PERFORMANCE CHARACTERIZATION OF A FULL-SCALE BIOFILTER AT AN ORGANIC WASTE TREATMENT PLANT

O. Díaz[1], X. Gamisans[2], D. Gabriel[1], J. Lafuente[1]
[1]Department of Chemical Engineering, Universitat Autònoma de Barcelona, Edifici C, 08193 Bellaterra, Barcelona, Spain. david.gabriel@uab.es
[2]Department of Mining Engineering and Natural Resources, Universitat Politècnica de Catalunya, Bases de Manresa 61-73, 08240 Manresa, Spain

ABSTRACT

Data from the regular monitoring of a full-scale biofilter at a municipal solid waste treatment facility for the integral treatment of domestic residues was analyzed in order to assess potential operational problems and to evaluate reactor's performance in terms of ammonia removal, the target odorous compound at the facility. Performance was assessed based on ammonia removal efficiency and elimination capacity. Average elimination capacities up to 1,6 g NH_3 m^{-3} h^{-1} at average inlet loads of 2,1 g NH_3 m^{-3} h^{-1} were found, which correspond to a low-loaded biofilter type. Year-round data collected and packing material analysis revealed a marked effect of water content in the packed bed of the biofilter which lead to reduced removal efficiencies.

INTRODUCTION

Municipal solid waste composting facilities (MSWCFs) are facilities for the integral treatment of domestic residues. Since people is not very concerned about selective collection, activities at these facilities include separation of received material and composting of the organic fraction from domestic waste, which are known as odour emitting activities. Odour compounds in MSWCFs mainly originate from decomposition of organic waste since the arrival of the waste to the facility until its separation and aerobic decomposition of composting. Amongst others, volatile organic compounds (VOCs), ammonia and hydrogen sulfide are produced during the composting process, which are noticed as annoying odours.

Biofiltration is an inexpensive and effective gaseous waste treatment method based on the ability of some microorganisms to degrade mainly malodorant compounds, under aerobic conditions, into biomass and mineral end-products (Dicks and Ottengraf, 1991). In a biological filter, the waste gas is forced through a layer of biologically active packing with a relatively high specific area. A water phase is then entrapped in the packing material (Devinny et al., 1999).

The aim of this research was to assess the performance of a full-scale biofilter designed to treat 345000 m^3/h of foul air from different areas of a completely covered municipal solid waste treatment facility. Performance parameters such as removal efficiency and elimination capacity over more than a year of operation are discussed coupled with some findings such as packing bed drying and probable nitrogen accumulation in the biofilter.

MATERIALS AND METHODS

Full-scale biofilter characteristics and biofilter monitoring plan

As shown in Figure 1, the MSWCF where the biofilter is located is divided in areas for raw materials processing, areas for organic waste treatment such as composting tunnels and anaerobic digesters, and areas for by-products treatment in a wastewater treatment plant and a biofilter. It should be noted that foul air from a total of 38 composting tunnels is first passed through an acidic chemical scrubber for ammonia absorption and then mixed with the air coming from all covered areas of the facility before entering the biofilter. Before the biofilter a humidifier raises air humidity up to 95-100% RH.

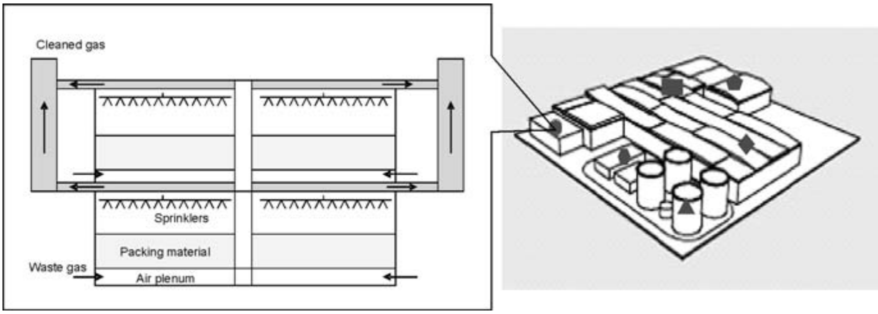

Figure 1. Front view of the biofilter and schematic of the overall facility: waste material reception and selection area (◆), anaerobic digesters (▲), composting tunnels (■), biofilter (●), compost storage area (⬟), wastewater treatment plant (⬢)

The biofilter is compartmentalized in four identical modules (Figure 1 callout) with a surface area of 625 m^2 each and a 21 m long and 30 m wide footprint. Each level is divided in two modules with independent waste air and clean air plenums. Design and recommended operational parameters are shown in Table 1.

***Table 1**. Design parameters for the biofilter and maximum and minimum operational parameters recommended by the biofilter maker.*

Design Parameters		Operational Parameters	
Surface (m^2)	2700	Air Relative Humidity (%)	95-100
Packed bed volume (m^3)	4050	Packing material humidity (%)	50-70
Gas velocity (m/h)	128	Temperature (ºC)	15-40
Gas flow rate (m^3/h)	345000	Pressure drop (Pa)	350-1000
Watering flow rate (m^3/d)	100-160	pH	6-9

A set of 20 sprinklers per module placed on the biofilter roof are used for humidification of the packing material. Watering is performed once a day for a period of 30 minutes at a flow rate of around 33 m^3/d per module. The packed bed has a first layer of around 25-30 cm height made of roots for proper air distribution and a second layer of 80-85 cm height made of coconut fiber as biological packing support. Notice in Table 1 that the design volume corresponded to a total height of 1,5 m but the height of the packed bed at the time of the study was noticeably lower probably due to coconut fiber compression.

A regular monitoring plan and operational testing was carried out in the biofilter in order to assess operation. Monitoring of the biofilter operation focused on NH_3 as the target pollutant. The lower right module in Figure 1, namely module 4, was chosen as representative of the whole biofilter for monitoring biofilter performance. Leacheate data was collected from a leacheate collection pipe. Measurements were performed once a week for inlet and outlet gas samples, while leacheate measurements were performed on a monthly basis. Foul airflow rate was periodically measured using a Pitot tube into the inlet duct of the biofilter. Ammonia and H_2S measurements were made with a portable Dräger MiniWarn meter. RH and temperature were measured with a Testo 400 portable hygrometer. Ammonium, nitrite, nitrate in samples collected in the leacheate were analyzed by an outside certified lab. pH was determined in the facility lab with a CRISON 507 pH meter.

RESULTS AND DISCUSSION

The full-scale biofilter was monitored for more than a year, starting January 2003, in order to fully cover seasonal effects such as temperature. In order to this, three clear periods were encountered along the monitored period (Figure 2). Firstly, a 150 days period (period I) with a low temperature of the inlet waste gas and marked fluctuations in the inlet and outlet RH. Secondly, period II showed a progressive raise in the off-gases temperature fed to the biofilter, which took place around day 150 until day 310 coincident with the hottest months of the year. In spite of some RH fluctuations until day 180, inlet airflow was maintained close to water saturation thereafter. Thirdly, named period III, the temperature of the inlet gas progressively decreased to a value of around 20ºC, a similar value on average to the corresponding to period I. Notice in Figure 2 that the outlet relative humidity (RH) was markedly below the inlet RH after day 180, consistent with a lower temperature measured at the outlet of the biofilter, thus indicating higher water requirements in the packing material during periods II and III.

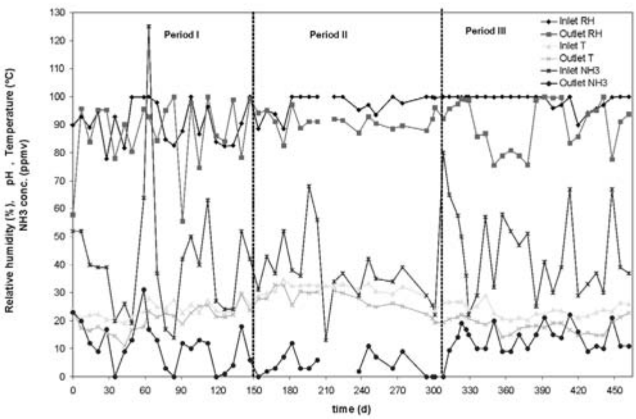

***Figure 2**. Evolution of inlet and outlet relative humidity, temperature, pH and ammonia concentration along the monitored period*

Inlet NH_3 concentration fluctuated during normal operation in the range of 13 to 80 ppm_v. On average, inlet ammonia concentration was 41±17 ppm_v for the monitored period. Outlet NH_3 concentration followed the same inlet pattern with average outlet ammonia discharge of 10±7 ppm_v. Although the discharge limit is not regulated, a value of 20 ppm_v averaged for 8 hours was established by the facility for ammonia concentration exiting the biofilter. H_2S levels found were markedly low, with an average inlet concentration along the monitored period of 2 ppm_v. Consequently, local acidification of the media by H_2S degradation is not probable. No control system was used to maintain the pH to *c.a.* 8.

It should be noted that measured outlet NH_3 concentrations in period III were notably higher compared to those in periods I and II even though the inlet loads were similar. Higher removal efficiencies were found in period II (89% on average) compared to period I (74% on average) and III (64% on average) probably due to the higher temperature in the biofilter which increased biological activity in the packing material.

A significant decrease in RE and EC were found in period III even when the volumetric load to the reactor, was kept almost constant along the monitored period. According to the results and plant personnel observations around days 150-180 in Figure 2, it was found that some parts of the surface of the packing material were not completely wetted because of a reduced pressure available in the spraying system, which caused a decrease in the area showed by the sprinklers. This is consistent with the increased water demand in period III according to RH data (Figure 2). Dried zones in biofilters have been reported to cause short-circuiting and in consequence reduced elimination efficiencies (Devinny et al., 1999).

In consequence, three samples of packing material were withdrawn from two zones of module 4 of the biofilter and analyzed for water content and water holding capacity according to Test Methods for the Examination of Composting and Compost (1995). One sample was withdrawn from the surface of a dry area that was not well sprinkled. Two other samples were withdrawn from a wet zone, one from the surface of the packing material and the other from a depth of about 50 cm. Results in figure 3 certify dry out of the packing material in the sampled area and that the drier the coconut fibre is the less water holding capacity has. In consequence, it is crucial to avoid dry out of the material, mainly because the lack of humidity implies a decrease of the microbiological activity and possible short-circuiting

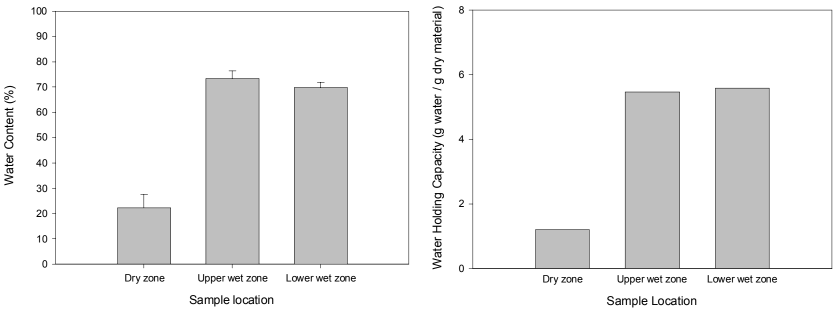

***Figure 3**. Water content and water holding capacity of packing material samples.*

The results discussed herein demonstrate the performance and capabilities of a biofilter in terms of ammonia removal. Full-scale biofilter monitoring revealed that proper watering of the packed bed is essential to preserve biofilter activity; otherwise reduced efficiencies and elimination capacities are likely to occur. According to the data, main parameters that influenced ammonia removal were temperature and, in special, watering and water content in the packing material. Activities towards maintenance and appropriate functioning of watering systems must be warranted.

REFERENCES

APHA. 1995. Standard Methods for the Examination of Water and Wastewater. 19th edition, American Public Health Association, Washington DC (US).

Chung Y., Huang C., Tseng C., Pan, J.R.v. 2000. Biotreatment of H_2S- and NH_3- containing waste gases by co-immobilized cells biofilter. Chemosphere., 41: 329-336.

Devinny, J. S., Deshusses, M. A., Webster, T. S. 1999. Biofiltration for Air Pollution Control. Lewis, Boca Raton, FL (US).

Dicks, R.M., Ottengraf, S.P.P. 1991. Process Engineering Aspects of Biological Waste Gas Purification. *Proceedings of the. International Symposium on Enviromental Biotechnology*, Ostende (B), 1991, pp 353-368.

U.S. Composting Council. 1995. In P.B. Leege and W.H. Thompson (ed.) *Test methods for the examination of composting and compost*. USCC, Bethesda, MD (US).