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Utilization of Biofilter for Ammonia Elimination in Composting Plant

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Abstract: This study presents the interim findings of a research project undertaken to develop an integrated NH_3 control strategy. This is especially important for treating composing facility off-gases where significant concentrations of ammonia are often present. A closed-field biofilter with dimensions 1×1 m was evaluated for its effectiveness in treating gases emanating from aerobic compost pilot. Air samples were collected for the determination of ammonia using detector tubes method. Ammonia emission had a positive correlation with high temperatures and alkaline pH levels during the aerobic composting process. In this research two substrate were compared as a biofilter medial. The results showed that the bed No.1 (50% peat and soil, 33.3% compost, 16.7% sand) was able to reduce ammonia emissions by maximum 97-99%. The overall ammonia removal efficiencies for sampling locations in bed No. 2 (53.3% sawdust, 27.5% clay, 18.2% straw) is approximately 94%. It is less than compost and peat filter efficiency but this media can provide good performance under optimum conditions. The performance of the biofilter was the most sensitive to moisture content and microbial growth conditions such as pH, temperature, oxygen, adequate nutrients, absence of toxic compound and so on.

Key words: Compost, NH_3 emission, biofilter

INTRODUCTION

Biofiltration is a biological process where by odorous gases and volatile organic compounds are broken down by bacteria, actinomycetes and fungi into carbon dioxide, water, minerals, non-odorous air and an increased biomass. The actual breakdown of the odors can be separated into two distinct phases: sorption and biological oxidation. As the waste gas stream passes through the filter medium, odorous compounds are diffused and absorbed into the moist biofilm surrounding the solid phase particles. Microorganisms then proceed to metabolize the sorbed gases to form CO_2, water and mineral such as nitrates and sulfates. Odors generated from composting facilities generally are gaseous and Volatile Organic Compounds (VOC).

The major groups being sulfur compounds, ammonia and amine compounds, fatty acids, ketoses, aldehydes and phenol, as reported by Williams and Miller[1].

Ammonia gas is released in large amounts and it usually masks the other odorous compounds that can, at times, be for more pervasive and offensive[2].

In this study, the performance of two distinct type of biofilter was examined for treatment of ammonia in a pilot scale composting plant (pits method). The concentrations of ammonia (12.5–37 ppm) emanating from composting pilot for green household vegetables waste (1.3 ton) in aerobic conditions.

The increase in NH_3 emission (>27 ppm) corresponds to an increase in the compost pile temperature (35-60°C) and alkaline pH levels (7-8.8).

In comparison with activated-carbon adsorption, biofiltration generates less residues since the organics are decomposed.

Other advantages of biofiltration include its simple operation and effectiveness for a wide range of compounds. The annualized capital and operating cost for a biofilter is 50% less than wet scrubbing, while thermal incineration and activated carbon adsorption methods cost almost three to four times as much as a biofilter system[2].

In this research, biofilters have shown good efficiency in NH_3 removal and bed No. 1 (compost and peat) reduced ammonia emissions by maximum 99%[3].

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MATERIALS AND METHODS

Filed measurements were conducted at the in–vessel composting plant with dimensions (1.4×1.05×1) m in the Science and Research Campus Islamic Azad University through regular visits from September 1997 to November 1997. The composting plant processes a variety of organic waste materials, including vegetable waste (lettuce, carrot, potato, etc) and additatives such as animal manure's as well as source separated waste (near 2 ton). The compost is agitated by a compressor or manual twice per day, for a retention time of 50-55 days.

As demonstrated in Fig. 1, an enclosed biofilter system with dimensions (1×1×1) m is installed next to the composting pit.

Compost gases are collected and transported to a biofilter by means of a blower and ventilation system. The gases must then be evenly distributed through the biofilter medium by way of a perforated plate surrounded by straw.

It is critical that uniform air distribution be designed into the system to prevent short circuiting of exhaust gases through the filter. Duct and hood designs, loss factors, static pressure of system, fan selection, were calculated by the velocity pressure method[4].

In this study two distinct substrate were compared as a biofilter media. We used peat and compost (bed No. 1) as a biofiltration media because of useful properties including its high surface area, air and water permeability, water holding capacity, active microbial population and relatively low cost. The bed No. 2 consists of sawdust and especially wheat straw, a substrate that has excellent hydraulic characteristics and high reactive surface area[2].

The depth of the biofilter actually varied from 0.2 to 0.3 m on the bed No. 1 and 0.3 to 0.4 m for the bed No. 2. The physical properties of the biofilter media were determined using standard laboratory methods; these include moisture content, organic carbon content, porosity and pH.

A hot-wire anemometer was used for measuring surface velocity and air volume flow rate.

Samples of off-gases emanation from the compost piles and leaving the biofilter were tested for odorous compounds[3].

A roof that covered the biofilter was used to facilitate sampling in five locations. Ammonia was routinely measured on-site by detector tubes. Sulfur compounds for example H_2S were not detected because of its low level.

An ammonia gas detector was also available for measuring ammonia concentration within the 1-35 and 0.5-1 ppm ranges.

As the source of odor entering the biofilter comes from the composting piles, the environmental factors for composting (temperature, C/N ratio, moisture content and pH) as well as compost characteristics were also monitored[3].

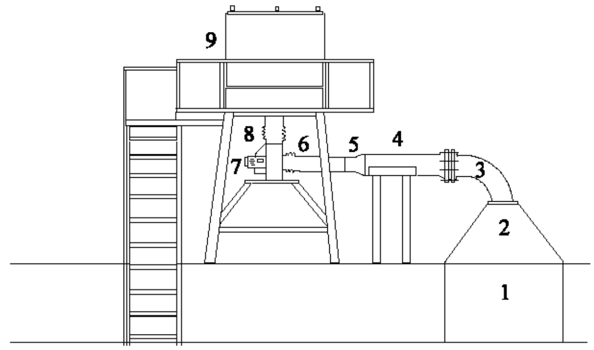

Fig. 1: Schematic diagram of pilot-scale biofilter 1. Compost pit; 2. Hood; 3. Elbow (90°); 4. Gas transport duct (8”); 5. Tapered contraction (8” into 6”); 6. Gas transport duct (6”); 7. Centrifugal fan; 8. Fan outlet duct; 9. Biofilter

To obtain each complete set of related data, sampling of the biofilter material and its operating parameters was made at the same time that compost samples and gas samples were obtained.

Finally, removal efficiency of biofilter in odor treatment was determined.

RESULTS AND DISCUSSION

Ammonia emission from compost pilot: Throughout the study period, ammonia concentration was measured within the 12.5–37 range (Fig. 2), where as hydrogen sulfide was hardly detected. The increase in NH_3 emission corresponding to an increase in the compost pile temperature. NH_3 level was higher (>27 ppm) when temperature of the compost was in the range of 35 to 60°C (Fig. 3).

Because of high microbial activity (mesophilic and termophilic bacteria) and ready compost seeding in

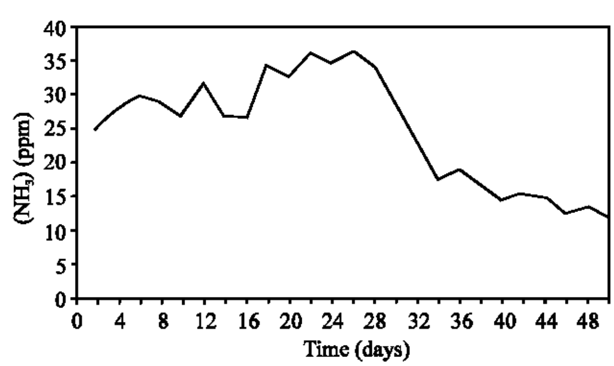

Fig. 2: Ammonia emissions from compost pit

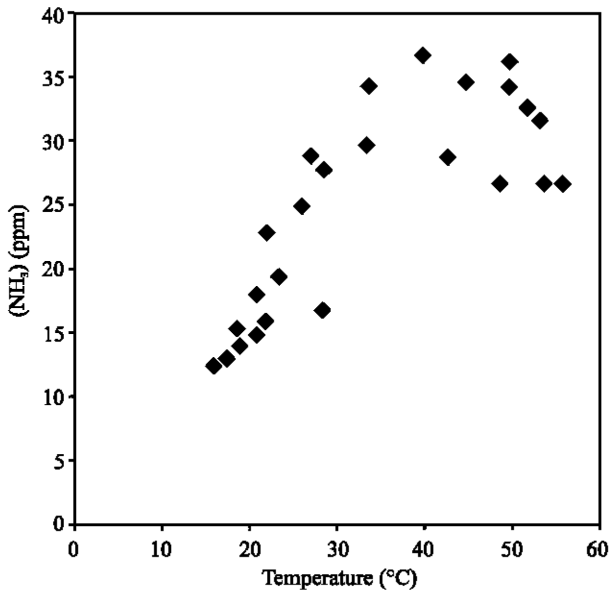

Fig. 3: Variations of ammonia emission with compost temperature

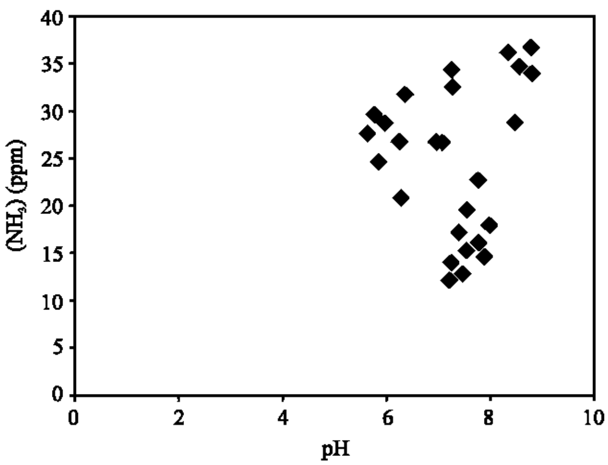

Fig. 4: Variations of NH_3 emission with compost pH

start–up step, the composting pile's temperature was enhanced.

In addition to high temperature, alkaline pH levels were also conductive to ammonia release during the aerobic composting process. As shown in Fig. 4, because of converting the inorganic nitrogen to ammonium during degradation of compost materials, ammonia emissions was considered within alkaline pH levels (7-8.8).

On the other hand, the accelerated ammonia rise was likely due to decreasing of C:N ration.

After 30th day, NH_3 concentration decreased from the peak values, which was related to factors such as reduction of ambient pile temperature and the end of compost activity.

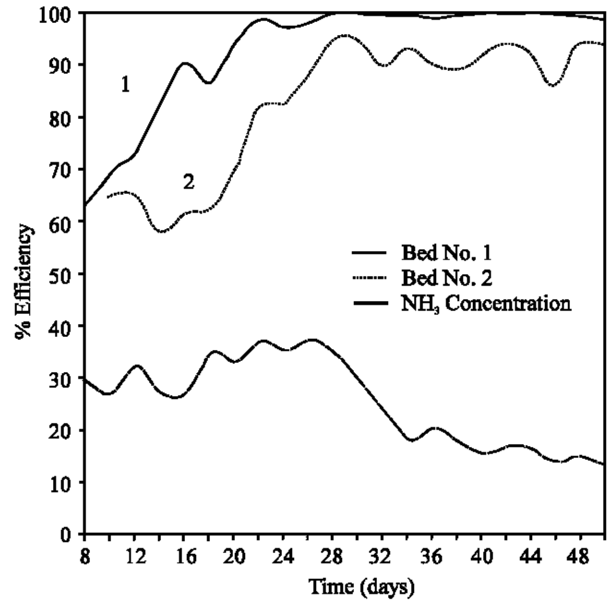

Fig. 5: Ammonia removal efficiency in 2 beds

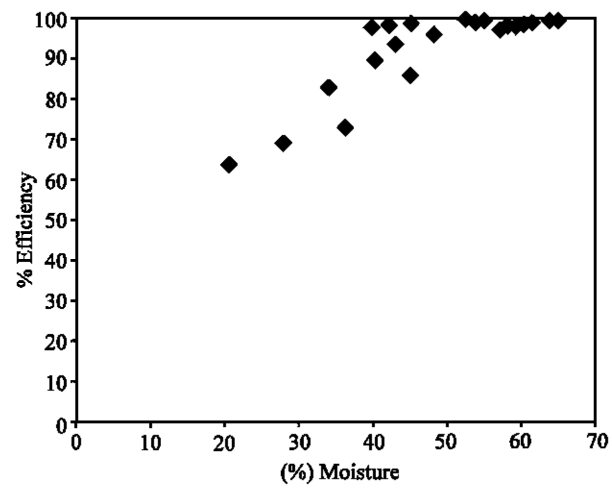

Fig. 6: Ammonia removal versus biofilter moisture content (Peat and compost media)

Biofiltration design and operating: Gas collection and transporting systems such as hood, ducts, elbows, tapered contractions, fan and biofilter have been introduced in Table 1 and Fig. 1. Also, duct designs and fan total pressure were calculated by the velocity pressure method.

The velocity pressure method of design is a balanced design approach which attempts to equate losses to fractions of velocity pressure[4]. The characteristics of natural beds that we used in this study have been listed in Table 2.

Ammonia removal efficiency for bed No. 1 was reported in within the 63-99% range and for most of the measurements was near 99% (Fig. 5).

Table 1: Collecting transmission and treatment of gaseous

System parts	Characteristics
Compost pit	Type: Concrete, dimensions: (1×1.05×1.4) m, two floors with inclined bottom and perforated plate for aeration.
Hood	Type: Iron, Kind: Canopy, lower base dimensions: (157×118) cm, upper base dimensions: (27×27) cm, hood height: 60 cm, angle: 45°
Elbow	Type: Iron alloy, Round section, elbow angle: 90°, diameter: 8″, $\frac{R}{D} = 2.5$,
Transport duct (Primary)	Type: Iron, Round section, diameter: 8″, length: 70 cm.
Tapered contraction	Type: Iron, divergence angle : 45°
Transport duct (Secondary)	Type: Iron, Round section, diameter: 6″, length: 50 cm.
Centrifugal fan	Blower, 3 phase with following characteristic: (Kw=0.25), (HZ= 50), (A =9), (V=220), (FTP = 2 in wg), (FSP= 1.5 in wg), (RPM = 1380) (Q=700 cfm)
Fan outlet duct	Type: Iron, Round section, diameter: 8″, length: 25 cm.
Biofilter	Type: Iron, qubic, dimensions: (1×1×1) m, system kind: Enclosed–Field biofilter with air distribution system in beneath.
Bed No. 1	Dimensions: (1×0.5×1) m, media type: mixing of peat and compost, primary height: 20 cm.
Bed No. 2	Dimensions: (1×0.5×1) m, media type: saw dust and straw, primary height: 30 cm.

Table 2: Summary of initial media properties

	Bed characteristic						
Bed	Organic nitrogen (%)	Total phosphorous (P_2O_2) (%)	Total potash (%)	Organic carbon (%)	pH	Material percent (by weight)	Porosity
(Bed No. 1)							
Peat	4.2	3.2	3.17	50	4.5	50	
Prepared compost	1.3	0.3	1.3	30	6.2	33.3	
Screened sand (Additive)	-	-	-	-	-	16.7	52
(Bed No. 2)							
Straw	-	-	-	-	-	18.2	
Saw dust	13	-	1.2	86	7.2	54.3	
Clay (additive)	-	-	-	-	-	27.5	

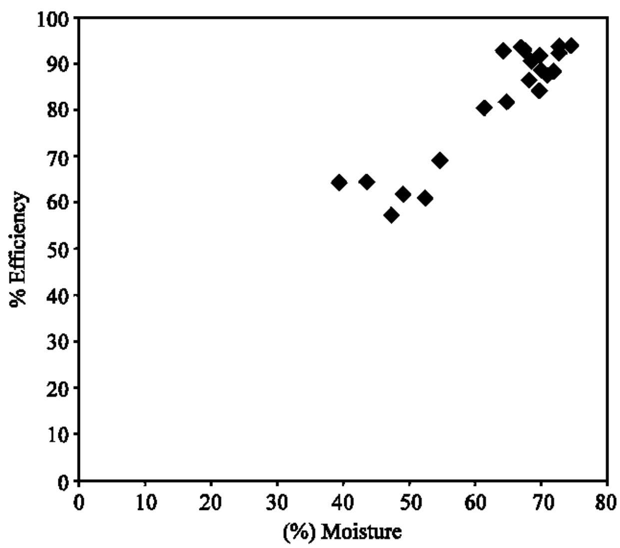

Fig. 7: NH_3 removal versus biofilter moisture content (Sawdust)

In terms of, following a few days of operation (after acclimation period), inlet and outlet gas sample concentrations were measured within the 12.5–37 and 0.02–10.7 ppm orderly.

As demonstrated in Fig. 5, until 26th day the increase in compost ammonia emission (near 37 ppm) was simultaneous with the accelerated NH_3 removal efficiency by more than 99%.

After decreasing the biofilter inlet gas concentration (from 26th day until end); high removal efficiencies hadn't any changes and microorganisms have continued biological oxidation process. The efficiency of bed No. 2 (Sawdust and straw) was lower than peat and compost media. It was reported 90-94% only for 7 days. But it is mentionable that the quality or removal changes were nearly the same in two beds.

It is generally recommended that bed temperatures be maintained in the psychrophilic and mesophilic regimes.

In this study, the temperature of filter No. 1 has been controlled in the range of 12-29°C. it account for high efficiency of this bed, because mesophilic range is too effective to nitrifying bacteria activities.

The effect of temperature on NH_3 removal efficiency was studied in the temperature range from 14 to 34°C for the bed No. 2. Collectively, this media showed good results.

Moisture content within the biofilter in one of the most critical operational parameters which must be controlled to maintain optimal performance because the basic odor removal mechanism is biooxidation, it is essential that the moisture content be optimal for the resident microorganisms to survive and metabolize waste gases[2].

As presented in Fig. 6 and 7, the moisture of biofilter have been controlled in optimum ranges (50 to 70% by weight).

In present study, to maintain moisture content in the filter media; methods applied on the media, such as irrigation and spray, because the air pollutant concentrations are low and compost gases are usually near saturation.

Oxidation of NH_3, H_2S, or organic sulfur within a biofilter can lead to acidic conditions. With the diversity of compounds present in composting gases, low pH conditions would adversely effect total odor removal.

Therefore, monitoring of pH and maintenance in the general range of 7 to 8.5 is recommended for biofilters at composting facilities[5].

For most of the measurements in compost and peat media, the pH values were 5 to 7. The release of hydrogen ions (H^+) due to the utilization of ammonium ions could be one reasons for the drop in pH.

The maximum NH_3 removal for bed No. 2 (Sawdust and Straw) accured at a pH values more than 7. Alkaline pH (7-9.3) can be considered suitable for this special media.

Biofilter as one of the biofiltration technology in control gas phase pollutants provides us a way to eliminate the pollutants from composting process or another industries completely through metabolic activities. Ammonia was found to be the most significant odor emanating from the compost reactor, ranging from 12 to 37 ppm in experimental conditions.

NH_3 emission had a positive correlation with temperature greater than 35 to 60°C. (Termophilic phase). Suitable C:N ration and pH control are essential for minimizing odor generation too. Sulfur compounds such as H_2S were either of very low concentrations or could not be detected with the means used. Compost and peat have been used to demonstrate their unique capabilities as biofilters for NH_3 removal from waste gas streams. The following optimum operating conditions are suggested for control of NH_3 by mixing of compost and peat biofilter systems:

Temperature: 15-30°C
pH: 5-7
Compost water content: 50-60%.

To work within the maximum loading capacity of the system, the waste gas flow rate should be adjusted to obtain the best reduction of NH_3 for various inlet concentrations. Further development of engineering information is needed as related to media selection which provides optimal adsorption capacity, while minimizing system headless and providing an environment suitable for the proliferation of microorganisms which oxidize odorous compounds.

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