

Combination of olfactometry and novel analytical method TSIFT

Assessment of Municipal Waste Compost as a daily cover material for odour control at landfill sites

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Abstract

The ability of municipal waste compost as a daily cover material to reduce the odorous emissions associated with landfill surfaces was investigated. Trials were carried out using landfill gas, a certified sulphurous gas mix and ambient air as a control. Odorous gas was passed through portable test column filled with compost at different densities (590kg/m³ and 740kg/m³). Gas samples were taken from the inlet, outlet and at varying column depths and examined using a combination of sensory analysis (olfactometry) and a novel analytical method (Transportable Selected Ion Flow Tube - TSIFT).

Results for the trials using landfill gas showed a 69% odour reduction (OU/m³) through the column for compost with a bulk density of 590kg/m³, and a reduction of 97% using compost with a bulk density of 740kg/m³. TSIFT analysis showed an overall decrease in the concentration of terpenes, and sulphurous compounds in the outlet gas from the column for both bulk densities. No significant trend could be identified for the concentrations at different depths within the column. Results show the ability of compost to reduce landfill odours under differing conditions. The inconclusive data provided by TSIFT analysis may be due to the analysis of compounds that are not contributing to odour, and thus highlights the potential for synergetic effects and the importance of sensory measurement when examining odorous emissions.

1. Introduction

Municipal waste landfills are large heterogeneous areas in which organic wastes undergo degradation in anaerobic, acidic environments resulting in a high generation rate of landfill gas [1]. Emissions from municipal landfill sites can potentially be detrimental to both local and global air quality [2]. Landfill gas consists of up to 65% v/v methane and 35% v/v carbon dioxide, both of which are considered to be greenhouse gases contributing to global climate change [2]. Trace volatile organic compounds represent less than 1% v/v of landfill gas. However these compounds are often odorous [3]. With increased levels of urbanisation and

consequent location of landfills in close proximity to highly populated areas, there has been an increasing level of intolerance to odour, which is now arguably the greatest nuisance associated with landfill sites [3]. Consequently odour control has become an increasingly important aspect of regulation of landfills. A reduction in odorous emissions is one of several objectives associated with the use of daily cover material at landfill sites [4]. Conventionally, material suitable for use as daily cover has been sourced from waste generated by the construction and demolition industry, however with a global decline of the industry, coupled with the introduction of landfill tax, and increasing pressure to recycle and reuse resources, the amount of suitable material for daily cover being sent to landfill is declining [5]. There is a need to identify suitable alternatives to traditional daily cover materials. Materials investigated to date include paper mill sludge, fly ash, mulched wood material and foams [3, 6 to 8]. With the increasing drive towards sustainable waste management, use of a waste derived product such as compost, widely used in bio filters, appears favourable, and the ability of compost to remove chlorinated hydrocarbons and sulphur compounds has been previously reported [9].

Investigating the capacity of alternative daily cover (ADC) materials to attenuate odorous emissions can be undertaken using olfactometry, or via the quantification of potentially odorous compounds using chemical analysis. The latter provides quantitative on the presence of potentially odorous emissions. In contrast, olfactometry provides information on the odour threshold and thus potential sensory impact from the perception of the individual. Therefore, ideally a combination of the two techniques would be required to assess the efficiency of a material to reduce the release of odorous compounds in to the atmosphere.

This study investigated the ability of compost to reduce both the sensory impact of the odour concentration from the landfill gas and an understanding of the chemical compounds and their reduction that can potentially contribute to that odour.

2. Materials and Methods

Test Apparatus

The test apparatus comprised of an 800mm long, 120mm diameter, gas proof, acrylic cylinder, sealed at each end with acrylic plates and rubber seals (Fig. 1). The effective packing height was 600mm, allowing entry and exit spaces of 100mm. Six gas sampling ports, with air tight valves, were located at 100mm intervals through out the packing height, allowing gas samples to be taken at different compost depths. Air tight valves were also located at the gas inlet and outlet points. The test material was supported on a perforated plastic plate.

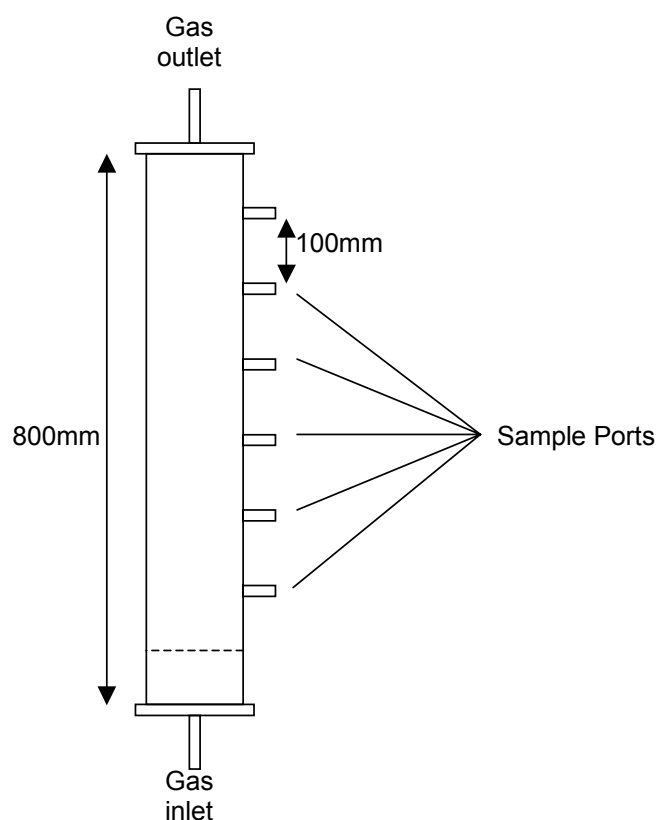


Fig. 1: Test rig used to assess effectiveness of compost as a daily cover material for odour reduction

Daily Cover Material

Municipal solid waste compost was used to represent daily cover material, however the experimental methodology may be applied to other materials.

Three compost treatments were investigated as shown in Table 1. The moisture content of the compost as supplied was 35% w/w. To achieve a moisture content of 50% w/w the appropriate volume was added. Two compost densities were investigated to represent the compaction likely to occur on site during the application process. Compost was placed in the column and compacted either by gently shaking to achieve a bulk density of 590 kg/m^3 , or rammed in four layers by dropping a 3kg weight 50cm onto the compost surface to achieve a bulk density of 740 kg/m^3 .

Table 1: Compost and Gas treatments

Treatment Number	Compost Treatment		Gas Treatment		
	Density (kg/m ³)	Moisture Content (%)	Landfill Gas	Standard Gas	Ambient Air
1	590	35	√	√	√
2	740	35	√	√	√
3	740	50		√	√

Sample Gases

Three sample gases were passed through the column in a series of experiments (Table 1). To test the robustness of the test column and sampling regime a certified standard gas (BOC Gases, Manchester, UK) containing sulphurous compounds was used (Table 2).

Table 2: Certified standard gas supplied by BOC Gases (Manchester, UK)

Component	Concentration
Dimethyl disulphide	0.25 ppm
Methyl mercaptan	2.5 ppm
Hydrogen sulphide	70 ppm
Carbon dioxide	35 % v/v
Methane	Balance

Experiments using landfill gas were undertaken at a landfill site in Eastern England. A single gas well, located in Stage 2 of the site was isolated from the main gas collection system.

To establish the background generated by the compost alone ambient air was passed through the column. The emissions generated from the compost are shown in Table 3. The heterogeneity of the compost material is indicated by the large standard deviations.

Operating Conditions

Once the column had been filled with appropriate compost treatment, all sampling ports, except the inlet and outlet, were closed. The column was operated in up-flow mode to simulate the landfill surface emissions. Gas flow rate through the column was measured and maintained at 250ml/min using a gas flow meter, providing an empty bed retention time (EBRT) of 36 min. Time restrictions dictated a gas flow rate greater than surface emission

rates likely at landfill sites, and it was recognised that similar, previous studies has used a considerably lower flow rate of 10ml/min [9, 10].

The column was allowed to equilibrate and vent to the atmosphere for a one hour. Gas samples were taken from the inlet and outlet points of the column for olfactometry and Transportable Selective Ion Flow Tube (TSIFT) analysis. Samples were also taken at different compost depths (10, 30 and 50cm) for TSIFT analysis.

Table 3: Emissions from compost when passing ambient air through a compost depth of 60cm at 250ml/min for 96 minutes. (Mean \pm standard deviation)

Parameter	Value
Odour Concentration (OU/m ³)	709 (\pm 463)
Terpenes (ppb)	120 (\pm 58)
Dimethyl sulphide + ethanethiol (ppb)	123 (\pm 53)
Dimethyl disulphide (ppb)	31 (\pm 25)
Hydrogen sulphide (ppb)	2 (\pm 7)
Ammonia (ppb)	31 (\pm 42)

Sample Analysis

Olfactometry

Odour concentration measurements were carried out in accordance with the CEN draft protocol 'Air quality – determination and odour concentration by dynamic dilution olfactometry' [11].

Transportable Selective Ion Flow Tube (TSIFT)

TSIFT combines gas kinetics, chemical ionisation, flow techniques and mass spectrometry to allow the detection and accurate quantification of trace gases without the need for pre concentration and water removal. Studies by Španěl and Smith [12] have indicated the suitability of the TSIFT technique for the detection and measurement of dimethyl sulphide (DMS), dimethyl disulphide (DMDS) and ethanethiol, with concentrations provided in parts per billion (ppb).

3. Results and Discussion

Odour reduction

One of the objectives of daily cover material is to reduce odour emissions from the working surface [4]. It is debated whether it is the newly deposited waste or rogue emissions of landfill gas that cause the odours associated with landfill sites, though it is recognised that the use of daily cover would be of an advantage when dealing with deposition of malodorous wastes [5].

Trials using landfill gas indicated a 69% reduction in the outlet odour concentration (OU/m^3) when compared with the inlet odour concentration 69% having passed through the column of compost with a bulk density of $590\text{kg}/\text{m}^3$, and a reduction of 97% when the bulk density of the compost increased to $740\text{kg}/\text{m}^3$, representing a significant ($p \leq 0.05$) improvement in odour reduction with increased bulk density.

Trials using the standard gas yielded a reduction in odour concentration ranging between 97% and 99%, with no significant difference between treatments (Fig. 2).

Mean odour emission from the compost alone ranged between 78 and $1\,510\text{OU}/\text{m}^3$, with an average value of $709\text{OU}/\text{m}^3$. No significant difference was found in the emissions from the different treatments. The large range of values may be a reflection of the heterogeneity of the compost, with the additional error associated with olfactometry analysis of up to $\pm 40\%$ [13].

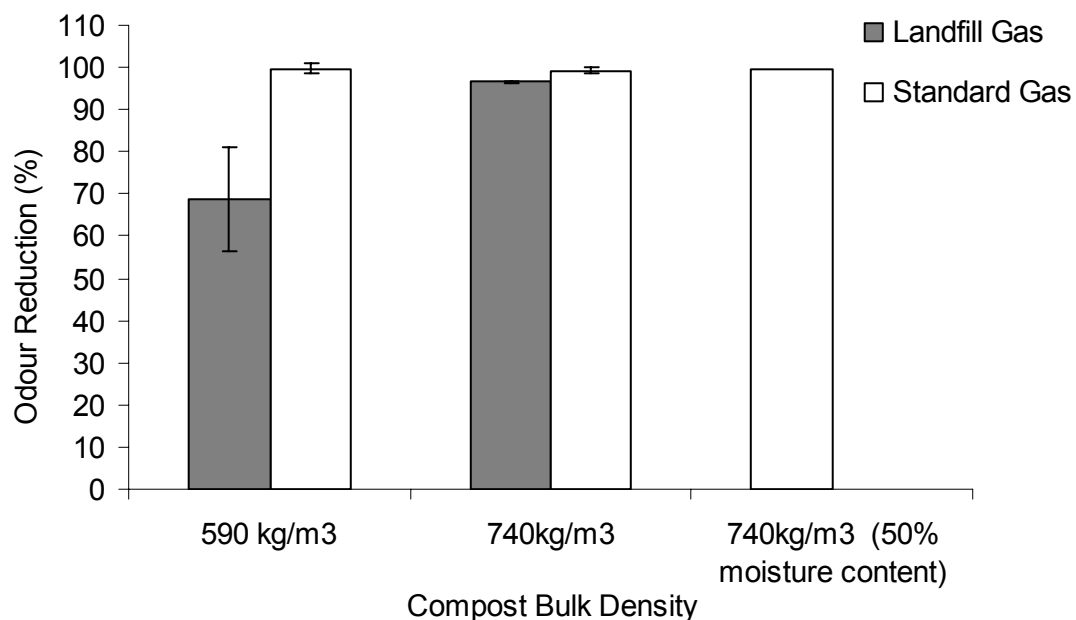


Fig. 2. Mean reduction in odour concentration achieved by passing landfill gas and standard gas through a 60cm column of MSW compost, at 250ml/min for 96 minutes ($n = 3$, means \pm SD).

Removal of Individual Compounds from standard gas

Compost with a bulk density of 590kg/m^3 and 35% w/w moisture content showed the ability to significantly ($p \leq 0.05$) reduce the concentration of all the compounds investigated within the first 10cm of the column. Concentrations of DMS and ethanethiol were reduced by 38% v/v, while concentrations of the DMDS, hydrogen sulphide and methanethiol were all reduced by more than 90% v/v. Increasing compost depth did not result in further significant reduction in compound concentration, with the exception of DMS and ethanethiol where concentrations were reduced by a further 7% v/v in the subsequent 20cm of compost. (Fig. 3).

No significant reduction in the concentration of any of the standard gas constituents was observed when the compost bulk density was increased to 740kg/m^3 .

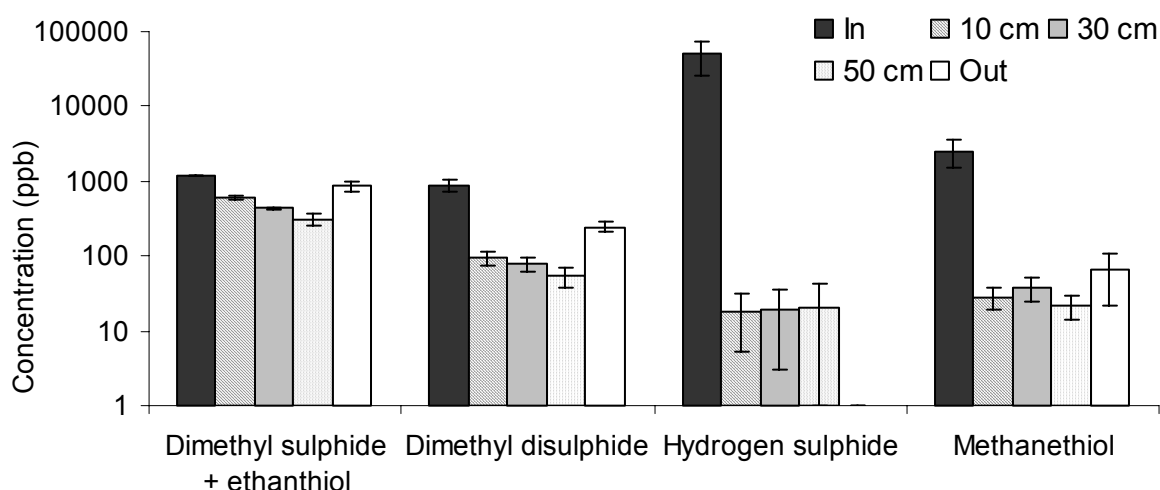


Fig. 3. Concentrations of selected compounds present in standard gas at increasing compost depth when passed through a column of MSW compost, with a bulk density of 590kg/m^3 , 35% moisture content, at 250ml/min for 96 minutes ($n = 3$, means \pm SD).

When the bulk density was maintained at 740kg/m^3 , and the moisture content increased to 50% significant reductions ($p \leq 0.05$) in concentration were observed when comparing inlet and outlet results. Concentration reductions ranged from 28% for DMS and ethanethiol to 100% for hydrogen sulphide. When examining the depth profile for compound reduction, all gases showed a significant reduction in concentration after the first 10cm of compost. Reductions of 67% were observed for DMS and ethanethiol, 82% for DMDS and more than 95% for hydrogen sulphide and methanethiol. DMS and ethanethiol were the only

compounds to show a significant reduction in concentration at each sampling depth, but still only achieved an overall removal of 28% through the entire column depth. (Fig. 4).

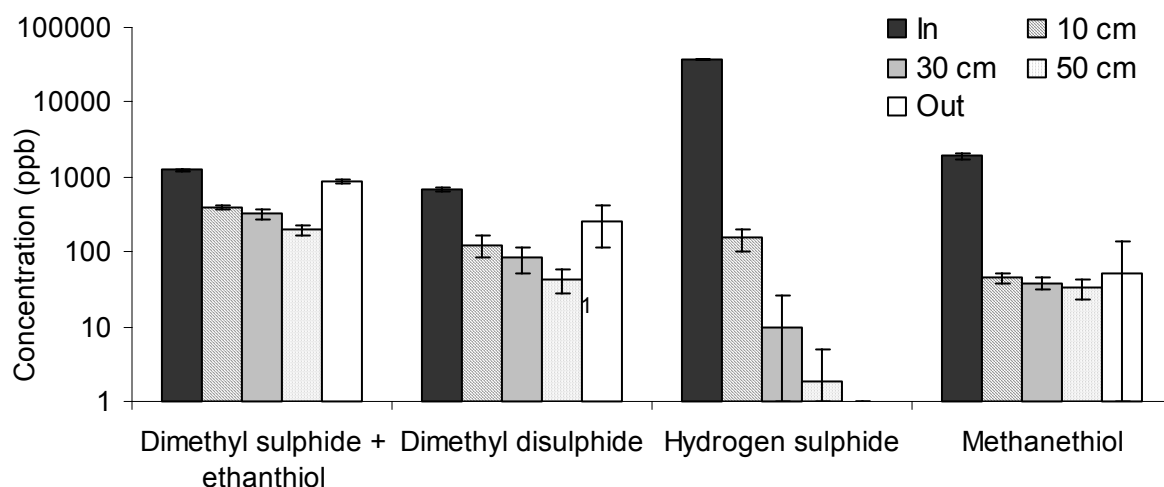


Fig. 4. Concentrations of selected compounds present in standard gas at increasing compost depth when passed through a column of MSW compost, with a bulk density of 740kg/m^3 , 50% moisture content, at 250ml/min for 96 minutes ($n = 3$, means $\pm\text{SD}$).

Removal of Individual Compounds from landfill gas

Results indicated that whilst compost with a bulk density of 590kg/m^3 exhibited a capacity to remove small amounts of terpenes, DMS, ethanethiol, DMDS and hydrogen sulphide, there were no significant reductions (Fig. 5).

However, when compost with a bulk density of 740kg/m^3 was used, there was a significant reduction ($p \leq 0.05$) in overall concentrations of terpenes, DMDS and hydrogen sulphide from the inlet to the outlet, representing a compost depth of 50 cm. The first 10 cm of compost was responsible for the most significant reduction in compound concentrations, removing between 63-100% v/v of the original concentrations, with subsequent depth increments of 10cm having no significant effect on the removal of the compounds. Interestingly, significant increases ($p \leq 0.05$) in the levels of terpenes, DMS & ethanethiol and DMDS were found when comparing concentrations in compost at a depth of 50cm and the outlet samples. Concentrations of ammonia did not differ significantly through the depth of the column.

The inconsistency of the results in the present study may be due a synergetic effect between additional compounds present in landfill gas. Odour and individual compound removal were both accompanied by insignificant changes in moisture content and pH within the column for all gas and compost treatments suggesting minimal biological activity within the column.

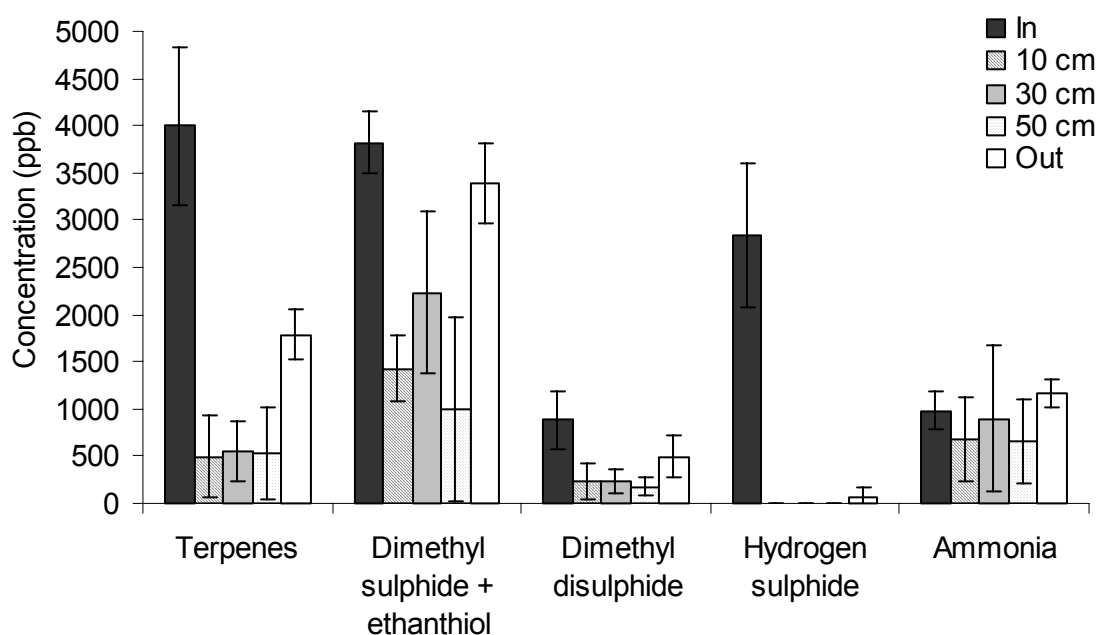


Fig. 5. Concentrations of selected compounds present in landfill gas at increasing compost depth when passed through a column of MSW compost, with a bulk density of 740kg/m^3 , at 250ml/min for 96 minutes ($n = 3$, means $\pm\text{SD}$).

Correlation between reduction of odour and individual compound concentrations

The quantification of odour is complex and not easily definable, with personal influences, cultural influences, education and expectation all having an influence. The analysis of odour can be carried out either by olfactometry or chemical analysis. In the present study the concentrations of all the individual compounds analysed using the TSIFT, with the exception of ammonia, consistently exceeded the odour threshold values shown in Table 4. An attempt was made to identify any correlations between odour measurements and individual chemical compound concentrations.

No significant correlation could be found between the concentration of individual compounds in the landfill gas and olfactometry results. Previous studies have noted that there appeared to be a pronounced synergetic effect between compounds, as when considered individually, few compounds produced a noticeably unpleasant odour, highlighting the difficulty in predicting emissions when several odours are combined [3].

There were significant correlations ($p \leq 0.05$) between the compound concentrations present in the standard gas with the exception of DMS.

In considering results from the ambient air samples, the inconsistent presence and low concentration of low level of hydrogen sulphide may account for the insignificant correlation

between analytical and sensory measurement. The high odour threshold of ammonia and measured concentrations not exceeding that threshold explains the absence of any correlation between TSIFT and olfactometry data in both the ambient air and landfill gas samples.

Table 4: Reported odour threshold ranges for the compounds analysed using TSIFT [14]

Compound	Reported Odour Threshold Ranges	
	(mg/m ³)	(ppb)
Terpenes	0.0000018-0.0001	0.0003-0.0177
Methanethiol	0.000003-0.038	0.0015-19.0
Ethanethiol	0.000043	0.0166
Dimethyl sulphide	0.00034-0.0011	0.1316-0.4259
Hydrogen sulphide	0.00076	0.536
Dimethyl disulphide	0.0011-0.046	0.2809-11.75
Ammonia	0.1-11.6	140.67-1631

Several attempts have been made to relate odour concentrations with the concentrations of individual odorants. Hobbs *et al.* [15] were unable to find any correlation between olfactometry response and measurements of hydrogen sulphide when examining emissions from pig slurry. In contrast, Noble *et al.* [16] found a close correlation between the combined concentration of hydrogen sulphide and DMS and odour concentration for on-site emissions from mushroom compost, with the relationship unaffected by compost conditions, i.e. whether it was aerated or unaerated, pre- or post-wetting. The relationship was not as good when comparing hydrogen sulphide and DMS separately with odour measurements. No correlation was found between ammonia and odour concentrations even though ammonia levels exceeded odour threshold levels in 95% of the samples taken.

Thus the results from this and previous studies [1, 3, 15] appear to confirm that a definitive assessment of the sensory impact of odour can only truly be measured via olfactometry.

4. Conclusions

The suitability of the developed sampling technique for the testing of compost material was shown by good repeatability of results obtained by passing a standard gas through the test column. This sampling technique could therefore be applied to other cover materials, under varying operating parameters to simulate different climatic conditions.

Results obtained by TSIFT analysis indicated the potential role of the technique in the study of landfill gas composition, while highlighting the need for a more comprehensive analysis suite.

Field trials have shown that MSW compost has the ability to reduce odorous emissions from landfill sites by up to 97%, with removal efficiency increasing with compost bulk density. Frechen [17] estimated that the specific emission rates from an active depositing area ranged between 4 000-30 000 OU/m²/h⁻¹ and therefore based on the findings of this trial, emissions could be potentially reduced to 120-900 OU/m²/h⁻¹ by the use of compost as a daily cover material.

Field trials have also indicated the ability of MSW compost to reduce emissions of selected sulphurous compounds, with between 63-100% of the inlet concentration removed in the initial 10cm of compost depth. Other studies support its ability to remove sulphur compounds and chlorinated hydrocarbons from landfill surface emissions [9]. Therefore the use of a compost daily cover could potentially reduce the impact of emissions on the health of the surrounding community, by reducing the release of individual compounds but by also reducing odour complaints, and thus facilitating better relations between the general public, operators and regulators.

Poor correlation between individual compound and odour concentrations obtained from trials using landfill gas, in comparison to those using standard gas, indicate the possibility of other compounds present in landfill gas contributing to a synergetic effect to produce odorous emissions. The potential synergy between compounds highlights the need for sensory measurement in the assessment of odorous emissions from landfill sites.

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