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Multi-stage biofiltration for air pollution control in composting processes

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Abstract

Odor is often produced in composting processes especially when the operating conditions are not optimal. To control the odor, the prior methods include improving the management and operation conditions, as well as treating waste gases through mitigation measures. Biofiltration has become one of the most commonly used odor control technologies due to its advantages of low cost, high efficiency, and capability of simultaneously processing several contaminants without secondary pollution. Biofilter adopts a solid filling bed supporting biological activities to absorb (or adsorb) and degrade contaminants in effluent gases.

In this study, a multi-layer biofilter setting was developed. The filter was filled with compost, timber sawdust, charcoal powder, and gravel in order to build a stereo-reticulation structure with properties of high porosity, adequate humidity and large permutation area. Microorganisms were screened from other composting processes and natural surroundings. The obtained microorganisms were domesticated with the existence of odorous components and/or BTEX compounds at different pH values and different temperatures to enhance their adaptability. They were classified according to growth compatibility. The obtained classified microorganism complexes were inoculated into different layers in the biofilter. A bench-scale odor control process was performed in such a biofilter setting. Odor sources from composting processes were well controlled during the operation.

1 Introduction

As odorous gases are inevitably released during the composting processes of organic wastes, odor control is significant for gaining public acceptance. The

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first application of microorganisms to odor control was reported in 1957 for mitigation of H_2S pollution [Brauer, 1981]. The first biofilter was originated in the Orange County, California, USA [Reynolds, 1999]. Since then a variety of biofilters have been developed and applied to odor control, and biofiltration has gradually become one of the most commonly used odor control technologies due to its moderate cost, high efficiency, and capability of simultaneously processing several contaminants without secondary pollution [Freeman, 1998]. However, some problems were reported with biofilters, such as the relatively low loading capability [Freeman, 1998], short circuiting and pH depression [Voutchkov, 1995]. In the previous studies, efforts were mostly focused on the filling media, the pH adjustment, moisture control and ventilation. Improvement of microorganism community populations in biofiltration processes was rarely investigated while, in fact, enhancement of microbial species and growing conditions could largely raise the process effectiveness.

A variety of microorganism strains from different species that are present in the surrounding environments are functioning in biofiltration processes, while each strain is able to degrade different odorous substances in different optimal conditions. For instance, some strains prefer lower temperatures but some prefer higher; some strains can endure low pH but some cannot; some species are strong and competitive while some are weaker and easier to be destroyed. Moreover, while different microorganisms are able to handle different contaminants, they might not be able to grow well with one another. A simple mixture of microorganisms will not likely produce acceptable results in most of biofiltration operations. Each functional microorganism strains in biofiltration process, if growing under their dedicated optimal growing conditions, will apparently degrade odors more effectively.

In this research, species screening, domestication and classification will be conducted to create a multi-stage biofiltration system where most of the functional strains will be performing under desired conditions. Thus, microorganisms will be more capable of degrading contaminants and be more resistant to odorous compounds.

2 Experimental methods

2.1 Materials

2.1.1 Samples

Soil samples were collected from the ground surface and at the depth of 3 feet at the Regina City Landfill, Regina, Canada. Solid yard and kitchen wastes were collected from Wascana Lake Park, Regina, Canada and kitchens in the authors' houses. In order to obtain samples that are rich in odor related microorganisms, bench-scale aerobic and anaerobic composting of the above wastes were conducted separately. Samples were collected during these processes. Final compost products were collected and used to form biofiltration media in the multi-layer biofilter illustrated hereinafter.

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2.1.2 Leachate
Composting leachate, as odor source used in the microorganism screening and bench-scale biofiltration, was collected during the anaerobic composting processes.

2.1.3 Screening medium
Liquid TSB medium (Difco) with 10% leachate was used to screen biofiltration microorganisms. Two subdivisions of such screening medium were obtained by setting pH to 4 and 7. Diluted sulfuric acid (1M) and sodium hydroxide (2M) were used to adjust the pH level.

2.1.4 Solid plate medium
Several 20-ml petri dishes with 10-ml solid agar TSB medium (Difco) were used to culture single colonies and to conduct plate counting of microorganisms.

2.1.5 Solid slant medium
Several 50-ml test tubes with 15-ml solid agar TSB medium (Difco) were used to culture and obtain microorganism complexes in the biofiltration processes.

2.2 Experimental equipment

2.2.1 Bench-scale screening vessel
A bench-scale vessel was designed and custom-manufactured for screening biofiltration microorganisms, as shown in Figure 1. The vessel was made of stainless steel with two chambers divided by a double-layer 60-mesh stainless steel sieve. The inner size of the vessel was 45 cm X 15 cm X 7.5 cm. Two outlets and two inlets were built on the vessel for supplementation of air and odor source, i.e. leachate. Thirty-six sampling holes were drilled in the cover plate to collect specimens from different locations and adjust moisture content inside the vessel (as shown at the lower part of Figure 1). The vessel was airtight relying on a number of rubber pads and o-rings.

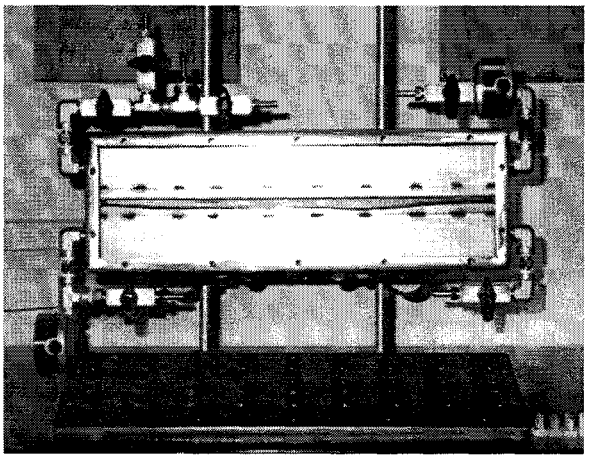

Figure 1: Screening vessel for biofiltration microorganisms.

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2.2.2 Bench-scale multi-layer biofiltration vessel

A bench-scale multi-layer biofiltration vessel was designed and custom-manufactured. It was made of Perspex and divided into four compartments by three Perspex supporting frames and three 60-mesh stainless steel sieves. The top three compartments were designed to hold biofiltration media, while the bottom one was to hold odor source, i.e. leachate. The upmost compartment was open to the atmosphere. The other compartments were wrapped with cotton from outside the vessel wall to reduce heat loss and create a higher temperature than the surrounding environment during the biofiltration processes. The structure of the vessel is shown in Figure 2.

2.2.3 Microbiological apparatus

These included typical apparatus equipped in microbiological laboratories.

2.3 Initial screening of biofiltration microorganisms

One soil sample, two compost samples and one part of timber sawdust were mixed and spread in the upper chamber of the screening vessel. The addition of timber sawdust was to maintain suitable porosity of the medium and permit odor gas from the lower chamber to pass through slowly. The sieve was totally covered by the mixed samples, which created an anaerobic environment for the lower chamber that was partially filled with leachate.

A minor airflow was supplied into the inlet valve through the upper chamber and exhausted through the outlet valve in order to provide sufficient oxygen for the microorganism. Tap water was sprayed every two days uniformly into the upper chamber through the sampling holes to keep 60% moisture. Leachate was supplemented through the lower valves into the lower chamber when the leachate was reduced significantly.

The vessel was laid at room temperature (approximately 22°C) for 28 days. Specimens from four different locations were collected on the 14^{th} and 28^{th} day from the upper chamber. Specimens collected on the same day were mixed. Each of the obtained mixtures was diluted 5 times by normal saline (weight/weight) and blended thoroughly.

2.4 Domestication of biofiltration microorganisms

2.4.1 pH and temperature enhancement

A volume of 1 ml obtained saline dilutions as described in section 2.3 was inoculated to the 50 ml screening media (pH = 4 and 7) and cultured in 250 ml Erlenmeyer flasks at 200 rpm under 20 and 40°C, respectively, for 48 hours.

2.4.2 BTEX adaptation

A volume of 1 ml saline dilutions as described in section 2.3 was inoculated to 50 ml screening media (pH = 7) with 10% gasoline (volume/volume) and cultured in 250 ml Erlenmeyer flasks sealed with Parafilm at 200 rpm at 20 and 40°C for 48 hours.

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2.5 Microorganism counting

A volume of 1 ml each 50 ml culture obtained from the pH and temperature enhancement processes were diluted 100 times by normal saline, and 1 ml of each 50 ml culture from the BTEX adaptation process was diluted 10 times by normal saline. A volume of 0.01 ml each obtained dilution was spread on solid plate medium and cultured at 37°C for 16 hours to obtain single colonies. Thus, the number of single colonies times 10,000 for pH and temperature enhancement or 1,000 for BTEX adaptation, results the microbe number per milliliter.

2.6 Acquisition of microorganism complexes

A volume of 1 ml each 50-ml culture was diluted 10 times by normal saline and stirred up. A volume of 0.1 ml each dilution was spread on solid slant medium with pH = 4 and 7 correspondingly. Culture them at 37°C for 24 hours before storing at 4°C.

2.7 Inoculation

Microorganism complexes were picked from solid slant media and inoculated into 250 ml Erlenmeyer flasks with 50 ml screening media. Culture them at 20 or 40°C under pH = 4 or 7 with or without gasoline for 48 hours. The obtained culture was mixed with the biofiltration media at a ratio of 1:10 (volume/volume) before the final assembly of the biofiltration layers.

3 Result

3.1 Classification of biofiltration microorganisms

Two sets of samples were collected from the screening processes. Each of them was cultured in screening media under a series of conditions. Microorganism concentrations were then calculated (Table 1).

Biofiltration microorganisms were then divided into three groups according to the growth situations. The microorganism complexes obtained on the 14^{th} and 28^{th} day, cultured at 40°C with pH = 4, were mixed and re-cultured to be the first group, while those obtained under pH = 7, were mixed and re-cultured to be the second group. The microorganism complexes obtained on the 14^{th} and 28^{th} day, cultured at 20°C with pH = 7 and 10% gasoline, were mixed and re-cultured to be the third group. These three groups were defined hereby as Acidophilic Complex, Neutral Complex, and BTEX Complex, respectively.

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Table 1: Microorganism concentrations in the screening media.

	Day 14			Day 28		
	pH = 4	pH = 7 (10%Gasoline)	pH = 7	pH = 4	pH = 7 (10%Gasoline)	pH = 7
20°C:						
Plate colony number	39	57	12	25	89	56
Microorganism concentration (unit/ml)	390,000	570,000	12,000	250,000	890,000	56,000
40°C:						
Plate colony number	67	322	10	55	301	12
Microorganism concentration (unit/ml)	670,000	3,220,000	10,000	550,000	3,010,000	12,000

3.2 Bench-scale multi-layer biofilter

Three layers of biofiltration media inoculated with the three microorganism complexes respectively were loaded in the bench-scale multi-layer biofiltration vessel, as shown in Figure 2. The structure of the layers is depicted in Table 2. Air was pumped through the compost leachate supplementation inlet. Compost leachate was supplemented through the same inlet while the remaining amount reduced obviously. In order to keep a 45-second retaining time for the odorous compounds in the second or third biofiltration layer, the flow rate was adjusted to 120 ml/second.

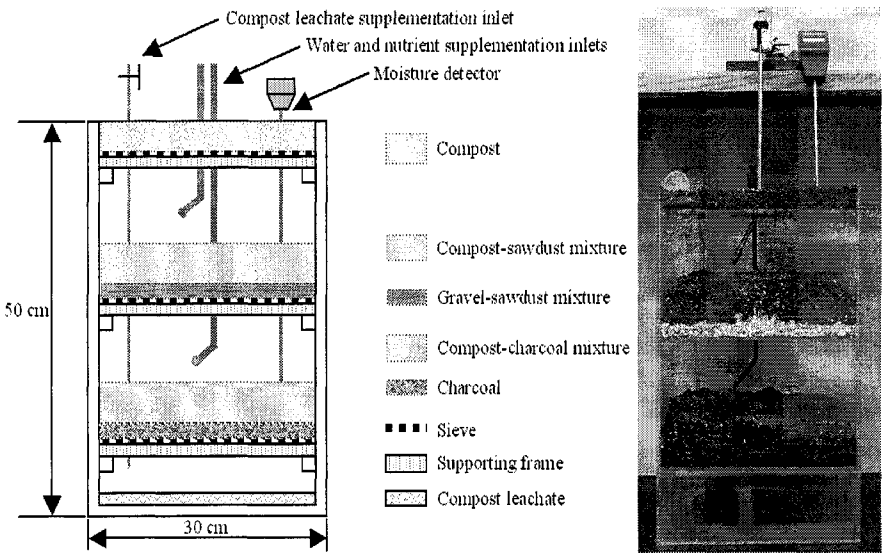

Figure 2: Structure of bench-scale multi-layer biofilter.

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Table 2: Structure of the bench-scale biofilter.

	1st layer	2nd layer		3rd layer	
		Upper sub-layer	Bottom sub-layer	Upper sub-layer	Bottom sub-layer
Thickness (cm)	3	6	2	6	2
Composition (volume/volume)	compost	compost:sawdust (5:1)	sawdust:gravel (1:1)	compost:charcoal (5:1)	charcoal
Inoculum	BTEX-adaptable Complex	neutral complex	none	acidophilic complex	none

3.3 Performance of bench-scale biofiltration

A bench-scale biofiltration odor control process was performed continuously in the multi-layer biofilter for 14 days. Moisture inside the three layers of biofiltration media was tested on each day and kept at 40 to 60%. 500 ml compost leachate was added on day 7. No cognizable odor was discovered by olfactory organ during the entire process.

4 Discussion

The main reason for the drop of pH in the biofiltration media is the conversion of bound sulfur to sulfuric acid. Such an event will lead to the death of functional microorganisms and the corrosion of biofiltration media. Normally, when pH is under 4, actions such as rinsing the filter bed or replacing the material should be undertaken. In this study, acidophilic microorganisms were isolated from the others and inoculated into a separate biofiltration layer to adapt the low pH circumstance. Charcoal was applied to resist corrosion from sulfuric acid so that the stereo-reticulation medium structure with properties of high porosity could be well kept.

The majority of the functional microorganisms in the bench-scale multi-layer biofilter that were screened under normal biofiltration conditions were present in the second layer. Timber sawdust and gravel were loaded to ensure suitable porosity.

Since the amount of odorous substances was reduced after the absorption (or adsorption) in the first two layers, a thinner single component biofiltration medium was applied in the top layer. BTEX-adapted microorganisms were inoculated in order to absorb the potential BTEX residues or other toxic hydrocarbons emitted from the odor source. The additional function of the top layer was blocking fungal spores from the other two layers, while the BTEX-adapted microorganisms were mainly bacterium species without air-suspending

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spores produced.

A three-layer biofilter is better than a single-layer one because of not only its higher efficiency of odor elimination, but also its larger capability to avoid short-circuiting. In addition, multi-layer biofilter is superior to multi-container one due to the lower costs of manufacture, operation and maintenance and the smaller land occupancy.

5 Conclusions

In this research, biofiltration microorganisms were screened and further classified in accordance with their degrading abilities and growth compatibilities. Three microorganism complexes, Acidophilic Complex, Neutral Complex, and BTEX Complex, were obtained and inoculated into a three-layer biofilter loaded with a series of materials in different combinations. The desired growing conditions for the biofiltration microorganisms were identified, with the emission of bio-aerosols being also reduced.

References

[1] Brauer H., Varma G., Air pollution control equipment. New York: Berling Heidilberg, 6(3), 1981, pp 30.
[2] Freeman, H.M., Standard handbook of hazardous waste treatment and disposal, 2nd edition, 1998, pp 12.
[3] Reynolds, F.E., Grafton, W.D., Biofiltration an old technology comes of age. Environmental Technology, July/August 1999, pp 51.
[4] Voutchkov, N., Composting odor control made easy. The American City & County, 110(9), August 1995, pp 49.