Comparison of the odour levels of biofiltered air and ambient farmyard air

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DeBruyn, J.C., Mann, D.D. and Zhang, Q. 2001. **Comparison of the odour levels of biofiltered air and ambient farmyard air**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **43**: 6.7-6.11. Two experimental biofilters were used to determine whether an airstream treated by a biofilter could be distinguished from ambient farmyard air. Odourous air (mean of 958 OU measured using olfactometry) from a nearby hog barn passed through the first biofilter, but "clean farmyard" air (mean of 34 OU) passed through the second biofilter. Six different biofilter media mixtures were formulated using three types of compost (yard-waste compost, grocery-waste compost, and poultry-manure compost) and three bulking agents (woodchips, hemp hurds, and unchopped wheat straw) blended in a 50%/50% mixture (by mass). Complete treatment of the airstream was achieved, based on outlet H_2S levels < 11 ppb, for mixtures containing yard-waste or grocery-waste compost combined with either woodchips or hemp hurds. Outlet odour concentrations ranged from 22 to 51 OU for the odourous-air biofilter and from 26 to 51 OU for the clean-air biofilter. Thus, the residual odour of an airstream following passage through a biofilter bed consisting of compost and a bulking agent cannot be distinguished from ambient farmyard odour using olfactometry. **Keywords**: biofilter, biofiltration, odour concentration, residual odour, olfactometry, ambient farmyard odour.

Deux biofiltres expérimentaux furent utilisés pour déterminer s'il était possible de distinguer l'air traité par un biofiltre, de l'air ambiant d'une cour de ferme. On fit circuler de l'air odorant (moyenne de 958 UO mesurées à l'aide d'un olfactomètre) d'une porcherie voisine à travers le premier biofiltre, alors que l'air "propre" de la cour de ferme (moyenne de 34 UO) passait dans le second biofiltre. Six mélanges différents de substrat furent fabriqués à partir de trois types de compost (résidus de cour de ferme, déchets d'épicerie et fumier de volailles) et de trois types de remplissage (copeaux de bois, étoupe de chanvre et paille de blé non-hachée), dans des proportions de 50%/50% (selon la masse). Pour des mélanges contenant des composts de résidus de cour de ferme ou des déchets d'épicerie, combinés avec des copeaux ou de l'étoupe de chanvre, le traitement de l'air fut complet, les taux de H_2S à la sortie étant inférieurs à 11 ppb. Les concentrations d'odeur à la sortie du biofiltre ayant servi à traiter l'air odorant allaient de 22 à 51 UO, alors qu'elles étaient de 26 à 51 UO à la sortie du biofiltre où circulait l'air propre. L'olfactométrie ne permet donc pas de distinguer l'odeur de l'air ayant passé au travers d'un biofiltre constitué de compost et de remplissage de celle de l'air ambiant d'une cour de ferme. **Mots-clés**: biofiltre, biofiltration, concentration d'odeur, odeur résiduelle, olfactométrie, air ambiant d'une cour de ferme.

INTRODUCTION

Low-cost, open-bed agricultural biofilters that use mature compost and woodchips as a filter medium have been shown to reduce odour emissions from swine production facilities with minimal management control (Nicolai and Janni 1999). DeBruyn (2000) operated four compost-woodchip biofilters on a Manitoba farm during the winter of 1999-2000. Despite conditions within the biofilters suitable for microbial activity, the average reduction in odour concentration was only 77%. Outlet odour concentrations ranged from 99 to 570 OU and, thus, were higher than expected based on previous research (Nicolai and Janni 1998, 1999). The biofilter outlet air had a distinct "earthy" or "musty" smell that the barn owner identified as being undesirable (DeBruyn 2000). This so-called "residual" odour is either the result of incomplete treatment of the airstream (i.e., incomplete removal of the barn odour) or the addition of a new odour to the airstream during passage through the biofilter medium. The objective of this research was to determine whether an airstream treated by biofiltration had a residual odour that was distinguishable from ambient farmyard air using olfactometry.

MATERIALS and METHODS

Location

Two experimental biofilters were constructed in May 2000 at the University of Manitoba, Glenlea Research Station near the swine unit (Fig. 1). Biofilter 1 (BF1) was constructed on the west side of a grower-finisher swine barn to treat the exhaust air from an operating ventilation exhaust fan. Biofilter 2 (BF2) was constructed on a gravel parking pad 5 m south of the same barn (away from any exhaust fans) so that "clean farmyard" air could be blown through the biofilter medium.

Biofilter media mixtures

Six different biofilter media mixtures (Table 1) were tested in separate biofilter cells. Each biofilter cell had a 50%/50% mixture (by mass) of a bulking agent and compost. The 50/50 mixture was selected because of better resistance to both drying and airflow short-circuiting than a 75/25 mixture (bulking agent to compost) (DeBruyn 2000). The six mixtures were as follows.

YWW Yard-waste compost mixed with woodchips. The yard-waste compost was obtained from the City of Winnipeg "Leaf It With Us" composting program (Shreds of plastic were present in the compost). The woodchips originated as debris wood (i.e., pine, spruce, fir, cedar, aspen, birch, willow, and alder) on Easter Lake in northern Manitoba. Woodchip length varied according to the following distribution (expressed as a percentage of total wet mass): < 64 mm (43%); 64-127 mm (29%); 127-191 mm (16%); 191-254 mm (6%); and > 254 mm (6%). All woodchips used in this research came from the same source.

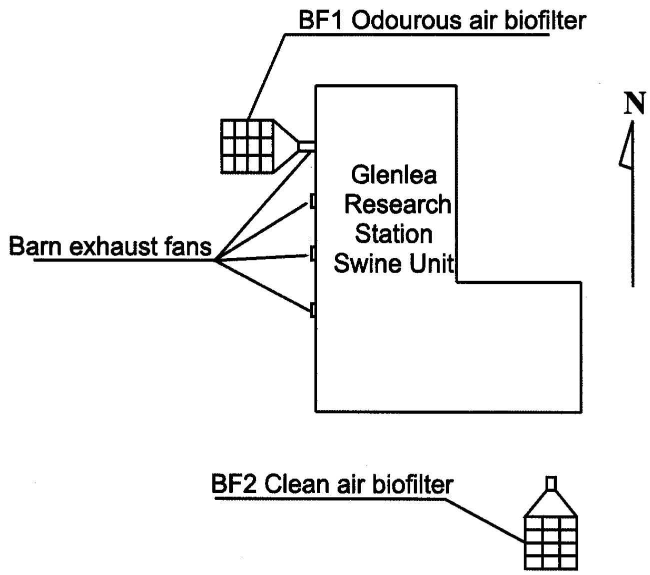

Fig. 1. Layout of the two experimental biofilters in relation to the swine unit at the University of Manitoba Glenlea Research Station.

GWW Grocery-waste compost mixed with woodchips. The grocery-waste compost was obtained from Rockwood Agribusiness, Stony Mountain, Manitoba and contained composted produce from local supermarkets.

PMW Poultry-manure compost mixed with woodchips. The poultry-waste compost was obtained from Milleni Egg, Dufrost, Manitoba.

GWH Grocery-waste compost mixed with hemp hurds. Hemp hurds are woody pieces from the centre of a hemp stalk. They are a by-product that remains following mechanical decortication of industrial hemp stalks.

GWS Grocery-waste compost mixed with unchopped wheat straw.

TS Topsoil mixed with unchopped wheat straw. The topsoil was obtained from a local garden centre.

Table 1. Compost and bulking agents used in the biofilter media mixtures.

Abbreviation	Type of compost	Type of bulking agent
YWW	Yard waste [1]	Woodchips [2]
GWW	Grocery waste [3]	Woodchips
PMW	Poultry manure [4]	Woodchips
GWH	Grocery waste	Hemp hurds [5]
GWS	Grocery waste	Straw [6]
TS	Topsoil [7]	Straw

[1] Leaf and garden waste compost containing shreds of plastic bags, from the City of Winnipeg, MB *Leaf It With Us* composting program.
[2] Woodchips chopped from mixed debris wood collected from a Northern Manitoba Lake. The chips consisted of wood from pine, spruce, fir, cedar, aspen, birch, willow, and alder trees.
[3] Grocery waste compost processed in turned windrows at Rockwood Agribusiness, Stony Mountain, MB.
[4] Poultry manure compost processed in turned windrows at Milleni Egg, Dufrost MB. The compost was not completely composted when used.
[5] Hemp hurds produced by mechanical decortication of industrial hemp stalks.
[6] Unchopped baled wheat straw.
[7] Topsoil was substituted for compost in one sample to determine whether commonly available materials could be used as a biofilter media material.

Biofilter cell construction

Each biofilter consisted of 12 cells (6 different media mixtures at 2 depths) constructed on an air plenum. The air plenum was designed to deliver appropriate airflow to each individual cell with the use of adjustable inlet gates (Fig. 2). Before covering with the biofilter medium, mesh netting was placed on top of the air plenum to prevent the biofilter medium from falling into the plenum. Each cell measured 0.9 m by 1.2 m and was separated from the other cells by plywood walls. The shallow cells had a depth of 0.35 m and the deep cells had a depth of 0.7 m (Fig. 2). Garden cloth was placed around the perimeter of each cell, 0.15 m below the surface of the biofilter medium to reduce short-circuiting of the airstream along the walls.

Airflow

Airflow rate is a critical factor in the design of a biofilter because airflow rate, depth of medium, and cross-sectional area determine the length of time that an airstream is in contact with the biofilter medium (Nicolai and Janni 1999). This is commonly referred to as "residence" time. The "true" residence time is defined as the total filter bed volume multiplied by the porosity of the filter medium, divided by the airflow rate (Devinny et al. 1999). Because the porosity of the filter medium is often unknown and changes over time due to compaction, residence time is often estimated by the "empty bed residence time" (EBRT). The EBRT is the biofilter volume divided by the airflow rate (Devinny et al. 1999). EBRT overestimates the true residence time.

Previous research (Nicolai and Janni 1999) concluded that a residence time of 5 s was sufficient to achieve 80% odour reduction from swine facilities. To achieve 90% odour reduction, a residence time of 7 s was required. Many of the previous researchers were interested in optimizing biofilter design; consequently, they were willing to sacrifice biofilter effectiveness (by reducing residence time) to prevent the need for excessive airflow rates.

For this research, we needed to ensure complete treatment of the airstream. It was hypothesized that H_2S concentration could be used as an indicator of complete treatment of the airstream by the biofilter. Yang and Allen (1994) observed 94% H_2S removal with a 7-s residence time in a compost biofilter, but the H_2S removal increased to 100% with a 23-s residence time. Thus, elevated H_2S levels in the outlet air indicate that the air is not being fully treated. For this research, residence times of 35 and 70 s were selected. It was assumed that residence times of 35 and 70 s would ensure total elimination of the H_2S (and all other odour-causing compounds) from the exhaust air. Thus, any

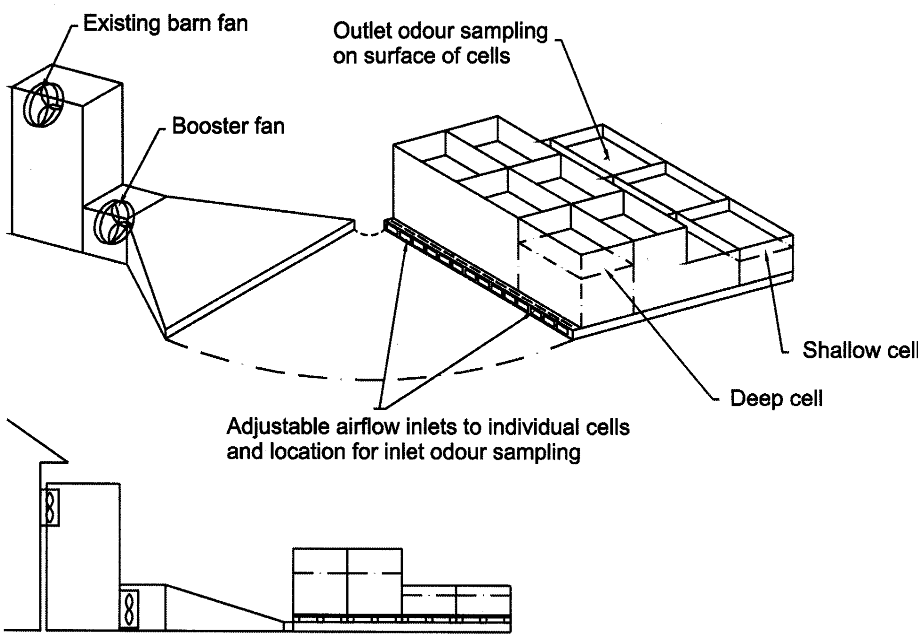

Fig. 2. Experimental biofilter configuration.

odour present at the biofilter outlet could be attributed to the biofilter medium.

For both biofilters, axial fans blew air through the biofilter beds. The surface loading rate was maintained at approximately 0.01 m/s in each cell, producing residence times of 35 and 70 s for the shallow and deep cells, respectively. Airflow was measured using a hotwire anemometer and a large funnel-like hood placed on the surface of the biofilter (Fig. 3). The hotwire anemometer was inserted into the pipe at a distance ten times the diameter of the pipe away from the pipe inlet to allow the development of laminar flow. Air velocity measurements taken in the pipe section were 100 times the surface airflow rate. Airflow was measured on the day prior to odour sampling. If necessary, the inlet gates (Fig. 2) were adjusted to correct the airflow. Airflow was re-measured immediately prior to the collection of odour samples.

Moisture application

Both biofilters were kept wet using garden sprinklers. The sprinklers were controlled using timers to apply water for 45 min at 0600h and again for 45 min at 2000h. Water application occurred twice daily to minimize the effect of short-circuiting of airflow due to dry-out along the plywood walls of the cells. Because the sprinkler pattern was greater than the surface area of the biofilter, the volume of water applied to each biofilter cell is not known.

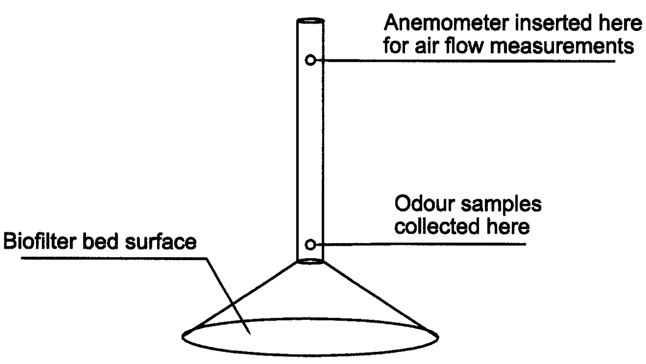

Fig. 3. Airflow sampling hood.

Odour measurement

Odour level reduction was measured by comparing the odour concentration of the air entering and leaving each biofilter cell. Odour concentration is measured by the dilution to detection threshold (or odour units, OU) which is the ratio of the volume of odour-free air required to dilute an odourous air sample so that only 50% of a group of human panellists is able to detect the odour (European Committee for Standardization 1999). The odour concentration was measured using a dynamic dilution olfactometer (AC'SCENT® International Olfactometer, St. Croix Sensory, Stillwater, MN). Odour samples were collected in 10 L Tedlar bags at the duct entering the biofilter and inside a collection hood (Fig. 3) placed on the surface of the biofilter cells (Fig 2). Odour samples were presented to six panellists within 24 h of collection. The first set of odour samples was collected four weeks after the biofilters became operational. Based on Nicolai and Janni (1998), this was sufficient time to ensure the development of a microbial community within the biofilter medium. Subsequent samples were collected every two weeks until the end of the eighth week of operation.

Hydrogen sulfide measurements

Hydrogen sulfide (H_2S) concentrations were measured from the air sample bags collected for odour measurements using a Jerome Meter (Jerome 631-X Hydrogen Sulfide Analyzer, Arizona Instrument Corporation, Phoenix, AZ). The Jerome Meter had a detecting limit of 1 ppb. As with the odour samples, H_2S concentrations were measured every two weeks.

RESULTS and DISCUSSION

Observed hydrogen sulfide

Based on measured H_2S levels, only three of the six types of biofilter media treated the odourous air completely (Table 2). The mixture containing the poultry-manure compost and both mixtures containing unchopped wheat straw had mean residual H_2S concentrations ranging from 32 to118 ppb compared with H_2S concentrations ranging from 6 to 9 ppb for the other three media mixtures. The detection threshold concentration for H_2S is 6 ppb (Lodge 1988). It can be concluded, therefore, that the odourous air was being fully treated by the three media mixtures which did not contain either poultry-manure compost or unchopped wheat straw.

Table 2. Hydrogen sulfide (H_2S) concentrations from the odourous-air biofilter.

Mixture	Location	Depth (m)	H_2S concentration (ppb)				
			Sampling week			Mean	SD
			4	6	8		
	Inlet		225	145	255	208	57
YWW	Outlet	0.70	6	9	2	6	4
GWW	Outlet	0.70	11	3	3	6	5
PMW	Outlet	0.70	112	235	6	118	115
GWH	Outlet	0.70	8	3	NA	6	4
GWS	Outlet	0.70	47	125	47	73	45
TS	Outlet	0.70	25	42	29	32	9
YWW	Outlet	0.35	15	6	3	8	6
GWW	Outlet	0.35	12	8	2	7	5
PMW	Outlet	0.35	26	6	74	35	35
GWH	Outlet	0.35	15	2	NA	9	9
GWS	Outlet	0.35	NA	NA	85	85	0
TS	Outlet	0.35	65	13	126	68	57

NA - Not available

Table 3. Hydrogen sulfide (H_2S) concentrations from the clean-air biofilter.

Mixture	Location	Depth (m)	H_2S concentration (ppb)				
			Sampling week			Mean	SD
			4	6	8		
	Inlet		4	6	2	4	2
YWW	Outlet	0.70	4	2	5	3	2
GWW	Outlet	0.70	13	21	1	11	10
GWH	Outlet	0.70	10	2	NA	6	6
YWW	Outlet	0.35	5	2	ND	2	3
GWW	Outlet	0.35	7	6	ND	4	4
GWH	Outlet	0.35	1	2	NA	1	1

NA - Not available
ND - Not detected

Table 4. Odour concentrations for the odourous-air biofilter.

Mixture	Location	Depth (m)	Odour concentration (OU)					Mean odour reduction (%)
			Sampling week			Mean	SD	
			4	6	8			
	Inlet		1166	923	784	958	193	
YWW	Outlet	0.70	15	39	26	27	12	97
GWW	Outlet	0.70	49	16	20	28	18	97
GWH	Outlet	0.70	NA	20	26	23	4	97
YWW	Outlet	0.35	16	35	56	36	20	96
GWW	Outlet	0.35	35	96	21	51	40	95
GWH	Outlet	0.35	NA	28	16	22	8	97

NA - Not available

Because complete treatment of the air was required, the PMW, GWS, and TS mixtures (Table 2) were eliminated from further analysis. Using only the remaining mixtures (i.e., YWW, GWW, and GWH), the mean inlet (i.e., ambient) and outlet H_2S levels for the clean-air biofilter were 4 and 5 ppb, respectively (Table 3).

It is not known why the mixture containing poultry-manure compost was not effective at reducing H_2S concentration. It is speculated that the poultry-manure compost may not have been as "mature" as the other two types of compost that were used. For the mixtures containing unchopped straw, the problem was more obvious. These mixtures readily dried out forming air channels through the biofilter medium (i.e., short-circuiting). When short-circuiting occurred, some of the odourous air passed through the filter bed without sufficient contact with the filter medium. The straw mixtures were also plagued by rapid growth of grasses on the biofilter surface which may have contributed to clogging of pore spaces. Based on these observations, unchopped straw is not a suitable component for biofilter medium.

Odour concentration

The inlet air to the odourous-air biofilter had a mean odour concentration of 958 OU with a standard deviation of 193 OU over the three sampling periods (Table 4). After flowing through the biofilter cells, the mean odour concentration ranged between 22 and 51 OU for both the shallow and deep cells (Table 4).

The inlet air to the clean-air biofilter had a mean odour concentration of 34 OU with a standard deviation of 9 OU over the three sampling periods (Table 5). After flowing through the biofilter cells, the mean concentration ranged from 26 to 51 OU for both the shallow and deep cells (Table 5). Although the air appeared to become more odourous as it passed through the biofilter cells, the differences between inlet and outlet odour concentrations were not significant ($p < 0.05$).

Thus, at high residence times, the outlet air from a compost-woodchip biofilter was not distinguishable from ambient farmyard air using olfactometry. There is no apparent difference between compost originating from yard waste or grocery waste, or between woodchips or hemp hurds as a bulking agent.

Table 5. Odour concentrations for the clean-air biofilter.

Mixture	Location	Depth (m)	Odour concentration (OU)					Mean odour reduction (%)
			Sampling week			Mean	SD	
			4	6	8			
	Inlet		44	30	28	34	9	
YWW	Outlet	0.70	18	32	28	26	7	24
GWW	Outlet	0.70	55	45	20	40	18	-18
GWH	Outlet	0.70	NA	51	20	36	22	-6
YWW	Outlet	0.35	44	30	16	30	14	12
GWW	Outlet	0.35	49	51	20	40	17	-16
GWH	Outlet	0.35	NA	32	69	51	26	-50

NA - Not available

CONCLUSIONS

When complete treatment of an odourous airstream (mean inlet odour concentration of 958 OU) was achieved (based on mean outlet H_2S levels < 9 ppb), the outlet odour concentrations ranged from 22 to 51 OU. Passage of ambient farmyard air (mean inlet odour concentration of 34 OU) through a compost-woodchip biofilter resulted in outlet odour concentrations ranging from 26 to 51 OU. There is no evidence to indicate that air treated by a biofilter consisting of mature compost and either woodchips or hemp hurds has a residual odour that is distinguishable from ambient farmyard air using olfactometry.

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