QUANTIFYING ODOUR EMISSION FROM COMPOSTING

P. Hobbs[1], R. Noble[2], J. Williams[1], A. Dobrovin-Pennington[2]
[1]Institute of Grassland and Environmental Research, North Wyke Research Station, Okehampton, Devon EX20 2SB
[2]Horticulture Research International, Wellesbourne, Warwick. CV35 9EF

ABSTRACT

Techniques for quantifying odour from composting need to be developed in order to assess new composting methods and to aid odour control. The method used for measuring odour concentration (OC) or offensiveness is based on human odour panel validation (olfactometry). In addition the chemical profile was determined using gas chromatography-mass spectrometry (GC-MS), electronic nose and colorimetric gas detection tubes. These were compared and major odorants were identified from samples obtained from 10 different composting yards.

Sulphur containing compounds were found to be the major contributors to compost odours. Compounds which were found with GC-MS to exceed their odour thresholds by the greatest order of magnitude were, in decreasing order: Hydrogen sulphide (H_2S), dimethyl sulphide (DMS), butanoic acid, methanethiol and trimethylamine. There was a close correlation between the compost emissions as an olfactory response and the combined H_2S and DMS concentrations from gas detector tubes. For most on-site measurements, H_2S and DMS detector tubes are more appropriate and can be transposed as an olfactory response within 80% accuracy. The chemical profiles of emissions from turned compost are also presented.

INTRODUCTION

Odorous emissions and subsequent complaints are a major problem facing the mushroom compost industry in several EU countries (Miller and Macauley, 1988; Derikx et al., 1990; Noble and Gaze, 1994). The problems appear to originate from conventional composting that involves wetting and mixing straw and animal manures in heaps (pre-wetting) and then in long stacks (Phase I composting). Uncontrolled fermentation can result in the emission of odorous compounds to cause nuisance to the local communities. Dilution olfactometry has been used to measure the odour concentration (OC), but is costly, time consuming, subject to error and incurs delays between sampling and measurement (Hobbs et al., 1995).

GC-MS has been used to show that compost odour includes amines, ammonia, organic acids and most importantly, sulphur containing compounds (Miller and Macauley, 1988; Derikx et al., 1990; Duns et al., 1997). However, major odorants can be measured quickly and cheaply using gas detection tubes. For the electronic nose systems for odour detection and measurement have been developed that employ an array of non-specific electronic gas sensors and use artificial intelligence for interpretation (Gardner et al., 1992) and have recently been used for agricultural malodour applications (Persaud et al., 1996; Misselbrook et al., 1997). An electronic nose has been shown to successfully distinguish between odours from pig and chicken slurry (Hobbs et al., 1995) and between odours from slurry from pigs fed with different diets (Byun et al., 1997). The objective of the present work was to analyse the odours from mushroom composting and compare the different methods outlined above.

MATERIALS AND METHODS

Different techniques for quantifying odour from mushroom composting were used to assess odour samples from the pre-wetting heaps (aerated or unaerated) of raw composting ingredients (wheat straw, animal manures and gypsum) and subsequent Phase I composting windrows or aerated tunnels of ten mushroom composting sites from across England. All the sites used proportions of wheat straw, broiler (poultry) litter and gypsum, although the proportions of these materials and addition of other manures and additives differed between sites. Samples were assessed using odour panel serial dilution (olfactometry) and the chemical composition of the samples was compared using GC-MS and gas detector tubes (on-site measurement). From each site, two replicate odour samples were drawn in 20 l Teflon bags over a 4 minute period from a sampling line. Background samples were collected 200 m upwind of the composting sites. A dynamic dilution olfactometer was used to assess odours where panellists were required to choose between two sniffing ports, one containing odourless air, and the other diluted, odorous air. Threshold values, at which 50% of the panel could just detect an odour, were determined and OC expressed as Odour Units m^{-3} (OU m^{-3}) air. OC was calculated according to the Dravneiks and Prokov (1975) method. Odour panellists were selected on the basis of their response to butan-1-ol of 60 ppb $\pm$ 20 ppb(v).

Volatile compounds were preconcentrated from a 600 ml odour sample onto silica and carbon adsorbents. The concentrated odorants were then thermally desorbed from the adsorbents into a Hewlett Packard GC-MS system for identification and quantification using an Optic thermal desorption system which was initially at 30^{o}C and heated at a rate of 16^{o}C s^{-1} min^{-1}. Volatile organic compounds (VOCs) were detected by the mass spectrometer and were identified using a probability based matching algorithm and a mass spectral library (National Institute of Standards and Technology, 100 Bureau Dr., Stop 2310, Gaithersburg, MD 20899-2310).

Gas detection tubes were used on-site in the same way as sampling odours for collection in Teflon bags, and also on the odour samples in the Teflon bags, 24 h after on-site sampling.

A commercially available electronic nose instrument with an array of 32 conducting polypyrrole sensors was used. The degree of response of each sensor to a given volatile depends upon the type of polymer used, so a pattern of resistance changes across the array was recorded for a particular odour.

RESULTS AND DISCUSSION

Maximum OCs (Fig.1) recorded during pre-wetting and turning of Phase I windrows were generally similar to those previously recorded in similar locations on a mushroom composting yard. Sulphur containing compounds in the compost odours exceeded odour detection thresholds (ODTs) (Table 1) and this agreed with Miller and Macauley (1988), Derikx, et al., (1990) and Duns, et al., (1997). There was a close correlation between the olfactometric OC and the combined concentration of H_2S + DMS in pre-wet and Phase I odour samples (Fig.1). Ammonia concentrations were above the detection threshold in most of the odour samples, but were not correlated with OC.

The polypyrrole based electronic nose was ineffective at enabling the determination of the olfactory response because the response characteristics to sulphides were poor. The electronic nose detection thresholds for H_2S and DMS were about 50 ppm and 20 ppm. Compost odour samples with OCs of 30,000 OU m^{-3} could not be distinguished from less odorous samples with OCs of less than 10,000 OU m^{-3}, which was similar to that reported by Hobbs et al., (1995) for

detecting odours from pig and chicken slurry. Concentrations of NH_3 measured with gas detector tubes were above the ODT, but were not correlated with OC. High OCs may be typically produced in anaerobic zones in composting windrows, where Miller *et al* (1991) recorded H_2S concentrations of up to 50,000 ppm.

CONCLUSIONS

Compounds which were found with GC-MS to exceed their ODT by the greatest order of magnitude were, in decreasing order: H_2S, DMS, butanoic acid, methanethiol and trimethylamine. Sulphides were the major components contributing towards the odour. There was a clear relationship between the combined concentration of H_2S and DMS to the olfactory response. The relationship should enable rapid and low cost identification of odour sources on mushroom composting sites.

Table 1. *Concentrations†, detection thresholds and characteristics of odorants identified with GC-MS in 24-h compost yard odour samples, μg m-3 air. Compounds with mean values exceeding the detection threshold are shown in bold.*

Odorant	Pre-wet	Phase I	Detection threshold	Characteristic odour
Acetic acid	1588(±941)	1952(±1362)	363	sour
Acetone	3007(±5644)	2679(±5114)	34674	chemical sweet
Ammonia*	27976(±28840)	75740(±62750)	4074	dry urine, pungent
Butanoic acid	481 *(5)*	2129(±3271)	14.4	rancid, sour
Butanol	3003(±6774)	2715(±6628)	1514	fusel oil, rancid
Dimethyl sulphide	1667(±3290)	3528(±6921)	5.9	decayed vegetable
Dimethyl disulphide	657(±1626)	287(±896)	47.9	foul
Dimethyl trisulphide	83(±170)	130(±292)	8.7	
Ethanol	53460(±103860)	10808(±16281)	54954	vinous, sweet
4-Ethyl phenol	75*(3)*	79(±90)	600	
Hexane	150(±276)	86(±112)	79433	ethereal
Hydrogen sulphide	730(±1310)	4362(±5369)	25.7	rotten egg
Indole	7*(3)*	3(±3)	0.2	faecal
Iso-propyl-alcohol	1837*(4)*	195(±245)	25704	sharp, musty
Methanethiol	211(±246)	126(±165)	2.1	rotten cabbage
2-Methyl butanoic acid	238*(2)*	165(±350)	7.9	unpleasant
3-Methyl butanoic acid	206*(2)*	869(±1531)	10.5	unpleasant
Methyl ethyl ketone	2757(±3542)	1758(±3616)	23442	sweet, sharp
4-Methyl phenol	101(±50)	196(±101)	8.3	tar-like
Methyl propanoic acid	26*(2)*	444(±379)	72.4	decayed vegetable
Pentanoic acid	216*(3)*	700(±1231)	20.4	body odour
Phenol	139(±77)	189(±170)	427	medicinal
Propanoic acid	2004(±2323)	351(±259)	110	rancid, sour
Propanol	5928(±13171)	678(±879)	6026	stupefying, sweet
Toluene	30*(2)*	18*(2)*	5888	sour, burnt, solvent
Trimethylamine	435*(3)*	582(±924)	5.9	ammonical, fishy
p-Xylene	113*(1)*	25*(2)*	3800	

† mean and ± standard deviation of 11 composting site samples; compounds without standard deviations were identified in less than six samples, number shown in italics.
**measured with gas detection tubes.*

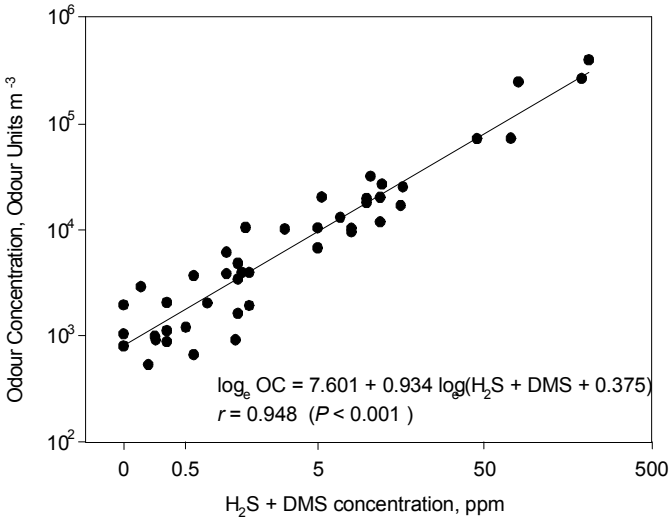

Figure. 1 *Relationship between the combined on-site hydrogen sulphide and dimethyl sulphide concentrations and the 24-h odour concentration of mushroom composting odour samples. Each point is the mean of two sample determinations.*

REFERENCE

Byun, H. G., Persaud, K. C., Khaffaf, S. M., Hobbs, P. J., Misselbrook, T. H. 1997. Application of unsupervised clustering methods to the assessment of malodour in agriculture using an array of conducting polymer odour sensors. Comput. Electron. Agr., 17: 233-247.

Derikx, P. L., Dencamp, H. O., Vanderdrift, C., Vangriensven, L. D., Vogels, G. D. 1990. Odorous sulfur-compounds emitted during production of compost used as a substrate in mushroom cultivation. Appl. Environ. Microb., 56: 176-180.

Dravneiks, A., Prokop, W.H., 1975. Source emission odour measurement by a dynamic forced choice triangle olfactometer. J. Air Pollut. Control Assurance. 25: 28-35.

Duns G.J, Ripley B.D, Rinker D.L 1997. The analysis of mushroom composting odours. Mushroom World 58-70.

Gardner, J. W., Shurmer, H. V., Tan, T. T. 1992. Application of an electronic nose to the discrimination of coffees. Sensor. Actuat. B-Chem., 6: 71-75.

Hobbs, P. J., Misselbrook, T. H., Pain, B. P. 1995. Assessment of odors from livestock wastes by a photoionization detector, an electronic nose, olfactometry and gas-chromatography mass-spectrometry. J. Agric. Eng. Res., 60: 137-144.

Miller, F. C., Macauley, B. J. 1988. Odors arising from mushroom composting - a review. Australian J. Exp. Agric., 28: 553-560.

Misselbrook, T. H., Hobbs, P. J., Persaud, K. C. 1997. Use of an electronic nose to measure odour concentration following application of cattle slurry to grassland. J. Agric. Eng. Res., 66: 213-220.

Noble, R., Gaze, R. H. 1994. Controlled environment composting for mushroom cultivation - substrates based on wheat and barley straw and deep litter poultry manure. J. Agric. Sci., 123: 71-79.

Persaud, K. C., Khaffaf, S. M., Hobbs, P. J., Sneath, R. W. 1996. Assessment of conducting polymer odor sensors for agricultural malodor measurements. Chem. Senses, 21: 495-505.