34	12:26	52	50	75		63	3.3
LF-A-111	11:34	12:26	52	50	60		55	2.9
LF-A-112	11:34	12:26	52	55	60		58	3.0
LF-A-113	11:34	12:26	52	50	50		50	2.6
LF-A-114	11:34	12:26	52	50	50		50	2.6
LF-A-115	11:34	12:26	52	45	45		45	2.3
LF-A-116	11:34	12:26	52	50	50		50	2.6
LF-A-117	11:34	12:26	52	50	50		50	2.6
LF-A-118	11:34	12:26	52	45	45		45	2.3
LF-A-119	11:34	12:26	52	50	50		50	2.6
LF-A-120	11:34	12:26	52	30	30		30	1.6
LF-A-121	11:34	12:26	52	45	45		45	2.3
LF-A-122	11:34	12:26	52	45	30		38	2.0
LF-A-123	11:34	12:26	52	30	30		30	1.6
LF-A-124	11:34	12:26	52	40	45		43	2.2
LF-A-125	11:34	12:26	52	70	155		113	5.9
LF-A-126	11:34	12:26	52	70	155		113	5.9
LF-A-127	11:34	12:26	52	155	155		155	8.1
LF-A-128	11:34	12:26	52	150	135		143	7.4
LF-A-129	11:34	12:26	52	70	155		113	5.9
LF-A-130	11:34	12:26	52	155	155		155	8.1
LF-A-131	11:34	12:26	52	150	135		143	7.4
LF-A-132	12:31	12:41	10	80	80		80	0.8
LF-A-133	12:31	12:41	10	55	55		55	0.5
LF-A-134	12:31	12:41	10	60	60		60	0.6
LF-A-135	14:32	16:19	107	2000			2000	214.0
LF-A-136	14:49	15:50	61	30	25		28	1.7
LF-A-137	14:49	15:50	61					
LF-A-138	14:49	15:50	61	30	35		33	2.0
LF-A-139	14:49	15:50	61	125	110		118	7.2
LF-A-140	14:49	15:50	61	115	105		110	6.7
LF-A-141	14:49	15:50	61	140	140		140	8.5
LF-A-142	14:49	15:50	61	170	160		165	10.1
LF-A-143	14:49	15:50	61	170	160		165	10.1
LF-A-144	14:49	15:50	61	20	20		20	1.2
LF-A-145								

TABLE 1 2002 SAMPLING VOLUMES (CONTINUED)

Sample ID	Time on	Time off	Time	Flow rate 1	Flow rate 2	Flow rate 3	Average flow rate	Total volume
			(mins)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(L)
LF-A-146	16:01	16:18	17	135	135		135	2.3
LF-A-147	16:01	16:18	17	140	140		140	2.4
LF-A-148	16:01	16:18	17	130	130		130	2.2
LF-A-149	16:01	16:18	17	25	25		25	0.4
LF-A-150	16:01	16:18	17	25	25		25	0.4
LF-A-151	16:01	16:18	17	30	30		30	0.5
LF-A-152	10:58	13:20	142	2000	2000		2000	284.0
LF-A-153	11:23	12:24	61	210	210		210	12.8
LF-A-154	11:23	12:24	61	160	145		153	9.3
LF-A-155	11:23	12:24	61	160	170		165	10.1
LF-A-156	11:23	12:24	61	65	55		60	3.7
LF-A-157	11:23	12:24	61	75	60		68	4.1
LF-A-158	11:23	12:24	61	70	65		68	4.1
LF-A-159	11:23	12:24	61	150	135		143	8.7
LF-A-160	11:23	12:24	61	120	105		113	6.9
LF-A-161	11:23	12:24	61	115	100		108	6.6
LF-A-162	13:00	13:19	19	100	100		100	1.9
LF-A-163	13:00	13:19	19	100	100		100	1.9
LF-A-164	13:00	13:19	19	90	110		100	1.9
LF-A-165	13:00	13:19	19	30	25		28	0.5
LF-A-166	13:00	13:19	19	30	30		30	0.6
LF-A-167	13:00	13:19	19	30	30		30	0.6
LF-A-168	09:41	12:14	153	2000	2000		2000	306.0
LF-A-169	10:02	11:40	98	250	240		245	24.0
LF-A-170	10:02	11:40	98	225	230		228	22.3
LF-A-171	10:02	11:40	98	220	220		220	21.6
LF-A-172	10:02	11:40	98	90	90		90	8.8
LF-A-173	10:02	11:40	98	90	85		88	8.6
LF-A-174	10:02	11:40	98	90	110		100	9.8
LF-A-175	10:02	11:40	98	180	225		203	19.8
LF-A-176	10:02	11:40	98	155	150		153	14.9
LF-A-177	10:02	11:40	98	150	150		150	14.7
LF-A-178	11:50	12:09	19	120	115		118	2.2
LF-A-179	11:50	12:09	19	130	130		130	2.5
LF-A-180	11:50	12:09	19	140	130		135	2.6
LF-A-181	11:50	12:09	19	25	25		25	0.5
LF-A-182	11:50	12:09	19	30	25		28	0.5
LF-A-183	11:50	12:09	19	35	35		35	0.7
LF-A-184	13:19	16:19	180	2000	2000		2000	360.0
LF-A-185	13:44	14:51	67	150	120		135	9.0
LF-A-186	13:44	14:51	67	125	100		113	7.5
LF-A-187	13:44	14:51	67	110	75		93	6.2
LF-A-188	13:44	14:51	67	80	60		70	4.7
LF-A-189	13:44	14:51	67	90	80		85	5.7
LF-A-190	13:44	14:51	67	130	100		115	7.7
LF-A-191	13:44	14:51	67	170	155		163	10.9
LF-A-192	13:44	14:51	67	165	155		160	10.7
LF-A-193	13:44	14:51	67	165	165		165	11.1
LF-A-194	15:10	15:42	32	45	45		45	1.4
LF-A-195	15:10	15:42	32	60	60		60	1.9

TABLE 1 2002 SAMPLING VOLUMES (CONTINUED)

Sample ID	Time on	Time off	Time	Flow rate 1	Flow rate 2	Flow rate 3	Average flow rate	Total volume
			(mins)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(L)
LF-A-196	15:10	15:42	32	45	45		45	1.4
LF-A-197	15:10	15:42	32	60	60		60	1.9
LF-A-198	15:10	15:42	32	50	60		55	1.8
LF-A-199	15:10	15:42	32	40	35		38	1.2
LF-A-200	15:10	15:42	32	60	60		60	1.9
LF-A-201	15:10	15:42	32	50	60		55	1.8
LF-A-202	15:10	15:42	32	40	35		38	1.2
LF-A-203	15:10	15:42	32	45	45		45	1.4
LF-A-204	15:10	15:42	32	50	50		50	1.6
LF-A-205	15:10	15:42	32	60	50		55	1.8
LF-A-206	15:10	15:42	32	45	45		45	1.4
LF-A-207	15:10	15:42	32	50	50		50	1.6
LF-A-208	15:10	15:42	32	60	50		55	1.8
LF-A-209	15:10	15:42	32	190	150		170	5.4
LF-A-210	15:10	15:42	32	190	185		188	6.0
LF-A-211	15:10	15:42	32	190	180		185	5.9
LF-A-212	15:10	15:42	32	190	150		170	5.4
LF-A-213	15:10	15:42	32	190	185		188	6.0
LF-A-214	15:10	15:42	32	190	180		185	5.9
LF-A-215	15:53	16:07	14	60	45		53	0.7
LF-A-216	15:53	16:07	14	60	55		58	0.8
LF-A-217	15:53	16:07	14	50	55		53	0.7
LF-A-218	10:18	11:40	82	220	230	225	225	18.5
LF-A-219	10:18	11:40	82	240	240	245	242	19.8
LF-A-220	10:18	11:40	82	255	250	250	252	20.6
LF-A-221	10:18	11:40	82	115	110	115	113	9.3
LF-A-222	10:18	11:40	82	110	110	110	110	9.0
LF-A-223	10:18	11:40	82	95	110	120	108	8.9
LF-A-224	10:18	11:40	82	140	140	160	147	12.0
LF-A-225	10:18	11:40	82	150	140	150	147	12.0
LF-A-226	10:18	11:40	82	155	150	150	152	12.4
LF-A-227	10:03	12:57	174	2000	2000		2000	348.0
LF-A-228	12:02	12:42	40	40	50		45	1.8
LF-A-229	12:02	12:42	40	50	50		50	2.0
LF-A-230	12:02	12:42	40	40	40		40	1.6
LF-A-231	12:02	12:42	40	40	40		40	1.6
LF-A-232	12:02	12:42	40	40	40		40	1.6
LF-A-233	12:02	12:42	40	50	50		50	2.0
LF-A-234	12:02	12:42	40	40	40		40	1.6
LF-A-235	12:02	12:42	40	50	60		55	2.2
LF-A-236	12:02	12:42	40	50	60		55	2.2
LF-A-237	12:02	12:42	40	50	50		50	2.0
LF-A-238	12:02	12:42	40	60	50		55	2.2
LF-A-239	12:02	12:42	40	50	50		50	2.0
LF-A-240	12:02	12:42	40	50	50		50	2.0
LF-A-241	12:02	12:42	40	60	50		55	2.2
LF-A-242	12:02	12:42	40	50	50		50	2.0
LF-A-243	12:02	12:42	40	180	250		215	8.6
LF-A-244	12:02	12:42	40	210	200		205	8.2
LF-A-245	12:02	12:42	40	200	200		200	8.0

TABLE 1 2002 SAMPLING VOLUMES (CONTINUED)

Sample ID	Time on	Time off	Time	Flow rate 1	Flow rate 2	Flow rate 3	Average flow rate	Total volume
			(mins)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(mLmin ⁻¹)	(L)
LF-A-246	12:02	12:42	40	180	250		215	8.6
LF-A-247	12:02	12:42	40	210	200		205	8.2
LF-A-248	12:02	12:42	40	200	200		200	8.0
LF-A-249	12:45	12:55	10	45	50		48	0.5
LF-A-250	12:45	12:55	10	50	50		50	0.5
LF-A-251	12:45	12:55	10	50	50		50	0.5
LF-A-252	14:32	15:43	71	200	205		203	14.4
LF-A-253	14:32	15:43	71	220	210		215	15.3
LF-A-254	14:32	15:43	71	200	190		195	13.8
LF-A-255	14:32	15:43	71	100	90		95	6.7
LF-A-256	14:32	15:43	71	90	80		85	6.0
LF-A-257	14:32	15:43	71	70	70		70	5.0
LF-A-258	14:17	15:43	86	2000			2000	172.0
LF-A-259	14:32	15:43	71	150	150		150	10.7
LF-A-260	14:32	15:43	71	150	140		145	10.3
LF-A-261	14:32	15:43	71	150	150		150	10.7
LF-A-262	16:05	16:23	18	130	140		135	2.4
LF-A-263	16:05	16:23	18	150	160		155	2.8
LF-A-264	16:05	16:23	18	120	120		120	2.2
LF-A-265	16:05	16:23	18	35	35		35	0.6
LF-A-266	16:05	16:23	18	25	25		25	0.5
LF-A-267	16:05	16:23	18	30	30		30	0.5

TABLE 2 2002 TOTAL MERCURY ANALYSIS BY ICP-MS

Site Name	Sampling Location	Sample Label	Volume	Total mercury on tube	Analytical l.o.d.	Total mercury concentration
Units			(L)	(ng)	(ng)	(ugm⁻³)
Dom/Dry	Main gas	LF-A-01	10.268	5	3	0.49
Dom/Dry	Main gas	LF-A-02	10.100	3	3	0.30
Dom/Dry	Main gas	LF-A-03	10.100	5	3	0.50
Commercial	Main gas	LF-A-17	13.260	4	3	0.30
Commercial	Main gas	LF-A-18	12.240	10	5	0.82
Commercial	Main gas	LF-A-19	17.340	5	3	0.29
Commercial	Older waste	LF-A-52	7.507	6	5	0.80
Commercial	Older waste	LF-A-53	7.315	1	0.9	0.14
Commercial	Older waste	LF-A-54	5.005	1	0.9	0.20
Commercial	Recent Waste	LF-A-68	24.735	10	5	0.40
Commercial	Recent Waste	LF-A-69	24.990	8	3	0.32
Commercial	Recent Waste	LF-A-70	25.500	7	0.9	0.27
Codisposal	Main gas	LF-A-85	12.167	7	5	0.58
Codisposal	Main gas	LF-A-86	18.667	10	5	0.54
Codisposal	Main gas	LF-A-87	19.333	8	5	0.41
Ash site	Main gas	LF-A-101	12.667	<5	5	<0.39
Ash site	Main gas	LF-A-102	14.000	3	0.9	0.21
Ash site	Main gas	LF-A-103	16.833	<5	5	<0.30
Ash site	Recent Waste	LF-A-136	1.678	<3	3	<1.8
Ash site	Recent Waste	LF-A-137	none	<5	5	no value
Ash site	Recent Waste	LF-A-138	1.983	20	5	10.09
Ash site	Older waste	LF-A-153	12.810	4	3	0.31
Ash site	Older waste	LF-A-154	9.303	6	3	0.64
Ash site	Older waste	LF-A-155	10.065	10	5	0.99
Dom/Leach	Recent Waste	LF-A-169	24.010	4	3	0.17
Dom/Leach	Recent Waste	LF-A-170	22.295	<3	3	<0.13
Dom/Leach	Recent Waste	LF-A-171	21.560	3	3	0.14
Dom/Leach	Main gas	LF-A-185	9.045	<3	3	<0.33
Dom/Leach	Main gas	LF-A-186	7.538	10	5	1.33
Dom/Leach	Main gas	LF-A-187	6.198	<5	5	<0.81
Dom/Leach	Leachate	LF-A-218	18.450	<5	5	<0.27
Dom/Leach	Leachate	LF-A-219	19.817	<5	5	<0.25
Dom/Leach	Leachate	LF-A-220	20.637	<5	5	<0.24
Dom/Leach	Older waste	LF-A-252	14.378	<5	5	<0.35
Dom/Leach	Older waste	LF-A-253	15.265	<5	5	<0.33
Dom/Leach	Older waste	LF-A-254	13.845	< 5	5	<0.36
Field blank		LF-A-26		20		
Field blank		LF-A-306		<3		
Field blank		LF-A-307		<3		
Field blank		LF-A-308		<3		
Field blank		LF-A-309		<3		
Field blank		LF-A-310		<3		
Field blank		LF-A-311		<3		
Field blank		LF-A-312		<5		
Field blank		LF-A-313		<3		

TABLE 3 2002 TOTAL INORGANIC ARSENIC ANALYSIS BY ICP-MS

Site Name	Sampling Location	Sample Label	Volume	Total inorganic arsenic on tube	Total inorganic arsenic concentration
Units			(L)	(ng)	(ug/m3)
Dom/Dry	Main gas	LF-A-004	11.4	10	0.87
Dom/Dry	Main gas	LF-A-005	12.0	11	0.92
Dom/Dry	Main gas	LF-A-006	11.3	10	0.89
Commercial	Main gas	LF-A-020	9.2	330	36
Commercial	Main gas	LF-A-021	9.9	280	28
Commercial	Main gas	LF-A-022	6.9	410	60
Commercial	Older waste	LF-A-056	5.7	4.4	0.77
Commercial	Older waste	LF-A-057	5.3	4	0.76
Commercial	Older waste	LF-A-058	5.4	12	2.2
Commercial	Recent Waste	LF-A-071	10.7	130	12
Commercial	Recent Waste	LF-A-072	11.2	140	12
Commercial	Recent Waste	LF-A-073	9.7	70	7.2
Codisposal	Main gas	LF-A-088	10.0	3.5	0.35
Codisposal	Main gas	LF-A-089	10.2	4.6	0.45
Codisposal	Main gas	LF-A-090	8.5	3.5	0.41
Ash site	Main gas	LF-A-104	10.2	33	3.2
Ash site	Main gas	LF-A-105	11.3	48	4.2
Ash site	Main gas	LF-A-106	11.2	42	3.8
Ash site	Recent Waste	LF-A-139	7.2	120	16.7
Ash site	Recent Waste	LF-A-140	6.7	130	19
Ash site	Recent Waste	LF-A-141	8.5	160	19
Ash site	Older waste	LF-A-156	3.7	12	3.3
Ash site	Older waste	LF-A-157	4.1	1	0.24
Ash site	Older waste	LF-A-158	4.1	3.4	0.83
Dom/Leach	Recent Waste	LF-A-172	8.8	16	1.8
Dom/Leach	Recent Waste	LF-A-173	8.6	17	2.0
Dom/Leach	Recent Waste	LF-A-174	9.8	15	1.5
Dom/Leach	Main gas	LF-A-188	4.7	0.6	< 0.08
Dom/Leach	Main gas	LF-A-189	5.7	0.6	< 0.08
Dom/Leach	Main gas	LF-A-190	7.7	0.4	< 0.08
Dom/Leach	Leachate	LF-A-122	2.0	1	0.51
Dom/Leach	Leachate	LF-A-222	9.0	1	0.11
Dom/Leach	Leachate	LF-A-223	8.9	1	0.11
Dom/Leach	Older waste	LF-A-255	6.7	2	0.30
Dom/Leach	Older waste	LF-A-256	6.0	2	0.33
Dom/Leach	Older waste	LF-A-257	5.0	1	0.20
Field blank	Field blank	LF-A-314		0.5	
Field blank	Field blank	LF-A-315		0.5	
Field blank	Field blank	LF-A-316		0.5	
Field blank	Field blank	LF-A-317		0.6	
Field blank	Field blank	LF-A-318		0.5	
Field blank	Field blank	LF-A-319		0.4	
Field blank	Field blank	LF-A-320		0.3	
Field blank	Field blank	LF-A-321		0.6	

TABLE 4A 2002 METHANAL ANALYSIS BY HPLC

Site Name	Sampling Location	Sample Label	Sample Volume	Mass of Formaldehyde	Formaldehyde Concentration	Combined Formaldehyde concentration
Units			L	µg	µg.m ⁻³	µg.m ⁻³
Dom/Dry	Main gas	LF-A-07	14.14	0.15	10.54	14
Dom/Dry	Main gas			0.05	3.86	
Dom/Dry	Main gas	LF-A-08	12.63	0.17	13.54	19
Dom/Dry	Main gas			0.07	5.31	
Dom/Dry	Main gas	LF-A-09	13.13	0.00	0.00	13
Dom/Dry	Main gas			0.17	13.10	
Commercial	Main gas	LF-A-23	16.32	0.12	7.11	11
Commercial	Main gas			0.06	3.43	
Commercial	Main gas	LF-A-24	13.01	0.13	9.61	14
Commercial	Main gas			0.06	4.23	
Commercial	Main gas	LF-A-25	15.56	0.13	8.42	12
Commercial	Main gas			0.05	3.34	
Commercial	Old	LF-A-59	4.95	0.14	27.84	46
Commercial	Old			0.09	18.28	
Commercial	Old	LF-A-60	4.95	0.15	30.10	52
Commercial	Old			0.11	22.02	
Commercial	Old	LF-A-61	4.95	0.12	24.04	43
Commercial	Old			0.10	19.29	
Commercial	Recent	LF-A-74	14.28	0.10	7.16	11
Commercial	Recent			0.06	4.04	
Commercial	Recent	LF-A-75	13.77	0.11	8.21	12
Commercial	Recent			0.05	3.72	
Commercial	Recent	LF-A-76	14.28	0.11	7.84	12
Commercial	Recent			0.06	3.92	
Codisposal	Main gas	LF-A-91	14.00	0.10	7.43	10
Codisposal	Main gas			0.04	2.71	
Codisposal	Main gas	LF-A-92	15.00	0.09	6.27	9.1
Codisposal	Main gas			0.04	2.87	
Codisposal	Main gas	LF-A-93	15.67	0.11	6.83	9.5
Codisposal	Main gas			0.04	2.68	
Ash	Main gas	LF-A-107	6.83	0.08	12.30	17
Ash	Main gas			0.03	4.25	
Ash	Main gas	LF-A-108	15.33	0.08	5.48	7.4
Ash	Main gas		0.00	0.03	1.96	
Ash	Main gas	LF-A-109	13.55	0.09	6.79	8.7
Ash	Main gas			0.03	1.92	
Ash	Recent	LF-A-142	10.07	0.02	2.28	2.28
Ash	Recent			<0.01		
Ash	Recent	LF-A-143	10.07	<0.01		< 0.001
Ash	Recent			<0.01		

TABLE 4A 2002 METHANAL ANALYSIS BY HPLC (CONTINUED)

Site Name	Sampling Location	Sample Label	Sample Volume	Mass of Formaldehyde	Formaldehyde Concentration	Combined Formaldehyde concentration
Units			L	µg	µg.m ⁻³	µg.m ⁻³
Ash	Recent	LF-A-144	?	0.02		no value
Ash	Recent			<0.01		
Ash	Old	LF-A-159	8.69	0.02	1.73	1.73
Ash	Old			<0.01		
Ash	Old	LF-A-160	6.86	0.02	2.92	2.92
Ash	Old			<0.01		
Ash	Old	LF-A-161	6.56	0.02	2.29	2.29
Ash	Old			<0.01		
Dom/Leach	Recent	LF-A-175	19.85	0.12	6.20	6.20
Dom/Leach	Recent			<0.01		
Dom/Leach	Recent	LF-A-176	14.95	0.07	4.55	6.2
Dom/Leach	Recent			0.03	1.67	
Dom/Leach	Recent	LF-A-177	14.70	0.16	10.61	13
Dom/Leach	Recent			0.03	2.11	
Dom/Leach	Main gas	LF-A-191	10.89	0.14	12.86	16
Dom/Leach	Main gas			0.04	3.40	
Dom/Leach	Main gas	LF-A-192	10.72	0.11	9.89	12
Dom/Leach	Main gas			0.02	1.68	
Dom/Leach	Main gas	LF-A-193	11.06	0.12	11.03	13
Dom/Leach	Main gas			0.02	1.63	
Dom/Leach	Leachate	LF-A-224	12.03	0.08	6.40	8.7
Dom/Leach	Leachate			0.03	2.33	
Dom/Leach	Leachate	LF-A-225	12.03	0.10	8.48	11.0
Dom/Leach	Leachate			0.03	2.49	
Dom/Leach	Leachate	LF-A-226	12.44	0.09	7.56	9.9
Dom/Leach	Leachate			0.03	2.33	
Dom/Leach	Old	LF-A-259	10.65	0.13	12.39	16
Dom/Leach	Old			0.04	3.66	
Dom/Leach	Old	LF-A-260	10.30	0.14	13.79	19
Dom/Leach	Old			0.06	5.54	
Dom/Leach	Old	LF-A-261	10.65	0.15	14.08	20
Dom/Leach	Old			0.07	6.38	
Field	Blank	LF-A-303		0.01		
Field	Blank			0.00		
Field	Blank	LF-A-304		0.01		
Field	Blank			0.00		
Field	Blank	LF-A-305		0.01		

TABLE 4B 2002 ETHANAL ANALYSIS BY HPLC

Site Name	Sampling Location	Sample Label	Sample Volume	Mass of Ethanal	Ethanal Concentration	Combined Ethanal concentration
Units			L	µg	µg.m ⁻³	µg.m ⁻³
Dom/Dry	Main gas	LF-A-07	14.14	0.68	48.09	54
Dom/Dry	Main gas			0.09	6.36	
Dom/Dry	Main gas	LF-A-08	12.63	0.68	53.86	67
Dom/Dry	Main gas			0.161	12.75	
Dom/Dry	Main gas	LF-A-09	13.13	0	0.00	12
Dom/Dry	Main gas			0.161	12.26	
Commercial	Main gas	LF-A-23	16.32	0.25	15.32	21
Commercial	Main gas			0.086	5.27	
Commercial	Main gas	LF-A-24	13.01	0.2553	19.63	25
Commercial	Main gas			0.0714	5.49	
Commercial	Main gas	LF-A-25	15.56	0.254	16.33	21
Commercial	Main gas			0.076	4.89	
Commercial	Old	LF-A-59	4.95	0.335	67.68	90
Commercial	Old			0.111	22.42	
Commercial	Old	LF-A-60	4.95	0.32	64.65	88
Commercial	Old			0.117	23.64	
Commercial	Old	LF-A-61	4.95	0.343	69.29	99
Commercial	Old			0.1495	30.20	
Commercial	Recent	LF-A-74	14.28	0.878	61.48	82
Commercial	Recent			0.2865	20.06	
Commercial	Recent	LF-A-75	13.77	0.93119	67.62	90
Commercial	Recent			0.308	22.37	
Commercial	Recent	LF-A-76	14.28	0.96309	67.44	90
Commercial	Recent			0.328	22.97	
Codisposal	Main gas	LF-A-91	14.00	0.404	28.86	38
Codisposal	Main gas			0.123	8.79	
Codisposal	Main gas	LF-A-92	15.00	0.348	23.20	31
Codisposal	Main gas			0.11	7.33	
Codisposal	Main gas	LF-A-93	15.67	0.362	23.10	31
Codisposal	Main gas			0.123	7.85	
Ash	Main gas	LF-A-107	6.83	2.56	374.82	456
Ash	Main gas			0.557	81.55	
Ash	Main gas	LF-A-108	15.33	2.93	191.13	254
Ash	Main gas		0.00	0.966	63.01	
Ash	Main gas	LF-A-109	13.55	3.11	229.52	298
Ash	Main gas			0.926	68.34	
Ash	Recent	LF-A-142	10.07	0.157	15.59	20
Ash	Recent			0.048	4.77	
Ash	Recent	LF-A-143	10.07	0	0.00	4.3
Ash	Recent			0.043	4.27	

TABLE 4B 2002 ETHANAL ANALYSIS BY HPLC (CONTINUED)

Site Name	Sampling Location	Sample Label	Sample Volume	Mass of Ethanal	Ethanal Concentration	Combined Ethanal concentration
Units			L	µg	µg.m ⁻³	µg.m ⁻³
Ash	Recent	LF-A-144	?	0.091		no value
Ash	Recent			0		
Ash	Old	LF-A-159	8.69	2.53	291.14	422
Ash	Old			1.14	131.19	
Ash	Old	LF-A-160	6.86	2.15	313.41	448
Ash	Old			0.923	134.55	
Ash	Old	LF-A-161	6.56	2.53	385.67	563
Ash	Old			1.16	176.83	
Dom/Leach	Recent	LF-A-175	19.85	1.09	54.91	73
Dom/Leach	Recent			0.353	17.78	
Dom/Leach	Recent	LF-A-176	14.95	0.646	43.21	68
Dom/Leach	Recent			0.367	24.55	
Dom/Leach	Recent	LF-A-177	14.70	1.2	81.63	117
Dom/Leach	Recent			0.524	35.65	
Dom/Leach	Main gas	LF-A-191	10.89	0.31	28.47	47
Dom/Leach	Main gas			0.205	18.82	
Dom/Leach	Main gas	LF-A-192	10.72	0.175	16.32	23
Dom/Leach	Main gas			0.072	6.72	
Dom/Leach	Main gas	LF-A-193	11.06	0.21	18.99	27
Dom/Leach	Main gas			0.084	7.59	
Dom/Leach	Leachate	LF-A-224	12.03	0.15	12.47	20
Dom/Leach	Leachate			0.089	7.40	
Dom/Leach	Leachate	LF-A-225	12.03	0.214	17.79	25
Dom/Leach	Leachate			0.084	6.98	
Dom/Leach	Leachate	LF-A-226	12.44	0.228	18.33	25
Dom/Leach	Leachate			0.085	6.83	
Dom/Leach	Old	LF-A-259	10.65	0.609	57.18	79
Dom/Leach	Old			0.232	21.78	
Dom/Leach	Old	LF-A-260	10.30	0.647	62.85	90
Dom/Leach	Old			0.281	27.29	
Dom/Leach	Old	LF-A-261	10.65	0.002	0.19	28
Dom/Leach	Old			0.295	27.70	
Field	blank	LF-A-303		0.008		
Field	blank			0.003		
Field	blank	LF-A-304		0.012		
Field	blank			0.002		
Field	blank	LF-A-305		0.01		

TABLE 4C 2002 ACETONE ANALYSIS BY HPLC

Site Name	Sampling Location	Sample Label	Sample Volume	Mass of Acetone	Acetone Concentration	Combined Acetone concentration
Units			L	ug	ug.m ⁻³	ug.m ⁻³
Dom/Dry	Main gas	LF-A-07	14.14	7	498	782
Dom/Dry	Main gas			4	284	
Dom/Dry	Main gas	LF-A-08	12.63	8	606	763
Dom/Dry	Main gas			2	157	
Dom/Dry	Main gas	LF-A-09	13.13	0	0	151
Dom/Dry	Main gas			2	151	
Commercial	Main gas	LF-A-23	16.32	11	703	1140
Commercial	Main gas			7	437	
Commercial	Main gas	LF-A-24	13.01	13	963	1547
Commercial	Main gas			8	584	
Commercial	Main gas	LF-A-25	15.56	12	752	1219
Commercial	Main gas			7	467	
Commercial	Old	LF-A-59	4.95	11	2257	3126
Commercial	Old			4	868	
Commercial	Old	LF-A-60	4.95	11	2185	3209
Commercial	Old			5	1024	
Commercial	Old	LF-A-61	4.95	10	2032	3109
Commercial	Old			5	1077	
Commercial	Recent	LF-A-74	14.28	16	1090	1700
Commercial	Recent			9	610	
Commercial	Recent	LF-A-75	13.77	14	1014	1620
Commercial	Recent			8	606	
Commercial	Recent	LF-A-76	14.28	16	1086	1730
Commercial	Recent			9	644	
Codisposal	Main gas	LF-A-91	14.00	2	138	216
Codisposal	Main gas			1	78	
Codisposal	Main gas	LF-A-92	15.00	2	129	204
Codisposal	Main gas			1	75	
Codisposal	Main gas	LF-A-93	15.67	2	124	189
Codisposal	Main gas			1	65	
Ash	Main gas	LF-A-107	6.83	11	1581	2520
Ash	Main gas			6	939	
Ash	Main gas	LF-A-108	15.33	10	621	1000
Ash	Main gas		0.00	6	379	
Ash	Main gas	LF-A-109	13.55	10	737	1154
Ash	Main gas			6	417	
Ash	Recent	LF-A-142	10.07	10	984	1416
Ash	Recent			4	432	
Ash	Recent	LF-A-143	10.07	0	28	470
Ash	Recent			4	443	
Ash	Recent	LF-A-144	?	10		no value
Ash	Recent			8		

TABLE 4C 2002 ACETONE ANALYSIS BY HPLC (CONTINUED)

Site Name	Sampling Location	Sample Label	Sample Volume	Mass of Acetone	Acetone Concentration	Combined Acetone concentration
Units			L	ug	ug.m ⁻³	ug.m ⁻³
Ash	Old	LF-A-159	8.69	11	1246	1835
Ash	Old			5	589	
Ash	Old	LF-A-160	6.86	10	1497	2171
Ash	Old			5	673	
Ash	Old	LF-A-161	6.56	12	1899	2640
Ash	Old			5	741	
Dom/Leach	Recent	LF-A-175	19.85	6	313	472
Dom/Leach	Recent			3	159	
Dom/Leach	Recent	LF-A-176	14.95	3	201	395
Dom/Leach	Recent			3	194	
Dom/Leach	Recent	LF-A-177	14.70	4	268	495
Dom/Leach	Recent			3	227	
Dom/Leach	Main gas	LF-A-191	10.89	1	67	85
Dom/Leach	Main gas			0	18	
Dom/Leach	Main gas	LF-A-192	10.72	1	77	96
Dom/Leach	Main gas			0	18	
Dom/Leach	Main gas	LF-A-193	11.06	1	73	90
Dom/Leach	Main gas			0	17	
Dom/Leach	Leachate	LF-A-224	12.03	0	35	56
Dom/Leach	Leachate			0	21	
Dom/Leach	Leachate	LF-A-225	12.03	0	36	54
Dom/Leach	Leachate			0	18	
Dom/Leach	Leachate	LF-A-226	12.44	1	45	66
Dom/Leach	Leachate			0	21	
Dom/Leach	Old	LF-A-259	10.65	6	593	635
Dom/Leach	Old			0	41	
Dom/Leach	Old	LF-A-260	10.30	7	634	694
Dom/Leach	Old			1	60	
Dom/Leach	Old	LF-A-261	10.65	7	670	766
Dom/Leach	Old			1	96	
BLANK	-	LF-A-303		0.45		
BLANK	-			0.14		
BLANK	-	LF-A-304		0.34		
BLANK	-			0.11		
BLANK	-	LF-A-305		0.30		

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS

Site Name	Sampling Location	Tube Number	Tube type	Dichlorodifluoro methane	Chloromethane	Chloroethene	Bromoethane	Chloroethane	Trichlorofluoro methane	1-Pentene	Acetone
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	<10	72	4900	<10	46	17000	6600	1700
Dom/Dry	Main gas	LF-A-012	DB-HF	<10	72	4900	<10	45	18000	6800	1700
Dom/Dry	Main gas	LF-A-013	DB-HF	<10	47	3400	<10	68	19000	7900	1900
Commercial	Main gas	LF-A-046	DB-HF	<10	<10	240	<10	<10	2200	1000	1400
Commercial	Main gas	LF-A-047	DB-HF	<10	<10	200	<10	<10	2600	3700	1300
Commercial	Main gas	LF-A-048	DB-HF	<10	<10	120	<10	<10	780	3300	1500
Commercial	Old	LF-A-062	DB-HF	<20	81	2100	<20	170	3100	4300	2900
Commercial	Old	LF-A-063	DB-HF	<20	83	1900	<20	150	2900	13000	2200
Commercial	Old	LF-A-064	DB-HF	<10	65	2900	<10	130	900	11000	2300
Commercial	Recent	LF-A-078	DB-HF	<10	57	110	<10	21	2200	5400	2500
Commercial	Recent	LF-A-079	DB-HF	<10	71	150	<10	<10	4300	4900	2100
Commercial	Recent	LF-A-080	DB-HF	<10	48	91	<10	<10	1100	6300	4200
Codisposal	Main gas	LF-A-094	DB-HF	12000	290	10000	<10	320	5300	15000	220
Codisposal	Main gas	LF-A-095	DB-HF	11000	220	9900	<10	290	5000	15000	230
Codisposal	Main gas	LF-A-096	DB-HF	11000	290	9500	<10	310	5000	15000	210
Ash	Main gas	LF-A-110	DB-HF	3700	230	220	<8	26	7800	6000	2100
Ash	Main gas	LF-A-111	DB-HF	4700	270	330	<9	26	8000	6500	2300
Ash	Main gas	LF-A-112	DB-HF	4700	<8	330	<8	<8	4500	7200	2400
Ash	Recent	LF-A-146	DB-HF	16000	<10	200	<10	<10	2900	3200	7000
Ash	Recent	LF-A-147	DB-HF	23000	<10	340	<10	<10	6300	4500	7200
Ash	Recent	LF-A-148	DB-HF	17000	<10	210	<10	<10	4800	6100	8100
Ash	Old	LF-A-162	DB-HF	17000	<10	440	<10	<10	7100	24000	9600
Ash	Old	LF-A-163	DB-HF	21000	<10	640	<10	<10	8000	32000	8900
Ash	Old	LF-A-164	DB-HF	25000	<10	750	<10	<10	9000	25000	10000
Dom/Leach	Recent	LF-A-178	DB-HF	310	<10	520	<10	<10	520	600	230
Dom/Leach	Recent	LF-A-179	DB-HF	290	<10	500	<10	<10	510	520	280
Dom/Leach	Recent	LF-A-180	DB-HF	490	<10	970	<10	<10	630	780	400
Dom/Leach	Main gas	LF-A-194	DB-HF	<20	<20	<20	<20	<20	<20	<20	100
Dom/Leach	Main gas	LF-A-195	DB-HF	<10	<10	27	<10	<10	<10	<10	83
Dom/Leach	Main gas	LF-A-196	DB-HF	<20	<20	37	<20	<20	<20	110	110
Dom/Leach	Leachate	LF-A-228	DB-HF	<10	<10	4600	<10	<10	1700	16000	300
Dom/Leach	Leachate	LF-A-229	DB-HF	15000	<10	3900	<10	<10	1600	16000	260
Dom/Leach	Leachate	LF-A-230	DB-HF	14000	<20	2200	<20	<20	1500	14000	270
Dom/Leach	Old	LF-A-262	DB-HF	26000	<10	3500	<10	120	11000	19000	2100
Dom/Leach	Old	LF-A-263	DB-HF	22000	<9	2600	<9	110	12000	19000	2100
Dom/Leach	Old	LF-A-264	DB-HF	28000	<10	2800	<10	140	12000	20000	2100

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	Furan	Propan-2-ol	Ethanethiol	1,1-Dichloro ethene	Methylsulfide	Dichloro methane	Carbon Disulfide	trans-1,2-Dichloroethene
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	64	120	480	48	210	400	1700	690
Dom/Dry	Main gas	LF-A-012	DB-HF	74	130	820	56	130	710	2100	800
Dom/Dry	Main gas	LF-A-013	DB-HF	84	180	860	62	160	750	2200	850
Commercial	Main gas	LF-A-046	DB-HF	77	<10	410	35	<10	33	230	340
Commercial	Main gas	LF-A-047	DB-HF	61	<10	400	38	<10	25	390	630
Commercial	Main gas	LF-A-048	DB-HF	45	<10	500	38	<10	18	180	630
Commercial	Old	LF-A-062	DB-HF	360	<20	460	66	810	1200	2600	400
Commercial	Old	LF-A-063	DB-HF	360	150	290	59	850	1100	970	320
Commercial	Old	LF-A-064	DB-HF	290	<10	410	29	690	940	1900	590
Commercial	Recent	LF-A-078	DB-HF	130	<10	<10	39	<10	91	970	460
Commercial	Recent	LF-A-079	DB-HF	110	<10	<10	38	<10	<10	860	350
Commercial	Recent	LF-A-080	DB-HF	100	<10	850	39	<10	90	880	88
Codisposal	Main gas	LF-A-094	DB-HF	52	700	1300	45	58	290	1200	1600
Codisposal	Main gas	LF-A-095	DB-HF	48	670	1700	49	55	110	500	1500
Codisposal	Main gas	LF-A-096	DB-HF	52	700	1600	55	63	110	790	1500
Ash	Main gas	LF-A-110	DB-HF	350	970	<8	59	530	120	840	480
Ash	Main gas	LF-A-111	DB-HF	380	1200	<9	47	550	120	820	470
Ash	Main gas	LF-A-112	DB-HF	390	1200	<8	69	600	130	930	610
Ash	Recent	LF-A-146	DB-HF	420	800	310	190	2100	100	2700	1700
Ash	Recent	LF-A-147	DB-HF	510	1300	<10	320	3400	180	3000	3400
Ash	Recent	LF-A-148	DB-HF	470	990	<10	220	2300	120	2200	2000
Ash	Old	LF-A-162	DB-HF	1300	4900	<10	340	9700	450	930	2700
Ash	Old	LF-A-163	DB-HF	1500	6000	<10	320	9100	370	850	2100
Ash	Old	LF-A-164	DB-HF	1700	6200	<10	380	11000	480	1000	2600
Dom/Leach	Recent	LF-A-178	DB-HF	<10	110	<10	<10	36	32	130	69
Dom/Leach	Recent	LF-A-179	DB-HF	<10	150	<10	<10	36	37	150	94
Dom/Leach	Recent	LF-A-180	DB-HF	<10	270	<10	<10	54	63	190	390
Dom/Leach	Main gas	LF-A-194	DB-HF	<20	98	<20	<20	<20	<20	130	120
Dom/Leach	Main gas	LF-A-195	DB-HF	<10	<10	<10	<10	<10	<10	26	<10
Dom/Leach	Main gas	LF-A-196	DB-HF	<20	100	<20	<20	<20	<20	29	36
Dom/Leach	Leachate	LF-A-228	DB-HF	<10	1300	410	16	<10	14	410	360
Dom/Leach	Leachate	LF-A-229	DB-HF	58	1200	400	18	25	13	380	350
Dom/Leach	Leachate	LF-A-230	DB-HF	58	1200	400	<20	34	<20	640	340
Dom/Leach	Old	LF-A-262	DB-HF	<10	2600	230	15	96	250	620	930
Dom/Leach	Old	LF-A-263	DB-HF	<9	2500	480	22	190	260	480	950
Dom/Leach	Old	LF-A-264	DB-HF	<10	430	530	18	160	260	440	940

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	1,1-Dichloro ethane	n-Hexane	2-Butanone	cis-1,2-Dichloroethene	Propanethiol	Chloroform	Tetrachloro methane	Benzene
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	240	5900	4200	7700	50	<10	<10	1400
Dom/Dry	Main gas	LF-A-012	DB-HF	260	8100	4400	8500	74	<10	<10	1500
Dom/Dry	Main gas	LF-A-013	DB-HF	270	8500	4900	9000	63	<10	<10	1600
Commercial	Main gas	LF-A-046	DB-HF	99	1400	1400	2500	30	<10	<10	4000
Commercial	Main gas	LF-A-047	DB-HF	93	1800	1800	3300	71	<10	<10	4500
Commercial	Main gas	LF-A-048	DB-HF	<10	1800	2200	2700	43	<10	<10	6400
Commercial	Old	LF-A-062	DB-HF	340	14000	13000	7800	110	19	<20	5700
Commercial	Old	LF-A-063	DB-HF	300	13000	12000	7000	75	<20	<20	5400
Commercial	Old	LF-A-064	DB-HF	260	9300	9500	6000	100	14	<10	4100
Commercial	Recent	LF-A-078	DB-HF	71	8000	7400	6300	440	<10	<10	7700
Commercial	Recent	LF-A-079	DB-HF	<10	2100	2700	1700	200	<10	<10	7600
Commercial	Recent	LF-A-080	DB-HF	<10	3200	2700	5300	200	<10	<10	7000
Codisposal	Main gas	LF-A-094	DB-HF	1400	11000	1000	10000	35	<10	<10	2600
Codisposal	Main gas	LF-A-095	DB-HF	1300	10000	920	9900	51	<10	<10	2600
Codisposal	Main gas	LF-A-096	DB-HF	1400	11000	820	10000	60	<10	<10	2700
Ash	Main gas	LF-A-110	DB-HF	85	3200	4200	5300	28	<8	<8	3500
Ash	Main gas	LF-A-111	DB-HF	84	4600	4600	5600	23	<9	<9	3900
Ash	Main gas	LF-A-112	DB-HF	93	4500	4600	5900	14	<8	<8	3900
Ash	Recent	LF-A-146	DB-HF	130	<10	12000	7100	<10	<10	<10	2300
Ash	Recent	LF-A-147	DB-HF	240	<10	15000	6500	<10	<10	<10	1600
Ash	Recent	LF-A-148	DB-HF	150	<10	14000	7600	<10	<10	<10	1600
Ash	Old	LF-A-162	DB-HF	430	4200	11000	9400	<10	<10	<10	15000
Ash	Old	LF-A-163	DB-HF	360	6800	11000	13000	<10	<10	<10	15000
Ash	Old	LF-A-164	DB-HF	420	5500	13000	14000	<10	<10	<10	16000
Dom/Leach	Recent	LF-A-178	DB-HF	<10	1100	1400	3500	<10	<10	<10	420
Dom/Leach	Recent	LF-A-179	DB-HF	<10	<10	1500	4200	<10	<10	<10	430
Dom/Leach	Recent	LF-A-180	DB-HF	12	<10	1700	4700	<10	<10	<10	400
Dom/Leach	Main gas	LF-A-194	DB-HF	<20	<20	770	910	<20	<20	<20	830
Dom/Leach	Main gas	LF-A-195	DB-HF	<10	160	580	890	<10	<10	<10	710
Dom/Leach	Main gas	LF-A-196	DB-HF	<20	<20	830	1200	<20	<20	<20	910
Dom/Leach	Leachate	LF-A-228	DB-HF	76	6100	790	1100	<10	<10	<10	1500
Dom/Leach	Leachate	LF-A-229	DB-HF	74	5400	740	1100	<10	<10	<10	1400
Dom/Leach	Leachate	LF-A-230	DB-HF	64	5600	570	910	<20	<20	<20	1400
Dom/Leach	Old	LF-A-262	DB-HF	330	3900	3300	1200	18	<10	<10	1100
Dom/Leach	Old	LF-A-263	DB-HF	340	3800	3200	1300	<9	<9	<9	970
Dom/Leach	Old	LF-A-264	DB-HF	350	3900	3500	1300	<10	<10	<10	1200

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	Butan-1-ol	n-Heptane	Trichloro ethene	1,2-Dichloro propane	Diethyl sulfide	Butanethiol	Methylcyclo hexane	4-Methyl-2-pentanone
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	3300	7200	1400	61	180.00	180.00	6000	1000
Dom/Dry	Main gas	LF-A-012	DB-HF	3600	8600	1500	75	190.00	230.00	6600	1100
Dom/Dry	Main gas	LF-A-013	DB-HF	4000	8300	1600	81	200.00	250.00	7100	1200
Commercial	Main gas	LF-A-046	DB-HF	860	2400	560	49	74.00	59.00	7100	1800
Commercial	Main gas	LF-A-047	DB-HF	<10	12000	1400	130	170.00	160.00	12000	2400
Commercial	Main gas	LF-A-048	DB-HF	1600	7000	530	68	110.00	<10	4200	3200
Commercial	Old	LF-A-062	DB-HF	3900	13000	2700	130	330.00	270.00	11000	1900
Commercial	Old	LF-A-063	DB-HF	3200	12000	2500	120	310.00	170.00	10000	1800
Commercial	Old	LF-A-064	DB-HF	2900	9900	2000	98	240.00	210.00	8300	1500
Commercial	Recent	LF-A-078	DB-HF	230	9500	1700	280	220.00	<10	17000	6000
Commercial	Recent	LF-A-079	DB-HF	400	9800	1800	270	220.00	<10	15000	5600
Commercial	Recent	LF-A-080	DB-HF	550	19000	1600	250	210.00	<10	12000	4900
Codisposal	Main gas	LF-A-094	DB-HF	750	2200	980	77	260.00	120.00	6000	480
Codisposal	Main gas	LF-A-095	DB-HF	640	2100	990	93	290.00	120.00	6200	430
Codisposal	Main gas	LF-A-096	DB-HF	580	1900	1000	87	290.00	120.00	6400	420
Ash	Main gas	LF-A-110	DB-HF	1700	4800	900	49	160.00	<8	5700	2300
Ash	Main gas	LF-A-111	DB-HF	1500	2500	930	<9	<9	<9	6300	2500
Ash	Main gas	LF-A-112	DB-HF	1700	3000	990	<8	<8	<8	1500	770
Ash	Recent	LF-A-146	DB-HF	1800	4400	5000	<10	<10	<10	9300	4600
Ash	Recent	LF-A-147	DB-HF	1300	3600	6700	<10	<10	<10	12000	6100
Ash	Recent	LF-A-148	DB-HF	1100	4700	5600	<10	<10	<10	9700	<10
Ash	Old	LF-A-162	DB-HF	<10	6200	2400	<10	<10	<10	2800	4000
Ash	Old	LF-A-163	DB-HF	<10	7600	2500	<10	<10	<10	7000	6100
Ash	Old	LF-A-164	DB-HF	<10	8300	2800	<10	<10	<10	4600	6300
Dom/Leach	Recent	LF-A-178	DB-HF	4400	440	520	<10	<10	<10	570	660
Dom/Leach	Recent	LF-A-179	DB-HF	4800	<10	600	<10	<10	<10	210	200
Dom/Leach	Recent	LF-A-180	DB-HF	5400	490	610	<10	<10	<10	200	710
Dom/Leach	Main gas	LF-A-194	DB-HF	2500	190	230	<20	<20	<20	110	190
Dom/Leach	Main gas	LF-A-195	DB-HF	2200	130	220	<10	<10	<10	77	190
Dom/Leach	Main gas	LF-A-196	DB-HF	3000	200	290	<20	<20	<20	120	240
Dom/Leach	Leachate	LF-A-228	DB-HF	1400	2000	210	<10	<10	<10	1800	240
Dom/Leach	Leachate	LF-A-229	DB-HF	1200	1700	200	<10	<10	<10	1500	190
Dom/Leach	Leachate	LF-A-230	DB-HF	1200	1900	180	<20	36.00	<20	1600	230
Dom/Leach	Old	LF-A-262	DB-HF	4200	2500	460	<10	<10	<10	2400	180
Dom/Leach	Old	LF-A-263	DB-HF	4200	2400	470	<9	<9	<9	2200	160
Dom/Leach	Old	LF-A-264	DB-HF	4400	2500	480	<10	<10	<10	2500	200

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	Dimethyl disulfide	Toluene	Butyric Acid	n-Octane	Ethyl butanoate	Butyl ethanoate	Tetrachloro ethene	Ethylcyclo hexane
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	52	7700	390	3600	3500	370	15000	130
Dom/Dry	Main gas	LF-A-012	DB-HF	59	8100	440	4100	3700	510	16000	3800
Dom/Dry	Main gas	LF-A-013	DB-HF	59	8900	550	4500	4100	550	17000	3900
Commercial	Main gas	LF-A-046	DB-HF	110	12000	73	2900	1800	<10	4200	2300
Commercial	Main gas	LF-A-047	DB-HF	140	14000	75	3100	1800	<10	6200	2700
Commercial	Main gas	LF-A-048	DB-HF	180	18000	15	5900	2400	160	2400	2400
Commercial	Old	LF-A-062	DB-HF	120	14000	970	5400	6800	940	22000	4400
Commercial	Old	LF-A-063	DB-HF	98	8000	810	4700	6300	620	21000	3400
Commercial	Old	LF-A-064	DB-HF	90	16000	770	3900	4900	730	16000	3600
Commercial	Recent	LF-A-078	DB-HF	1600	19000	31	4800	640	120	11000	6000
Commercial	Recent	LF-A-079	DB-HF	1500	17000	43	4800	590	240	6100	2800
Commercial	Recent	LF-A-080	DB-HF	1400	16000	23	4200	530	230	4400	2400
Codisposal	Main gas	LF-A-094	DB-HF	<10	14000	43	4100	2500	370	13000	2800
Codisposal	Main gas	LF-A-095	DB-HF	15	14000	38	<10	2200	<10	13000	2400
Codisposal	Main gas	LF-A-096	DB-HF	18	15000	71	4600	2300	450	14000	2600
Ash	Main gas	LF-A-110	DB-HF	<8	15000	22	2100	4300	1000	6900	300
Ash	Main gas	LF-A-111	DB-HF	<9	16000	49	2600	4800	560	4100	500
Ash	Main gas	LF-A-112	DB-HF	710	16000	33	2500	4700	1000	5700	260
Ash	Recent	LF-A-146	DB-HF	<10	18000	<10	2800	5700	890	15000	4000
Ash	Recent	LF-A-147	DB-HF	<10	22000	<10	<10	6200	1700	15000	3400
Ash	Recent	LF-A-148	DB-HF	<10	20000	<10	<10	6200	1600	20000	2100
Ash	Old	LF-A-162	DB-HF	<10	27000	<10	3500	7000	480	18000	<10
Ash	Old	LF-A-163	DB-HF	<10	30000	<10	2400	7700	2000	32000	5300
Ash	Old	LF-A-164	DB-HF	5200	31000	<10	5000	8300	2400	37000	5500
Dom/Leach	Recent	LF-A-178	DB-HF	<10	17000	<10	<10	9300	1200	14000	220
Dom/Leach	Recent	LF-A-179	DB-HF	79	16000	<10	250	8300	1200	12000	210
Dom/Leach	Recent	LF-A-180	DB-HF	170	16000	<10	200	8000	1400	16000	240
Dom/Leach	Main gas	LF-A-194	DB-HF	92	38000	<20	130	2200	220	7400	51
Dom/Leach	Main gas	LF-A-195	DB-HF	86	31000	<10	<10	2300	280	7000	45
Dom/Leach	Main gas	LF-A-196	DB-HF	110	42000	<20	<20	2800	330	8900	66
Dom/Leach	Leachate	LF-A-228	DB-HF	70	12000	780	2500	2700	280	7200	1600
Dom/Leach	Leachate	LF-A-229	DB-HF	69	11000	680	1800	2500	<10	6600	1200
Dom/Leach	Leachate	LF-A-230	DB-HF	62	13000	520	2000	2500	170	6500	1200
Dom/Leach	Old	LF-A-262	DB-HF	<10	9200	<10	2200	<10	460	9400	2000
Dom/Leach	Old	LF-A-263	DB-HF	41	8300	<9	1600	4300	760	8900	1700
Dom/Leach	Old	LF-A-264	DB-HF	51	10000	<10	1700	5300	370	10000	2000

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	Chlorobenzene	EthylBenzene	m-Xylene + p-Xylene	n-Nonane	Styrene	o-Xylene	2-Butoxy Ethanol	1,1,2,2-Tetrachloro ethane
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	820	6300	8200	4000	560	3700	2700	220
Dom/Dry	Main gas	LF-A-012	DB-HF	900	4500	6200	4300	510	3900	2700	330
Dom/Dry	Main gas	LF-A-013	DB-HF	930	5100	6900	4800	590	4500	3200	330
Commercial	Main gas	LF-A-046	DB-HF	8700	16000	31000	1000	440	4400	610	190
Commercial	Main gas	LF-A-047	DB-HF	6200	19000	27000	3000	210	3100	150	42
Commercial	Main gas	LF-A-048	DB-HF	5700	14000	31000	4000	390	7200	270	110
Commercial	Old	LF-A-062	DB-HF	2800	6100	15000	5500	870	7100	390	420
Commercial	Old	LF-A-063	DB-HF	2800	10000	7800	4900	840	6800	330	220
Commercial	Old	LF-A-064	DB-HF	2200	4800	7900	3800	630	5000	290	320
Commercial	Recent	LF-A-078	DB-HF	4600	5000	2700	4100	970	4800	2200	380
Commercial	Recent	LF-A-079	DB-HF	1900	5200	18000	3800	950	4300	2100	350
Commercial	Recent	LF-A-080	DB-HF	1400	9800	9200	3200	770	3900	130	290
Codisposal	Main gas	LF-A-094	DB-HF	1800	7000	8500	2700	650	4300	280	120
Codisposal	Main gas	LF-A-095	DB-HF	2000	7100	8500	2900	260	4400	<10	<10
Codisposal	Main gas	LF-A-096	DB-HF	2000	7200	8800	3300	290	4400	120	<10
Ash	Main gas	LF-A-110	DB-HF	140	3700	4900	1800	250	1800	<8	<8
Ash	Main gas	LF-A-111	DB-HF	120	3700	4600	1900	200	1300	<9	<9
Ash	Main gas	LF-A-112	DB-HF	54	2300	3600	1800	190	1200	<8	<8
Ash	Recent	LF-A-146	DB-HF	570	7400	9000	1500	550	3600	<10	<10
Ash	Recent	LF-A-147	DB-HF	880	9400	8200	3500	650	3900	<10	<10
Ash	Recent	LF-A-148	DB-HF	310	5800	8000	3300	420	3000	<10	<10
Ash	Old	LF-A-162	DB-HF	490	5000	16000	3700	260	4600	<10	<10
Ash	Old	LF-A-163	DB-HF	1300	5500	23000	5300	360	5100	<10	<10
Ash	Old	LF-A-164	DB-HF	1400	7700	22000	5900	410	4800	<10	<10
Dom/Leach	Recent	LF-A-178	DB-HF	260	5600	9300	1500	980	3800	<10	<10
Dom/Leach	Recent	LF-A-179	DB-HF	200	4400	6700	1100	490	2500	<10	<10
Dom/Leach	Recent	LF-A-180	DB-HF	510	5800	8900	1500	840	3600	<10	<10
Dom/Leach	Main gas	LF-A-194	DB-HF	140	2400	4200	1300	370	1600	240	<20
Dom/Leach	Main gas	LF-A-195	DB-HF	140	2300	3700	1100	400	1500	240	<10
Dom/Leach	Main gas	LF-A-196	DB-HF	170	2900	4700	1300	480	1800	300	<20
Dom/Leach	Leachate	LF-A-228	DB-HF	500	5800	7800	3700	240	3600	<10	<10
Dom/Leach	Leachate	LF-A-229	DB-HF	470	5300	7000	3400	230	3300	<10	<10
Dom/Leach	Leachate	LF-A-230	DB-HF	420	6000	7900	3500	220	3500	<20	<20
Dom/Leach	Old	LF-A-262	DB-HF	270	4800	6500	3200	180	2800	<10	<10
Dom/Leach	Old	LF-A-263	DB-HF	270	4400	5800	1500	190	2500	<9	<9
Dom/Leach	Old	LF-A-264	DB-HF	290	5400	7200	3400	240	3100	<10	<10

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	n-Propyl benzene	p-Ethyl toluene	n-Decane	1,2,4-Trimethyl benzene	Limonene	1,2-Dichloro benzene	Tetramethyl benzene	Dichlorofluoro methane
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	1200	2500	3200	1900	1900	17	73	3300
Dom/Dry	Main gas	LF-A-012	DB-HF	1000	2500	3300	2000	2000	20	86	3500
Dom/Dry	Main gas	LF-A-013	DB-HF	1200	1000	3800	2300	2300	21	83	3500
Commercial	Main gas	LF-A-046	DB-HF	3600	1900	190	1100	1800	<10	120	380
Commercial	Main gas	LF-A-047	DB-HF	3400	1900	230	2700	1400	<10	110	310
Commercial	Main gas	LF-A-048	DB-HF	4000	4000	4200	4000	2300	50	87	180
Commercial	Old	LF-A-062	DB-HF	2400	1700	4900	2500	3400	100	140	4000
Commercial	Old	LF-A-063	DB-HF	2300	1800	4400	2400	3000	92	140	3700
Commercial	Old	LF-A-064	DB-HF	1700	2300	3400	3000	2300	75	91	3100
Commercial	Recent	LF-A-078	DB-HF	3000	2000	3000	3100	2500	110	160	1200
Commercial	Recent	LF-A-079	DB-HF	3100	180	2100	1900	1800	100	140	1300
Commercial	Recent	LF-A-080	DB-HF	1800	220	1800	1400	1500	59	120	990
Codisposal	Main gas	LF-A-094	DB-HF	1200	3900	2500	2200	2400	92	600	<10
Codisposal	Main gas	LF-A-095	DB-HF	1300	2800	2500	2200	2200	110	550	2400
Codisposal	Main gas	LF-A-096	DB-HF	1300	2900	2400	2300	2300	110	560	2400
Ash	Main gas	LF-A-110	DB-HF	450	1400	1900	1000	1600	21	950	900
Ash	Main gas	LF-A-111	DB-HF	410	1500	2600	1400	1900	24	1600	930
Ash	Main gas	LF-A-112	DB-HF	500	2000	2600	1300	1600	18	610	1100
Ash	Recent	LF-A-146	DB-HF	860	2700	3300	2100	2600	33	120	4000
Ash	Recent	LF-A-147	DB-HF	850	2700	3400	2300	2600	48	300	<10
Ash	Recent	LF-A-148	DB-HF	760	2600	2700	2000	2700	25	200	4600
Ash	Old	LF-A-162	DB-HF	1400	4300	4300	3700	4300	65	240	2800
Ash	Old	LF-A-163	DB-HF	1300	4000	4200	3200	4400	44	210	2500
Ash	Old	LF-A-164	DB-HF	1300	3800	4200	3300	3800	49	260	3000
Dom/Leach	Recent	LF-A-178	DB-HF	1200	3100	2700	2700	3900	30	190	35
Dom/Leach	Recent	LF-A-179	DB-HF	1400	3000	2700	3100	3000	40	290	32
Dom/Leach	Recent	LF-A-180	DB-HF	1200	2800	3000	3000	3000	43	290	45
Dom/Leach	Main gas	LF-A-194	DB-HF	630	2300	2600	2400	4400	28	640	<20
Dom/Leach	Main gas	LF-A-195	DB-HF	590	2000	2100	1900	3500	28	360	<10
Dom/Leach	Main gas	LF-A-196	DB-HF	730	2500	2700	2500	4500	34	430	<20
Dom/Leach	Leachate	LF-A-228	DB-HF	1200	2800	3200	3000	3700	83	920	3000
Dom/Leach	Leachate	LF-A-229	DB-HF	1100	2700	3100	2800	3500	77	750	2900
Dom/Leach	Leachate	LF-A-230	DB-HF	1100	2600	3500	2700	3900	55	560	2600
Dom/Leach	Old	LF-A-262	DB-HF	720	1900	2400	1900	2700	56	720	1500
Dom/Leach	Old	LF-A-263	DB-HF	700	1800	2100	1700	2400	57	690	1500
Dom/Leach	Old	LF-A-264	DB-HF	830	2200	2700	2100	3100	61	770	2000

TABLE 5 2002 VOC ANALYSIS BY ATD-GC-MS (continued)

Site Name	Sampling Location	Tube Number	Tube type	Ethyl ethanoate	Methanethiol	1,4-Dichloro benzene	1,3-Butadiene	total ug
				µg.m ³	µg.m ³	µg.m ³	µg.m ³	µg.m ³
Dom/Dry	Main gas	LF-A-011	DB-HF	1800	9700	470	8900	176521
Dom/Dry	Main gas	LF-A-012	DB-HF	2000	9800	500	8700	188288
Dom/Dry	Main gas	LF-A-013	DB-HF	2100	10000	550	11000	116900
Commercial	Main gas	LF-A-046	DB-HF	220	580	900	4900	143342
Commercial	Main gas	LF-A-047	DB-HF	230	420	950	9900	117150
Commercial	Main gas	LF-A-048	DB-HF	290	1700	610	4000	27530
Commercial	Old	LF-A-062	DB-HF	4000	31000	850	16000	627
Commercial	Old	LF-A-063	DB-HF	3700	28000	780	16000	32549
Commercial	Old	LF-A-064	DB-HF	3000	25000	610	12000	413
Commercial	Recent	LF-A-078	DB-HF	400	4500	940	7100	21991
Commercial	Recent	LF-A-079	DB-HF	120	5200	880	18000	3518
Commercial	Recent	LF-A-080	DB-HF	350	3800	590	17000	43809
Codisposal	Main gas	LF-A-094	DB-HF	680	<10	360	<10	0
Codisposal	Main gas	LF-A-095	DB-HF	670	<10	440	<10	59001
Codisposal	Main gas	LF-A-096	DB-HF	710	<10	480	<10	0
Ash	Main gas	LF-A-110	DB-HF	1500	3900	250	<8	51977
Ash	Main gas	LF-A-111	DB-HF	1600	3700	350	<9	0
Ash	Main gas	LF-A-112	DB-HF	1600	4000	240	<8	129709
Ash	Recent	LF-A-146	DB-HF	2400	<10	550	<10	157435
Ash	Recent	LF-A-147	DB-HF	3400	1200	620	<10	156504
Ash	Recent	LF-A-148	DB-HF	2800	290	580	<10	427880
Ash	Old	LF-A-162	DB-HF	6600	8700	1700	<10	435340
Ash	Old	LF-A-163	DB-HF	6000	2000	1400	<10	442430
Ash	Old	LF-A-164	DB-HF	6300	3200	1400	<10	256546
Dom/Leach	Recent	LF-A-178	DB-HF	1100	77	1100	<10	237137
Dom/Leach	Recent	LF-A-179	DB-HF	1200	200	1300	<10	204072
Dom/Leach	Recent	LF-A-180	DB-HF	1200	<10	1300	<10	645886
Dom/Leach	Main gas	LF-A-194	DB-HF	290	<20	690	<20	666800
Dom/Leach	Main gas	LF-A-195	DB-HF	250	<10	660	<10	813721
Dom/Leach	Main gas	LF-A-196	DB-HF	330	<20	800	<20	172770
Dom/Leach	Leachate	LF-A-228	DB-HF	170	<10	1400	<10	164762
Dom/Leach	Leachate	LF-A-229	DB-HF	160	<10	1200	<10	158198
Dom/Leach	Leachate	LF-A-230	DB-HF	150	<20	990	<20	592090
Dom/Leach	Old	LF-A-262	DB-HF	5300	<10	910	<10	618530
Dom/Leach	Old	LF-A-263	DB-HF	5200	150	920	<9	553800
Dom/Leach	Old	LF-A-264	DB-HF	5800	<10	1000	<10	161372

TABLE 6 DIOXIN AND FURAN ANALYSIS BY GC-HRMS

Sample No	LF-A-10		LF-A-27		LF-A-84		LF-A-100
Our Sample No	HA3373		HA3390		HA3447		HA3463
Site	Dom/Dry		Commercial		Codisposal		Ash site
	Result	ITEQ	Result	ITEQ	Result	ITEQ	
	ng.m3	ng.m3	ng.m3	ng.m3	ng.m3	ng.m3	
Dioxins							
2378	0.0018	0.0018	<0.001	0.001	0.0021	0.0021	NA
12378	0.0130	0.0065	<0.004	0.002	<0.004	0.002	
123478	0.0020	0.0002	<0.002	0.0002	0.0091	0.00091	
123678	<0.002	0.0002	0.0058	0.00058	0.0041	0.00041	
123789	0.0034	0.00034	<0.002	0.0002	0.0048	0.00048	
1234678	0.0030	0.00003	<0.003	0.00003	0.009	0.00009	
OCDD	0.1000	0.0001	0.012	0.000012	0.062	0.000062	
Total Dioxins	0.1252	0.00917	0.0298	0.004022	0.0951	0.006052	
Furans							
2378	0.0029	0.00029	<0.001	0.0001	0.0025	0.00025	
12378	<0.003	0.00015	<0.003	0.00015	<0.003	0.00015	
23478	<0.003	0.0015	<0.003	0.0015	<0.003	0.0015	
123478	0.0049	0.00049	<0.003	0.0003	0.0038	0.00038	
123678	<0.003	0.0003	<0.003	0.0003	0.003	0.0003	
123789	<0.003	0.0003	<0.003	0.0003	<0.003	0.0003	
234678	0.0094	0.00094	<0.003	0.0003	0.0079	0.00079	
1234678	0.015	0.00015	0.012	0.00012	0.031	0.00031	
1234789	<0.003	0.00003	<0.003	0.00003	0.0053	0.000053	
OCDF	0.0093	0.0000093	0.0061	0.0000061	0.025	0.000025	
Total Furans	0.0565	0.0041593	0.0401	0.0031061	0.0875	0.004058	
Grand Total	0.1817	0.0133293	0.0699	0.0071281	0.1826	0.01011	
Dioxins							
Total Tetra	0.220		0.086		0.11		
Total Penta	0.340		0.14		0.15		
Total Hexa	0.160		0.064		0.083		
Total Hepta	0.062		0.015		0.06		
Furans							
Total Tetra	0.230		0.082		0.16		
Total Penta	0.140		0.085		0.16		
Total Hexa	0.160		0.072		0.14		
Total Hepta	0.096		0.055		0.13		
Extraction Recovery	52		70		74		
Sampling Recovery	107		116		114		

TABLE 6 DIOXIN AND FURAN ANALYSIS BY GC-HRMS (CONTINUED)

Sample No	LF-A-184		LF-A-300		LF-A-301		LF-A-302	
Our Sample No	HA3547		HA3663		HA3664		HA3665	
Site	Dom/Leach		Blank 1		Blank 2		Blank 3	
	Result	ITEQ	Result	ITEQ	Result	ITEQ	Result	ITEQ
	ng.m3	ng.m3	ng.m3	ng.m3	ng.m3	ng.m3	ng.m3	ng.m3
Dioxins								
2378	0.0021	0.0021	0.0012	0.0012	<0.001	0.001	0.0029	0.0029
12378	<0.004	0.002	<0.004	0.002	0.0045	0.00225	<0.004	0.002
123478	0.0023	0.00023	0.0028	0.00028	0.0028	0.00028	<0.002	0.0002
123678	0.0022	0.00022	0.0031	0.00031	<0.002	0.0002	0.015	0.0015
123789	0.0048	0.00048	0.0033	0.00033	<0.002	0.0002	0.0041	0.00041
1234678	0.0039	0.000039	0.025	0.00025	<0.003	0.00003	0.0049	0.000049
OCDD	0.014	0.000014	0.059	0.000059	0.01	0.00001	0.041	0.000041
Total Dioxins	0.0333	0.005083	0.0984	0.004429	0.0253	0.00397	0.0739	0.0071
Furans								
2378	<0.001	0.0001	0.0025	0.00025	<0.001	0.0001	0.0017	0.00017
12378	<0.003	0.00015	<0.003	0.00015	<0.003	0.00015	<0.003	0.00015
23478	<0.003	0.0015	0.0036	0.0018	<0.003	0.0015	<0.003	0.0015
123478	<0.003	0.0003	0.006	0.0006	<0.003	0.0003	<0.003	0.0003
123678	<0.003	0.0003	0.003	0.0003	<0.003	0.0003	<0.003	0.0003
123789	<0.003	0.0003	<0.003	0.0003	<0.003	0.0003	<0.003	0.0003
234678	0.0061	0.00061	0.011	0.0011	0.0052	0.00052	<0.003	0.0003
1234678	0.014	0.00014	0.07	0.0007	0.011	0.00011	0.0099	0.000099
1234789	<0.003	0.00003	0.013	0.00013	0.0026	0.000026	<0.003	0.00003
OCDF	0.0081	0.0000081	0.05	0.00005	0.0088	0.0000088	0.0098	0.0000098
Total Furans	0.0472	0.0034381	0.1651	0.00538	0.0436	0.0033148	0.0424	0.0031588
Grand Total	0.0805	0.0085211	0.2635	0.009809	0.0689	0.0072848	0.1163	0.0102588
Dioxins								
Total Tetra	0.093		0.045		0.083		0.068	
Total Penta	0.1		0.058		0.1		0.091	
Total Hexa	0.05		0.056		0.042		0.026	
Total Hepta	0.021		0.039		0.025		0.0033	
Furans								
Total Tetra	0.062		0.051		0.084		0.071	
Total Penta	0.037		0.05		0.061		0.049	
Total Hexa	0.048		0.11		0.063		0.04	
Total Hepta	0.0039		0.14		0.039		0.035	
Extraction Recovery	85		83		53		94	
Sampling Recovery	98		111		116		110	

TABLE 7 PRESENTATION OF BUTYRIC ACID ANALYSIS BY GC-FID

Site Name	Sampling Location	Waste	Age if known	Sample Label	Sample Volume	Mass of Butyric Acid	Butyric Acid Concentration
Units			Years		L	µg	µgm ⁻³
Commercial	Main gas			LF-A-40	2.3575	626.5	266000*
Commercial	Main gas			LF-A-42	4.51	7.65	1700
Commercial	Main gas			LF-A-44	4.51	11.65	2600
Ash	Main gas			LF-A-125	5.85	59.1	10000
Ash	Main gas			LF-A-128	7.41	21.95	4800
Ash	Main gas			LF-A-130	11.055	<5	<450
Dom/Leach	Main gas			LF-A-209	5.44	<5	<920
Dom/Leach	Main gas			LF-A-210	6	5.85	<980
Dom/Leach	Main gas			LF-A-211	5.92	<5	<850
Dom/Leach	Leachate			LF-A-243	8.6	5.65	<660
Dom/Leach	Leachate			LF-A-244	8.2	<5	<610
Dom/Leach	Leachate			LF-A-245	8	<5	<630
Blank				LF-A-292	0	<5	<5
Blank				LF-A-293	0	<5	<5
Blank				LF-A-294	0	<5	<5
Blank				LF-A-295	0	<5	<5
Blank				LF-A-296	0	<5	<5
Blank				LF-A-297	0	<5	<5
Blank				LF-A-298	0	<5	<5
Blank				LF-A-299	0	<5	<5

* High value is likely to be due to peak interference

Appendix 3: 2003 monitoring data

TABLE 1 2003 BULK GAS ANALYSIS

Waste Type	Sampling Location	Data Source	Oxygen %v/v		Carbon Dioxide %v/v		Methane %v/v		Nitrogen %v/v		Carbon Monoxide ppm _v		Hydrogen ppm _v		Hydrogen Sulphide ⁽¹⁾ ppm _v		Hydrogen Sulphide ⁽²⁾ ppm _v		Hydrogen Cyanide ppm _v		Temp. °C	Atm. Pressure mbar		
			2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003				
Domestic with Leachate	Monitoring Event																							
	Main Gas	Field TES	0.0	1.2	34.5	19.9	53.5	-----	-	-	76.0	382.0	-	-	80	-	10.2	2.0	-	22.7	34.2	0.0	32.5	1011
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mature	Field TES Shanks	-	1.2	-	31.0	-	28.0	-	-	-	64.7	-	-	90	-	-	68.2	-	18.2	-	0.0	31.2	1008
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Recent	Field TES Shanks	0.0	0.8	42.5	32.3	54.0	55.0	-	-	942.0	622.0	-	-	1655	-	160.0	65.4	-	>50	-----	0.0	32.5	1004
0.5			0.4	43.2	42.3	54.3	56.6	2.1	0.7	20.0	-	-	-	-	-	-	219.9	-	-	-	-	-	-	
Domestic with less Leachate	Recent with Leachate	Field TES Shanks	0.0	2.4	25.0	28.3	70.5	52.7	-	-	17.0	71.5	-	-	220	-	16.6	44.5	-	-	43.0	0.0	29.2	~1004
			0.5	-	29.6	38.5	68.6	55.1	1.3	4.9	<20	-	-	5.0	-	-	-	424.8	-	-	-	-	-	-
	Main Gas	Field TES Shanks	0.2	0.7	37.0	34.7	51.0	48.7	-	-	42.0	70.3	-	-	-	-	26.9	12.5	-	35.6	>100	0	31.1	1016
			-	-	-	-	-	-	-	-	-	4.0	-	69	-	-	-	-	48.5	-	-	-	-	-
Commercial and Industrial	Main Gas	Field TES Shanks	1.2	1.0	38.1	37.6	50.7	50.1	-	11.3	<20	-	-	115	-	-	-	-	-	-	-	-	-	-
			2.1	2.2	33.0	27.0	44.8	40.0	-	-	45.0	77.3	-	-	170	-	93.9	18.5	-	>50	-----	-	-	1008
	Recent	Field TES Shanks	4.4	2.4	31.6	33.1	43.2	40.7	20.9	23.8	<20	-	<50	-	-	79.4	-	-	-	-	-	-	-	-
			0.0	0.6	39.5	28.5	58.5	55.0	-	-	155.0	38.5	-	-	55	-	115.0	28.6	-	>50	-----	-	33.8	1005
	Recent with Leachate	Field TES	0.3	0.5	42.1	40	57.1	56.2	0.5	3.4	<20	-	337	-	-	-	-	149.7	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-	-	25.7	-	45	-	-	33.3	-	38.9	-	-----	-	28.6
Fragmentiser	Mature	Field TES	0.0	0.6	47.5	24.7	50.8	49.7	-	-	132.0	21.0	-	-	35	-	74.6	0.0	-	1.8	-----	0.0	38.5	1006
			-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
	Main Gas	Field TES	0.0	1.5	34.0	30.0	44.0	42.0	-	-	16.0	41.7	-	-	80	-	21.0	0.0	-	>50	95.0	0.0	34.0	1007
			-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
	Leachate	Field	5.6	-	21	-	27	-	-	-	56	-	-	-	-	75.0	-	-	-	-	>100	-	-	-
			6.7	2.9	23.0	23.0	29.0	36.0	-	-	225.0	714.7	-	-	1030	-	37.9	0.0	-	39.9	>100	-----	36.9	1014
Ash	Recent	Field TES	0.0	0.0	37.5	32.0	60.5	62.0	-	-	407.0	398.0	-	-	310	-	>200	197.0	-	>50	>100	0.0	26.3	1010
			-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
	Mature	Field TES	0.0	0.2	26.5	25.0	27.5	41.2	-	-	>1000	41.7	-	-	75	-	17.6	-----	-	5.3	-	0.0	41.2	1014
			-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Recent with Leachate	Field TES	-	0.2	-	28.0	-	60.3	-	-	-	752.7	-	-	890	-	-	97.0	-	>50	-	-----	33.5	1014	
		-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	
Codisposal	Main Gas	Field TES	0.0	1.7	34.5	31.7	49.8	53.0	-	-	38.0	71.3	-	-	140	-	29.2	0.0	-	37	>100	0.0	24.1	1016
			-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	

Notes:

- denotes not analysed.
- denotes instrument out of range.
- %v/v percentage composition by volume.
- ppm_v concentration by volume in parts per million.
- Field Readings taken using portable instruments in the field: Gas Data LMSxi Portable Gas Analyser and Jerome 631-X H2S Analyser. Average reading from Tedlar bag samples.
- Lab 2 Third party laboratory analysis of Tedlar bag samples.
- Lab 1 Laboratory analysis of Tedlar bag sample using direct injection GC-MS by Lab 1.
- (1) Reading taken by LMSxi. Also includes H2S by GC-MS for Lab 1' samples.
- (2) Reading taken by Jerome 631-X H2S Analyser.

TABLE 2 2003 TOTAL MERCURY ANALYSIS BY CV-AFS

	Waste Type	Location	Sample Label	Extract Solution Conc. (mg L ⁻¹)	Mass on tube (ng)	Sample Volume (L)	Concentration (µg m ⁻³)	Comments
	Domestic with Leachate	Main gas	LF-E-001	0.015	225	10.0	22.5	Front
			LF-E-002	0.0064	96	10.0	9.6	Back
			LF-E-003	0.012	180	10.0	18.0	Front
			LF-E-004	0.01	150	10.0	15.0	Back
		Mature	LF-E-016	0.0082	123	9.8	12.6	Front
			LF-E-017	0.0074	111	9.8	11.4	Back
			LF-E-018	0.0086	129	9.8	13.2	Front
			LF-E-019	0.0072	108	9.8	11.1	Back
		Recent	LF-E-026	0.0058	87	10.0	8.7	Front
			LF-E-027	0.0056	84	10.0	8.4	Back
			LF-E-028	0.006	90	10.0	9.0	Front
			LF-E-029	0.006	90	10.0	9.0	Back
		Leachate	LF-E-046	0.0056	84	10.0	8.4	
			LF-E-047	0.006	90	10.0	9.0	
	Domestic with little Leachate	Main gas	LF-E-048	0.0086	129	10.0	12.9	
			LF-E-049	0.0024	36	10.0	3.6	
	Commercial & Industrial	Main gas	LF-E-059	0.0048	72	10.0	7.2	
			LF-E-060	0.005	75	10.0	7.5	
		Leachate	LF-E-070	0.0048	72	10.0	7.2	
			LF-E-071	0.0044	66	10.0	6.6	
		Recent	LF-E-086	0.004	60	10.2	5.9	
			LF-E-087	0.0042	63	10.2	6.2	
		Mature	LF-E-093	0.004	60	10.0	6.0	Front
			LF-E-094	0.0044	66	10.0	6.6	Back
			LF-E-095	0.0036	54	10.0	5.4	Front
			LF-E-096	0.0036	54	10.0	5.4	Back
Blank Trip 1			LF-E-092	0.0036	54	10.0	5.4	Blank
			LF-E-097	0.0036	54	10.0	5.4	Blank
	Fragmentiser	Main gas	LF-E-201	0.0032	48	10.0	4.8	
			LF-E-202	0.0032	48	10.0	4.8	
	Substantial Ash	Main gas	LF-E-212	0.0034	51	10.0	5.1	
			LF-E-213	0.0032	48	10.0	4.8	
		Recent	LF-E-223	0.0032	48	10.0	4.8	
			LF-E-224	0.0036	54	10.0	5.4	
		Mature	LF-E-233	0.003	45	10.2	4.4	
			LF-E-234	0.0032	48	10.2	4.7	
		Leachate	LF-E-243	0.0026	39	10.2	3.8	
			LF-E-244	0.0026	39	10.2	3.8	
	Codisposal	Main gas	LF-E-253	0.0026	39	10.0	3.9	
			LF-E-254	0.0028	42	10.0	4.2	
Blank Trip 2			LF-E-264	0.0028	42	10.0	4.2	Blank
			LF-E-265	0.0024	36	10.0	3.6	Blank
Blank Spike			SPIKE	0.031	465	10.0	46.5	Blank Spike

Notes:

Laboratory data was based upon mercury dissolved in 15ml of reagent solution. To convert laboratory concentrations to mass in ng, multiply by 15000, as described by the following equation:

$$M(\text{ng}) = C_s \left(\frac{\text{mg}}{\text{L}} \right) \times 15(\text{ml}) \times \frac{1}{1000} \left(\frac{\text{L}}{\text{ml}} \right) \times 1000000 \left(\frac{\text{ng}}{\text{mg}} \right)$$

Where: M = mass of mercury (ng)
 C_s = Concentration of extract solution (mg L⁻¹)

APPENDIX 3 - TABLE 3. 2003 TOTAL INORGANIC ARSENIC ANALYSIS BY ICP-MS

Waste Type	Sampling Location	Sample Label	Mass of Arsenic (ng)	Sample Volume (L)	Concentration in gas (μgm^{-3})	Average Concentration (μgm^{-3})	RPD (%)
Domestic with Leachate	Main Gas	LF-E-05	412	10.0	41.2	28.7	69
		LF-E-06	200	10.0	20.0		
	Mature	LF-E-07	470	9.8	48.2	43.9	19
		LF-E-08	390	9.8	40.0		
	Recent	LF-E-30	34	10.0	3.4	3.7	-19
		LF-E-31	41	10.0	4.1		
	Leachate	LF-E-38	59	10.0	5.9	4.9	38
		LF-E-39	40	10.0	4.0		
Domestic with little Leachate	Main Gas	LF-E-50	46	10.0	4.6	4.2	19
		LF-E-51	38	10.0	3.8		
Commercial & Industrial	Main Gas	LF-E-61	280	10.0	28.0	34.3	-40
		LF-E-62	420	10.0	42.0		
	Leachate	LF-E-72	110	10.0	11.0	11.0	0
		LF-E-73	110	10.0	11.0		
	Recent	LF-E-82	65	10.2	6.4	5.5	30
		LF-E-83	47	10.0	4.7		
	Mature	LF-E-98	5.8	10.0	0.6	0.6	7
		LF-E-99	5.4	10.0	0.5		
Fragmentiser	Main Gas	LF-E-203	62	10.0	6.2	6.8	-18
		LF-E-204	74	10.0	7.4		
Substantial Ash	Main Gas	LF-E-214	330	10.0	33.0	31.5	10
		LF-E-215	300	10.0	30.0		
	Recent	LF-E-225	3900	10.0	390.0	409.5	-10
		LF-E-226	4300	10.0	430.0		
	Mature	LF-E-235	17	10.2	1.7	1.6	13
		LF-E-236	15	10.2	1.5		
	Leachate	LF-E-245	1100	10.2	107.8	117.2	-17
		LF-E-246	1300	10.2	127.5		
Codisposal	Main Gas	LF-E-255	31	10.0	3.1	3.1	0
		LF-E-256	31	10.0	3.1		

Notes:

RPD denotes Relative Percentage Difference and is the difference between concentrations, divided by the mean and multiplied by 100.

TABLE 4 2003 ARSENIC RESULTS FROM DIFFERENT SAMPLING PERIODS

Sampling Location	Waste Type	Maximum Concentration		RPD (%)	ABS RPD (%)
		2002 (μgm^{-3})	2003 (μgm^{-3})		
Domestic with little Leachate	Main Gas	0.9	4.6	-133	133
Ash	Main Gas	4.4	33.0	-153	153
	Recent	19.4	430	-183	183
	Mature	3.3	1.7	63	63
	Leachate	-	128	-	-
Domestic with Leachate	Main Gas	0.1	41.2	-199	199
	Mature	0.3	48.2	-197	197
	Recent	2.0	4.1	-70	70
	Leachate	0.1	5.9	-193	193
Codisposal	Main Gas	0.5	3.1	-149	149
Commercial & Industrial	Main Gas	59.6	42.0	35	35
	Leachate	-	11.0	-	-
	Recent	12.5	6.4	64	64
	Mature	2.2	0.6	115	115
Fragmentiser	Main Gas	<0.8	7.4	-161	161
	Leachate	33.0	-	-	-
Average		10.6	51.1	-89	132
Median		2.2	7.4	-149	149
Geomean		2.2	12.5	-	117
Max		59.6	430	115	199
Min		0.1	0.6	-199	35

Notes:

Geomean denotes geometric average.
 RPD denotes Relative Percentage Difference.
 ABS RPD denotes Absolute Relative Percentage Difference.

TABLE 5A 2003 METHANAL ANALYSIS BY HPLC

Waste Type	Sampling Location	Sample Label	Total Volume (L)	Mass of Methanal (µg)	Concentration in gas (µg m ⁻³)	Total Concentration (µg m ⁻³)	RPD
Domestic with Leachate	Main Gas	LF-E-009 F	10.0	0.93	93	93	-68
		LF-E-009 B	10.0	<0.12	<12		
		LF-E-010 F	10.0	1.8	176		
		LF-E-010 B	10.0	0.13	13		
	Recent	LF-E-032 F	10.0	0.59	59	99	78
		LF-E-032 B	10.0	0.40	40		
		LF-E-033 F	10.0	0.43	43		
		LF-E-033 B	10.0	<0.12	<12		
	Mature	LF-E-020 F	9.8	0.33	34	55	-11
		LF-E-020 B	9.8	0.20	20		
		LF-E-021 F	9.8	0.38	39		
		LF-E-021 B	9.8	0.21	22		
	Leachate	LF-E-040 F	10.0	0.43	43	72	17
		LF-E-040 B	10.0	0.29	29		
		LF-E-041 F	10.0	0.48	48		
		LF-E-041 B	10.0	0.13	13		
Domestic with less Leachate	Main Gas	LF-E-052 F	10.0	0.22	22	22	-19
		LF-E-052 B	10.0	<0.12	<12		
		LF-E-053 F	10.0	0.26	26		
		LF-E-053 B	10.0	<0.12	<12		
Commercial & Industrial	Main Gas	LF-E-063 F	10.0	0.47	47	72	8
		LF-E-063 B	10.0	0.26	26		
		LF-E-064 F	10.0	0.49	49		
		LF-E-064 B	10.0	0.18	18		
	Recent	LF-E-084 F	10.2	0.33	32	32	11
		LF-E-084 B	10.2	<0.12	<12		
		LF-E-085 F	10.2	0.30	29		
		LF-E-085 B	10.2	<0.12	<12		
	Mature	LF-E-100 F	10.0	0.36	36	36	18
		LF-E-100 B	10.0	<0.12	<12		
		LF-E-101 F	10.0	0.30	30		
		LF-E-101 B	10.0	<0.12	<12		
	Leachate	LF-E-074 F	10.0	0.43	43	43	-45
		LF-E-074 B	10.0	<0.12	<12		
		LF-E-075 F	10.0	0.55	55		
		LF-E-075 B	10.0	0.13	13		
Fragmentiser	Main Gas	LF-E-205 F	10.0	0.54	54	68	6
		LF-E-205 B	10.0	0.14	14		
		LF-E-206 F	10.0	0.515	52		
		LF-E-206 B	10.0	0.125	13		

TABLE 5A 2003 METHANAL ANALYSIS BY HPLC (CONTINUED)

Waste Type	Sampling Location	Sample Label	Total Volume (L)	Mass of Methanal (µg)	Concentration in gas (µg m ⁻³)	Total Concentration (µg m ⁻³)	RPD
Substantial Ash	Main Gas	LF-E-216 F	10.0	0.725	73	86	-3
		LF-E-216 B	10.0	0.13	13		
		LF-E-217 F	10.0	0.76	76	89	
		LF-E-217 B	10.0	0.125	13		
	Recent	LF-E-227 F	10.0	0.26	26	38	-24
		LF-E-227 B	10.0	0.12	12		
		LF-E-228 F	10.0	0.335	34	49	
		LF-E-228 B	10.0	0.15	15		
	Mature	LF-E-237 F	10.2	0.44	43	43	71
		LF-E-237 B	10.2	<0.11	<13		
		LF-E-238 F	10.2	0.21	21	21	
		LF-E-238 B	10.2	<0.11	<11		
	Leachate	LF-E-247 F	10.2	0.333	33	45	-73
		LF-E-247 B	10.2	0.125	12		
		LF-E-248 F	5.0	0.46	92	97	
		LF-E-248 B	5.0	0.025	5		
Codisposal	Main Gas	LF-E-257 F	10.0	0.43	43	56	55
		LF-E-257 B	10.0	0.125	13		
		LF-E-258 F	10.0	0.315	32	32	
		LF-E-258 B	10.0	<0.11	<11		

Notes:

F and B denote front and back derivatising agent, respectively.
RPD denotes Relative Percentage Difference.

TABLE 5B 2003 ETHANAL ANALYSIS BY HPLC

Waste Type	Sampling Location	Sample Label	Total Volume (L)	Mass of Ethanal (µg)	Concentration in gas (µg m ⁻³)	Total Concentration (µg m ⁻³)	RPD
Domestic with Leachate	Main Gas	LF-E-009 F	10.0	15	1513	1924	-28
		LF-E-009 B	10.0	4.1	411		
		LF-E-010 F	10.0	19	1870	2546	
		LF-E-010 B	10.0	6.8	677		
	Recent	LF-E-032 F	10.0	4.5	451	508	67
		LF-E-032 B	10.0	0.57	57		
		LF-E-033 F	10.0	2.5	253	253	
		LF-E-033 B	10.0	<0.13	<13		
	Mature	LF-E-020 F	9.8	0.90	92	118	-14
		LF-E-020 B	9.8	0.26	26		
		LF-E-021 F	9.8	1.0	105	136	
		LF-E-021 B	9.8	0.30	31		
	Leachate	LF-E-040 F	10.0	2.1	211	238	34
		LF-E-040 B	10.0	0.27	27		
		LF-E-041 F	10.0	1.7	168	168	
		LF-E-041 B	10.0	<0.13	<13		
Domestic with less Leachate	Main Gas	LF-E-052 F	10.0	0.60	60	60	-33
		LF-E-052 B	10.0	<0.13	<13		
		LF-E-053 F	10.0	0.84	84	84	
		LF-E-053 B	10.0	<0.13	<13		
Commercial & Industrial	Main Gas	LF-E-063 F	10.0	2.4	245	266	5
		LF-E-063 B	10.0	0.21	21		
		LF-E-064 F	10.0	2.4	240	253	
		LF-E-064 B	10.0	0.14	14		
	Recent	LF-E-084 F	10.2	0.94	92	92	9
		LF-E-084 B	10.2	<0.13	<13		
		LF-E-085 F	10.2	0.86	84	84	
		LF-E-085 B	10.2	<0.13	<13		
	Mature	LF-E-100 F	10.0	0.75	75	75	28
		LF-E-100 B	10.0	<0.13	<13		
		LF-E-101 F	10.0	0.56	56	56	
		LF-E-101 B	10.0	<0.13	<13		
	Leachate	LF-E-074 F	10.0	0.67	67	67	-45
		LF-E-074 B	10.0	<0.13	<13		
		LF-E-075 F	10.0	1.1	105	105	
		LF-E-075 B	10.0	<0.13	<13		
Fragmentiser	Main Gas	LF-E-205 F	10.0	1.915	192	225	1
		LF-E-205 B	10.0	0.33	33		
		LF-E-206 F	10.0	1.925	193	222	
		LF-E-206 B	10.0	0.295	30		

TABLE 5B 2003 ETHANAL ANALYSIS BY HPLC (CONTINUED)

Waste Type	Sampling Location	Sample Label	Total Volume (L)	Mass of Ethanal (µg)	Concentration in gas (µg m ⁻³)	Total Concentration (µg m ⁻³)	RPD
Substantial Ash	Main Gas	LF-E-216 F	10.0	12.595	1260	1450	-1
		LF-E-216 B	10.0	1.9	190		
		LF-E-217 F	10.0	12.575	1258	1458	
		LF-E-217 B	10.0	2	200		
	Recent	LF-E-227 F	10.0	0.5	50	73	-15
		LF-E-227 B	10.0	0.225	23		
		LF-E-228 F	10.0	0.575	58	84	
		LF-E-228 B	10.0	0.265	27		
	Mature	LF-E-237 F	10.2	0.85	83	97	76
		LF-E-237 B	10.2	0.14	14		
		LF-E-238 F	10.2	0.275	27	43	
		LF-E-238 B	10.2	0.17	17		
	Leachate	LF-E-247 F	10.2	1.995	196	241	-22
		LF-E-247 B	10.2	0.465	46		
		LF-E-248 F	5.0	1.505	301	301	
		LF-E-248 B	5.0	<0.09	<18		
Codisposal	Main Gas	LF-E-257 F	10.0	2.225	223	249	0
		LF-E-257 B	10.0	0.26	26		
		LF-E-258 F	10.0	2.305	231	248	
		LF-E-258 B	10.0	0.17	17		

Notes:

F and B denote front and back derivatising agent, respectively.

RPD denotes Relative Percentage Difference.

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS

Waste Type	Sample Location	Sample ID	Sample Volume	Dichlorodifluoromethane	Chloromethane	Chloroethene	Bromoethane	Chloroethane	Trichlorofluoromethane	1-Pentene	Acetone	Furan
			(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
Domestic with Leachate	Main Gas	LF-E-011	300	47000	<100	350000	170	5300	17000	13000	25700	3000
		LF-E-012	401	35000	<80	280000	130	1270	12500	11500	20000	1470
		LF-E-013	100	100000	<300	730000	620	1800	25000	21000	48000	6200
		LF-E-014	100	79000	<300	550000	<200	<100	15000	12000	38000	4600
	Mature	LF-E-022	400	18500	<80	100000	40	<30	550	3500	2130	1130
		LF-E-023	400	10300	<80	43000	<50	<30	580	2500	1830	750
		LF-E-024	100	17000	<300	57000	<200	<100	390	1200	1500	420
		LF-E-025	100	12000	<300	40000	<200	<100	280	1800	1100	310
	Recent	LF-E-034	401	15200	<80	7700	<50	<30	1470	3500	4700	700
		LF-E-035	400	17300	<80	<80	<50	<30	980	2200	4800	240
		LF-E-036	100	27000	<300	<300	<200	<100	2700	6000	20000	1600
		LF-E-037	100	25000	<300	<300	<200	<100	1300	5400	7200	380
	Leachate	LF-E-042	400	14300	<80	55000	<50	<30	1100	5300	18000	1530
		LF-E-043	400	10000	<80	28000	<50	<30	680	4800	12300	850
		LF-E-044	100	14000	<300	36000	170	<100	340	1100	11000	220
		LF-E-045	100	14000	<300	36000	<200	<100	620	3800	19000	1100
Domestic with little Leachate	Main Gas	LF-E-055	400	8800	<80	24300	<50	<30	750	2800	650	<20
		LF-E-056	400	12500	<80	38000	<50	<30	1680	4500	3800	530
		LF-E-057	100	46000	<300	180000	<200	<100	3200	8800	11000	1200
		LF-E-058	100	39000	<300	150000	<200	<100	2800	6400	9900	1100
Commercial & Industrial	Main Gas	LF-E-065	400	3500	<80	6000	<50	<30	300	1250	1280	150
		LF-E-066	400	1400	<80	1700	<50	<30	120	280	430	50
		LF-E-067	100	22000	<300	41000	<200	<100	2100	5200	9800	1300
		LF-E-068	100	7200	<300	12000	<200	<100	620	2800	2800	340
	Leachate	LF-E-076	400	3300	<80	2450	<50	<30	180	880	600	130
		LF-E-077	400	9500	<80	9000	190	<30	550	3500	980	530
		LF-E-078	100	<400	<300	<300	<200	<100	<50	<200	200	<70
		LF-E-079	100	<400	<300	<300	<200	<100	<50	<200	220	<70
	Recent	LF-E-088	400	14000	<80	17500	<50	<30	240	2030	1550	120
		LF-E-089	400	9500	<80	14800	80	<30	200	1750	1150	120
		LF-E-090	108	11100	<280	17600	<190	<100	230	2870	1670	150
		LF-E-091	108	7040	<280	5190	<190	<100	160	1390	1200	140
	Mature	LF-E-102	400	<100	<80	<80	<50	<30	<20	<50	160	20
		LF-E-103	400	<100	<80	<80	<50	<30	<20	<50	<30	<20
		LF-E-104	100	<400	<300	1100	<200	<100	<50	<200	230	<70
		LF-E-105	100	<400	<300	810	<200	<100	<50	240	220	<70

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	Dichlorodifluoromethane	Chloromethane	Chloroethene	Bromoethane	Chloroethane	Trichlorofluoromethane	1-Pentene	Acetone	Furan
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<40	<30	<30	<20	<10	<5	<20	16	<7
	Blank		LF-E-081	Blank	<40	<30	<30	<20	<10	<5	<20	<10	<7
	Blank		LF-E-106	Blank	<40	<30	<30	<20	<10	<5	<20	39	9
	Blank		LF-E-107	Blank	<40	<30	<30	<20	<10	<5	<20	15	7
	Fragmentiser	Main Gas	LF-E-207	400	7300	<80	13000	<50	<30	2030	700	530	70
			LF-E-208	400	13000	<80	21500	<50	<30	4000	1380	1050	210
			LF-E-209	100	11000	<300	20000	<200	<100	2400	1100	580	110
			LF-E-210	100	<400	<300	46000	<200	<100	6900	2700	1900	340
	Substantial Ash	Main Gas	LF-E-218	502	12400	<60	11800	160	<20	1830	5200	6800	2600
			LF-E-219	502	13700	<60	13100	<40	<20	2200	6200	8400	3000
			LF-E-220	133	20300	<230	22600	<160	<80	4590	14300	21800	5560
			LF-E-221	133	19500	<230	21800	<160	<80	4290	13500	19500	5340
		Recent	LF-E-229	400	12500	<80	2200	<50	<30	330	480	21500	680
			LF-E-230	400	13800	<80	2300	<50	<30	330	700	21800	700
			LF-E-231	100	16000	<300	<300	<200	<100	420	560	24000	450
			LF-E-232	100	16000	<300	2100	<200	<100	400	550	22000	560
		Mature	LF-E-239	400	5300	<80	21800	<50	<30	40	830	2130	30
			LF-E-240	400	6300	<80	28000	<50	<30	60	1150	2500	30
			LF-E-241	100	8800	<300	31000	<200	<100	380	2400	11000	130
			LF-E-242	100	5400	<300	20000	<200	<100	100	770	2300	<70
		Leachate	LF-E-249	400	19500	<80	3300	<50	<30	12300	680	8800	380
			LF-E-250	400	<100	<80	<80	<50	<30	<20	<50	110	<20
			LF-E-251	100	32000	<300	11000	<200	<100	27000	2100	27000	820
			LF-E-252	100	43000	<300	17000	<200	<100	24000	1800	24000	790
	Codisposal	Main Gas	LF-E-259	417	14900	<80	108000	<50	1610	2900	2900	3100	110
			LF-E-260	433	10200	<70	81000	<50	320	790	550	650	140
			LF-E-261	133	20300	<230	135000	<160	1130	3230	3080	4890	230
			LF-E-262	133	19500	<230	271000	<160	620	2560	3680	4660	160
	Blank		LF-E-270	Blank	<40	<30	<30	<20	<10	<5	<20	73	<7
	Blank		LF-E-271	Blank	<40	<30	<30	<20	<10	<5	<20	80	<7

TABLE 6 2003. VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	Propan-2-ol	Ethyl Mercaptan	1,1-Dichloroethene	Methylsulfide	Dichloromethane	Carbon Disulfide	trans-1,2-Dichloroethene	1,1-Dichloroethane	n-Hexane
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Domestic with Leachate	Main Gas	LF-E-011	300	<70	<100	14000	16000	43000	133000	2570	2830	4700
			LF-E-012	401	<50	<80	10200	12200	35000	112000	1670	2270	2700
			LF-E-013	100	270000	<300	19000	13000	82000	170000	2600	3900	12000
			LF-E-014	100	<200	<300	11000	13000	55000	160000	1600	2300	6500
		Mature	LF-E-022	400	<50	<80	1880	140	700	12000	250	300	1330
			LF-E-023	400	<50	<80	1350	120	380	12800	170	250	900
			LF-E-024	100	<200	<300	760	<100	580	11000	310	360	1400
			LF-E-025	100	<200	<300	1100	<100	420	5200	180	250	1000
		Recent	LF-E-034	401	<50	<80	1450	3000	3200	32000	140	550	4000
			LF-E-035	400	<50	<80	950	1950	2500	30000	280	800	3000
			LF-E-036	100	<200	<300	2800	4700	7400	87000	300	1100	8000
			LF-E-037	100	<200	<300	2200	4600	6300	69000	470	940	6600
		Leachate	LF-E-042	400	<50	<80	2800	1480	3000	68000	700	380	8300
			LF-E-043	400	<50	<80	1530	800	1580	38000	210	200	3800
			LF-E-044	100	<200	<300	520	320	780	21000	410	230	6900
			LF-E-045	100	<200	<300	2100	960	1600	54000	320	240	7100
	Domestic with little Leachate	Main Gas	LF-E-055	400	<50	<80	730	300	1000	12000	200	160	830
			LF-E-056	400	<50	<80	1150	400	1150	14000	150	250	2300
			LF-E-057	100	<200	<300	2800	650	3000	32000	350	590	6400
			LF-E-058	100	<200	<300	1900	730	2500	29000	320	490	5200
	Commercial & Industrial	Main Gas	LF-E-065	400	<50	<80	330	160	330	4800	50	70	750
			LF-E-066	400	<50	<80	110	60	140	1880	<20	20	280
			LF-E-067	100	<200	<300	1400	590	2100	59000	420	560	4800
			LF-E-068	100	<200	<300	710	350	700	14000	120	140	1600
		Leachate	LF-E-076	400	<50	<80	280	<30	240	3800	110	90	780
			LF-E-077	400	<50	<80	1980	90	210	7000	120	150	1630
			LF-E-078	100	<200	<300	<90	<100	140	2300	<70	<60	160
			LF-E-079	100	<200	<300	<90	<100	90	660	<70	<60	140
		Recent	LF-E-088	400	<50	<80	280	220	330	18000	60	140	1500
			LF-E-089	400	<50	<80	240	220	280	9000	60	120	1280
			LF-E-090	108	<190	<280	240	160	340	17600	<70	120	1570
			LF-E-091	108	<190	<280	130	240	270	11100	<70	80	1020
		Mature	LF-E-102	400	<50	<80	<30	<30	30	500	<20	<20	40
			LF-E-103	400	<50	<80	<30	<30	40	120	<20	<20	<30
			LF-E-104	100	<200	<300	<90	<100	80	420	<70	<60	360
			LF-E-105	100	<200	<300	<90	<100	170	1400	<70	<60	270

TABLE 6 2003. VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	Propan-2-ol	Ethyl Mercaptan	1,1-Dichloroethene	Methylsulfide	Dichloromethane	Carbon Disulfide	trans-1,2-Dichloroethene	1,1-Dichloroethane	n-Hexane
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<20	<30	<9	<10	<7	21	<7	<6	<10
	Blank		LF-E-081	Blank	<20	<30	<9	<10	<7	<10	<7	<6	<10
	Blank		LF-E-106	Blank	<20	<30	<9	<10	<7	130	<7	<6	<10
	Blank		LF-E-107	Blank	<20	<30	<9	<10	<7	110	<7	<6	<10
	Fragmentiser	Main Gas	LF-E-207	400	<50	<80	<30	<30	170	280	40	70	880
			LF-E-208	400	<50	<80	<30	90	600	1180	150	170	1800
			LF-E-209	100	<200	<300	<90	<100	250	320	<70	80	1500
			LF-E-210	100	<200	<300	140	190	1200	1400	230	280	3700
	Substantial Ash	Main Gas	LF-E-218	502	<40	<60	160	3200	460	2600	200	120	7000
			LF-E-219	502	<40	<60	100	2200	340	1770	260	170	6000
			LF-E-220	133	<160	<230	140	1800	490	1880	170	130	9800
			LF-E-221	133	<160	<230	150	2180	480	2030	150	130	9800
		Recent	LF-E-229	400	<50	<80	40	12800	70	11800	160	40	530
			LF-E-230	400	<50	<80	80	24300	130	17500	220	50	200
			LF-E-231	100	<200	<300	<90	7500	140	35000	110	<60	990
			LF-E-232	100	<200	<300	<90	5500	90	30000	110	<60	860
		Mature	LF-E-239	400	<50	<80	<30	80	50	240	70	70	630
			LF-E-240	400	<50	<80	<30	160	100	150	60	60	800
			LF-E-241	100	<200	<300	<90	790	160	900	<70	70	1100
			LF-E-242	100	<200	<300	<90	120	<70	270	<70	<60	740
		Leachate	LF-E-249	400	<50	<80	70	1030	750	5300	210	230	1180
			LF-E-250	400	<50	<80	<30	<30	<20	<30	<20	<20	<30
			LF-E-251	100	<200	<300	120	1900	1300	11000	170	280	1800
			LF-E-252	100	<200	<300	140	2500	1300	13000	170	260	1800
	Codiposal	Main Gas	LF-E-259	417	<50	<80	40	190	650	1180	410	380	3400
			LF-E-260	433	<50	<70	<30	120	170	370	60	160	30
			LF-E-261	133	<160	<230	<70	440	720	1650	500	420	3910
			LF-E-262	133	980	<230	<70	180	620	530	400	430	4140
	Blank		LF-E-270	Blank	<20	<30	<9	<10	<7	<10	<7	<6	<10
	Blank		LF-E-271	Blank	<20	<30	<9	<10	<7	<10	<7	<6	<10

TABLE 6 2003. VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

Waste Type	Sample Location	Sample ID	Sample Volume	Methylethylketone	cis-1,2-Dichloroethene	Propyl Mercaptan	Chloroform	Tetrachloromethane	Benzene	Butan-1-ol	n-Heptane	Trichloroethene
			(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
Domestic with Leachate	Main Gas	LF-E-011	300	53000	20700	<70	430	<30	37000	4000	23000	43000
		LF-E-012	401	47000	11000	<50	370	<20	32000	3700	17700	37000
		LF-E-013	100	93000	46000	<200	660	<70	73000	17000	41000	88000
		LF-E-014	100	68000	31000	<200	390	<70	55000	18000	29000	55000
	Mature	LF-E-022	400	7300	3800	<50	<20	<20	15000	4000	4500	3500
		LF-E-023	400	4800	2500	<50	<20	<20	12000	1600	3300	1830
		LF-E-024	100	7300	3900	<200	<50	<70	19000	2200	5000	2500
		LF-E-025	100	4600	2500	<200	<50	<70	13000	1200	3500	1500
	Recent	LF-E-034	401	11200	2290	<50	<20	<20	7000	3700	6700	2500
		LF-E-035	400	16300	3300	<50	<20	<20	8300	11800	9000	4000
		LF-E-036	100	39000	5700	<200	<50	<70	15000	32000	19000	7300
		LF-E-037	100	35000	4300	<200	<50	<70	12000	31000	16000	5900
	Leachate	LF-E-042	400	24000	8300	<50	<20	<20	14000	4300	13500	8000
		LF-E-043	400	17500	4800	<50	<20	<20	9300	2800	9500	4300
		LF-E-044	100	26000	6000	<200	<50	<70	15000	9300	15000	5200
		LF-E-045	100	28000	6400	<200	<50	<70	17000	11000	16000	5400
Domestic with little Leachate	Main Gas	LF-E-055	400	7300	1430	<50	<20	<20	3500	5500	5300	1950
		LF-E-056	400	7000	1730	<50	<20	<20	4800	4500	7800	2800
		LF-E-057	100	22000	5000	<200	<50	<70	15000	13000	20000	7100
		LF-E-058	100	17000	3900	<200	<50	<70	12000	9600	17000	5600
Commercial & Industrial	Main Gas	LF-E-065	400	3000	530	<50	<20	<20	8500	1480	2800	730
		LF-E-066	400	830	150	<50	<20	<20	2000	250	930	180
		LF-E-067	100	22000	3900	<200	<50	<70	60000	6300	21000	6700
		LF-E-068	100	7700	1100	<200	<50	<70	25000	3200	6800	1800
	Leachate	LF-E-076	400	3300	850	<50	<20	<20	10000	2430	3800	1480
		LF-E-077	400	2400	1450	<50	<20	<20	15500	2800	5800	2450
		LF-E-078	100	480	200	<200	<50	<70	3100	540	770	520
		LF-E-079	100	730	230	<200	<50	<70	3100	750	760	550
	Recent	LF-E-088	400	2180	450	<50	<20	<20	7800	1130	5800	900
		LF-E-089	400	1750	400	<50	<20	<20	6800	930	5000	800
		LF-E-090	108	2500	380	<190	<50	<70	7410	1760	6020	810
		LF-E-091	108	1940	320	<190	<50	<70	5280	930	4170	670
	Mature	LF-E-102	400	330	50	<50	<20	<20	2250	300	530	120
		LF-E-103	400	<20	<20	<50	<20	<20	100	<50	<20	<10
		LF-E-104	100	860	130	<200	<50	<70	7900	590	2700	250
		LF-E-105	100	690	100	<200	<50	<70	6200	470	2100	200

TABLE 6 2003. VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	Methylethylketone	cis-1,2-Dichloroethene	Propyl Mercaptan	Chloroform	Tetrachloromethane	Benzene	Butan-1-ol	n-Heptane	Trichloroethene
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<7	<5	<20	<5	<7	13	<20	<8	10
	Blank		LF-E-081	Blank	<7	<5	<20	<5	<7	<3	<20	<8	<4
	Blank		LF-E-106	Blank	<7	<5	<20	<5	<7	56	<20	<8	<4
	Blank		LF-E-107	Blank	<7	<5	<20	<5	<7	36	<20	<8	<4
	Fragmentiser	Main Gas	LF-E-207	400	380	250	<50	<20	<20	880	160	1180	120
			LF-E-208	400	1300	550	<50	<20	<20	1980	1050	2480	280
			LF-E-209	100	400	210	<200	<50	<70	820	420	1500	60
			LF-E-210	100	2300	1000	<200	<50	<70	3500	1500	4700	540
	Substantial Ash	Main Gas	LF-E-218	502	9800	1970	<40	<10	<20	13100	2800	4000	1060
			LF-E-219	502	11800	2200	<40	<10	<20	15300	3200	4600	1140
			LF-E-220	133	15800	1730	<160	<40	<60	24800	5710	4810	830
			LF-E-221	133	12000	1580	<160	<40	<60	24100	7500	4660	690
		Recent	LF-E-229	400	22000	1080	<50	<20	<20	1350	430	1380	300
			LF-E-230	400	25000	1400	<50	<20	<20	1700	630	1750	400
			LF-E-231	100	17000	630	<200	<50	<70	3100	480	1300	140
			LF-E-232	100	17000	590	<200	<50	<70	2600	470	1200	130
		Mature	LF-E-239	400	3000	450	<50	<20	<20	1200	480	980	240
			LF-E-240	400	4300	580	<50	<20	<20	1200	650	1180	330
			LF-E-241	100	6300	410	<200	<50	<70	5000	1400	1100	190
			LF-E-242	100	4400	230	<200	<50	<70	2800	980	730	110
		Leachate	LF-E-249	400	14300	1530	90	<20	<20	2400	4000	2450	550
			LF-E-250	400	60	<20	<50	<20	<20	130	<50	<20	<10
			LF-E-251	100	16000	1700	<200	<50	<70	3300	1600	3400	510
			LF-E-252	100	12000	1500	<200	<50	<70	3400	1400	3100	420
	Codisposal	Main Gas	LF-E-259	417	5000	3400	<50	<20	<20	3600	9400	4300	1270
			LF-E-260	433	160	1960	<50	<20	<20	1290	100	<20	440
			LF-E-261	133	7500	3680	<160	<40	<60	5640	9800	5490	1650
			LF-E-262	133	7500	3980	<160	<40	<60	5190	9800	5560	1200
	Blank		LF-E-270	Blank	12	<5	<20	<5	<7	14	<20	<8	<4
	Blank		LF-E-271	Blank	16	<5	<20	<5	<7	14	<20	<8	<4

TABLE 6 2003. VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

Waste Type	Sample Location	Sample ID	Sample Volume	1,2-Dichloropropane	1,1-Dichloroethane	1,1,1-Trichloroethane	1,2-Dichloroethane	1,1,2-Trichloroethane	1,1,1,2-Tetrachloroethane	1,2-Dibromochloroethane	1,1,2,2-Tetrachloroethane	1,1,1,2,2-Pentachloroethane
			(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
Domestic with Leachate	Main Gas	LF-E-011	300	<20	<30	<100	80000	3700	1770	10300	<140	21000
		LF-E-012	401	<20	<20	<80	62000	820	1300	9000	<100	8200
		LF-E-013	100	<60	<80	<300	130000	6200	2500	25000	<400	47000
		LF-E-014	100	<60	<80	<300	83000	3700	1600	20000	<400	39000
	Mature	LF-E-022	400	<20	<20	<80	12500	680	70	4300	<100	10500
		LF-E-023	400	<20	<20	<80	10500	500	30	3800	<100	7800
		LF-E-024	100	<60	<80	<300	15000	730	<100	12000	<400	12000
		LF-E-025	100	<60	<80	<300	9700	470	<100	10000	<400	8100
	Recent	LF-E-034	401	<20	<20	<80	30000	230	300	3000	<100	9200
		LF-E-035	400	<20	<20	<80	43000	500	530	3800	<100	10000
		LF-E-036	100	<60	<80	<300	53000	1100	790	13000	<400	29000
		LF-E-037	100	<60	<80	<300	57000	860	550	12000	<400	24000
	Leachate	LF-E-042	400	<20	<20	<80	53000	1430	180	5800	<100	21800
		LF-E-043	400	<20	<20	<80	38000	800	90	4500	<100	16500
		LF-E-044	100	<60	<80	<300	58000	1100	150	13000	<400	31000
		LF-E-045	100	<60	<80	<300	45000	1200	150	13000	<400	33000
Domestic with little Leachate	Main Gas	LF-E-055	400	<20	<20	<80	19800	530	80	3800	4300	9300
		LF-E-056	400	<20	<20	<80	33000	800	60	4300	17500	14300
		LF-E-057	100	<60	<80	<300	60000	2100	170	15000	<400	42000
		LF-E-058	100	<60	<80	<300	49000	1800	150	14000	<400	36000
Commercial & Industrial	Main Gas	LF-E-065	400	<20	<20	<80	11000	190	60	2800	<100	4800
		LF-E-066	400	<20	<20	<80	2800	40	<30	880	<100	1150
		LF-E-067	100	<60	<80	<300	96000	2500	210	18000	8300	41000
		LF-E-068	100	<60	<80	<300	24000	620	<100	11000	600	13000
	Leachate	LF-E-076	400	<20	<20	<80	15300	530	40	4300	<100	8800
		LF-E-077	400	<20	<20	<80	19300	780	60	5300	<100	12800
		LF-E-078	100	<60	<80	<300	2500	140	<100	8700	<400	3300
		LF-E-079	100	<60	<80	<300	2500	150	<100	8600	<400	3300
	Recent	LF-E-088	400	<20	<20	<80	22000	380	30	3800	<100	11800
		LF-E-089	400	<20	<20	<80	18500	300	<30	3500	<100	10300
		LF-E-090	108	<60	<80	<280	20400	330	<100	8800	<380	12000
		LF-E-091	108	<60	<80	<280	14800	220	<100	7780	<380	11100
	Mature	LF-E-102	400	<20	<20	<80	1530	50	<30	2500	190	2400
		LF-E-103	400	<20	<20	<80	<20	<20	<30	10	<100	<20
		LF-E-104	100	<60	<80	<300	10000	80	<100	6100	<400	8200
		LF-E-105	100	<60	<80	<300	7200	60	<100	4400	410	5400

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	1,2-Dichloropropane	Diethylsulfide	Butyl Mercaptan	Methylcyclohexane	Methylisobutylketone	Dimethyldisulfide	Toluene	Butyric Acid	n-Octane
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<6	<8	<30	<6	<5	<10	<3	<40	12
	Blank		LF-E-081	Blank	<6	<8	<30	<6	<5	<10	<3	<40	<5
	Blank		LF-E-106	Blank	<6	<8	<30	<6	<5	<10	7	<40	<5
	Blank		LF-E-107	Blank	<6	<8	<30	<6	<5	<10	<3	<40	<5
	Fragmentiser	Main Gas	LF-E-207	400	<20	<20	<80	1680	100	<30	2250	<100	700
			LF-E-208	400	<20	<20	<80	3800	280	<30	3800	<100	1480
			LF-E-209	100	<60	<80	<300	1400	<50	<100	470	<400	340
			LF-E-210	100	<60	<80	<300	5400	480	<100	10000	<400	2600
	Substantial Ash	Main Gas	LF-E-218	502	<20	<20	<60	2400	620	440	3800	<80	2200
			LF-E-219	502	<20	<20	<60	3000	780	480	4200	<80	2400
			LF-E-220	133	<50	<70	<230	2330	440	460	6390	<310	2260
			LF-E-221	133	<50	<70	<230	2110	370	400	5710	<310	2110
		Recent	LF-E-229	400	<20	<20	<80	2050	630	9500	3300	<100	650
			LF-E-230	400	<20	<20	<80	2100	730	10500	3500	<100	700
			LF-E-231	100	<60	<80	<300	1000	90	12000	1300	<400	360
			LF-E-232	100	<60	<80	<300	1000	90	9000	1100	<400	330
		Mature	LF-E-239	400	<20	<20	<80	1400	280	70	2800	<100	830
			LF-E-240	400	<20	<20	<80	1880	330	90	3300	<100	1080
			LF-E-241	100	<60	<80	<300	820	170	130	2400	<400	640
			LF-E-242	100	<60	<80	<300	610	100	170	1400	<400	350
		Leachate	LF-E-249	400	<20	<20	<80	3800	400	380	3300	<100	980
			LF-E-250	400	<20	<20	<80	<20	<20	<30	40	<100	<20
			LF-E-251	100	<60	<80	<300	3200	340	940	4300	<400	1500
			LF-E-252	100	<60	<80	<300	2600	350	960	3900	<400	1200
	Codisposal	Main Gas	LF-E-259	417	<20	<20	<80	5800	550	60	5800	<100	2600
			LF-E-260	433	<20	<20	<70	<20	<20	<30	10	<100	<20
			LF-E-261	133	<50	<70	<230	6390	530	150	11300	<310	3760
			LF-E-262	133	<50	<70	<230	4890	450	140	11300	<310	3760
	Blank		LF-E-270	Blank	<6	<8	<30	<6	<5	<10	<3	<40	<5
	Blank		LF-E-271	Blank	<6	<8	<30	<6	<5	<10	<3	<40	<5

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

Waste Type	Sample Location	Sample ID	Sample Volume	Ethyl Butyrate	Butyl Acetate	Tetrachloroethene	Ethyl Cyclohexane	Chlorobenzene	Ethyl Benzene	m-Xylene + p-Xylene	n-Nonane	Styrene
			(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
Domestic with Leachate	Main Gas	LF-E-011	300	16700	4000	17000	16300	800	5700	9000	20300	370
		LF-E-012	401	14200	3200	14500	14500	1000	5000	8200	7500	450
		LF-E-013	100	42000	10000	41000	25000	2100	16000	26000	50000	<40
		LF-E-014	100	33000	6900	31000	17000	1200	13000	23000	39000	<40
	Mature	LF-E-022	400	3500	500	2430	3300	100	2800	4500	8500	150
		LF-E-023	400	1980	300	1250	3000	90	2800	4500	7800	170
		LF-E-024	100	2800	440	1500	4100	160	8500	13000	21000	430
		LF-E-025	100	1600	270	930	2300	100	7000	9600	17000	240
	Recent	LF-E-034	401	3200	300	1450	2700	20	1650	2290	4500	80
		LF-E-035	400	6300	1080	3500	5500	30	2050	3000	6000	100
		LF-E-036	100	20000	2800	7200	8000	80	6200	8200	21000	230
		LF-E-037	100	20000	2700	6100	7100	70	5500	7200	19000	200
	Leachate	LF-E-042	400	6300	2000	7300	10300	150	3800	6000	11300	300
		LF-E-043	400	5000	1300	4800	6800	80	4300	5300	8000	500
		LF-E-044	100	10000	2000	6500	9100	120	9100	16000	21000	1100
		LF-E-045	100	11000	2000	6700	7900	120	9200	16000	22000	1100
Domestic with little Leachate	Main Gas	LF-E-055	400	5000	1230	3000	4300	70	2800	4800	6800	430
		LF-E-056	400	4300	1080	3000	7300	250	3800	5800	9000	430
		LF-E-057	100	11000	2200	7200	13000	770	13000	21000	29000	1500
		LF-E-058	100	8100	1600	5400	11000	650	12000	20000	27000	1400
Commercial & Industrial	Main Gas	LF-E-065	400	1330	230	500	1130	30	1880	2800	4000	110
		LF-E-066	400	190	30	110	210	<20	600	780	1200	30
		LF-E-067	100	5900	1200	3500	14000	4500	14000	25000	25000	1900
		LF-E-068	100	2400	450	1000	3100	490	8200	14000	13000	360
	Leachate	LF-E-076	400	2800	530	1150	3500	1230	3500	6300	6300	630
		LF-E-077	400	3800	800	1950	4300	2430	4500	8000	8500	750
		LF-E-078	100	570	110	360	1100	2200	9500	18000	11000	570
		LF-E-079	100	710	130	390	1100	2100	9300	18000	11000	500
	Recent	LF-E-088	400	1580	330	800	4000	1300	3800	6300	8000	530
		LF-E-089	400	1430	300	730	3500	1180	3800	6000	7500	480
		LF-E-090	108	1940	390	730	3520	850	8890	16700	15700	570
		LF-E-091	108	930	190	520	2690	1110	8330	15700	13000	440
	Mature	LF-E-102	400	350	60	160	680	780	3800	6800	4800	140
		LF-E-103	400	<30	<20	<10	<10	<20	30	60	10	<10
		LF-E-104	100	700	120	240	2100	930	11000	21000	12000	220
		LF-E-105	100	480	<80	180	1300	620	9600	19000	8600	140

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	Ethyl Butyrate	Butyl Acetate	Tetrachloroethene	EthylCyclohexane	Chlorobenzene	Ethyl Benzene	m-Xylene + p-Xylene	n-Nonane	Styrene
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<9	<8	<3	<4	<5	<5	<6	<3	<4
	Blank		LF-E-081	Blank	<9	<8	<3	<4	<5	<5	<6	<3	<4
	Blank		LF-E-106	Blank	<9	<8	<3	<4	<5	<5	<6	3	<4
	Blank		LF-E-107	Blank	<9	<8	<3	<4	<5	<5	<6	<3	<4
	Fragmentiser	Main Gas	LF-E-207	400	350	50	190	430	110	1980	9000	1430	60
			LF-E-208	400	700	120	430	1000	240	3000	12500	2800	150
			LF-E-209	100	<90	110	40	110	<50	3400	4700	160	<40
			LF-E-210	100	730	110	670	1400	90	11000	26000	8200	190
	Substantial Ash	Main Gas	LF-E-218	502	1060	440	1160	600	20	2800	7000	1970	20
			LF-E-219	502	1290	300	1470	840	20	3200	8400	2400	20
			LF-E-220	133	1050	170	740	680	210	4290	19500	3160	120
			LF-E-221	133	900	200	590	600	220	4060	18000	3010	140
		Recent	LF-E-229	400	400	80	280	330	80	1650	7500	1330	50
			LF-E-230	400	480	90	330	330	80	1530	6300	1300	50
			LF-E-231	100	170	100	160	90	<50	1900	2800	520	<40
			LF-E-232	100	140	<80	140	90	<50	1600	2400	470	<40
		Mature	LF-E-239	400	450	100	450	500	120	2430	9500	2130	110
			LF-E-240	400	630	140	630	680	190	3000	12000	2500	130
			LF-E-241	100	360	<80	310	160	<50	4400	6700	1100	40
			LF-E-242	100	190	<80	190	110	<50	2500	3700	730	<40
		Leachate	LF-E-249	400	830	130	750	450	20	3000	5500	1330	22.5
			LF-E-250	400	<30	<20	<10	<10	<20	100	160	20	<10
			LF-E-251	100	640	420	690	710	140	3700	15000	3800	100
			LF-E-252	100	520	130	480	500	140	2900	13000	2600	90
	Codisposal	Main Gas	LF-E-259	417	4800	790	3600	1680	100	3800	12500	4100	80
			LF-E-260	433	<30	<20	<10	<10	<20	<20	<20	<10	<10
			LF-E-261	133	4290	410	3910	1650	220	5790	21800	6320	260
			LF-E-262	133	3980	410	2780	1500	180	5410	20300	6240	130
	Blank		LF-E-270	Blank	<9	<8	<3	<4	<5	<5	<6	<3	<4
	Blank		LF-E-271	Blank	<9	<8	<3	<4	<5	<5	<6	5	<4

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

Waste Type	Sample Location	Sample ID	Sample Volume	o-Xylene	2-ButoxyEthanol	1,1,2,2-Tetrachloroethane	n-PropylBenzene	p-Ethyl Toluene	n-Decane	1,2,4-TrimethylBenzene	Limonene	1,2-Dichloro Benzene
			(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
Domestic with Leachate	Main Gas	LF-E-011	300	4000	<70	<20	1730	5700	13000	3700	10300	<20
		LF-E-012	401	3700	<50	<10	2070	5500	12000	4000	9500	60
		LF-E-013	100	13000	<200	<40	7800	22000	40000	15000	34000	310
		LF-E-014	100	12000	<200	<40	6700	18000	31000	12000	29000	160
	Mature	LF-E-022	400	2030	<50	<10	480	680	3800	450	3300	<20
		LF-E-023	400	2230	<50	<10	600	880	4000	700	3500	<20
		LF-E-024	100	4300	<200	<40	1200	1800	12000	1300	9200	<60
		LF-E-025	100	2600	<200	<40	760	1200	10000	880	5700	<60
	Recent	LF-E-034	401	570	<50	<10	170	270	2090	270	1500	<20
		LF-E-035	400	900	<50	<10	300	400	2800	350	2250	<20
		LF-E-036	100	2000	<200	<40	500	850	7200	780	4500	<60
		LF-E-037	100	1500	<200	<40	430	720	6700	650	4000	<60
	Leachate	LF-E-042	400	3000	<50	<10	1600	4800	8500	3300	7800	20
		LF-E-043	400	2800	<50	<10	1350	4000	5500	2800	6300	<20
		LF-E-044	100	6400	<200	<40	2500	6800	14000	5900	16000	<60
		LF-E-045	100	6700	<200	<40	2600	7000	14000	6200	16000	<60
Domestic with little Leachate	Main Gas	LF-E-055	400	2450	<50	<10	1080	3000	4500	2200	5500	<20
		LF-E-056	400	3000	<50	<10	1600	4300	6000	3000	6500	20
		LF-E-057	100	11000	<200	<40	6900	16000	19000	11000	20000	70
		LF-E-058	100	10000	<200	<40	6300	15000	17000	10000	18000	70
Commercial & Industrial	Main Gas	LF-E-065	400	830	<50	<10	380	880	2800	850	2330	<20
		LF-E-066	400	220	<50	<10	110	280	1130	250	700	<20
		LF-E-067	100	13000	<200	<40	7100	17000	15000	10000	15000	<60
		LF-E-068	100	4200	<200	<40	1400	3800	8400	2900	6400	<60
	Leachate	LF-E-076	400	3300	<50	<10	2130	5000	4300	3000	4500	<20
		LF-E-077	400	4300	<50	<10	2800	6500	7300	2800	6300	40
		LF-E-078	100	8400	<200	<40	3900	13000	12000	9600	9700	<60
		LF-E-079	100	8200	<200	<40	3700	12000	11000	9100	9200	<60
	Recent	LF-E-088	400	3500	<50	<10	2500	5800	6000	2800	5500	60
		LF-E-089	400	3300	<50	<10	2800	5500	5500	3800	5300	60
		LF-E-090	108	7310	<190	<40	3520	10200	12000	7780	9300	<60
		LF-E-091	108	7310	<190	<40	3520	11100	11100	8890	9300	<60
	Mature	LF-E-102	400	3500	<50	<10	2350	5300	3800	3000	2280	20
		LF-E-103	400	10	<50	<10	<10	10	20	20	<20	<20
		LF-E-104	100	9700	<200	<40	2900	10000	10000	7400	5700	<60
		LF-E-105	100	8000	<200	<40	1800	6500	6700	4600	3500	<60

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	o-Xylene	2-ButoxyEthanol	1,1,2,2-Tetrachloroethane	n-PropylBenzene	p-Ethyl Toluene	n-Decane	1,2,4-TrimethylBenzene	Limonene	1,2-DichloroBenzene
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<5	<20	<4	<4	<4	<4	<4	<5	<6
	Blank		LF-E-081	Blank	<5	<20	<4	<4	<4	<4	<4	<5	<6
	Blank		LF-E-106	Blank	<5	<20	<4	5	5	5	8	<5	<6
	Blank		LF-E-107	Blank	<5	<20	<4	<4	<4	<4	<4	<5	<6
	Fragmentiser	Main Gas	LF-E-207	400	1450	<50	<10	280	1100	1550	1300	1280	<20
			LF-E-208	400	2500	<50	<10	600	2300	2800	2500	3500	20
			LF-E-209	100	430	<200	<40	<40	90	220	90	180	<60
			LF-E-210	100	3100	<200	<40	570	1300	7800	1200	3200	<60
	Substantial Ash	Main Gas	LF-E-218	502	660	<40	<10	50	120	660	90	440	<20
			LF-E-219	502	940	<40	<10	60	140	860	110	640	<20
			LF-E-220	133	2860	<160	<40	530	2180	3610	2630	2930	<50
			LF-E-221	133	2560	<160	<40	560	2110	3910	2710	3980	<50
		Recent	LF-E-229	400	1150	<50	<10	220	850	1350	1050	1480	<20
			LF-E-230	400	880	<50	<10	180	650	1100	780	500	<20
			LF-E-231	100	280	<200	<40	<40	80	420	70	340	<60
			LF-E-232	100	240	<200	<40	<40	70	400	60	330	<60
		Mature	LF-E-239	400	1730	<50	<10	380	1480	2330	1950	2800	<20
			LF-E-240	400	2500	<50	<10	580	2180	2800	2500	3300	20
			LF-E-241	100	690	<200	<40	60	140	1200	200	960	<60
			LF-E-242	100	390	<200	<40	<40	70	660	100	560	<60
		Leachate	LF-E-249	400	580	<50	<10	40	90	750	130	680	<20
			LF-E-250	400	17.5	<50	<10	<10	<10	30	<10	20	<20
			LF-E-251	100	2200	<200	<40	460	1200	4200	2200	3400	<60
			LF-E-252	100	1800	<200	<40	370	1000	3000	1900	2800	<60
	Codisposal	Main Gas	LF-E-259	417	2040	<50	<10	230	620	2900	410	2900	<20
			LF-E-260	433	<20	<50	<10	<10	<10	10	<10	<20	<20
			LF-E-261	133	3380	<160	<40	630	2410	4660	3080	4890	<50
			LF-E-262	133	3010	<160	<40	540	2110	4440	2480	3680	<50
	Blank		LF-E-270	Blank	<5	<20	<4	<4	<4	9	<4	<5	<6
	Blank		LF-E-271	Blank	<5	<20	<4	<4	<4	7	<4	<5	<6

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

Waste Type	Sample Location	Sample ID	Sample Volume	Tetramethylbenzene	Dichlorofluoromethane	Ethyl Acetate	Methyl Mercaptan	1,4-Dichlorobenzene	1,3-Butadiene	1,2-Dichloroethane
			(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
Domestic with Leachate	Main Gas	LF-E-011	300	<20	227000	27000	<400	160	<30	870
		LF-E-012	401	<10	160000	22900	<300	470	<20	720
		LF-E-013	100	<40	1160000	49000	<1000	2400	<70	1200
		LF-E-014	100	<40	890000	35000	<1000	1100	<70	710
	Mature	LF-E-022	400	<10	115000	1150	<300	<10	<20	70
		LF-E-023	400	<10	113000	550	<300	10	<20	50
		LF-E-024	100	<40	79000	700	<1000	<30	<70	<70
		LF-E-025	100	<40	51000	470	<1000	<30	<70	<70
	Recent	LF-E-034	401	<10	92000	8200	<300	10	<20	90
		LF-E-035	400	<10	78000	10500	<300	10	<20	150
		LF-E-036	100	<40	320000	24000	<1000	<30	<70	300
		LF-E-037	100	<40	130000	20000	<1000	<30	<70	230
	Leachate	LF-E-042	400	<10	250000	4300	<300	180	<20	200
		LF-E-043	400	<10	70000	2500	<300	130	<20	100
		LF-E-044	100	<40	86000	3300	<1000	170	<70	130
		LF-E-045	100	<40	160000	3600	<1000	190	<70	130
Domestic with little Leachate	Main Gas	LF-E-055	400	<10	143000	1480	<300	60	<20	50
		LF-E-056	400	<10	145000	1880	<300	230	<20	70
		LF-E-057	100	<40	510000	5100	<1000	1100	<70	180
		LF-E-058	100	<40	440000	4200	<1000	1100	<70	150
Commercial & Industrial	Main Gas	LF-E-065	400	<10	30000	580	<300	40	<20	30
		LF-E-066	400	<10	11500	160	<300	12.5	<20	<20
		LF-E-067	100	<40	220000	4000	<1000	490	<70	340
		LF-E-068	100	<40	63000	1100	<1000	100	<70	100
	Leachate	LF-E-076	400	<10	35000	580	<300	70	<20	40
		LF-E-077	400	<10	143000	550	<300	210	<20	60
		LF-E-078	100	<40	<50	<100	<1000	270	<70	<70
		LF-E-079	100	<40	<50	140	<1000	230	<70	<70
	Recent	LF-E-088	400	<10	108000	240	<300	450	<20	20
		LF-E-089	400	<10	93000	190	<300	430	<20	20
		LF-E-090	108	<40	102000	230	<1000	180	<70	<70
		LF-E-091	108	<40	63000	260	<1000	250	<70	<70
	Mature	LF-E-102	400	<10	1080	50	<300	110	<20	<20
		LF-E-103	400	<10	<20	<30	<300	<10	<20	<20
		LF-E-104	100	<40	3300	170	<1000	150	<70	<70
		LF-E-105	100	<40	2700	130	<1000	80	<70	<70

TABLE 6 2003 VOC ANALYSIS BY ATD-GC-MS (CONTINUED)

	Waste Type	Sample Location	Sample ID	Sample Volume	Tetramethylbenzene	Dichlorofluoromethane	Ethyl Acetate	Methyl Mercaptan	1,4-Dichlorobenzene	1,3-Butadiene	1,2-Dichloroethane
				(ml)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)	($\mu\text{g m}^{-3}$)
	Blank		LF-E-080	Blank	<4	<5	<10	<100	<3	<7	<7
	Blank		LF-E-081	Blank	<4	<5	<10	<100	<3	<7	<7
	Blank		LF-E-106	Blank	<4	<5	<10	<100	<3	<7	<7
	Blank		LF-E-107	Blank	<4	<5	<10	<100	<3	<7	<7
	Fragmentiser	Main Gas	LF-E-207	400	30	43000	5500	<300	40	<20	<20
			LF-E-208	400	130	95000	14800	<300	120	<20	20
			LF-E-209	100	<40	55000	4400	<1000	<30	<70	<70
			LF-E-210	100	<40	160000	26000	<1000	90	<70	<70
	Substantial Ash	Main Gas	LF-E-218	502	<10	92000	96000	<200	20	<20	70
			LF-E-219	502	<10	104000	94000	<200	10	<20	90
			LF-E-220	133	80	128000	83000	<800	80	<60	50
			LF-E-221	133	110	113000	90000	<800	110	<60	<60
		Recent	LF-E-229	400	30	110000	18800	<300	30	<20	<20
			LF-E-230	400	20	115000	24500	<300	30	<20	<20
			LF-E-231	100	<40	100000	15000	<1000	<30	<70	<70
			LF-E-232	100	<40	96000	14000	<1000	<30	<70	<70
		Mature	LF-E-239	400	80	19500	3000	<300	70	<20	<20
			LF-E-240	400	100	28000	3500	<300	90	<20	<20
			LF-E-241	100	<40	33000	11000	<1000	<30	<70	<70
			LF-E-242	100	<40	19000	5600	<1000	<30	<70	<70
		Leachate	LF-E-249	400	<10	233000	108000	<300	10	<20	40
			LF-E-250	400	<10	<20	<30	<300	<10	<20	<20
			LF-E-251	100	70	520000	110000	<1000	70	<70	<70
			LF-E-252	100	70	480000	100000	<1000	70	<70	<70
	Codisposal	Main Gas	LF-E-259	417	<10	125000	113000	<300	30	<20	30
			LF-E-260	433	<10	46000	67000	<300	<10	<20	<20
			LF-E-261	133	120	143000	128000	<800	100	<60	<60
			LF-E-262	133	70	143000	120000	<800	70	<60	<60
	Blank		LF-E-270	Blank	<4	<5	<10	<100	<3	<7	<7
	Blank		LF-E-271	Blank	<4	<5	<10	<100	<3	<7	<7

TABLE 7 2003 SUMMARY OF VOC RESULTS

Analyte	Maximum Concentration			Geomean of mean		Geometric mean RPD			Count Max		Best Volume
	Median (µgm ⁻³)	Average (µgm ⁻³)	Geomean (µgm ⁻³)	100 (µgm ⁻³)	400 (µgm ⁻³)	100 (%)	400 (%)	400-100 (%)	100 (%)	400 (%)	
Dichlorodifluoromethane	18500	24847	20941	19235	11317	3	32	28	9	5	100
Chloromethane	0	0	-	-	-	-	-	-	0	0	ND
Chloroethene	31000	102087	29889	27802	17714	13	33	39	10	5	100
Bromoethane	0	84	167	325	108		27	122	2	4	400
Chloroethane	0	461	2921	1255	1780	58	128	24	0	2	400
Trichlorofluoromethane	2100	5199	2004	1667	940	32	15	52	10	4	100
1-Pentene	3500	5486	3473	2646	2060	28	38	49	11	4	100
Acetone	11000	13560	8477	4924	2681	24	30	43	13	2	100
Furan	820	1429	826	625	306	27	5	68	10	5	100
Propan-2-ol	0	18065	16267	270000	-	-	-	-	2	0	100
Ethyl Mercaptan	0	0	-	-	-	-	-	-	0	0	ND
1,1-Dichloroethene	280	2233	770	749	560	35	49	54	6	7	400
Methylsulfide	730	3693	1045	1056	565	10	13	56	8	6	100
Dichloromethane	720	6864	1161	785	499	13	39	21	12	3	100
Carbon Disulfide	13000	33983	13616	8000	5137	41	40	47	10	5	100
trans-1,2-Dichloroethene	260	435	288	304	179	2	14	32	7	7	100
1,1-Dichloroethane	280	564	312	311	187	7	37	27	8	6	100
n-Hexane	3700	4399	3384	2156	1228	5	52	50	13	2	100
Methylethylketone	15800	19391	12401	7837	5010	6	36	43	12	3	100
cis-1,2-Dichloroethene	2200	5713	2734	1501	1243	23	36	33	9	6	100
Propyl Mercaptan	0	6	-	-	90	-	-	-	0	1	400
Chloroform	0	44	-	525	400	51	15	27	1	0	100
Tetrachloromethane	0	0	-	-	-	-	-	-	0	0	ND
Benzene	15000	18376	11782	8944	4681	9	17	61	13	2	100
Butan-1-ol	4000	7619	4849	2970	1856	10	41	67	11	4	100
n-Heptane	5560	10528	7087	4986	3535	15	31	36	12	3	100
Trichloroethene	1650	8587	2330	1272	1110	25	38	48	7	8	400
1,2-Dichloropropane	0	0	-	-	-	-	-	-	0	0	ND
Diethylsulfide	0	0	-	-	-	-	-	-	0	0	ND
ButylMercaptan	0	0	-	-	-	-	-	-	0	0	ND
Methylcyclohexane	15000	32658	14813	9418	8402	6	27	34	9	6	100
Methylisobutylketone	730	1238	897	468	426	9	43	38	7	8	400
Dimethyldisulfide	170	1185	308	480	181	4	30	33	8	5	100
Toluene	10000	10559	9325	7387	3329	3	29	84	13	2	100
Butyric Acid	0	1747	3905	1351	1439	173	121	73	2	1	100
n-Octane	12000	16603	7917	5794	3985	4	28	42	11	4	100
Ethyl Butyrate	3500	7240	3292	1975	1741	11	31	46	8	7	100
Butyl Acetate	500	1468	691	469	342	1	36	45	8	7	100
Tetrachloroethene	1950	5292	2311	1233	1190	28	13	41	7	8	400
EthylCyclohexane	4000	6029	3121	1893	1764	6	11	24	8	7	100
Chlorobenzene	220	901	375	376	141	3	4	39	9	6	100
EthylBenzene	8890	8491	7201	6676	2673	13	5	67	15	0	100
m-Xylene + p-Xylene	18000	17780	16430	13510	5627	3	11	90	13	2	100
n-Nonane	12000	15467	10165	8026	3862	7	31	80	13	2	100
Styrene	260	535	339	293	134	8	1	28	11	4	100
o-Xylene	4300	6040	4464	3421	1602	8	30	82	13	2	100
2-ButoxyEthanol	0	0	-	-	-	-	-	-	0	0	ND
1,1,2,2-Tetrachloroethane	0	0	-	-	-	-	-	-	0	0	ND
n-PropylBenzene	1200	2631	1391	1285	508	6	30	31	12	3	100
p-EthylToluene	2410	7325	3978	2483	1221	19	28	105	12	3	100
n-Decane	10000	11061	8011	6235	2594	8	36	97	13	2	100
1,2,4-TrimethylBenzene	3080	5614	3745	2251	992	20	30	118	12	3	100
Limonene	5700	9597	7008	4946	2522	5	29	82	12	3	100
1,2-DichloroBenzene	20	37	41	128	29	0	0	115	2	6	400
Tetramethylbenzene	0	37	84	86	56	1	48	-	3	3	100
Dichlorofluoromethane	143000	261887	193989	115187	68063	12	22	46	10	5	100
Ethyl Acetate	11000	32271	10384	5728	4121	22	26	33	10	5	100
Methyl Mercaptan	0	0	-	-	-	-	-	-	0	0	ND
1,4-Dichlorobenzene	120	373	136	208	54	3	5	57	9	6	100
1,3-Butadiene	0	0	-	-	-	-	-	-	0	0	ND
1,2-Dichloroethane	60	170	98	198	62	3	7	48	4	8	400

Notes:

- denotes unable to quantify.
Geomean denotes geometric average.
Count Max is the number of times the specific sampling volume has the highest concentration.
Best Volume denotes dominant sample volume (100ml or 400ml).
RPD denotes Relative Percentage Difference.
ND denotes non-detect

TABLE 8 2003 DIOXIN AND FURAN ANALYSIS BY GC-HRMS

Waste Type Location Sample Label Volume (L)	Dom with Leachate Main gas LF-E-15 25		Dom. Little Leachate Main gas LF-E-54 100		Com & Ind. Main gas LF-E-69 100		Blank E344 100	
	Result	ITEQ	Result	ITEQ	Result	ITEQ	Result	ITEQ
	(ngm ⁻³)	(ngm ⁻³)	(ngm ⁻³)	(ngm ⁻³)	(ngm ⁻³)	(ngm ⁻³)	(ngm ⁻³)	(ngm ⁻³)
Dioxins								
2378	<0.020	0.02	<0.005	0.005	0.0077	0.0077	<0.005	0.005
12378	<0.040	0.02	<0.009	0.0045	0.024	0.012	<0.009	0.0045
123478	<0.010	0.001	<0.004	0.0004	0.023	0.0023	<0.004	0.0004
123678	<0.010	0.001	<0.004	0.0004	0.011	0.0011	<0.004	0.0004
123789	0.015	0.0015	<0.004	0.0004	0.018	0.0018	<0.004	0.0004
1234678	0.036	0.00036	0.0044	0.000044	0.018	0.00018	0.0065	0.000065
OCDD	0.1	0.0001	0.023	0.000023	0.04	0.00004	0.018	0.000018
Total Dioxins	0.23	0.044	0.053	0.011	0.14	0.025	0.051	0.011
Furans								
2378	<0.020	0.002	<0.005	0.0005	0.018	0.0018	<0.005	0.0005
12378	<0.0090	0.00045	0.0024	0.00012	0.0045	0.00023	<0.002	0.0001
23478	<0.0080	0.004	<0.002	0.001	0.0057	0.0029	0.0021	0.0011
123478	0.018	0.0018	0.0033	0.00033	0.0058	0.00058	0.0026	0.00026
123678	<0.010	0.001	0.0021	0.00021	0.0045	0.00045	<0.002	0.0002
123789	0.063	0.0063	0.0058	0.00058	0.0062	0.00062	<0.005	0.0005
234678	<0.010	0.001	<0.005	0.0005	0.032	0.0032	<0.005	0.0005
1234678	0.086	0.00086	0.02	0.0002	0.009	0.00009	0.019	0.00019
1234789	<0.020	0.0002	<0.005	0.00005	<0.005	0.00005	<0.005	0.00005
OCDF	0.17	0.00017	0.024	0.000024	0.046	0.000046	0.018	0.000018
Total Furans	0.41	0.018	0.075	0.0035	0.14	0.0099	0.066	0.0034
Grand Total	0.64	0.062	0.13	0.015	0.28	0.035	0.12	0.014
ITEQ(<LOD=0)		0.011		0.0015		0.035		0.0016
Dioxins								
Total Tetra	0.49		1.3		12		1	
Total Penta	0.75		2.1		11		1.4	
Total Hexa	0.32		0.67		4.7		0.51	
Total Hepta	0.19		0.56		1.9		0.59	
Furans								
Total Tetra	0.37		1.3		12		1.6	
Total Penta	0.34		0.68		3.9		0.56	
Total Hexa	1		4.2		3.5		4.4	
Total Hepta	0.16		0.36		1.6		0.35	
Recovery								
Extraction	83		85		27		67	
Sampling	101		104		112		112	

TABLE 8 2003 DIOXIN AND FURAN ANALYSIS BY GC-HRMS (CONTINUED)

Waste Type Location Sample Label Volume (L)	Fragmentiser Main gas LF-E-211 100		Substantial Ash Main gas LF-E-222 100		Codisposal Main gas LF-E-263 200		Blank E349 100	
	Result (ngm ⁻³)	ITEQ (ngm ⁻³)	Result (ngm ⁻³)	ITEQ (ngm ⁻³)	Result (ngm ⁻³)	ITEQ (ngm ⁻³)	Result (ngm ⁻³)	ITEQ (ngm ⁻³)
Dioxins								
2378	<0.003	0.003	0.0038	0.0038	<0.0020	0.002	<0.003	0.003
12378	<0.007	0.0035	0.008	0.004	<0.0040	0.002	<0.007	0.0035
123478	<0.008	0.0008	<0.008	0.0008	<0.0040	0.0004	<0.008	0.0008
123678	<0.008	0.0008	0.014	0.0014	<0.0040	0.0004	<0.008	0.0008
123789	<0.008	0.0008	<0.008	0.0008	<0.0040	0.0004	<0.008	0.0008
1234678	0.0032	0.000032	0.0043	0.000043	<0.0030	0.00003	0.0047	0.000047
OCDD	0.021	0.000021	0.02	0.00002	0.013	0.000013	<0.02	0.00002
Total Dioxins	0.058	0.009	0.066	0.011	0.034	0.0052	0.059	0.009
Furans								
2378	<0.004	0.0004	0.008	0.0008	<0.0020	0.0002	<0.004	0.0004
12378	<0.003	0.00015	0.0043	0.00022	0.0039	0.0002	<0.003	0.00015
23478	<0.008	0.004	<0.008	0.004	<0.0040	0.002	<0.008	0.004
123478	<0.007	0.0007	<0.007	0.0007	<0.0040	0.0004	<0.007	0.0007
123678	<0.006	0.0006	<0.006	0.0006	<0.0030	0.0003	<0.006	0.0006
123789	<0.008	0.0008	0.015	0.0015	<0.0040	0.0004	<0.008	0.0008
234678	<0.02	0.002	<0.02	0.002	<0.010	0.001	<0.02	0.002
1234678	<0.02	0.0002	0.024	0.00024	<0.0080	0.00008	<0.02	0.0002
1234789	<0.005	0.00005	0.0062	0.000062	0.0016	0.000016	<0.005	0.00005
OCDF	<0.01	0.00001	0.038	0.000038	0.016	0.000016	0.017	0.000017
Total Furans	0.091	0.0089	0.14	0.01	0.057	0.0046	0.098	0.0089
Grand Total ITEQ(<LOD=0)	0.15	0.018	0.21	0.021	0.091	0.0098	0.16	0.018
		0.000053		0.012		0.00024		0.000064
Dioxins								
Total Tetra	0.23		0.34		0.12		0.23	
Total Penta	0.019		0.31		0.097		0.11	
Total Hexa	0.11		0.16		0.049		0.078	
Total Hepta	0.04		0.087		0.021		0.027	
Furans								
Total Tetra	0.26		1.1		0.22		0.38	
Total Penta	0.097		0.22		0.042		0.088	
Total Hexa	0.19		0.16		0.062		0.12	
Total Hepta	0.062		0.075		0.026		0.084	
Recovery								
Extraction	72		67		71		63	
Sampling	84		103		110		104	

TABLE 9 REVISED TOXICITY SIGNIFICANCE RANKING

Chemical Name	CAS No.	Chemical Group	Toxicity Ranking	Physical Ranking	Toxicological Importance	Average Database Concentration picogram ⁻³	Toxicity Score (database)	Average P1-491 Concentration picogram ⁻³	Toxicity Score (P1-491)	Comments
chloroethane	75-00-3	Halogenated organics	25	2	50	7.68E+10	500	4.61E+08	400	Lower score
chloroethene	75-01-4	Halogenated organics	25	2	50	6.63E+10	500	1.02E+11	550	Higher score
benzene	71-43-2	Aromatic hydrocarbons	25	2	50	4.86E+09	450	1.84E+10	500	Higher score
2-butoxy ethanol	111-76-2	Ether	25	1	25	2.00E+08	200	ND (2.0E+08)	200	Assumed the detection limit
arsenic	7440-38-2	Inorganic Compounds	25	-	25	3.65E+06	150	5.11E+07	175	Higher score
1,1-dichloroethane	75-34-3	Halogenated organics	5	2	10	4.77E+11	110	5.64E+08	80	Lower score
trichloroethene	79-01-6	Halogenated organics	5	2	10	1.50E+10	100	8.59E+09	90	Lower score
tetrachloromethane	56-23-5	Halogenated organics	5	2	10	5.26E+09	90	ND (7.0E+07)	70	Assumed the detection limit
methanal	50-00-0	Aldehydes	5	2	10	2.93E+09	90	5.90E+07	70	Lower score
hydrogen sulphide	7783-06-4	Organosulphur compounds	4	2	8	1.34E+11	88	1.33E+11	88	
1,2-dichloroethene	540-59-0	Halogenated organics	4	2	8	1.65E+10	80	6.15E+09	72	Lower score
1,1-dichloroethene *	75-35-4	Halogenated organics	5	2	10	1.00E+08	80	2.23E+09	90	Higher score
furan	110-00-9	Oxygenated Compounds	5	2	10	9.75E+08	80	1.43E+09	90	Higher score
1,3-butadiene	106-99-0	Alkenes	5	2	10	1.82E+08	80	ND (7.0E+07)	70	Assumed the detection limit
mercury	7439-97-6	Inorganic Compounds	10	1	10	4.09E+06	60	**5.00E+05	50	Lower score
carbon disulphide	75-15-0	Organosulphur compounds	4	2	8	7.66E+07	56	3.40E+10	80	Higher score
tetrachloroethene	127-18-4	Halogenated organics	5	1	5	1.13E+11	55	5.29E+09	45	Lower score
1,2-dichloroethane	107-06-2	Halogenated organics	5	1	5	1.95E+10	50	1.20E+08	40	Lower score
dichloromethane	75-09-2	Halogenated organics	5	1	5	1.93E+10	50	6.86E+09	45	Lower score
chloromethane	74-87-3	Halogenated organics	3	2	6	8.18E+08	48	ND(3.0E+08)	48	Assumed the detection limit
trichloromethane	67-66-3	Halogenated organics	5	1	5	3.67E+09	45	4.40E+07	35	Lower score
ethanal	75-07-0	Aldehydes	5	1	5	2.93E+09	45	3.91E+08	40	Lower score
styrene	100-42-5	Aromatic hydrocarbons	5	1	5	2.82E+09	45	5.35E+08	40	Lower score
n-hexane	110-54-3	Alkanes	2	2	4	2.09E+10	40	4.40E+09	36	Lower score
dichlorodifluoromethane	75-71-8	Halogenated organics	2	2	4	1.27E+10	40	2.48E+10	40	
trans-1,2-dichloroethene	156-60-5	Halogenated organics	2	2	4	1.07E+10	40	4.35E+08	32	Lower score
naphthalene	91-20-3	Aromatic hydrocarbons	5	1	5	9.35E+08	40	ND	NA	Not on analytical list
dichlorobenzene (mixed isomers)	25321-22-6	Halogenated organics	5	-	5	7.79E+08	40	4.10E+08	40	
chlorotrifluoroethene	79-38-9	Halogenated organics	5	-	5	5.03E+08	40	ND	NA	Not on analytical list
1,1,2,2-tetrachloroethane	79-34-5	Halogenated organics	5	1	5	4.88E+08	40	ND(4.0E+07)	35	Assumed the detection limit
ethand	64-17-5	Alcohol	5	1	5	2.57E+08	40	ND	NA	Not on analytical list
turfural	98-01-1	Oxygenated Compounds	5	1	5	2.00E+08	40	ND	NA	Not on analytical list
bromodichloromethane	75-27-4	Halogenated organics	5	1	5	1.92E+08	40	ND	NA	Not on analytical list
chloromethylbenzene	100-44-7	Halogenated organics	5	1	5	1.05E+08	40	ND	NA	Not on analytical list
trichlorofluoromethane	75-69-4	Halogenated organics	2	2	4	3.08E+09	36	5.20E+09	36	
1,1,1,2-tetrachloroethane	630-20-6	Halogenated organics	5	1	5	5.00E+07	35	ND	NA	Not on analytical list
dibromochloromethane	124-48-1	Halogenated organics	5	1	5	5.00E+07	35	ND	NA	Not on analytical list

- signifies Not Available

* Denotes compound whose P1-438 toxicological significance score based on median concentration rather than average.

ND- signifies Not Detected

** Mercury average excludes wet sample

TABLE 10 REVISED ODOUR SIGNIFICANCE RANKING

Chemical Name	CASRN	Chemical Group	Physical Ranking	Odour Ranking	Odour Importance	Average Database Concentration picogm-3	Odour Score (database)	Average P1-491 Concentration picogm-3	Odour Score (P1-491)	Comments
hydrogen sulphide	7783-06-4	Organo Sulphur Compounds	2	5	10	1.34E+11	110	1.33E+11	110	
methanethiol	74-93-1	Organo Sulphur Compounds	2	5	10	7.26E+09	90	ND(1.0E+09)	90	Assumed detection limit
butyric acid	107-92-6	Carboxylic Acids	1	5	5	8.96E+09	45	1.75E+09	45	
ethanal	75-07-0	Aldehydes	1	5	5	2.93E+09	45	3.91E+08	40	Lower Score
carbon disulphide	75-15-0	Organo Sulphur Compounds	2	3	6	7.66E+07	42	3.40E+10	60	Higher Score
1-propanethiol	107-03-9	Organo Sulphur Compounds	1	5	5	4.33E+08	40	6.00E+06	30	Lower score
dimethyl disulphide	624-92-0	Organo Sulphur Compounds	1	5	5	2.15E+08	40	1.19E+09	45	Higher Score
ethanethiol	75-08-1	Organo Sulphur Compounds	1	5	5	1.45E+08	40	ND(3.0E+08)	40	Assumed detection limit
1-pentene	109-67-1	Alkenes	2	2	4	1.72E+09	36	5.49E+09	36	
ethyl butyrate *	105-54-4	Esters	1	4	4	3.29E+10	32	7.24E+09	36	
dimethyl sulphide	75-18-3	Organo Sulphur Compounds	1	4	4	4.80E+08	32	ND(1.1E+08)	32	Assumed detection limit
1-butanethiol	109-79-5	Organo Sulphur Compounds	1	4	4	2.00E+08	32	ND(1.1E+08)	32	Assumed detection limit
propionic acid	79-09-4	Carboxylic Acids	1	3	3	2.96E+09	27	ND	NA	Not on Analytical List
butanal	123-72-8	Aldehydes	1	3	3	2.00E+08	24	ND	NA	Not on Analytical List
formic acid	64-18-6	Carboxylic Acids	1	3	3	2.00E+08	24	ND	NA	Not on Analytical List
pentanal	110-62-3	Aldehydes	1	3	3	2.00E+08	24	ND	NA	Not on Analytical List
propanal	123-38-6	Aldehydes	1	3	3	1.90E+08	24	ND	NA	Not on Analytical List
butyl acetate	123-86-4	Esters	1	3	3	1.36E+08	24	1.47E+09	27	
diethyl sulphide	352-93-2	Organo Sulphur Compounds	1	3	3	1.22E+08	24	ND(8.0E+07)	21	Assumed detection limit
chlorobenzene	108-90-7	Halogenated Organics	1	2	2	2.46E+11	22	9.01E+08	16	
1,1,1-trichloroethane	71-55-6	Halogenated Organics	2	1	2	1.91E+11	22	ND	NA	Not on Analytical List
n-butane	106-97-8	Alkanes	2	1	2	7.03E+10	20	ND	NA	Not on Analytical list

* Denotes compound whose P1-438 odour significance score based on median concentration rather than average.

ND means not detected

NA means not available

Appendix 4: Statistical distribution of priority trace components for different waste types

Priority Chemicals of Interest	Codisposal mg m ⁻³	Commercial and Industrial				Domestic with Leachate				Domestic (less Leachate) mg m ⁻³	Substantial Ash			
		Min mg m ⁻³	Max mg m ⁻³	Mean mg m ⁻³	Range mg m ⁻³	Min mg m ⁻³	Max mg m ⁻³	Mean mg m ⁻³	Range mg m ⁻³		Min mg m ⁻³	Max mg m ⁻³	Mean mg m ⁻³	Range mg m ⁻³
chloroethane	1.61	<0.03	<0.03	<0.03	0	<0.03	5.3	1.3475	>5.27	<0.03	<0.03	<0.03	<0.03	0
chloroethene	271	1.1	41	17.175	39.9	7.7	730	223.175	722.3	180	2.3	31	18.225	28.7
benzene	5.64	7.8	60	22.8	52.2	15	73	31	58	15	3.1	24.8	9.075	21.7
2-butoxy ethanol	<0.05	<0.05	<0.05	<0.05	0	<0.05	<0.05	<0.05	0	<0.05	<0.05	<0.05	<0.05	0
arsenic	0.0031	0.0006	0.042	0.015	0.0414	0.0041	0.0482	0.02485	0.0441	0.0046	0.0017	0.43	0.14805	0.4283
1,1-dichloroethane	0.43	<0.02	0.56	0.2175	>0.54	0.36	3.9	1.435	3.54	0.59	0.05	0.28	0.1425	0.23
trichloroethene	1.65	0.25	6.7	2.575	6.45	3.5	88	26.7	84.5	7.1	0.33	1.14	0.605	0.81
tetrachloromethane	<0.02	<0.02	<0.02	<0.02	0	<0.02	<0.02	<0.02	0	<0.02	<0.02	<0.02	<0.02	0
methanal	0.056	0.032	0.072	0.052	0.04	0.061	0.188	0.105	0.127	0.026	0.043	0.097	0.0695	0.054
hydrogen sulphide	52	2.4	200	91.35	197.6	25	580	234	555	49	7	>69	>49	>62
cis-1,2-dichloroethene	3.98	0.13	3.9	1.4825	3.77	3.9	46	15.975	42.1	5	0.58	2.2	1.47	1.62
trans-1,2-dichloroethene	0.5	<0.02	0.42	0.155	>0.40	0.31	2.6	1.02	2.29	0.35	0.07	0.26	0.19	0.19
1,1-dichloroethene	0.04	<0.03	1.98	0.9225	>1.95	1.88	19	6.62	17.12	2.8	<0.03	0.16	0.1025	0.13
furan	0.23	0.02	1.3	0.5	1.28	1.13	6.2	2.615	5.07	1.2	0.13	2.6	1.0625	2.47
1,3-butadiene	<0.02	<0.02	<0.02	<0.02	0	<0.02	<0.02	<0.02	0	<0.02	<0.02	<0.02	<0.02	0
mercury	0.00058	0.0004	0.00082	0.00067333	0.00042	0.00017	0.00133	0.0005325	0.00116	0.0005	0.00021	0.00099	0.0006	0.00078
carbon disulphide	1.65	1.4	59	21.35	57.6	12.8	170	84.45	157.2	32	0.9	35	12.875	34.1
methanethiol	<0.3	<0.3	<0.3	<0.3	0	<0.3	<0.3	<0.3	0	<0.3	<0.3	<0.3	<0.3	0
butyric acid	<0.1	<0.1	8.3	2.3	>8.2	<0.1	<0.1	<0.1	0	17.5	<0.1	<0.1	<0.1	0
ethanal	0.249	0.075	0.266	0.1345	0.191	0.136	2.546	0.857	2.41	0.084	0.084	1.458	0.485	1.374
1-propanethiol	<0.05	<0.05	<0.05	<0.05	0	<0.05	<0.05	<0.05	0	<0.05	<0.04	0.09	0.0575	>0.04
dimethyl disulphide	0.15	<0.03	0.17	0.0725	0.14	0.07	0.79	0.2775	0.72	0.17	0.17	12	3.4025	11.83
ethanethiol	<0.08	<0.08	<0.08	<0.08	0	<0.08	<0.08	<0.08	0	<0.08	<0.08	<0.08	<0.08	0
1-pentene	3.68	0.24	5.2	2.9525	4.96	3.5	21	8.95	17.5	8.8	0.7	14.3	4.875	13.6
ethyl butyrate	4.8	0.41	5.9	3.0125	5.49	3.5	42	19.125	38.5	11	0.48	1.29	0.8075	0.81
dimethyl sulphide	0.44	<0.03	0.59	0.2375	>0.56	0.14	16	5.58	15.86	0.73	0.79	24.3	7.6975	23.51
1-butanethiol	<0.07	<0.08	<0.08	<0.08	0	<0.08	<0.08	<0.08	0	<0.08	<0.08	<0.08	<0.08	0

Appendix 5: Screen test comparison

TABLE 1. NON-PRIORITY COMPOUND SCREENING TEST COMPARISONS – LAB 2 / ATD-TUBE

NON-PRIORITY COMPOUNDS																						
Waste Type	Sample Location	Sample Collection Media	1,2-Dichloroethane µg m ⁻³	Dichlorodifluoromethane µg m ⁻³	Chloromethane µg m ⁻³	Trichlorofluoromethane µg m ⁻³	Chloroform µg m ⁻³	n-Heptane µg m ⁻³	1,2-Dichloropropane µg m ⁻³	Toluene µg m ⁻³	Tetrachloroethene µg m ⁻³	Chlorobenzene µg m ⁻³	Ethylbenzene µg m ⁻³	m-Xylene + p-Xylene µg m ⁻³	Styrene µg m ⁻³	o-Xylene µg m ⁻³	1,1,2,2-Tetrachloroethane µg m ⁻³	n-Propylbenzene µg m ⁻³	1,2,4-Trimethylbenzene µg m ⁻³	Limonene µg m ⁻³	1,2-Dichlorobenzene µg m ⁻³	1,4-Dichlorobenzene µg m ⁻³
Domestic with Leachate	Main Gas	ATD Tedlar	<200	100000 20800	<80 300	25000 2200	660 <200	47000 6680	<20 <200	25000 33400	41000 200	2100 <200	16000 15200	26000 29300	450 <200	13000 8400	<10 <200	7800 2600	15000 11600	34000 41410	310 <200	2400 900
	Mature	ATD Tedlar	<200	18500 5000	<80 300	580 <200	<20 <200	5000 <200	<20 <200	12000 8200	2430 <200	160 <200	8500 7300	13000 10100	430 <200	4300 3600	<10 <200	1200 1300	1300 5800	9200 15380	<20 <200	300 <200
	Recent	ATD Tedlar	<200	27000 38400	<80 <200	2700 1900	<20 <200	19000 14290	<20 <200	13000 54400	7200 200	80 <200	6200 21900	8200 38600	230 4100	2000 11600	<10 <200	500 3300	780 14200	4500 82930	<20 <200	10 <200
	Leachate	ATD Tedlar	<200	14300 13200	<80 600	1100 <200	<20 <200	16000 11500	<20 <200	13000 30000	7300 200	150 <200	9200 18400	16000 24900	1100 <200	6700 7900	<10 <200	2600 2500	6200 13100	16000 18750	<20 <200	190 900
Domestic with little Leachate	Main Gas	ATD Tedlar	<200	46000 5800	<80 400	3200 400	<20 <200	20000 2430	<20 <200	15000 7500	7200 <200	770 <200	13000 9900	21000 12500	1500 <200	11000 3900	<10 <200	6900 1300	11000 5500	20000 13460	70 <200	1100 500
Commercial and Industrial	Main Gas	ATD Tedlar	<200	22000 5100	<80 <200	2100 500	<20 <200	21000 3360	<20 <200	18000 24900	3500 <200	4500 2200	14000 24700	25000 52900	1900 <200	13000 15100	<10 <200	7100 4300	10000 24500	15000 7300	<20 <200	490 200
	Leachate	ATD Tedlar	<200	9500 6800	<80 <200	550 <200	<20 <200	5800 3930	<20 <200	8700 24800	1950 <200	2430 8700	9500 40300	18000 89200	750 <200	8400 <200	<10 <200	3900 6000	9600 34400	9700 6530	40 <200	270 1000
	Recent	ATD Tedlar	<200	14000 18500	<80 <200	240 <200	<20 <200	6020 6450	<20 <200	8800 10500	800 200	1300 930	8890 20800	16700 27500	570 <200	7310 8700	<10 <200	3520 3600	8890 14800	9300 32610	60 <200	450 1500
	Mature	ATD Tedlar	<200	<100 1900	<80 <200	<20 <200	<20 <200	2700 2240	<20 <200	6100 4500	240 <200	930 1300	11000 34200	21000 80100	220 <200	9700 21000	<10 <200	2900 3500	7400 20600	5700 <200	<20 <200	150 <200
Fragmentiser	Main Gas	ATD Tedlar	<200	13000 1700	<80 <200	6900 <200	<20 <200	4700 <200	<20 <200	10000 1500	670 <200	240 <200	11000 3100	26000 3400	190 <200	3100 1300	<10 <200	600 700	2500 2800	3500 7930	<20 <200	120 500
Substantial Ash	Main Gas	ATD Tedlar	<200	20300 46800	<60 <200	4590 16000	<10 <200	4810 <200	<20 <200	6390 59200	1470 200	220 <200	4290 19400	19500 36000	140 <200	2860 11800	<10 <200	560 4300	2710 23800	3980 70480	<20 <200	110 1500
	Recent	ATD Tedlar	<200	16000 16800	<80 <200	420 <200	<20 <200	1750 <200	<20 <200	3500 31000	330 200	80 <200	1900 18900	7500 33000	50 <200	1150 8600	<10 <200	220 2800	1050 10800	1480 48340	<20 <200	30 700
	Mature	ATD Tedlar	<200	8800 14200	<80 <200	380 2900	<20 <200	1180 <200	<20 <200	3300 18200	630 <200	190 <200	4400 18000	12000 24400	130 <200	2500 7600	<10 <200	580 2800	2500 10800	3300 20280	<20 <200	90 900
	Leachate	ATD Tedlar	<200	43000 16100	<80 300	27000 1100	<20 <200	3400 <200	<20 <200	4300 41700	750 200	140 <200	3700 29300	15000 29900	100 <200	2200 9400	<10 <200	460 3200	2200 13800	3400 55100	<20 <200	70 1500
Codisposal	Main Gas	ATD Tedlar	<200	20300 26100	<70 <200	3230 300	<20 <200	5560 <200	<20 <200	11300 32200	3910 200	220 <200	5790 11200	21800 21200	260 <200	3390 6900	<10 <200	630 2600	3080 16500	4890 94900	<20 <200	100 1200

TABLE 2 NON-PRIORITY COMPOUND SCREENING TEST COMPARISONS

			Lab 1 / ATD-Tube							
			NON-PRIORITY COMPOUNDS							
Waste Type	Sample Location	Sample Collection Media	1,2-Dichloroethane $\mu\text{g m}^{-3}$	Dichlorodifluoromethane $\mu\text{g m}^{-3}$	Trichlorofluoromethane $\mu\text{g m}^{-3}$	Dichloromethane $\mu\text{g m}^{-3}$	Diethylsulfide $\mu\text{g m}^{-3}$	Toluene $\mu\text{g m}^{-3}$	Tetrachloroethene $\mu\text{g m}^{-3}$	Chlorobenzene $\mu\text{g m}^{-3}$
Domestic with Leachate	Mature	ATD	70	18500	580	700	<20	12000	2430	160
		Lab 1	<1000	10250	<1000	<1000	<1000	32340	<1000	<1000
	Recent	ATD	300	27000	2700	7400	<20	13000	7200	80
		Lab 1	<1000	29740	2430	6770	<1000	81560	20020	<1000
	Leachate	ATD	200	14300	1100	3000	<20	13000	7300	150
		Lab 1	<1000	11950	<1000	<1000	<1000	43950	2190	<1000
Domestic with little Leachate	Main Gas	ATD	180	46000	3200	3000	<20	15000	7200	770
		Lab 1	<1000	8760	890	1350	<1000	18640	4450	430
Commercial & Industrial	Main Gas	ATD	340	22000	2100	2100	<20	18000	3500	4500
		Lab 1	ND	6760	810	<1000	<1000	60700	1380	4240
	Recent	ATD	20	14000	240	340	<20	8800	800	1300
		Lab 1	<1000	12080	<1000	<1000	<1000	11210	<1000	780

Notes:	White	denotes compounds not in a comparable range (i.e. detected ATD concentrations are lower than the Tedlar bag detection limit)
	Blue	denotes good to excellent comparison (RPD \leq 150%) when one methodology is out of range
	Green	denotes excellent comparison (RPD \leq 100%)
	Orange	denotes good comparison (100 < RPD < 150%)
	Yellow	denotes poor comparison of an undetermined magnitude
	Red	denotes very poor comparison (greater than an order of magnitude)
	NC	denotes no calibration factor for this compound. A response was observed.
	-	denotes no reading

