COUPLING COMPOSTING AND BIOFILTRATION FOR AMMONIA AND VOLATILE ORGANIC COMPOUNDS REMOVAL

E. Pagans, X. Font, A. Sánchez
Escola Universitària Politècnica del Medi Ambient (Universitat Autònoma de Barcelona), Rbla. Pompeu Fabra 1, 08100-Mollet del Vallès (Barcelona), Spain. asanchez@eupma.uab.es

ABSTRACT

In this study, the efficiency of a compost biofilter for the removal of ammonia and volatile organic compounds (VOCs) from the exhaust gases of the composting process is studied. Average ammonia removal efficiency of 93.6% was obtained in the biofilter for an average loading rate range of 20-1252 g $NH_3 \cdot m^{-3}$ biofilter$\cdot d^{-1}$. However, a sharp reduction in NH_3-removal was observed when the waste gas contained high (more than 2000 $mg \cdot m^{-3}$) NH_3 concentration. Removal efficiency of 97.0% was achieved for an average loading rate of 921 g $C \cdot m^{-3}$ biofilter$\cdot d^{-1}$.
Keywords: *biofiltration, ammonia, VOCs, composting.*

INTRODUCCION

At present, bad odour and atmospheric pollution are the most common problems associated with composting process. The problem of gaseous emissions can be approached from several points of view: occupational health and safety, olfactory nuisance, and atmospheric impact (Sironi and Botta, 2001). Ammonia has received much attention as it can be easily identified from other composting odours, and can be released in large quantities. Ammonia is produced from either the aerobic or anaerobic decomposition of proteins and amino acids. Other malodorous pollutants found in off-gases from solid wastes treatment facilities are volatile organic compounds (VOCs). According to Eitzer (1995), most VOCs in aerobic composting plants are emitted at the early stages of process *i.e.* at the tipping floors, at the shredder and in the initial active composting area.

Biofiltration has been used successfully in odour control and for the elimination of organic and inorganic pollutants in air from stationary sources (Ortiz et al., 2002). It is considered a clean technology, with low capital and operating cost, low energy requirements, and an absence of residual products requiring further treatment or disposal (Singh et al., 2002). The process is based on passing a contaminated stream through a microbial biofilm immobilized on a porous support. The pollutants diffuse from the gas into the thin layer of biofilm attached to the support media and are metabolized. The end products of the complete biodegradation are CO_2, water and microbial biomass (Cox and Deshusses, 2000).

The quality of the filter media has been reported as one of the key factors in biofilter performance. Compost-based media have been extensively used in recent years because they are cheap and have several microbial communities capable of degrading various pollutants.

This research studies the efficiency of a compost biofilter for the removal of ammonia and volatile organic compounds (VOCs) from the exhaust gases of the composting of source-selected organic fraction of municipal solid wastes (OFMSW), digested wastewater sludge (DS) and animal by-products (AP).

MATERIALS AND METHODS

Source-selected organic fraction of municipal solid wastes, digested wastewater sludge and animal by-products were composted in a 30-L laboratory reactor equipped with forced aeration. All wastes were mixed with bulking agents to ensure an optimal porosity. The aeration rate (5 $L \cdot min^{-1}$) was supplied intermittently to control the content of oxygen in the composting material. The experiments were conducted continuously for about 20 days.

The exhaust gas from composting was passed through a pilot-scale-biofilter filled with mature compost. The biofilter dimensions were: diameter: 0.2 m, height: 0.23 m, resulting in a total bed volume of 7.2 L and a gas retention time of 86 s.

Inlet and outlet concentrations of ammonia and VOCs from biofilter were analysed periodically. Ammonia emissions were measured online by an electrochemical gas sensor (Bionics Instrument Co, Tokyo, Japan). VOCs (expressed as total C) were sampled using a gas-tight syringe and immediately analyzed using a Gas Chromatograph equipped with a FID detector.

Periodic measurements of temperature and pressure drop of biofilter were carried out. The packing material was sampled in order to determine moisture content (MC), organic matter content (OM), respirometric index (RI), NH_4^+-N, pH and electrical conductivity (El. Cond.) according to the standards methods (TMECC, 2001).

RESULTS AND DISCUSSION

Properties of the compost material before and after filtering operation are shown in Table 1. The OM decreased as the effluent gas from the composting reactor was biofiltered, while the MC and NH_4^+-N increased by absorbing moisture and ammonia included in exhaust gas. The value of pH and electrical conductivity did not change significantly. The biological activity (measured as RI) slightly increased throughout the biofiltration process.

***Table 1**. Changes in properties of biofilter compost before and after biofiltration process.*

	MC (% wb)	OM (% db)	pH	El. Cond. ($mS \cdot cm^{-1}$)	NH_4^+-N (% db)	RI (mg $O_2 \cdot g$ $OM^{-1} \cdot h^{-1}$)
Initial	40.40	59.69	8.70	3.33	0.33	1.03
Final	60.80	48.57	8.98	3.95	0.93	1.82

wb: wet basis; db: dry basis.

The composting temperatures for all experiments are presented in Figure 1. The maximum temperature for the OFMSW, DS and AP were 52 ºC, 61 ºC and 66 ºC respectively.

Figure 1 describes the variation of ammonia and VOCs concentration in the inlet and outlet gas stream of biofilter and the resulting removal efficiencies (RE) for the three wastes composted.

The ammonia inlet concentration ranges from 16 to 36 mg $NH_3 \cdot m^{-3}$, 10 to 650 mg$NH_3 \cdot m^{-3}$ and 60 to 3150 mg $NH_3 \cdot m^{-3}$ for OFMSW, DS and AP respectively. The exhaust gas from biofilter ranges from 0 to 12 mg $NH_3 \cdot m^{-3}$, 0 to 17 mg $NH_3 \cdot m^{-3}$ and 30 to 590 mg $NH_3 \cdot m^{-3}$ for OFMSW, DS and AP respectively.

The highest value of ammonia concentration always occurred when the composting temperature was high showing an intimate relationship between the composting temperature and ammonia emissions.

No delay or start-up phase in the biofilter was observed for the removal of ammonia, probably due to the high ammonia absorption capacity of the compost media. However, for AP from day 3 on, the NH_3 removal in biofilter decreased (Table 2). This phenomenon may be explained because compost biofilter achieves the maximum ammonia absorption capacity, and the microbial activity is inhibited by waste gases containing high NH_3 concentrations (>2000 mg·m^{-3}). According to Hartikainen et al. (1996), due to toxification the biofilter removal efficiency for NH_3 was reported to drop drastically at a waste gas concentration level exceeding 45-50 mg·m^{-3}.

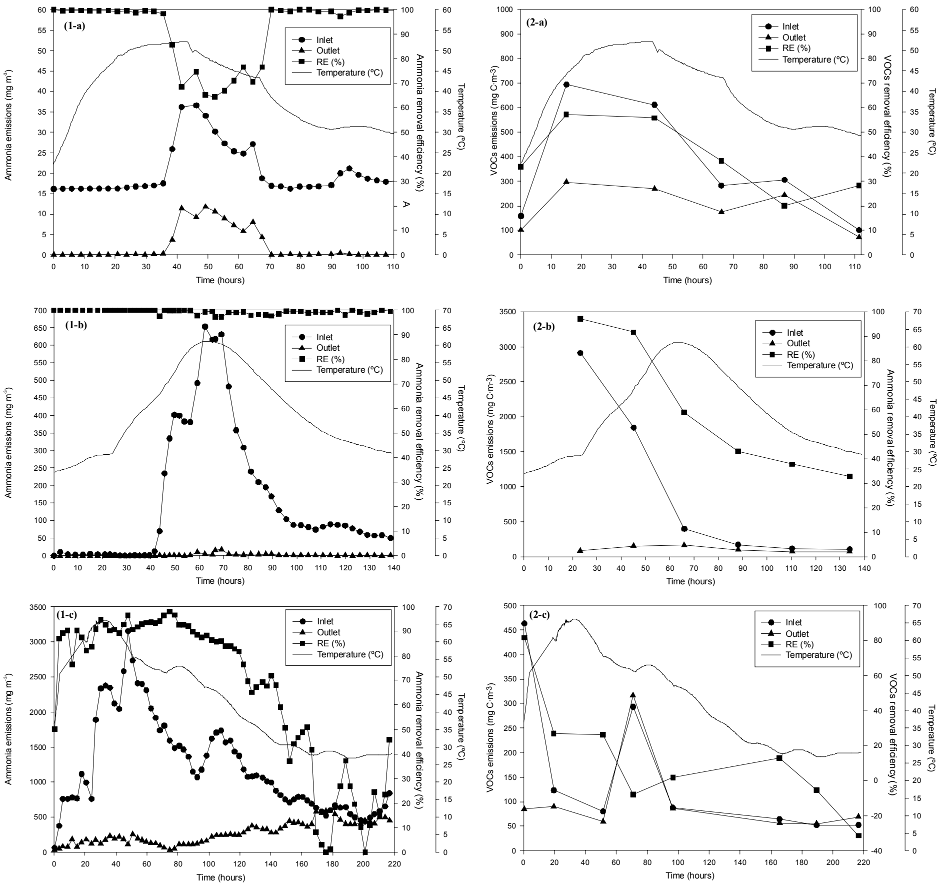

Figure 1. Ammonia (1) and VOCs (2) emissions in inlet and outlet gas streams of biofilter, removal efficiency and temperature of composting process of source-selected organic fraction of municipal solids wastes (a), digested wastewater sludge (b) and animal by-products (c).

In relation to VOCs, inlet concentration ranges from 100 to 694.6 mg C·m^{-3}, 106 to 2909.5 mg C·m^{-3} and 52.3 to 463.4 mg C·m^{-3} for OFMSW, DS and AP respectively. The exhaust gas from biofilter ranges from 72.5 to 296.4 mg C·m^{-3}, 71.2 to 163.5 mg C·m^{-3} and 55 to 317.2 mg C·m^{-3} for OFMSW, DS and AP respectively.

VOCs reduction found at the initial stages of composting process is higher despite VOCs emissions are also high (Table 2). For all experiments from day 3 on, the VOCs concentration before and after filtration tend to be similar. This could be due to VOCs emissions from the biofilter itself.

During the course of the experiments, biofilter operated at a temperature in the range of 21 to 26 ºC and the pressure drop exhibited a small increase (5 mm H_2O) due to the gradual compaction of the packing material.

***Table 2**. Loading rate, elimination capacity and the resulting removal efficiencies for ammonia and VOCs obtained for the three wastes composted.*

	Ammonia			VOCs		
	LR	**EC**	**RE**	**LR**	**EC**	**RE**
OFMSW	20.3	18	92.2	357.8	165.2	20 - 57.3
DS	169.9	168.1	99.4	921.1	814.2	32.8 - 97
AP (day 0-3)	1252.2	1151.5	89.2	151.8	55.2	-31 - 81.7
(day 3-9)	711.1	461	53.7			

LR:Loading rate (g NH_3 or $C \cdot m^{-3}$ biofilter$\cdot d^{-1}$); EC:Elimination capacity (g NH_3 or $C \cdot m^{-3}$ biofilter$\cdot d^{-1}$); RE:Removal efficiency (%).

CONCLUSIONS

According to these results, biofiltration technology using compost as biofilter media can effectively remove part of the ammonia and VOCs contents from the composting process of source-selected organic fraction of municipal solids wastes, digested wastewater sludge and animal by-products.

The maximum levels of ammonia in exhaust gases corresponded to the thermophilic range of temperature (60-70ºC). No start-up phase in the biofilter was observed for the removal of ammonia probably due to the high ammonia absorption capacity of the compost media.

Better VOCs reduction was found at the initial stages of composting process although VOCs emissions reached a maximum value. The removal rate showed negative value probably due to the release of VOCs from the compost biofilter.

Acknowledgements. The authors wish to thank the financial support provided by the Spanish Ministerio de Ciencia y Tecnología (Project REN2003-00823).

REFERENCES

Cox, H.I., Deshusses, M.A. 2000. Innovative experimental setup for the parallel operation of multiple bench scale biotrickling filters for waste treatment. Environ. Technol., 21: 427-435.

Eitzer, B.D. 1995. Emissions of volatile organic chemicals from municipal solid waste composting facilities. Environ. Sci. Technol., 29: 896-902.

Hartikainen, T., Ruuskanen, J., Vanhatalo, M., Martikainen, P. 1996. Removal of ammonia from air by a peat biofilter. Environ. Technol., 17: 45-53.

Ortiz, I., Revah, S., Auria, R. 2002. Effects of packing material on the biofiltration of benzene, toluene and xylene vapours. Environ. Technol., 24: 265-275.

Singh, H., Sanders, D.A., Veenstra, J.N. 2002. Biofiltration of airstreams contaminated with MTBE. Remediation J., 12: 81-96.

Sironi, S., Botta, D. 2001. Biofilter efficiency in odor abatement at composting plants. Compost Sci. Util., 9: 149-155.

US Composting Council Research and Education, U. S. D. of Agriculture. 2001. Test Methods for the Examination of Composting and Compost - TMECC.