Performance of a Biofilter for Odor Removal during Manure Composting

K. J. Park, J. H. Hong, M. H. Choi

Abstract: Odor generated during composting of livestock manure is mainly due to ammonia emission. Biofiltration is a desirable method to control composting odor. This study was conducted to analyze the efficiency of using fresh compost as a biofilter. A mixture of cattle manure and recycled compost was composted in a bin equipped with a suction-type blower. The exhaust gas was filtered through the fresh compost. Residence time was controlled by the flow rate of exhaust gas and the depth of filtering materials. At the aeration rate of 30 L/min(experiment I), ammonia reduction rate varied from 100% to −15% for biofilter A(residence time 56.5 s) and almost 100% for biofilter B(residence time 113 s). At the aeration rate of 30 L/min, the cumulative ammonia reduction rate was 80.5% for biofilter A and 99.9% for biofilter B. At the aeration rate of 50 L/min(experiment II), the lowest reduction rate showed a negative value of -350% on the 8th and 9th day for biofilter A(residence time 33.9 s), and 50% on the 10th day for biofilter B(residence time 67.8s). At the aeration rate of 50 L/min, the cumulative ammonia reduction rate was 82.5% for biofilter A and 97.4% for biofilter B. Filtering efficiency was influenced by residence time. The moisture content(MC) and total nitrogen(T-N) of the filtering material were increased by absorbing moisture and ammonia included in the exhaust gas, while pH was decreased and total carbon(T-C) remained unchanged during the filtering operation.
Keywords: Biofiltration, Ammonia Emission, Fresh Compost, Odor

Introduction

Organic composting facilities in Korea produce compost using cattle manure, food waste, sewage sludge and fish disposal products. The odor generated from the composting facilities usually brings complaints from the people who live near the factory. Ammonia generated during the composting process causes the most significant odor problem.

For successful composting, it is necessary to control the odor generated during the process. Composting is a process which converts the odorous organic materials into an odorless compost. The odor generated during composting can be eliminated by various methods such as water flushing, burning, chemicals, air dilution, and biofiltering. Biofiltering is a desirable method in terms of waste recycling, filtering effect and, construction and operating cost(Lang and Jager, 1992). Materials that may be used in biofiltering are soil, rock wool, peat moss, and compost. In this experiment, fresh compost was used as a biofilter to reduce the ammonia emission while curing the compost(Hong et al, 1997).

Biofilter has two principal elements: the porous media through which contaminated air passes, and the air distribution system. The flow rate of air, depth of the biofilter, and porosity of the biofilter determine the residence time of air in the filter. Recommended residence time is typically from 30 to 60 seconds and moisture content is in the range of 40~60% for decomposition of volatile organic compounds(VOC) generated during composting (Toffney, 1997). Optimal physical characteristics of a filter material include pH between 7 and 8, air-filled pore space between 40% and 80%, and organic matter content of 35% to 55% for the treatment of odorous gases collected from composting(Todd and Miller, 1992; Tim et al., 1993).

The objective of this research is to analyze the

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efficiency of using the fresh compost as a biofilter and to give the fundamental data required for the design of a biofiltering system.

Materials and Procedures

1. Experimental Materials

A pilot scale bin composting system was made as shown in Fig. 1 to compost a cattle manure mixture, while filtering the exhaust gas with fresh compost. A suction-type blower draws the air through the compost mass from the eight holes of the reactor sidewalls and discharges the exhaust gas to the filter system. The composting bin(200L) was insulated with polystyrene to prevent the composting heat from escaping to the outside. The biofilters were made using a pipe(diameter 0.3 m) to make a closed space. A perforated steel grate formed a plenum at the reactor and the biofilter base to distribute the air uniformly.

A personal computer and 21X data logger system (Campbell Scientific Inc.) were used to monitor and record the temperatures. A K type thermocouple was used to measure the temperature of the compost and an HMP 35C sensor was used for the ambient temperature measurement. All the values were measured and recorded on the memory of the data logger at one-hour intervals.

Physicochemical properties - pH, moisture content (MC), total carbon(T-C), total nitrogen(T-N), C/N and ash content - of fresh compost were analyzed before and after filtration. The above parameters were analyzed according to a standard method for soil chemical properties(R.D.A, 1988).

2. Experimental Procedures

Composting experiments were conducted from September 9 to 18, 1999 for experiment I and from October 14 to 23, 1999 for experiment II, respectively.

Cattle manure and fresh compost mixtures were composted in a bin composting reactor for experiment I and II. Air was supplied to the compost by a suction-type blower having maximum flow rate of 80 L/min. Aeration rate was controlled by the flow control valve and air return pipe as shown in Fig. 1. Preliminary experiment was carried out to make fresh compost using the mixtures of cattle manure and rice hulls in similar manner as the experiment I and II. Fresh compost produced from the preliminary experiment was used as the composting materials and

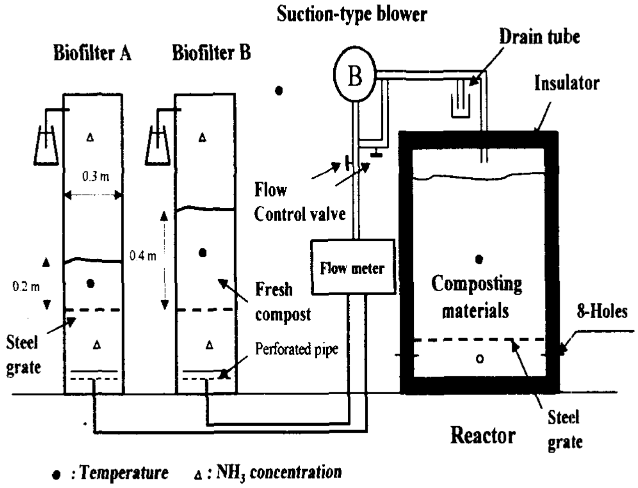


Fig. 1 General layout of experimental apparatus.

the biofilter in experiment I and the fresh compost from experiment I was used as the composting materials and the biofilter in experiment II.

For experiment I, composting was done with a continuous aeration rate of 30 L/min. When the composting temperature decreased abruptly at the initial stage, aeration was stopped once during one hour to avoid the cooling effect of aeration. For experiment II, continuous aeration with a aeration rate of 50 L/min was supplied except for two stopping periods at the initial stage of the first two days. However, from the 3rd day onward, aeration of 50 L/min was supplied intermittently for one hour twice a day with a 12 hour interval to control the composting temperature.

The biofiltration test was conducted for two levels of filter depth, 0.2 m(Biofilter A) and 0.4 m(Biofilter B). The residence time was calculated from the filter depth and the flow rate as shown in Table 1. Ammonia concentrations at the inlet and outlet of the biofilter were measured with a gas detector(GASTEC No. 3) once a day. For experiment II, ammonia concentration was measured after the blower had been running for one hour.

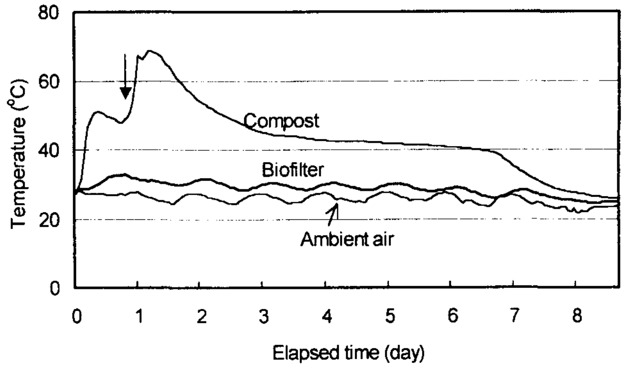
Ammonia concentration in ppm was converted to the ammonia emission in units of mg/h using the following formula.

$$NH_3(mg/h) = NH_3(ppm) \times \frac{17g}{mole} \times \frac{mole}{22.4L} \times \text{Sampling flow rate(L/h)} \times \frac{1}{1000}$$

Table 1 Residence time for each treatment

Test conditions	Residence time (s)
Flow rate of 30 L/min	
Biofilter A	56.5
Biofilter B	113.0
Flow rate of 50 L/min	
Biofilter A	33.9
Biofilter B	67.8

Notes : The biofitler A and B have the medium depth of 0.2 m and 0.4 m, respectively.



↓ : Arrow position means the stoppage of blower operation for one hour.

Fig. 2 Temperature variations of ambient air, compost and biofilter for the experiment I.

Results and Discussion

Physicochemical properties of the fresh compost materials before and after filtering operation are shown in Table 2. The values are the averages from two samples. While the pH decreased during filtering operation, MC and T-N increased by absorbing moisture and ammonia included in exhaust gas. T-C and ash content did not change during the filtering operation.

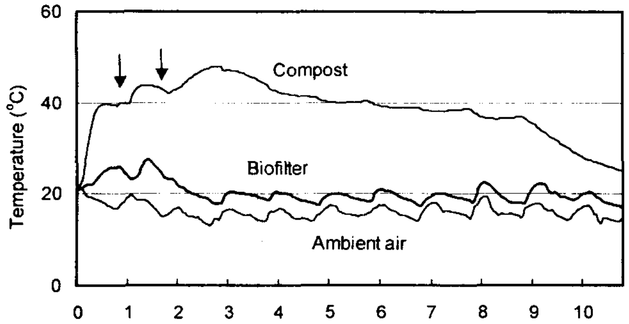
Temperatures of the ambient air, compost and biofilter for experiment I are presented in Fig. 2. At the initial stage of experiment I, the composting temperature was controlled by stopping the blower when the temperature dropped due to the cooling effect. Composting temperature for experiment I rose up 68.6℃ on the 2nd day and stayed above 40℃ for the next 6 days. Biofilter temperatures varied according to the ambient air temperatures. The average temperatures of the ambient air and the biofilter over the course of the experiment were 25.7℃ and 28.8℃, respectively, showing a difference of 3.1℃.

Temperatures of the ambient air, compost and biofilter for experiment II are presented in Fig. 3. For experiment II, the composting temperature varied between 40℃ and 50℃ for the first six days. The average temperatures of the ambient air and biofilter over the course of the experiment were 16.2℃ and 20.3℃, showing a difference of 4.1℃.

Fig. 4 represents the instantaneous(a) and cumulative(b) values of ammonia emission for the two biofilters A and B in experiment I with a aeration rate of 30 L/min. Ammonia emission of exhaust gas before filtering varied from 0 to 683 mg/h during the composting period. After filtering, ammonia emission dropped to 0-157 mg/h for biofilter A(residence time;

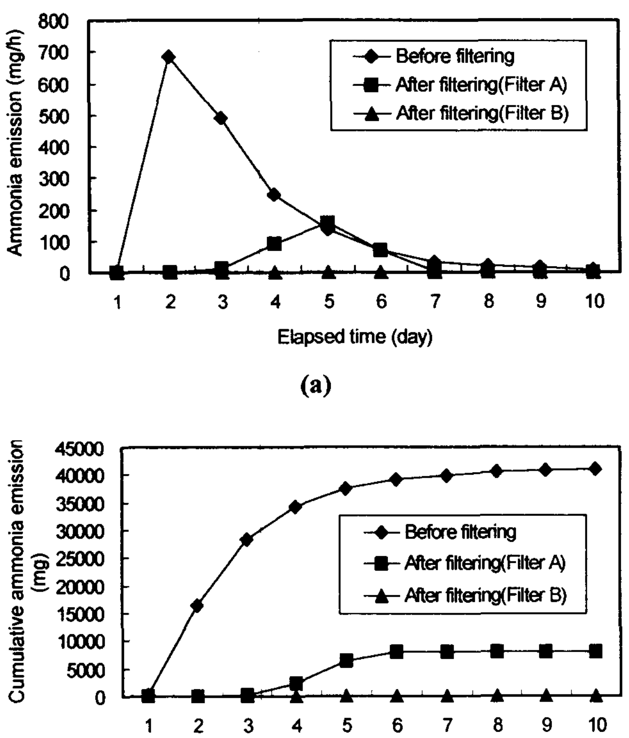
Table 2 Physicochemical properties of fresh compost as a biofilter

Properties	Experiment I			Experiment II		
	Before	After		Before	After	
		Biofilter A	Biofilter B		Biofilter A	Biofilter B
pH	7.21	6.82	6.91	8.09	7.76	8.01
MC(%, wb)	62.17	64.84	64.00	44.12	47.17	45.62
Total carbon(%, db)	36.44	36.64	36.67	37.91	37.19	36.93
Total nitrogen(%, db)	2.72	2.89	2.79	2.37	2.54	2.57
C/N	13.40	12.68	13.14	16.00	14.64	14.37
Ash(%, db)	5.85	8.06	8.11	11.91	11.86	11.84
Bulk density(kg/m^3)	485	504	492	320	323	336



↓ : Arrow positions mean the stoppage of blower operation for one hour.

Fig. 3 Temperature variations of ambient air, compost and biofilter for the experiment II.



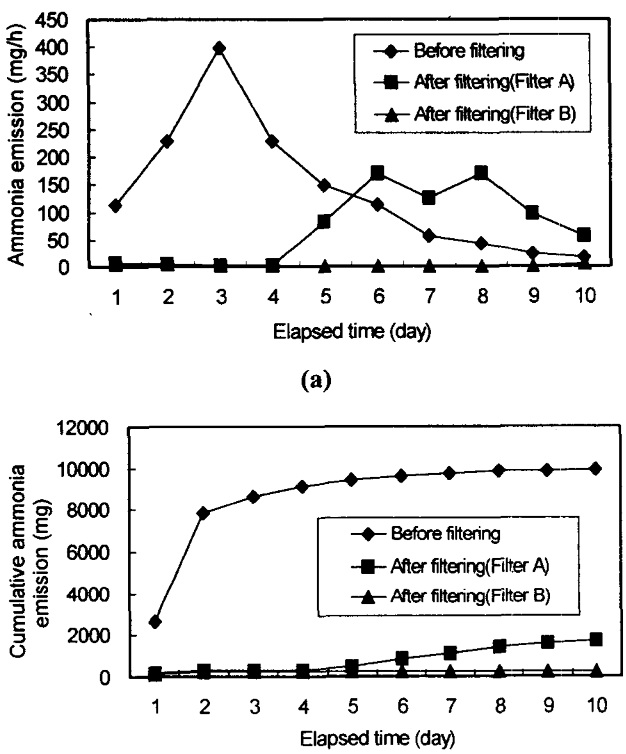
(a)

(b)

Fig. 4 Instantaneous(a) and cumulative(b) profiles of ammonia emission variation during experiment I (aeration rate : 30 L/min).

56.5s), and 0-2 mg/h for biofilter B(residence time; 113s). During the entire experiment period, output value of biofilter A began to appear on the 3rd day and recorded the maximum value of 157 mg/h on the 5th day. Output value of biofilter B was 3 mg/h on the 3rd day only. Cumulative input values during composting period amounted to 41,108mg, while the cumulative output values were 8,016mg and 49mg for biofilter A and B, respectively. Filtering effect was almost perfect for biofilter B for this period.

Fig. 5 represents the instantaneous(a) and cumulative (b) values of ammonia emission for the two biofilters A and B in experiment II with a aeration rate of 50 L/min. Ammonia emission of exhaust gas before filtering varied from 17 to 398 mg/h during the composting period. Output value of biofilter A (residence time; 33.9s) showed 3-8 mg/h at the initial stage and began to increase on the 5th day and showed the maximum value of 171 mg/h on the 6th and 8th day. Output value of biofilter B(residence time; 67.8s) showed 2-6 mg/h during the first 4 days and the last day of the composting period. Cumulative input values during composting period amounted to 9,911 mg/h, while the cumulative output values were 1,733 mg/h and 256 mg/h for biofilter A and B, respectively.



(a)

Fig. 5 Instantaneous(a) and cumulative(b) profiles of ammonia emission variation during experiment II (aeration rate : 50 L/min).

Fig. 6 and 7 represent the ammonia reduction rate by using the fresh compost as a filtering material. The reduction ratio was calculated as the ratio of reduced

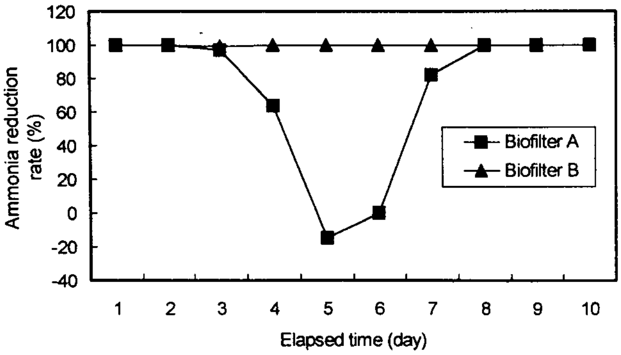


Fig. 6 Ammonia reduction rate during experiment I (aeration rate : 30 L/min).

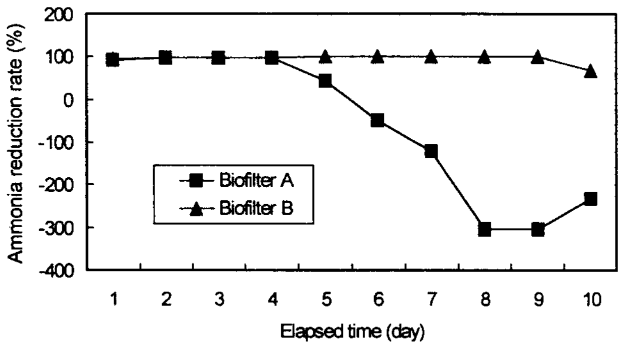


Fig. 7 Ammonia reduction rate during experiment II (aeration rate : 50 L/min).

emission through the biofilter to the inlet value before filtering. At the aeration rate of 30 L/min, reduction rate varied from 100% to −15% for biofilter A and from 100% to 99.6% for biofilter B. For biofilter A, the negative value of −15% is considered due to the release of the ammonia gas which had been previously absorbed and accumulated in the biofilter material. At the aeration rate of 50 L/min, reduction rate began to drop on the 4th day of composting and showed the lowest value of -350% on the 8th and 9th day for biofilter A. However, for biofilter B, reduction rate began to drop to 50% on the last day, showing better efficiency than biofilter A.

The cumulative ammonia reduction rate was calculated as the ratio of cumulative value of reduced ammonia emission through the biofilter to the cumulative input value during the experiment. The cumulative ammonia reduction rate during the experiment I with a aeration rate of 30 L/min was 80.5% for biofilter A and 99.9% for biofilter B. The cumulative ammonia reduction rate during the experiment II with a aeration rate of 50 L/min was 82.5% for biofilter A and 97.4% for biofilter B.

Conclusions

The filtering efficiencies of fresh compost as a biofilter during composting were investigated by varying the flow rate and filter depth. Flow rate and filter depth determine the residence time of exhaust gas inside the biofilter.

There was a discernible relationship between the composting temperature and the ammonia emission. When the composting temperature became relatively high, higher levels of ammonia emissions-683 mg/h for experiment I and 398 mg/h for experiment II- were also recorded. Values of MC and T-N of the biofilter increased by absorbing moisture and ammonia included in the exhaust gas, while the value of pH was decreased during filtering operation. The value of T-C and ash did not change during the filtering operation.

At the aeration rate of 30 L/min, ammonia reduction rate varied from 100 to −15% for biofilter A(residence time 56.5s) and was almost 100% for biofilter B(residence time 113s). The reduction rate for biofilter A had negative value on the 5th day, reflecting the release of ammonia gas previously trapped in the biofilter. The cumulative ammonia reduction rate during the experiment I was 80.5% for biofilter A and 99.9% for biofilter B.

At the aeration rate of 50 L/min, reduction rate began to drop on the 4th day of composting and recorded the maximum negative value of -350% on the 8th and 9th day for biofilter A(residence time 33.9s). For biofilter B(residence time 67.8s), the reduction rate began to drop to 50% on the last day. The cumulative ammonia reduction rate during the experiment II was 82.5% for biofilter A and 97.4% for biofilter B. Compared to the result for experiment I, the cumulative ammonia emission for the experiment II was not decreased in spite of the shorter detention time because the cumulative input value was much lower on account of the intermittent aeration.

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