World Academy of Science, Engineering and Technology
International Journal of Agricultural and Biosystems Engineering
Vol:5, No:5, 2011

Ammonia Gas Removal from Gas Stream by Biofiltration using Agricultural Residue Biofilter Medias in Laboratory-scale Biofilter

Thaniya Kaosol, Nuttawut Pongpat

***Abstract*—**In this research, a biofiltration process to remove ammonia gas from gas stream using agricultural residue biofilter medias is studied. The experiments were conducted in laboratory-scale biofilter. The biofilter medias were a mixture of manure fertilizer and bagasse at various ratios i.e., 1:3, 1:5 and 1:7. The experiments were performed for a period of 40 days. The empty bed retention time (EBRT) is 78s. The moisture content of biofilter media was maintained at 45-60% using water. The results showed that the agricultural residues (manure fertilizer and bagasse) are suitable as biofilter media for ammonia gas removal in biofiltration process.

The maximum efficiency of ammonia gas removal is observed from the 1:5 of manure fertilizer: bagasse ratio at 89.93%. The biofiltration is more effective at low ammonia gas concentration. In addition, the mixture ratio of biofilter media is not a significant factor in biofiltration operation while the most significant factor for biofiltration operation is the inlet ammonia gas concentration.

***Keywords*—** ammonia gas, biofiltration, biofilter media, removal efficiency, elimination capacity

I. Introduction

An ammonia (NH_3) is a colorless, toxic, odorous and corrosive gas produced from several sources, including wastewater treatment plants, composting and fertilizer plants [1], livestock farming such as intensive swine, and poultry or cattle production [2-3] and the chemical and manufacturing industries [4]. Many air pollution techniques for NH_3 removal, such as biological filtration [5-9], liquid absorption [10-11], solid adsorption [12-13], and catalytic oxidation [14-15] have been used to eliminate the ammonia gas emission.

A typical biofiltration is a pollution control method using living material to capture and biologically degrade process pollutants. Biofiltration is the most attractive process for treating ammonia due to its high elimination efficiency, low operational cost, low maintenance cost and modest environmental impact [16]. It is a proven technology as a method of reducing emission of odor and volatile organic compounds (VOCs) from commercial and industrial sources [17]. In the biofiltration process for air pollution control, a contaminated gas stream passes through a biologically enriched layer of a biofilter media material such as soil, wood chips, compost, peat, vegetable mulch, bark or mixed materials, followed by biodegradation of the adsorbed pollutants [18]. Biofilter medias use microorganisms (i.e. bacteria, fungi) to remove air pollution.

In this study, we evaluated the ammonia gas removal by a laboratory-scale biofilter using manure fertilizer and bagasse as biofilter media materials operating. Emissions of ammonia gas, before and after biofiltration were observed to determine how the biofilter affected them.

T. Kaosol, Asst. Prof. Dr., is with the Environmental Engineering Program, Civil Engineering Department, Prince of Songkla University, Hat-Yai, Songkhla, Thailand, 90110 (phone: 006681-4006323; fax: 006674-459396; e-mail: thaniya.k@psu.ac.th).

N. Pongpat, is with the Environmental Engineering Program, Civil Engineering Department, Prince of Songkla University, Hat-Yai, Songkhla, Thailand, 90110 (e-mail: oho_beer@hotmail.com).

The authors would like to acknowledge Prince of Songkla University, Thailand for providing the financial support for this research project (ENG520250S).

II. Materials and Methods

A. Experimental Raw Materials

The agricultural residue biofilter media in these experiments are manure fertilizer and bagasse (shown in 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. Manure fertilizer contains nitrogen, phosphorus, potassium, trace nutrients and soil microorganism stimulants.

(a) (b)

Fig. 1 The agricultural residue biofilter media
(a) manure fertilizer (b) bagasse

Bagasse is the fibrous matter remaining after the extraction of juice from the sugarcane stalks which is an agro-industry waste from sugar factory. The moisture content of bagasse is slightly high at 40-50%. The typical chemical analysis of bagasse is 45-55% of cellulose, 20-25% of hemicelluloses, 18-24% of lignin, 1-4% of ash, and less than 1% of waxes.

B. Experimental Setup

The set-up of the laboratory-scale agricultural residue – based biofilter is illustrated in Fig. 2. In this research, three biofiltration reactors were used. Each reactor consists of a cylindrical vessel of 10 cm in diameter and 100 cm in height. The reactor has the biofilter media as manure fertilizer combined with 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 constant height of 50 cm. Table I shows the properties of the biofiltration operation in this study. The gas flow rate was maintained at 50 cm^3/s. The empty bed retention time (EBRT) was 78 s. The moisture content of biofilter media was maintained at 45-60%. The experiments were carried out continuously until the biofitration process reaches steady state. The pH value during all experiments was maintained in a range between 6 and 8.

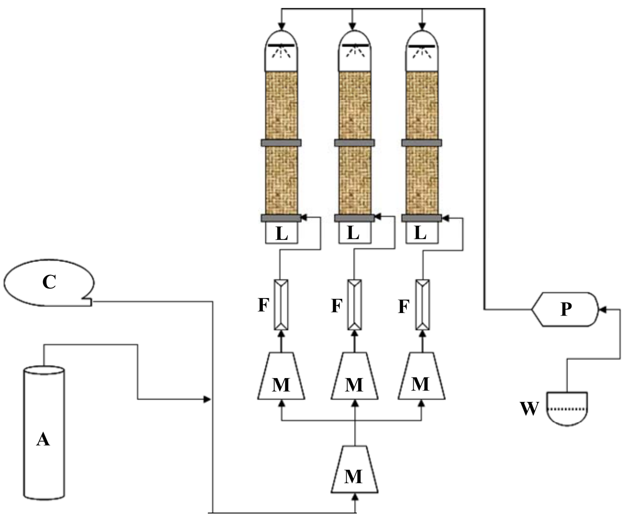


Fig. 2 Flow diagram of biofiltration process (A= NH_3 gas tank, C= compressed air equipment, F = flow meter, L = Leachate tank, M = mixed air and NH_3 gas tank, P = peristaltic pump, and W = water tank)

TABLE I
PROPERTIES OF BIOFILTRATION OPERATION

Parameters	Experimental Operation
1. Height of biofilter media	50 cm
2. NH_3 flow rate	50 cm^3/s
3. Moisture content of biofilter media	45-60%
4. EBRT	78 s
5. pH	6-8
6. NH_3 concentration	500 and 1,000 ppm

C. Monitoring parameters

Ammonia gas samples from the inlet and the outlet of each reactor were taken to be analyzed. Ammonia gas was analyzed using sampling pump in 1 min at flow rate 2 l/min then passing ammonia gas direct to Erlenmeyer flask within 50 ml of boric acid containing. Then the sample was titrated using 0.02 N HCl for concentration of ammonia gas.

III. RESULTS AND DISCUSSIONS

A. Biofilter Media Characteristics

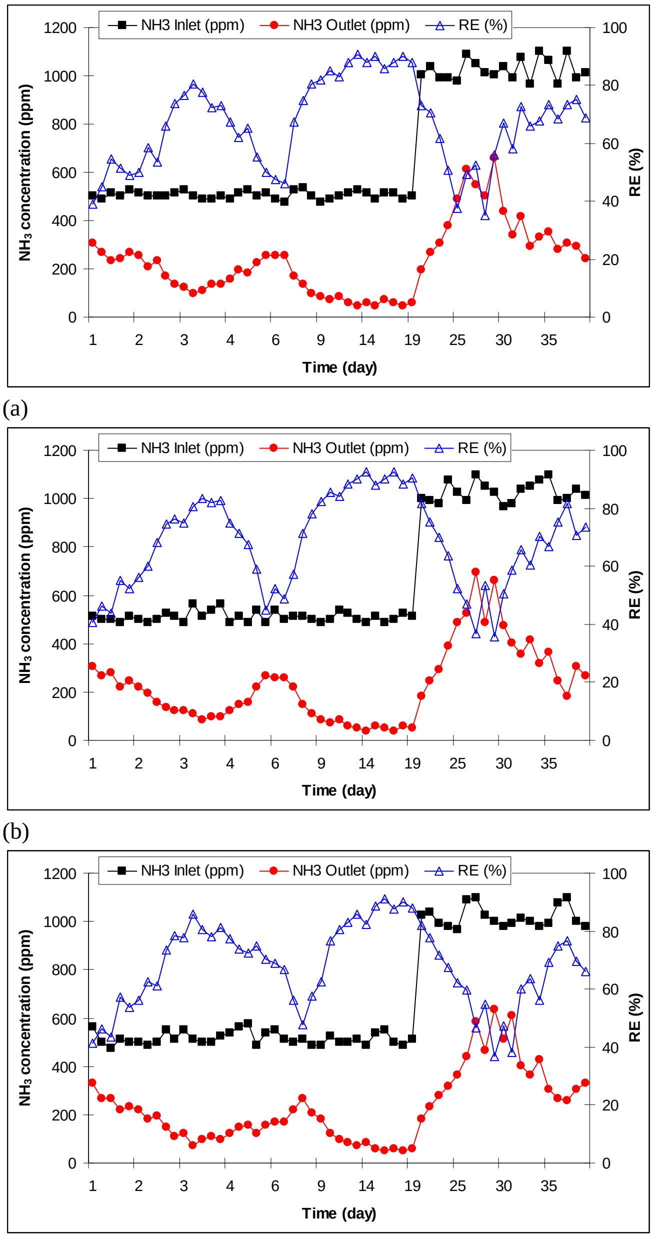
The characteristics of biofilter media, which are manure fertilizer and bagasse, are shown in Table II. The moisture content of manure fertilizer and bagasse were 2.66% and 9.10%, respectively. Optimum moisture content in a biofilter media is the major operational requirement for a biofiltration process. Moisture content between 40-60% is considered an optimal value [19]. Thus, the water must be added into the media in this study to keep the moisture content with in the optimal range. The bulk density is 0.23 g/m^3 and 0.16 g/m^3 for manure fertilizer and bagasse, respectively. The nutrient elements (N: P: K) of manure fertilizer and bagasse for microorganism are 2.37: 0.78: 0.91 and 0.20: 0.03: 0.42, respectively. These nutrients are suitable for microorganism activity in biofiltration process.

TABLE II
CHARACTERISTICS OF BIOFILTER MEDIA MATERIALS

Characteristics	Unit	Manure fertilizer	Bagasse
Moisture content	%	2.66	9.10
Bulk Density	g/m^3	0.23	0.16
pH	-	8.6	5.1
Organic carbon	% dry weight	13.1	24.0
Organic matter	% dry weight	22.7	41.4
Nutrient element			
- N	%	2.37	0.20
- P	%	0.78	0.03
- K	%	0.91	0.42
C/N ratio	-	5.5	120

B. Overall biofilter performance

Experiments were performed for a period of 40 days. The relationship among the inlet ammonia gas concentration, the outlet ammonia gas concentration and the overall performance of the ammonia gas was shown in Fig. 3. The performance of all three ratios (i.e., 1:3, 1:5 and 1:7) of manure fertilizer and bagasse are shown in Fig. 3(a)-(c). The overall results of all three ratios have the same trend that is ammonia gas removal efficiencies were 72-90% with the inlet ammonia gas concentrations of 500 and 1,000 ppm.



(a)

(b)

(c)

Fig. 3 Relationship between ammonia inlet, ammonia outlet and removal efficiency at manure fertilizer: bagasse ratio (a) 1:3 ratio (b) 1:5 ratio (c) 1:7 ratio

Ammonia gas elimination capacity (EC) of 23.33, 23.88 and 23.48 g/m^3-h was observed with the ammonia gas removal efficiency of 71.86%, 75.24% and 72.05% at 1:3, 1:5 and 1:7 of manure fertilizer and bagasse ratios, respectively. The ammonia gas elimination capacity of 13.98, 14.45 and 14.60 g/m^3-h was observed with ammonia gas removal efficiency (RE) of 88.32%, 89.93% and 89.13% (see Table III and Fig. 5 for details). The results showed that the biofilter media ratio was not a significant impact factor for ammonia gas removal in biofiltration process. The maximum of elimination capacity of ammonia gas achieved is 23.88 g/m^3-h at the inlet ammonia gas concentration of 1,000 ppm.

TABLE III
PROPERTIES OF BIOFILTRATION PROCESS IN INLET AMMONIA CONCENTRATION VARIATION

Manure : bagasse ratio	Mass loading (g/m^3-h)		RE (%)		EC (g/m^3-h)	
	Inlet ammonia concentration (ppm)					
	500	1,000	500	1,000	500	1,000
1:3	15.94	32.29	88.32	71.86	13.98	23.33
1:5	16.14	32.35	89.93	75.24	14.45	23.88
1:7	16.31	32.10	89.13	72.05	14.60	23.48

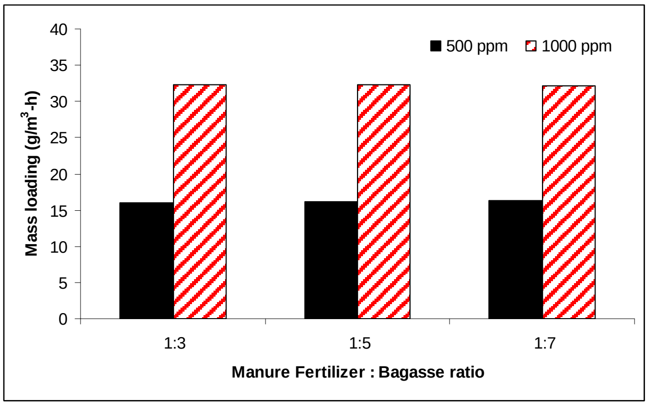


Fig. 4 Mass loading of biofiltration process at various biofilter media ratio

Fig.4 showed the mixture of biofilter media ratio and mass loading. The inlet ammonia gas concentration increases while the mass loading also increases in all experiments. At the same inlet ammonia concentration level, the ammonia gas removal efficiency (RE) is tended toward the same result. It can be indicated that the mixture of manure fertilizer and bagasse ratio is not significant to the value of ammonia gas removal efficiency (Fig. 5).

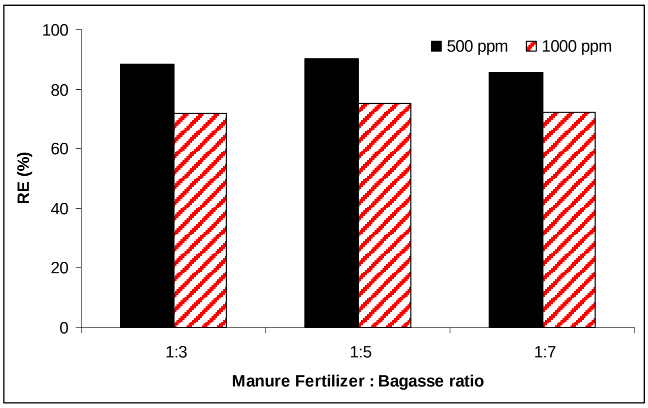


Fig. 5 Removal efficiency of biofiltration process at various biofilter media ratio

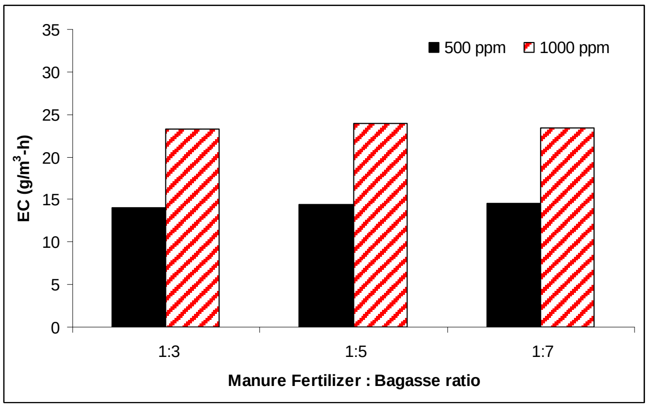


Fig. 6 Elimination capacity of filtration process at various biofilter media ratio

The results in Fig. 6 suggested that the concentration of ammonia gas improved the elimination capacity of ammonia gas. The results also imply that the mixture of manure fertilizer and bagasse ratio is not significant to the elimination capacity of ammonia at both the inlet ammonia gas concentration 500 ppm and 1,000 ppm.

The experimental operation divided into four periods (A, B, C, D) according to the inlet ammonia gas concentration (Fig. 7). In phase A, the biofiltration process starts at 500 ppm of the ammonia gas concentration until the process is steady (phase B). The biofiltration process changes the concentration of the ammonia gas to 1,000 ppm (phase C). The biofiltration process operates until the biofiltration is steady (phase D). The result shows that the biofilter media ratio is not a significant factor for the ammonia gas removal efficiency value. However, the inlet concentration of ammonia gas is the main influence in the removal efficiency. The ammonia gas removal efficiency at 500 ppm of ammonia gas concentration provided the highly ammonia gas removal efficiency.

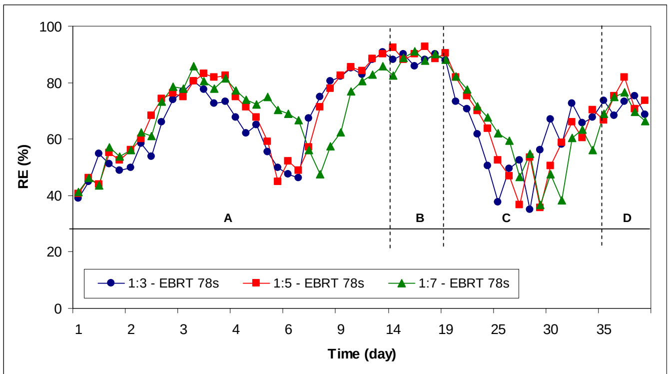


Fig. 7 Ammonia removal at ammonia concentration 500 and 1,000 ppm at various biofilter media ratio

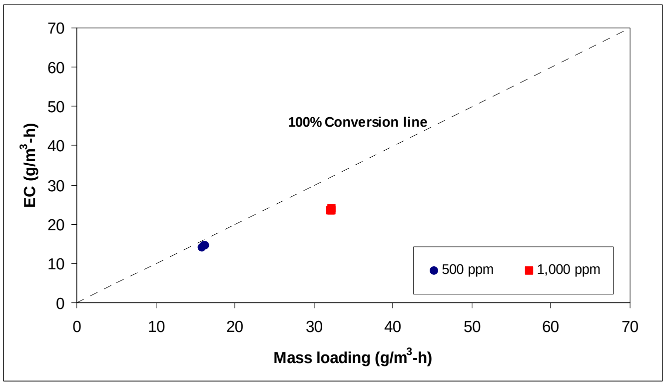


Fig. 8 Relation between mass loading and elimination capacity using manure fertilizer and bagasse as biofilter media

The relation of elimination capacity (EC) versus mass loading during the whole experimental period is shown in Fig. 8. All mixture of biofilter media ratios at 500 ppm ammonia gas concentration in this study converses according to the theory. The elimination capacity value given from the mass loading value is very close to the 100% conversion line. At 1,000 ppm ammonia gas concentration, on the other hand, the elimination capacity values of all three mixtures of biofilter media ratios are not as close to the 100% conversion line as those observed from the 500 ppm ammonia gas concentration. Thus, the ammonia gas removal using agricultural residue biofilter medias in biofiltration process is quite effective at low ammonia gas concentration.

IV. Conclusion

The experimental results in this study demonstrated that the elimination capacity increases when the inlet ammonia gas concentration increases. The low ammonia gas concentration at the inlet results in a higher or more effective biofiltration process than that when the ammonia gas concentration at the inlet is high. The mixture ratio is not a significant factor of the ammonia gas removal in this study. The maximum ammonia gas removal efficiency achieved is 89.93% in the 1:5 of manure: bagasse ratio for biofiltration process.

In conclusion, the agricultural residues are suitable biofilter media for biofiltration process. The significant factor of the ammonia gas removal in biofiltration process is the level of ammonia gas concentration at the inlet. The mixture ratio of biofilter media in this study (i.e., manure fertilizer and bagasse) has no significant effect on the ammonia gas removal efficiency.

References

[1] G. Busca, C. Pistarino, “Abatement of ammonia and amines from waste gases: a summary”, *J. Loss Prevent. Proc.*, 16, 2003, 157-163.

[2] Y.C. Chung, C. Huang, C.P’ Tseng, “Reduction of H_2S/NH_3 production from pig feces by controlling environmental conditions”, *J. Environ. Sci. Health*, A31, 1996, 139-155.

[3] J. Arogo, P.W. Westerman, A.J. Heber, “A review of ammonia emissions from confined swine feeding operations”, *Transactions of the ASAE*, 46(3), 2003, 805-817.

[4] J.H. Kim, E.R. Rene, H.S. Park, "Performance of an immobilized cell biofilter for ammonia removal from contaminated air stream", *Chemosphere,* 68, 2007, 274-280.

[5] E. Smet, H.V. Langenhove, K. Maes, "Abatement of high concentrated ammonia loaded waste gases in compost biofilters", *Water Air Soil Pollut.,* 119, 2000, 177-190.

[6] J.H. Hong, K.J. Park, "Compost biofiltration of ammonia gas from bin composting", *Bioresour. Technol.,* 96, 2005, 741-745.

[7] E. Pagans, X. Font, A. Sánchez, "Biofiltration for ammonia removal from composting exhaust gases", *Chem. Eng. J.,* 113, 2005, 105-110.

[8] N.J. Kim, M. Hirai, M. Shoda, "Comparison of organic and inorganic packing materials in the removal of ammonia gas in biofilters", *J. Hazard. Mater.,* 72, 2000, 77-90.

[9] Y.C. Chung, Y.Y. Lin, C.P. Tseng, "Removal of high concentration of NH_3 and coexisted H_2S by biological activated carbon (BAC) biotrickling filter", *Bioresour. Technol.,* 96, 2005, 1812-1820.

[10] W.H. Chen, "Atmospheric ammonia scavenging mechanisms around a liquid droplet in convective flow", *Atmos. Environ.,* 38, 2004, 1107-1116.

[11] K. Terasaka, J. Oka, H. Tsuge, "Ammonia absorption from a bubble expanding at a submerged orifice into water", *Chem. Eng. Sci.,* 57, 2002, 3757-3765.

[12] C.C. Rodrigues, D. Moraes Jr., S.W. Nóbrega, M.G. Barboza, "Ammonia adsorption in a fixed bed of activated carbon", *Bioresour. Technol.,* 98, 2007, 886-891.

[13] J. Guo, W.S. Xu, Y.L. Chen, A.C. Lua, "Adsorption of NH_3 onto activated carbon prepared from palm shells impregnated with H_2SO_4", *J. Colloid Interf. Sci.,* 281, 2005, 285-290.

[14] S.J. Juutilainen, P.A. Simell, A.Q.I. Krause, "Zirconia: selective oxidation catalyst for removal of tar and ammonia from biomass gasification gas", *Appl. Catal. B: Envioron.,* 62, 2006, 86-92.

[15] W. Wang, N. Padban, Z. Ye, A. Anderesson, I. Bjerle, "Kinetics of ammonia decomposition in hot gas cleaning", *Ind. Eng. Chem. Res.,* 38, 1999, 4175-4182.

[16] A.H. Wani, R.M.R. Branion, and A.K. Lau, "Biofiltration: a promising and cost-effective control technology for odors, VOCs and air toxics", *J. Environ. Sci. Health,* A32, 1997, 2027-2055.

[17] K. Vaith, M. Cannon, D. Milligan, J. Heydorn, "Comparing scrubbing technology", *Water Environment & Technology,* 8(6), 1996, 35-38.

[18] E. Pagans, X. Font, A. Sánchez, "Coupling composting and biofiltration for ammonia and volatile organic compound removal", *Biosystems Engineering,* 97, 2007, 491-500.

[19] G. Leson, A.M. Winer, "Biofiltration: an innovative air pollution control technology for VOC emissions", *Journal of Air and Waste Management Association,* 41(8), 1991, 1045-1054.

Thaniya Kaosol was born in 1972 at Ubonratchathanee, Thailand. Assistant Professor Dr. Kaosol received her Doctorat (Génie des Procédés); Degree from Université Montpellier II, France in 2007. She received her Master Engineering (M.Eng) in Environmental Engineering; degree in 1997 and Bachelor of Engineering (B.Eng) in Agricultural Engineering; degree in 1995 from Kasetsart University, Bangkok, Thailand. She worked at Guarantee Engineering Co., Ltd. and NS Consultant Co., Ltd.; during her graduated study. Currently, she is a lecturer in the Environmental Engineering Program, Department of Civil Engineering, Prince of Songkla University, Thailand. She is also holding a position of assistant dean for human resource development of the Faculty of Engineering at the same institute. Her research interests include solid waste management, waste minimization, air pollution control, wastewater treatment, and waste recovery and recycling. She is a member of Council of Engineers and The Environmental Engineering Association of Thailand.