

## Biofilter Treating Ammonia Gas Using Agricultural Residues Media

Thaniya Kaosol and Nutthawut Pongpat  
Department of Civil Engineering,  
Faculty of Engineering, Environmental Engineering Program,  
Prince of Songkla University, Songkhla, 90110, Thailand

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**Abstract: Problem statement:** Agricultural residues such as manure and sugarcane bagasse are wastes from agro-industry which has low value and requires some sustainable waste management method. In this research, a mixture of manure fertilizer and sugarcane bagasse is used as a biofilter media for an ammonia gas removal application. The aim of this research is to study the ammonia gas removal efficiency of such media. **Approach:** The experiments were conducted in laboratory-scale biofilters. Two inlet ammonia gas concentrations were used which are 500 and 1,000 ppm. Three ratios of manure fertilizer and sugarcane bagasse were studied including 1:3, 1:5 and 1:7 by volume. All experiments were conducted for a period of 40 days. Two Empty Bed Retention Time (EBRT) of these experiments were used which is 39s and 78s. The moisture content of the biofilter media was maintained at 45-60% by adding water. **Results:** The maximum ammonia gas removal efficiency at 89.93% is observed from the following conditions: 500 ppm of the inlet ammonia gas concentration, the manure fertilizer and sugarcane bagasse mixture ratio of 1:5 and the EBRT of 78s. The important factors of the ammonia gas removal in biofiltration process are the inlet ammonia gas concentration and the EBRT. **Conclusion:** The experimental results showed that the mixture of manure fertilizer and sugarcane bagasse is an effective biofilter media for ammonia gas removal applications. However, the biofilter is more effective at low inlet ammonia gas concentration, while the ratio of manure fertilizer and sugarcane bagasse has no significant effect on the ammonia gas removal efficiency. Therefore, using both residues as biofilter media for ammonia gas removal application is an alternative sustainable way to such manage agro-industry waste.

**Key words:** Biofiltration, biofilter media, elimination capacity, ammonia gas

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### INTRODUCTION

Ammonia gas is a colorless, odorous, corrosive and toxic gas. It is produced from several sources such as composting and fertilizer plant (Busca and Pistarino, 2003), wastewater treatment plants, livestock farming (Chung *et al.*, 1996; Ndegwa *et al.*, 2008) and the chemical and manufacturing industries (Kim *et al.*, 2007). There are many technologies for ammonia removal such as the catalytic oxidation (Juutilainen *et al.*, 2006; Wang *et al.*, 1999), liquid absorption (Chen, 2004; Terasaka *et al.*, 2002), solid adsorption (Rodrigues *et al.*, 2007; Guo *et al.*, 2005) and biological filtration (Smet *et al.*, 2000; Hong and Park, 2005; Pagans *et al.*, 2005; Chung *et al.*, 2005; Kim *et al.*, 2000).

The biological treatment is an emerging technology for treating odorous air pollution. The biofiltration is one of several biological treatment methods. The

biofiltration is an ammonia gas pollution control method using living materials to capture and biodegrade pollutants. Biofiltration is the most attractive alternative method for ammonia gas treating because its high removal efficiency, low operation and maintenance cost and modest environmental impact (Wani *et al.*, 1997). In the biofiltration process, a contaminated gas stream passes through a biofilter media layer such as compost, soil, wood chips, peat, mulch, bark or mixed materials. These layers will help adsorbed the ammonia gas in the stream. After that a biodegradation occurs due to the microorganisms activity in the biofilter followed by biodegradation of adsorbed pollutants (Pagans *et al.*, 2007). The biofilter media uses the microorganisms to remove the air pollution. Moreover the biofiltration is a proven technology as an odor and volatile organic compound reducing emission method from industrial and commercial emission sources (Taghipour *et al.*, 2008).

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**Corresponding Author:** Thaniya Kaosol, Department of Civil Engineering, Environmental Engineering Program,  
Faculty of Engineering, Prince of Songkla University, Songkhla, 90110, Thailand

A good biofilter media should have rich nutrients for microorganisms. Thus, manure fertilizer has sufficient nutrient as required. However, the dense and packed volume characteristics of manure fertilizer may not allow gas to pass through easily. Therefore, another media such as sugarcane bagasse that can increase void space in the manure fertilizer must be added. Sugarcane bagasse is an agro-industry waste from sugarcane industry. By using sugarcane bagasse as a biofilter media, the waste can be reduced and managed in a sustainable way. However, a study on how to mix both materials to get the highest efficiency must be conducted.

In this study, the ammonia gas removal is evaluated by a laboratory-scale biofilter using a mixture of manure fertilizer and bagasses as the biofilter media. The ammonia gas, before and after biofiltration were analyzed to determine the effect of the biofilter on the removal efficiency.

### MATERIALS AND METHODS

**Raw materials:** The manure fertilizer and sugarcane bagasses are used as the agricultural residue biofilter media in these experiments (Fig. 1). The manure fertilizer is a product from animal waste composting which has the advantage of adding a balanced set of nutrients to soil. It contains many nutrients for microorganisms such as nitrogen, phosphorus, potassium, trace nutrients and soil microorganism stimulants.

The typical sugarcane bagasse is a fibrous matter that remaining from the juice extraction from the sugarcane stalk. The moisture content is high in range 40-50%. The typical sugarcane bagasse contains 45-55% of cellulose, 20-25% of hemicelluloses, 18-24% of lignin, 1-4% of ash and less than 1% of waxes.

**Experimental setup:** The diagram of the biofiltration process used is shown in Fig. 2. In this study, three biofilter reactors were used; each reactor consists of a cylindrical vessel. The biofilter column height is 100 cm. The filter column has an inner diameter of 0.10 m. The filter bed has two layers and each layer has a height of 0.25 and 0.50 m. The overall volume of the filter bed is 1.96 l and 3.93 l. The gas feeding apparatus is set up to produce an ammonia gas with desired concentration and flow rate. A peristaltic pump is used to send water from a water tank to filter bed. The manure fertilizer and sugarcane bagasse (2×2 cm in weight × length) were packed into the filter bed at 1:3, 1:5 and 1:7 of manure fertilizer and sugarcane bagasse ratio. The sugarcane bagasses were proved to be very effective in preventing bed compaction of organic packing media.

The reactor has the biofilter media as manure fertilizer combined with sugarcane bagasse at 1:3, 1:5 and 1:7 ratios for reactor 1, 2 and 3, respectively. The biofilter media height is set as at a constant height of 0.25 and 0.50 m. Table 1 shows the operating conditions of the biofilter in this study. The inlet ammonia gas flow rate was maintained at 50 cm<sup>3</sup> sec<sup>-1</sup>. The moisture content of the biofilter media was maintained at 45-60% for optimum operation condition. The Empty Bed Retention Time (EBRT) was 39s and 78s. The experiments were started at 500 ppm of inlet ammonia gas concentration.



Fig. 1: Biofilter media (a) manure fertilizer (b) sugarcane bagasse

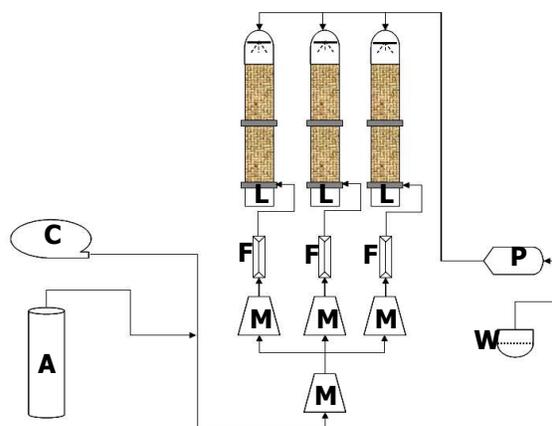


Fig. 2: Schematic of biofiltration process (A = NH<sub>3</sub> gas tank, C = compressed air equipment, F = flow meter, L = leachate tank, M = mixed air and NH<sub>3</sub> gas tank, P = peristaltic pump, and W = water tank)

Table 1: Operating conditions of the biofilters

Parameters	Experimental operation
1. NH <sub>3</sub> flowrate	50 cm <sup>3</sup> s <sup>-1</sup>
2. inlet NH <sub>3</sub> concentration	500 ppm and 1,000 ppm
3. Moisture content of biofilter media	45-60%
4. EBRT	39s and 78s
5. Height of biofilter media	0.50 m and 0.25 m
6. Manure fertilizer: Sugarcane bagasse ratio	1:3, 1:5 and 1:7
7. pH	6-8

The experiments were carried out continuously until the biofiltration process reached the steady state then the experiments were changed to 1,000 ppm of inlet ammonia gas concentration.

The experiments were carried out continuously until the biofilter got into another steady state. Then the experiments finished. The pH value during experiments was maintained in a range between 6 and 8.

**Monitoring parameters:** During the experimental period, the inlet and outlet ammonia gas concentration of each reactor were monitored to evaluate the ammonia gas removal capacity of the biofilter. The ammonia gas was collected using the sampling pump for 1 min at the flow rate 2l min. Then, the passing ammonia gas is directed to the Erlenmeyer flask containing 50 mL<sup>-1</sup> of boric acid. After that the 0.02N Hydrochloric acid is used to titrate the sample in order to analyze the ammonia gas concentration.

## RESULTS

**Biofilter media characteristics:** The properties of biofilter media, manure fertilizer and sugarcane bagasse, are shown in Table 2. The moisture content of manure fertilizer and sugarcane bagasse were 2.7% and 9.1%, respectively. The moisture content is a major parameter for the operation control of the biofiltration process. The optimum moisture content of a biofilter media should be 40-60% (Gaudin *et al.*, 2008). Thus, water must be added to the biofilter media in order to maintain the moisture content within the optimal range.

The pH is 8.6 and 5.1 for manure fertilizer and sugarcane bagasse, respectively. The bulk density is 0.23 and 0.16 g m<sup>-3</sup> for manure fertilizer and sugarcane bagasse, respectively. The nutrient elements in N: P: K form of manure fertilizer and sugarcane bagasse are 2.37: 0.78: 0.91 and 0.20: 0.03: 0.42, respectively. These nutrient elements are suitable for microorganism activity in the biofiltration process.

The C/N ratio of manure fertilizer and sugarcane bagasse is 5.5 and 120, respectively. The organic carbon of manure fertilizer and sugarcane bagasses is 13.1% and 24.0% dry weight, respectively. The organic matter of manure fertilizer and sugarcane bagasse is 22.7% and 41.4% dry weight, respectively.

**Overall biofilter performance:** The experiments were conducted for a period of 40 days. Figure 3-5 show the relationship between the inlet and outlet ammonia gas concentration and the ammonia gas removal efficiency

at EBRT 39s and 78s at 1:3, 1:5 and 1:7 of manure fertilizer and sugarcane bagasse ratio.

The removal efficiency of the whole 40-day period is plotted in Fig. 6-8. Figure 6 shows the RE at EBRT 39s of all three ratios of manure fertilizer and sugarcane bagasse, while Fig. 7 shows the RE at EBRT 78s of all three ratios as well. Figure 8, on the other hand, combines the plots of both figures (EBRT 39s and EBRT 78s) for comparison purpose.

Table 2: Properties of biofilter media

Properties	Unit	Manure Fertilizer	Sugarcane bagasse
1. Moisture content	%	2.70	9.10
2. pH	-	8.60	5.10
3. Bulk density	g m <sup>-3</sup>	0.23	0.16
4. C/N ratio	-	5.50	120.00
5. Organic carbon	% dry weight	13.10	24.00
6. Organic matter	% dry weight	22.70	41.40
7. Nutrient elements			
- N	%	2.37	0.20
- P	%	0.78	0.03
- K	%	0.91	0.42

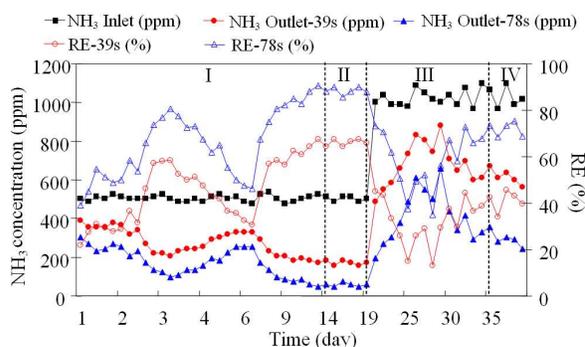


Fig. 3: Relationship between inlet ammonia gas, outlet ammonia gas and removal efficiency at 1:3 of manure fertilizer: sugarcane bagasse ratio

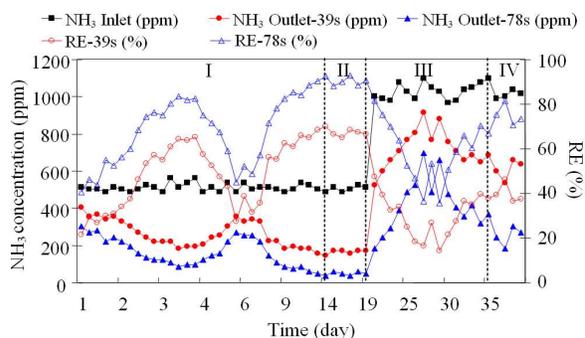


Fig. 4: Relationship between inlet ammonia gas, outlet ammonia gas and removal efficiency at 1:5 of manure fertilizer: sugarcane bagasse ratio

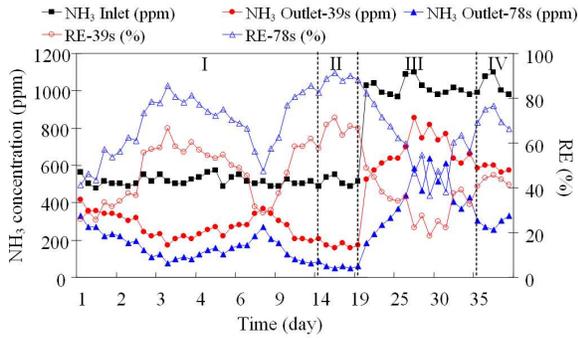


Fig. 5: Relationship between inlet ammonia gas, outlet ammonia gas and removal efficiency at 1:7 of manure fertilizer: sugarcane bagasse ratio

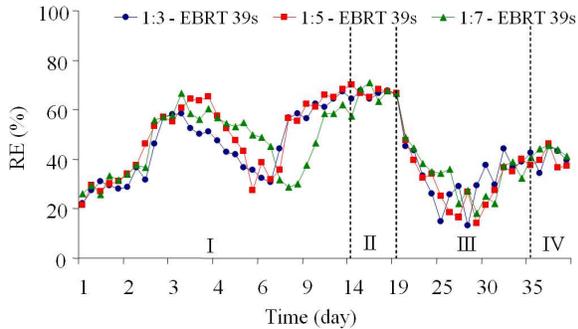


Fig. 6: Ammonia gas removal at EBRT 39s at various biofilter media ratios

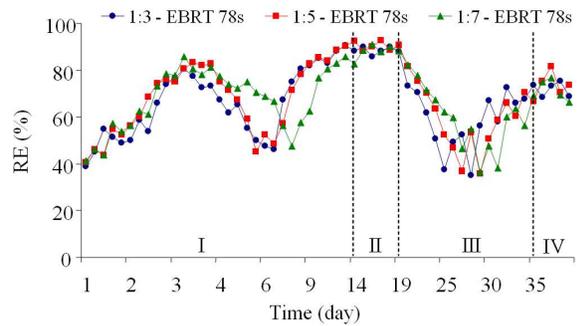


Fig. 7: Ammonia gas removal at EBRT 78s at various biofilter media ratios

The properties of the biofiltration process are shown in Table 3, including the ratio of manure fertilizer and sugarcane bagasse, inlet ammonia concentration, EBRT, mass loading, RE and Elimination Capacity (EC). Furthermore, the relationship of mass loading, RE and EC versus all three ratios of manure fertilizer and sugarcane bagasse as biofilter media are shown in Fig. 9-11, respectively.

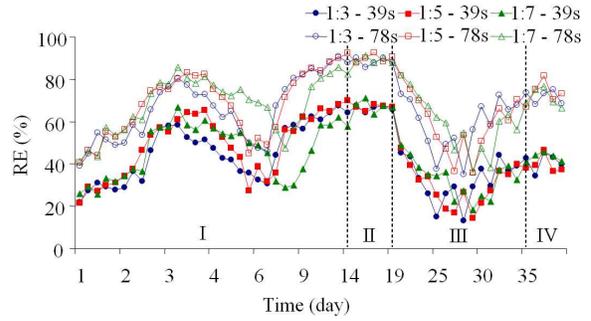


Fig. 8: Ammonia gas removal at EBRT 39s and 78s at various biofilter media ratios

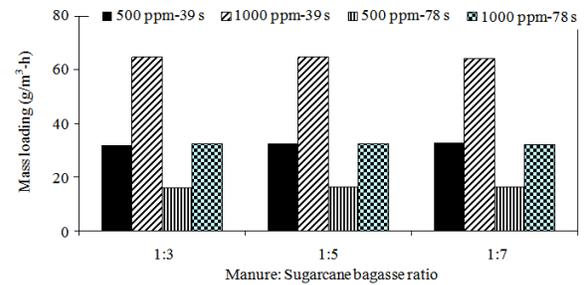


Fig. 9: Mass loading of biofiltration process at various biofilter media ratio

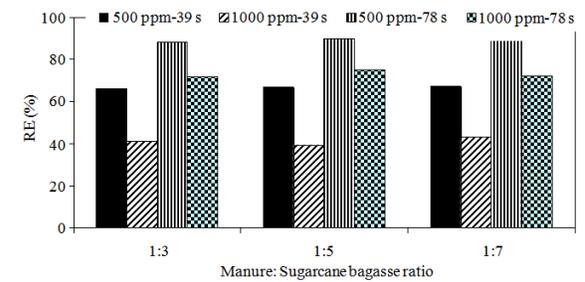


Fig. 10: Removal Efficiency (RE) of biofiltration process at various biofilter media ratio

Table 3: Properties of biofiltration process

Manure fertilizer :sugarcane bagasse ratio	Inlet NH <sub>3</sub> conc. (ppm)	EBRT (s)	Mass loading (g m <sup>-3</sup> h <sup>-1</sup> )	RE (%)	EC (g m <sup>-3</sup> h <sup>-1</sup> )
1:3	500	39	31.89	66.36	21.01
		78	15.94	88.32	13.98
	1,000	39	64.58	41.05	26.73
		78	32.29	71.86	23.33
1:5	500	39	32.27	66.81	21.48
		78	16.14	89.93	14.45
	1,000	39	64.70	39.43	25.03
		78	32.35	75.24	23.88
1:7	500	39	32.62	67.37	22.09
		78	16.31	89.13	14.60
	1,000	39	64.20	43.40	28.27
		78	32.10	72.05	23.48

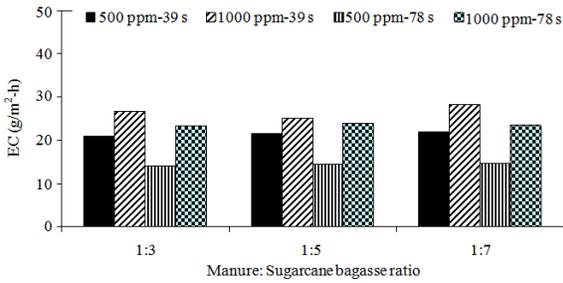


Fig. 11: Elimination Capacity (EC) of biofiltration process at various biofilter media ratio

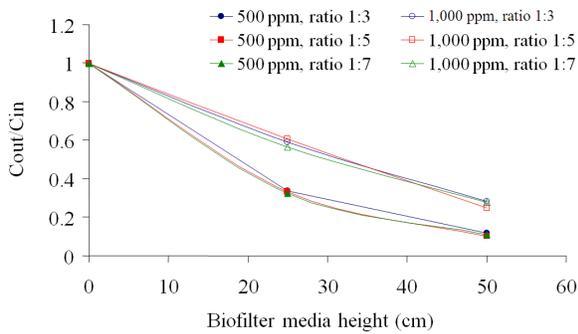


Fig. 12: Relation between biofilter media height and  $C_{out}/C_{in}$  at various biofilter media ratios

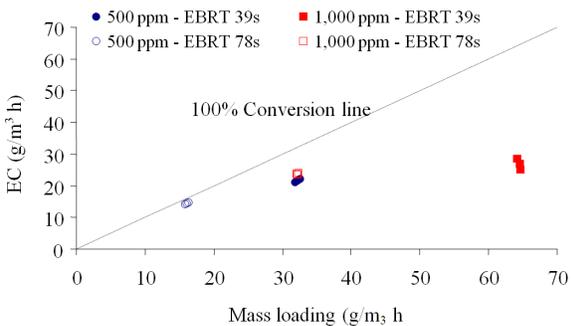


Fig. 13: Relation between mass loading and elimination capacity using manure fertilizer and sugarcane bagasse as biofilter media at various ammonia concentrations

The relationship of biofilter media height versus the outlet concentration and inlet concentration ratio at various biofilter media ratios during the whole experimental period is shown in Fig. 12.

The relationship of EC versus mass loading at various ammonia concentrations and various EBRT values during the whole experimental period is shown in Fig. 13.

## DISCUSSION

The overall performance of all three biofilter media ratios (i.e., 1:3, 1:5 and 1:7) of manure fertilizer and sugarcane bagasse shows the similar trends (Fig. 3-5). The ammonia Removal Efficiencies (RE) were 66.36-67.37% at 500 ppm of inlet ammonia air concentration and the EBRT 39s. While RE were 88.32-89.93% at 500 ppm of inlet ammonia air concentration and the EBRT 78s. RE were 39.43-43.40% at 1,000 ppm of inlet ammonia air concentration and the EBRT 39s. RE were 71.86-75.24% at 1,000 ppm of inlet ammonia air concentration and the EBRT 78s.

The results revealed that the ammonia air removal is more efficient at 500 ppm of inlet ammonia air concentration when comparing with the efficiency at 1,000 ppm of inlet ammonia air concentration. The ammonia air removal efficiency at the EBRT 78s is better than that at the EBRT 39s.

The experimental operation can be divided into four periods (I, II, III, IV) according to the inlet ammonia gas concentration and the steady state of the ammonia gas removal (Fig. 6-8). In phase I, the biofiltration process starts at the lowest inlet ammonia gas concentration (500 ppm). The biofiltration process run until the biofiltration process achieves the steady state (phase II). After that the inlet ammonia gas is changed to 1,000 ppm (phase III). The biofiltration process operates until the biofiltration process is steady (phase IV). The biofiltration experiment period was 40 days. The RE results at each EBRT value (39s and 78s) Fig. 6 and 7 show similar trend.

The results show that the biofilter media ratio is not a significant factor in the ammonia gas removal process. The inlet ammonia gas concentration is the main factor influencing the biofiltration operation. The highest removal efficiency is found at 500 ppm of inlet ammonia gas concentration.

The ammonia gas removal efficiency comparison of the EBRT 39s and 78s showed that the ammonia gas removal efficiency at EBRT of 78s is better than that at EBRT of 39s at the various ratios of manure fertilizer and sugarcane bagasse in biofilter media were 1:3, 1:5 and 1:7. All of manure fertilizer and sugarcane bagasse ratios in Fig. 8 showed that the ammonia gas removal efficiency was found to be similar. In conclusion, the EBRT has a significant impact on the ammonia gas removal efficiency while the ratio of manure fertilizer and sugarcane bagasse has no significant impact.

The properties of the biofiltration process are shown in Table 3. The highest performance observed in this study at the EBRT 78s and 500 ppm of inlet ammonia gas concentration, with the ammonia gas Elimination Capacity (EC) of 13.98, 14.45 and 14.60

$\text{g m}^{-3} \text{h}^{-1}$  and the ammonia gas Removal Efficiency (RE) of 88.32%, 89.93% and 89.13% at 1:3, 1:5 and 1:7 of manure fertilizer and sugarcane bagasse ratios, respectively. While the lowest performance observed in this study at the EBRT 39s and 1,000 ppm of inlet ammonia gas concentration with the EC of 26.73, 25.03 and 28.27  $\text{g m}^{-3} \text{h}^{-1}$  and the RE of 41.05%, 39.43% and 43.40% at 1:3, 1:5 and 1:7 of manure fertilizer and sugarcane bagasse ratios, respectively (Fig. 9-10). The results indicated that the manure fertilizer and sugarcane bagasse ratio of biofilter media was not a significant influence factor for ammonia gas removal efficiency in the biofiltration operation process. The maximum EC of ammonia gas is 28.27  $\text{g m}^{-3} \text{h}^{-1}$  at the EBRT of 39s, the manure fertilizer and sugarcane bagasse ratio of 1:7 and the inlet ammonia gas concentration of 1,000 ppm.

The result in Fig. 9 shows the inlet ammonia gas concentration increases and the mass loading also increases in all experiments. At the same inlet ammonia gas concentration level, the ammonia gas Removal Efficiency (RE) is tended toward the same result. The result can be indicated that the ratio of manure fertilizer and sugarcane bagasse as a biofilter media has no significant impact on the value of ammonia gas removal efficiency (Fig. 10). The result in Fig. 10 showed that the inlet ammonia gas concentration in the biofiltration process improved the EC of ammonia gas. The results also imply that the manure fertilizer and sugarcane bagasse ratio in biofilter media has no significant impact on the EC of ammonia gas at both the inlet ammonia gas concentration 500 ppm and 1,000 ppm. However, the EBRT has significant influent on the EC of ammonia gas. In addition, the EC of biofiltration at EBRT 78s is lower than that at EBRT 39s (Fig. 11).

The result in Fig. 12 showed that increasing of the biofilter media height provides the low outlet ammonia gas concentration and the low inlet ammonia gas concentration ratio (Cout/Cin ratio). The lowest Cout/Cin ratio at 500 ppm and 1,000 ppm is observed at 50 cm of biofilter media height. The result in Fig. 13 shows all mixtures of manure fertilizer and sugarcane bagasse ratios at 500 ppm of inlet ammonia gas concentration for EBRT 39s and 78s and at 1,000 ppm of inlet ammonia gas concentration for EBRT 78s, converse according to the theory. The EC value from the mass loading value is very close to the 100% conversion line. Except at 1,000 ppm of inlet ammonia gas concentration at EBRT 39s, the elimination capacity value from the mass loading value is not close to the 100% conversion line. Thus, the ammonia gas removal using manure fertilizer and sugarcane bagasse as the biofilter media in biofiltration process is quite effective at low inlet ammonia gas concentration and high EBRT value.

## CONCLUSION

The experimental results demonstrated that the ammonia gas was successfully eliminated in a laboratory scale biofiltration process using manure fertilizer and sugarcane bagasse as biofilter media in this study. The EC increases when the inlet ammonia gas concentration increases. The low inlet ammonia gas concentration results in a higher or more effective in biofiltration process than the high inlet ammonia gas concentration. However, the high EBRT provides the good ammonia gas removal efficiency. The manure fertilizer and sugarcane bagasse ratio (i.e., 1:3, 1:5 and 1:7) has no significant impact on the ammonia gas removal efficiency in this study. The maximum ammonia gas removal efficiency is 89.93% at 1:5 ratio of manure fertilizer: sugarcane bagasse ratio for biofiltration process.

The experiments can concluded that the manure fertilizer and sugarcane bagasse are suitable biofilter media for a biofiltration process. The mixture ratio between manure fertilizer and sugarcane bagasse has no significant effect on the ammonia gas removal efficiency. The influence factors of ammonia gas removal efficiency in biofiltration process are the degree of inlet ammonia gas concentration and the EBRT.

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