The Thai Journal of Veterinary Medicine

Volume 46
Issue 3 *September, 2016*

Article 11

9-1-2016

Performance analysis of the combined plug-flow anaerobic digester (PFAD) and upflow anaerobic sludge blanket (UASB) for treating swine wastewater in Thailand

Chackrit Nuengjamnong

Pichaya Rachdawong

Original Article

Performance analysis of the combined plug-flow anaerobic digester (PFAD) and upflow anaerobic sludge blanket (UASB) for treating swine wastewater in Thailand

Chackrit Nuengjamnong[1] and Pichaya Rachdawong[2*]

Abstract

The objective of this research was to analyze the overall performance, especially the removal efficiency, of the combined plug-flow anaerobic digester (PFAD) and upflow anaerobic sludge blanket (UASB) system, at a large swine farm in Thailand. Eighty-four wastewater samples from the digester were collected during the observation period of 302 days. Appropriate influent and effluent regions were selected for wastewater collection. Treatment efficiencies of the system were evaluated by key parameters such as chemical oxygen demand (COD), soluble chemical oxygen demand (SCOD), total solids (TS), total suspended solids (TSS) and total Kjeldahl nitrogen (TKN). In addition, microbiological parameters such as *E. coli* and *Salmonella* spp. were measured. These parameters were analyzed according to the Standard Method for Examination of Water and Wastewater. The average removal efficiencies of COD, SCOD, TS, TSS and TKN were 80.6%, 85.6%, 58.7%, 82.7% and 33.9%, respectively. For the COD removal, the solid part was removed by sedimentation process while the soluble part was stabilized anaerobically. The TSS removal efficiency was quite high, indicating that the system could separate suspended solid from wastewater. The effluent had dramatically lower amount of *E. coli* compared with the influent. The most common *Salmonella* serovars in the influent samples were Stanley, Rissen, and Anatum, respectively. Biogas production rates fluctuated due to variable organic inputs to the system. These results clearly indicate that the system of PFAD and UASB is capable of treating both solid and soluble portions of swine wastewater as well as reducing pathogenic bacteria to a certain extent. However, a polishing step is required to reduce organic content of the effluent in order to meet the limit set by the regulatory agency of Thailand.

Keywords: anaerobic digester, performance, swine farm, Thailand, wastewater

[1]*Department of Animal Husbandry, Faculty of Veterinary Science, Chulalongkorn University, Henri-Dunant Rd, Pathumwan, Bangkok 10330, Thailand*

[2]*Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Phayathai Rd, Pathumwan, Bangkok 10330, Thailand*

***Correspondence:** pichaya.r@chula.ac.th*

Introduction

Thailand is the largest swine producer in Southeast Asia, with the production of 13.07 million heads in 2013 (The Office of Agricultural Economics, 2013). Environmental problems are becoming a worldwide concern as swine production has changed from small farms to large scale production. Most wastewater from small and medium swine farms is directly discharged into natural water body, worsening the situation of water and soil pollution. Large scale farms, on the contrary, generally use a variety of anaerobic digestion technologies to manage manure and wastewater. Anaerobic digestion provides a number of environmental and economic benefits. Examples of common anaerobic digestion processes in Thai swine farms are covered anaerobic lagoons, plug-flow anaerobic digester (PFAD), upflow anaerobic sludge blanket (UASB) and combination of PFAD and UASB. PFAD has been successfully employed for livestock waste and other biological waste management because of its uncomplicated structure, low capital investment, low operational energy demand, minimal chance of short circuiting, moderate pathogen eradication, and ability to handle high solid stream. Nonetheless, some disadvantages of PFAD have been reported such as low mass transfer due to inadequate mixing, low treatment efficiency for low solid stream, thermal stratification and sedimentation of solids along flow path (Adl et al., 2012). UASB, on the other hand, focuses on improving solid retention time (SRT) and hydraulic retention time (HRT) in the digester. Solids requiring a high degree of digestion can remain in the reactors for up to 80 days. Soluble substances (e.g. sugars) dissolved in the liquid phase can be rapidly converted into gas which can exit the system within a day. Compared to conventional anaerobic digestion, the lengthy SRT highly improves biological activity while the short HRT minimizes reactor volume (Finstein et al., 2004). However, UASB digester can operate well only for low solid influent (Hamilton, 2014), therefore, swine wastewater with high solid influent requires a reduction treatment process, e.g. PFAD. The biogas system for medium to large scale swine farms in Thailand is usually composed of PFAD plus UASB digesters.

To date, there is still lack of information regarding the actual operation of large scale PFAD combined with UASB digesters in Thailand. Therefore, the objective of this study was to investigate the combined system's overall performances, especially the removal efficiencies and possible mechanisms, in the treatment of swine wastewater. The information provided would give better insight into the existing processes on farms across the country.

Materials and Methods

Sample collection: This study was conducted on a large scale swine farm that contained 930 parent breeders, 1,800 piglets and 6,500 finishers. The farm is located in Ratchaburi province. The treatment system is a combination of PFAD and UASB digesters, and is schematically illustrated in Figure 1. The digester system has been operated for three years. Wastewater was collected 14 times during the observation period of 302 days using the composite sampling technique. The total volume of wastewater sample was 6 liters/day.

Figure 1 Schematic diagram of PFAD and UASB with influent and effluent regions

Analytical Procedures: Influent wastewater flow rate was measured using an electromagnetic flow meter (Proline Promag 50D®; Endress + Hauser Pty Ltd). Effluent wastewater flow rate was measured using a rectangular weir. Biogas flow rate was recorded using differential pressure flow (Deltatop D063C®; Endress + Hauser Pty Ltd). A flow meter (Deltabar differential pressure transmitter) was set up in a biogas pipe and was used to measure biogas production rate per day. Biogas volume was collected in gas bags (Tedlar®) and then percentage of methane was quantified using gas chromatography. Data of wastewater and biogas flow rates were operated by processing unit and read by ReadWin 2000 program. Oxidation reduction potential (ORP) was measured using ORP meter (SMWW 2580B).

Quantitative analysis of key parameters (i.e. chemical oxygen demand (COD), soluble chemical oxygen demand (SCOD), total solids (TS), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), volatile fatty acid (VFA) and alkalinity) was determined according to the Standard Method for Examination of Water and Wastewater (APHA, 1998). Furthermore, the influent and effluent wastewater samples were diluted (ISO 6887-1, 1999) and cultured using the spread-plate technique (Prescott, 2002), then *E. coli* was identified using biochemical assays (FDA, 1998). The diluted wastewater was also cultured and identified for *Salmonella* spp. using biochemical assays (WHO, 1996). Determination of *Salmonella* serovars was done by a serology test (Bangtrakulnonth et al., 2004).

Results

Information on the operating parameters of the digester was collected and is shown in Table 1. Wastewater characteristics of the influent and effluent samples as well as treatment efficiencies were calculated and analyzed, and are shown in Table 2. The biogas production rate during the observation period (302 days) is shown in Figure 2. During the initial period (1-43 d) the biogas production was stable, but later it highly fluctuated. The average rate of biogas production was 1,246.05±619.41 m^3/d. The investigation into *Salmonella* spp. in the wastewater is shown in Table 2. *Salmonella* spp. could not be found in the effluent samples. However, it was detected in the influent samples and was then subdivided into several serovars (Figure 3). The main serovars of *Salmonella* spp. detected were S. Stanley (31.33%), S. Anatum (24.10%) and S. Rissen (24.10%).

Table 1 Operating parameters of the combined anaerobic digester

Parameters	Value
Wastewater flow rate*	
-Influent	186.4±39.8 m^3/d**
- Effluent	174.1±44.9 m^3/d**
Digester volume	5,184 m^3
Hydraulic retention time (HRT)	27.8 d
Organic loading rate (OLR)	0.60 kg COD/m^3/d

* Mean ± standard deviation
**Difference between influent and effluent represents sludge flow rate discharged from the system.

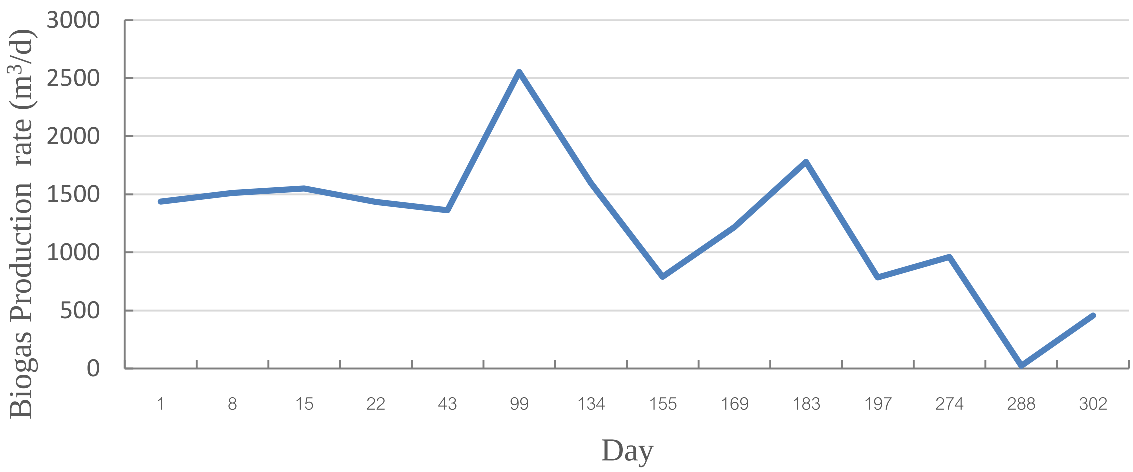

Figure 2 Biogas production rate during the experimental period

Table 2 Parameter characteristics and treatment efficiencies of the combined anaerobic digester
*Mean ± standard deviation

Parameters*	Influent	Effluent	Treatment efficiencies
pH	7.2±0.4	7.4±0.1	-
Temperature (ºC)	31.5±3.2	32.2±3.8	-
Alkalinity (mg/l $CaCO_3$)	318.8±69.7	392.4±50.8	-
ORP (mV)	-324.3±4.8	-290.5±11.7	-
COD (mg/l)	16,647.5±10,819.8	1,963.2±1,283.9	80.6±24.3%
SCOD (mg/l)	3,558.7±1,343.3	462.4±87.1	85.6±4.7%
TS (mg/l)	11,761.9±1,0782.2	3,399.7±1,577.2	57.3±19.8%
TSS (mg/l)	10,653.5±10,323.4	907.1±906.8	82.7±15.1%
VSS (mg/l)	8,903.1±8,485.8	746.8±626.3	
TKN (mg/l)	406.5±254.6	271.9±170.4	33.9±17.8%
VFA (mg/l)	-	119.8±67.8	-
VSS/TSS	0.8±0.2	0.85±0.1	-
COD/N (kgCOD/kgN)	42.2±15.6	12.8±13.7	-
E. coli (CFU/mL)	13,226.1±11,329.8	271.4±158.2	94.8±6.1%
Salmonella spp.** (%)	88.89%	0%	-

**Presented as percentage of prevalence found in wastewater samples

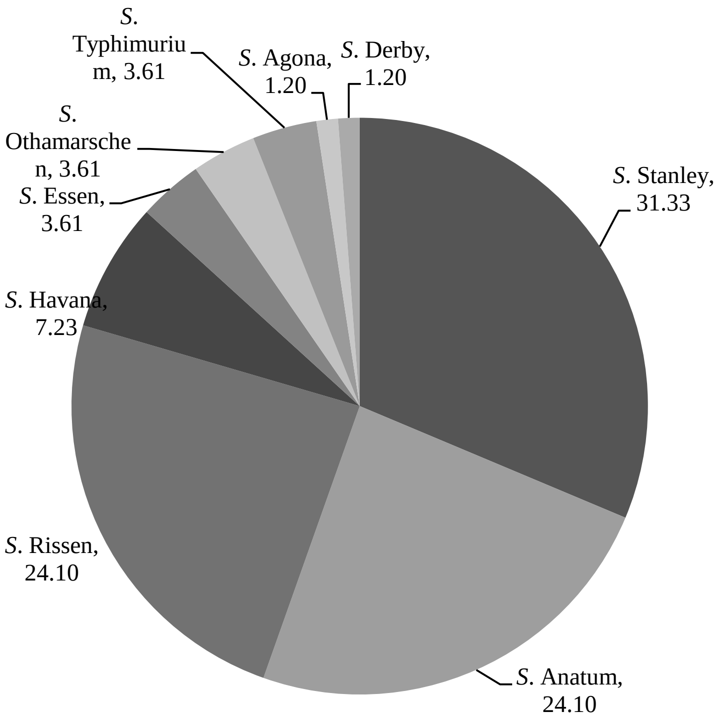

Figure 3 Percentage of *Salmonella* spp. serovars in the influent wastewater

Discussion

The average flow rate of wastewater to the system was 186.4 m^3/d. The flow rate was highly dependent on the number of swine in the farm at the time of sample collection. The number of swine present was, however, inversely related to market price. The average organic loading rate (OLR) was in the typical range for AD at about 0.5-0.6 kg COD/m^3/d (Tchobanoglous et al., 2003). The average hydraulic retention time (HRT) in this digester (27.8 d) was in the normal range (20-30 d) for digesting manure (Luostarinen et al., 2011).

The temperature in the biogas system was in acceptable range. The optimal temperatures of acidifying bacteria are 32-42ºC for mesophilic bacteria and 48-55ºC for thermophilic bacteria. However, most methanogenic archea belong to the mesophilic group (Deublein and Steinhauser, 2008). Therefore, the temperature of the biogas system was suitable for acidifying and methanogenic communities. In this study, pH values of the influent and effluent wastewater were in the neutral range and quite stable. The average pH of the system was in the normal range of well-operated anaerobic digestion system, which is from 6.5 to 8.5 (Ahn et al., 2010). Therefore, anaerobic archea could grow in this biogas system.

The average alkalinity of the influent and effluent was lower than the typical values for anaerobic process, which is in the range of 1,500-2,000 mg/l (Tuntoolavest MS and Tuntoolavest MR, 2004). However, the combined anaerobic process could still be operable in this range due to the relatively stable pH values. Moreover, swine wastewater usually has a high ammonia content, therefore it could increase alkalinity in the digester. It was noted that the alkalinity values of the effluent were higher than those of the influent during the observation period because denitrification bacteria could convert nitrogenous compounds into ammonia gas. When the gas reacts with CO_2 and H_2O, it can produce (NH_4) HCO_3, which is a buffering agent (Boyle et al., 1985).

ORP measures electrical charges from particles called ions, and these charges are converted to millivolts (mV). The ORP values of both the influent and effluent were in the range of acid and methane-forming communities, which could thrive over a large range of ORP values, -300 and -500 mV, respectively (Tuntoolavest MS and Tuntoolavest MR, 2004).

The influent total solids (TS), total suspended solids (TSS), and volatile suspended solids (VSS) had intensely high average and standard variation values due to no solid separation practices in the farm. The solids came from swine feces and remaining feed in the pen. These solids mixed with wastewater of washed house and contributed significantly to the COD values. All solid values were in the range of those in conventional anaerobic digesters. Such digesters could receive feeding influent with TS, TSS and VSS at the level of 20,000-60,000 mg/l, 5,000-20,000 mg/l, and 25,000-35,000 mg/l, respectively (Udomsinroj, 2000). However, the average influent TSS of this farm was higher than the value recommended by The Pollution Control Department (2007) of 4,800 mg/l for large scale farms that possibly have solid separation. The average effluent TSS was in accord with that of Kamalasing (2006) at the level of 260-990 mg/l. Furthermore, the ratio of VSS/TSS was about 0.8 in both the influent and effluent, indicating that the majority of suspended solids in the system were volatile suspended solids.

The influent streams had high average and standard deviation for the COD values. The organic content of the wastewater was primarily from high solids in the stream since influent SCOD / COD = 0.21. The average effluent COD of this system was higher than the standard effluent limit at 300 mg/l for large scale farm (The Pollution Control Department, 2003). SCOD of the influent and effluent is a key parameter for understanding the removal efficiency of organic compounds of a system. As solid COD settled in the settling section of the system (the entrance of the combined system), SCOD remained the main source of organics for bacterial utilization to produce methane. The average influent SCOD in this study was in the range reported by Kamalasing (2006) of 580-16,460 mg/l. The average effluent SCOD in this study was less than that of Muenjee (2010) at 574.65mg/l.

In terms of treatment efficiencies, the removal rate of COD was at 80.6% on average, which is lower than that of an anaerobic filter reactor combined with hybrid UASB system at 94.3% (Inpramoon, 2010) but still higher than that of an anaerobic digester at 62-69% (Tchobanoglous et al., 2003). The treatment efficiency of SCOD in this study was relatively high compared to those of previous reports at 56.1% (Maneechote, 2002) and 72% (Tanarat, 2005). The soluble COD portion was converted to biogas and resulted in complete organic stabilization. The treatment efficiency for TSS was better than TS, and was achieved by sedimentation process at the beginning of the combined system. Moreover, the average treatment efficiency of TSS in this study was similar to that of domestic wastewater using UASB at 53.8-89.5% (Ninprayoon, 1993).

The volatile fatty acids mostly occurred during the second step of the anaerobic digestion. VFA in the effluent of the system was in the proper range of anaerobic process, which is 50-500 mg/l (Gelegenis et al., 2007). The VFA value in this observation was in agreement with the findings of Inpramoon (2010) and Muenjee (2010), who found that VFA of the biogas system for swine farm was in the range of 50-500 mg/l. It means that the condition was suitable for methanogenic bacteria to produce methane gas.

The influent and effluent TKN values in this study were different from those reported by Santadsaerianan in 2002, which had the influent and effluent TKN of 254 and 178 mg/l, respectively, for a UASB system. The nitrogen removal of this study was similar to that of Santadsaerianan (2002) but was less than the TKN removal using anaerobic baffled reactor (ABR) to treat swine wastewater (Ruchirased and Chinwetkitvanich, 2008). Therefore, it is necessary to further treat the N remaining in the effluent of swine wastewater. One of the biological processes for NH_4^+-N removal is the partial nitrification-denitrification (Campos et al., 2010). The C/N ratios in the influent and effluent were still higher than the optimum ratio for organic matter in wastewater to be used for denitrification at the level of 4-5 kgCOD/kgN (Henze et al., 1995). Belmonte and Vidal (2013) recommended that the anaerobic digestion was suitable for swine wastewater with high COD/N ratio (> 10).

The effluent of the combined system could not meet the limit of most parameters (i.e. COD, TSS, TKN) based on the Thai standard for effluent from large scale swine farms. Therefore, the addition of further treatment processes (e.g. pond polish, constructed wetlands) would be required for the digester.

The average rate of biogas production in this system was relatively high compared with the rate of 700m^3/d on a swine farm with 1,560 livestock units as reported by Suwathanachao (2000). The biogas production rate in the first period of the study was quite stable because the system had been operated nearly a year prior to the trial. The bacteria in the digester could adapt themselves for living in swine wastewater. The rates during 99-302 d highly fluctuated due to the variable organic loading into the system. The organic content of the stream is very dependent on the number of pigs remaining on the farm and is due to market price of pork. However, the average ratio between VFA and alkalinity in this system was 0.3±0.15, indicating an acceptable degree of stability since the ratio of 0.1-2.5 is considered as the optimum for operating the biogas system (Ertem, 2011). The percentage of methane in the biogas system was 53% and was in accord with results reported by the Pollution Control Department (2006), which suggests methane percentage at the level 50% for general swine farms in Thailand. However, the methane percentage of anaerobic process from some swine farms could be as high as 67.6-69.5% (Maneechote, 2002). The methane percentages are dependent on many factors such as wastewater characteristics, digester operational parameters, and farm management system.

The amount of *E.coli* could be greatly decreased in the effluent of the biogas system. This result is consistent with that of a previous study stating that *E.coli* could be reduced to 1.4-2.2 log MPN/100 ml in two types of biogas system, i.e. cover lagoon and fixed dome (Nuengjamnong and Muangkeao, 2008). However, most animal manures treated by mesophilic biological processes are questionable to decrease pathogen levels by more than 1-2 $\log_{10}$ or 90-99%, with the exception of using several treatment processes in series (Sobsey et al., 2006). Possible reasons for such reduction in the biogas system are the physico-chemical processes, as well as natural growth and death of the individual pathogen other than bio-chemical processes (Pant and Mittal, 2007). Sedimentation is also one of the mechanisms that could result in the removal of *E.coli* from anaerobically pre-treated sewage (Tawfik et al., 2004).

The prevalence of *Salmonella* spp. in the influent was 88.89% (8 samples from 9 samples). This result agreed with a study indicating that *Salmonella* spp. could be found generally in swine manure and could survive under suitable environment for more than a year (Misscherlich and Marth, 1984). The main commonly identified serovars of *Salmonella* spp. in this study were similar to the trend of previous studies in that the most common *Salmonella* serovars found in pigs from northern Thailand were Rissen, Weltevreden, Anatum, and Stanley, respectively. The most common serovar found in pig farm workers was Rissen (Padungtod and Kaneene, 2006). Serovar Anatum seems to be related to non-poultry food products and water contamination in Thailand (Bangtrakulnonth et al., 2004). Moreover, Sirichote et al. (2010) reported that the most common serovars from stool samples of patients in central Thailand were Weltevreden, Stanley, Anatum, and Rissen, respectively. The prevalence of *Salmonella* serovars from several findings indicates that humans possibly serve as a source of *Salmonella* contamination for pigs.

The prevalence of *Salmonella* spp. in the effluent was not observed. Muangkeao (2005) tentatively proposed that there was a competition between *Salmonella* spp. and other bacteria (i.e. Coliforms, Enterobacteria, *E.coli*) in the pre-enrichment media and selective media during the isolation method. Therefore, few numbers of *Salmonella* spp. could not increase in number in the media. Nonetheless, there was prevalence of *Salmonella* spp. in the influent but not in the effluent. It could be inferred that the removal of *Salmonella* spp. by the biogas was favorable. Pant and Mittal (2007) found that the elimination of *Salmonella* spp. by the UASB based sewage treatment plant was 88.5% and the overall percentage reduction in *Salmonella* spp. after a pond polish was 95.46%.

In conclusion, the treatment efficiency of the combined PFAD and UASB anaerobic digester was efficient for swine wastewater with high COD/N ratio but inefficient for nitrogen removal. However, the system was capable of functioning as both settling tank and anaerobic digestion, and could successfully handle high loads of COD containing high organic solid portion, which is the major characteristic of swine farm effluent in Thailand.

Acknowledgements

This research was supported by Thai Foods Swine Line Co., Ltd. The authors would like to dedicate this work in memory of Assoc. Prof. Dr. Thongchai Chalernchaikit.

References

Adl M, Sheng KC, Xia, YH, Gharibi A and Chen X 2012. Examining a hybrid plug-flow pilot reactor for anaerobic digestion of farm-based biodegradable solids. Int J Environ Res. 6(1): 335-344.

Ahn HK, Smith MC, Kondrad, SL and White JW 2010. Evaluation of biogas production potential by dry anaerobic digestion of switchgrass-animal manure mixtures. Appl Biochem Biotechnol. 160: 965-975.

APHA 1998. Standard methods for examination of water and wastewater. 20th ed., Washington, DC: American Public Health Association.

Bangtrakulnonth A, Pornreongwong A, Pulsrikarn C, Sawanpanyalert P, Hendriksen RS, Wong D and Aarestrup FM 2004. *Salmonella* serovars from humans and other sources in Thailand, 1993-2002. Emerg Infect Dis. 10:131-136.

Belmonte M and Vidal G 2013. Effect of COD/N ratio on treatment of swine wastewater. Proceedings of the 3rd Symposium on Agricultural and Agroindustrial Waste Management, Sao Pedro, SP, Brazil, March 12-14.

Boyle WC, James CC, Ripley LE and Kmet NM 1985. The effect of ammonia nitrogen on the anaerobic digestion of poultry manure. Proc 40th Industrial Waste Conference, Purdue University: 73-80.

Campos JL, Vázquez-Padín JR, Figueroa M, Fajardo C, Mosquera-Corral A. and Méndez, R 2010. Novel biological nitrogen-removal processes: applications and perspectives. In: Fluid Waste Disposal, KW Canton (ed), 153-181.

Deubleinn D and Steinhauser A 2008. Biogas from waste and renewable resources. Weinheim: Willey-VCH Verlag GmbH & Co.KGaA.

Ertem FC 2011. Improving biogas production by anaerobic digestion of different substrates. Master Thesis, Halmstad University.

Finstein MS, Zadik Y, Marshall AT and Brody D 2004. The ArrowBio process for mixed municipal solid waste – responses to requests for information. Proceedings of the 1st UK Conference and Exhibition on Biodegradable and Residual Waste Management, Harrogate, UK. February 18-19: 407-413.

FDA 1998.Bacteriological analytical manual. 8th ed RL Merker (ed) Gaithersburg: AOAC International.

Gelegenis J, Georgakakis D, Angelidaki I and Mavris V 2007. Optimization of biogas production by co-digesting whey with diluted poultry manure. Renew Energ. 32: 2147-2160.

Hamilton DW 2014. "Anaerobic digestion of animal manures: Types of digesters." [Online]. Available: http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-7056/BAE-1750web2014.pdf. Accessed September 29, 2015.

Henze M, Harremoës P, Jansen JC and Arvin E 1995. Wastewater treatment: Biological and chemical processes. Berlin: Springer-Verlag.

Inpramoon A. 2010. Enhancement of biogas production from swine waste using hybrid UASB and anaerobic filter reactor. Master Thesis. Chiang Mai University (in Thai).

ISO 6887-1, 1999. Preparation of test samples, initial suspension and decimal dilations for microbiological examination. Thai Industrial Standards Institute (TISI) Library.

Kamalasing U 2006. Nitrogen removal from simulated anaerobic ally treated swine wastewater by two-sludge sequencing batch reactor. Master Thesis. King Mongkut's University of Technology Thonburi (in Thai).

Luostarinen S, Normak A and Edström M 2011. " Overview of biogas technologies." [Online]. Available: http://www.balticmanure.eu/download/Reports/baltic_manure_biogas_final_total.pdf. Accessed September 21, 2015.

Maneechote N 2002. Performance comparison of upflow anaerobic sludge blanket and hybrid UASB&AF processes in pig waste treatment. Master Thesis. Kasetsart University (in Thai).

Misscherlich E and Marth EH 1984. Microbial survival in the Environment. Berlin: Springer. 563-573.

Muangkeao 2005. Study on type and quantify of pathogenic microorganisms from leachate in Bangkok, Pathumthanee and Ayutthaya. Master Thesis. Chulalongkorn University (in Thai).

Muenjee J 2010. Biogas production from piggery wastewater by co-digesting with napier grass and food waste by ASBR. Master Thesis. Chiang Mai University (in Thai).

Ninprayoon S 1993. Domestic wastewater treatment by upflow anaerobic sludge blanket (UASB) reactor. Master Thesis. Chiang Mai University (in Thai).

Nuengjamnong C and Muangkeao S 2008. Comparison of two biogas systems (covered lagoon and fixed dome) for swine wastewater treatment. J Environ Res. 30(2): 97-107 (in Thai).

Padungtod P and Kaneene JB 2006. *Salmonella* in food animals and humans in northern Thailand. Int J Food Microbiol. 108: 346-354.

Pant A and Mittal AK 2007. Monitoring of pathogenicity of effluent from the UASB based sewage treatment plant. Environ Monit Assess. 133: 43-51.

Prescott H. 2002. Laboratory exercise in Microbiology. 5th ed New York: Smith Pub 133pp.

Ruchirased A and Chinwetkitvanich S 2008. Biological removal of organic and TKN using anaerobic baffled reactor (ABR) treating swine wastewater. J Public Health. 38 (1): 82-91 (in Thai).

Santadsaerianan S 2002. Effect of upflow velocity on granulation in UASB treating proteinaceous wastewater. Master Thesis. King Mongkut's University of Technology Thonburi (in Thai).

Sirichote P, Bangtrakulnonth A, Tianmanee K, Unahalekhaka A, Oulai A, Chittaphithakchai P, Kheowrod W and Hendriksen RS 2010. Serotypes and antimicrobial resistance of *Salmonella* Enterica SSP in central Thailand. Southeast Asian J Trop Med Public Health.41 (6): 1405-1415.

Sobsey MD, Khatib LA, Hill VR, Alocilja E and Pillai S. 2006. Pathogens in animal wastes and the impacts of waste management practices on their survival, transport and fate. In: Animal Agriculture and the Environment: National Center for Manure and Animal Waste Management White Papers. JM Rice et al. (eds) St Joseph: ASABE Pub 609-666.

Suwathanachao T 2000. Efficiency and economic scale for investment of wastewater treatment system in pig farms. Master Thesis. Chulalongkorn University (in Thai).

Tanarat S 2005. Effect of COD: $NH4^+$-N ratio on pH of UASB system. Master Thesis. Chiang Mai University (in Thai).

Tawfik A, Klapwijk B, Van Buuren J, El-Gohary F, Lettinga G 2004. Physico-chemical factors affecting the E. coli removal in a rotating biological contactor (RBC) treating UASB effluent. Water Res. 38:1081-1088.

Tchobanoglous G, Burton FL, Stensel HD 2003. Wastewater Engineering: Treatment and Reuse, 4th ed, New York: Metcalf and Eddy.

The Office of Agricultural Economics 2013. Agricultural product data (Swine). [Online]. Available: http://www.oae.go.th/download/prcai/livestock/swine.pdf. Accessed April 17, 2015 (in Thai).

The Pollution Control Department 2003. Manual of selection and maintenance wastewater treatment system from swine farm according to Department of Livestock's standard (in Thai).

The Pollution Control Department 2006. Manual of treatment technology for manure and wastewater from swine farm using biogas in combined characteristic (in Thai).

The Pollution Control Department 2007. Manual of wastewater treatment system from swine farm (in Thai).

Tuntoolavest MS and Tuntoolavest MR 2004. Water and Wastewater Chemistry. 2nd ed. Bangkok: Chulalongkorn University Press. 608 pp (in Thai).

Udomsinroj K 2000. Wastewater Engineering (4). Environmental Engineering. Bangkok: Rangsit University (in Thai).

WHO 1996. "Guidelines for Drinking Water Quality - Volume 2 Health criteria and other supporting information." [Online]. Available: http://www.who.int/water_sanitation_health/dwq/2edvol2p1.pdf. Accessed August 27, 2015 (in Thai).

บทคัดย่อ

การวิเคราะห์ความสามารถของระบบถังหมักแบบไหลตามยาวร่วมกับระบบหมักแบบยูเอเอสบีในการบำบัดน้ำเสียฟาร์มสุกรในประเทศไทย

จักรกริศน์ เนื่องจำนงค์[1] และ พิชญ รัชฎาวงศ์[2]*

วัตถุประสงค์ของงานวิจัยนี้คือเพื่อวิเคราะห์ความสามารถในภาพรวม โดยเฉพาะประสิทธิภาพการกำจัด ของระบบถังหมักแบบไหลตามยาวร่วมกับระบบหมักแบบยูเอเอสบีในการบำบัดน้ำเสียฟาร์มสุกรขนาดใหญ่แห่งหนึ่งในประเทศไทย ทำการเก็บตัวอย่างน้ำเสียจำนวน 84 ตัวอย่างตลอดช่วงเวลาการศึกษา 302 วัน โดยเลือกจุดเก็บตัวอย่างอย่างเหมาะสมทั้งบริเวณน้ำเข้าและน้ำออกของระบบบำบัดน้ำเสียของฟาร์ม การประเมินประสิทธิภาพของระบบใช้ตัวแปรสำคัญ ๆ เช่น ค่าซีโอดี (COD) ค่าซีโอดีละลาย (SCOD) ค่าของแข็งทั้งหมด (TS) ค่าของแข็งแขวนลอยทั้งหมด (TSS) และค่าเจลดาห์ลไนโตรเจน (TKN) นอกจากนี้ ยังทำการวิเคราะห์ค่าตัวแปรทางจุลชีววิทยาที่สำคัญ เช่น ปริมาณอีโคไล (*E. Coli*) และซัลโมเนลลา (*Salmonella*) อีกด้วย โดยการวิเคราะห์ค่าตัวแปรต่าง ๆ เหล่านี้เป็นไปตามกรรมวิธีมาตรฐานในการวิเคราะห์น้ำและน้ำเสีย การศึกษาพบว่าประสิทธิภาพการกำจัดเฉลี่ยของซีโอดี ซีโอดีละลาย ของแข็งทั้งหมด ของแข็งแขวนลอยทั้งหมด และเจลดาห์ลไนโตรเจนมีค่าเท่ากับ 80.6% 85.6% 58.7% 82.7% และ 33.9% ตามลำดับ สำหรับการกำจัดซีโอดีนั้น พบว่าส่วนที่เป็นของแข็งถูกกำจัดโดยกระบวนการตกตะกอน ขณะที่ส่วนที่ละลายได้ถูกกำจัดโดยปฏิกิริยาชีวภาพแบบไร้อากาศ ประสิทธิภาพในการกำจัดของแข็งแขวนลอยทั้งหมดค่อนข้างสูง ซึ่งแสดงให้เห็นว่าระบบสามารถแยกของแข็งแขวนลอยออกจากน้ำเสียได้ น้ำทิ้งออกจากระบบมีปริมาณอีโคไลที่ลดลงมากเมื่อเทียบกับขาเข้า ซีโรวาร์ของซัลโมเนลลาที่พบในน้ำเสียขาเข้าคือ Stanley, Rissen และ Anatum ตามลำดับ อัตราการการผลิตก๊าซชีวภาพมีความแปรปรวนเนื่องจากปริมาณของสารอินทรีย์ในน้ำเสียที่มีความแปรปรวนเช่นกัน ผลการศึกษาชี้ให้เห็นว่าระบบถังหมักแบบไหลตามยาวร่วมกับระบบหมักแบบยูเอเอสบีสามารถบำบัดของแข็งและส่วนที่ละลายได้ของน้ำเสียฟาร์มสุกร พร้อมกับลดปริมาณเชื้ออีโคไลได้ในระดับหนึ่ง ทั้งนี้หากต้องการลดระดับของสารอินทรีย์ในน้ำทิ้งให้เป็นไปตามค่ากำหนดตามกฎหมายจำเป็นต้องมีระบบบำบัดอื่นเพิ่มเติม

คำสำคัญ: ถังหมักไร้อากาศ ความสามารถของระบบ ฟาร์มสุกร ประเทศไทย น้ำเสีย

[1]*ภาควิชาสัตวบาล คณะสัตวแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ถนนอังรีดูนังต์ ปทุมวัน กรุงเทพฯ 10330*

[2]*ภาควิชาวิศวกรรมสิ่งแวดล้อม คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ถนนพญาไท ปทุมวัน กรุงเทพฯ 10330*

***ผู้รับผิดชอบบทความ** *E-mail: pichaya.r@chula.ac.th*