International Journal of Environmental Engineering – IJEE
Volume 1: Issue 2 *[ISSN 2374-1724]*
Publication Date : 25 June 2014

Struvite Formation from Swine Farm Effluent

Thongchai Umpornpanga[a], Ramnaree Netvichien[b] and Sutha Khaodhiar[a*]

***Abstract*-The swine farm effluent that is released into the environment, contained high nutrients concentrations such as nitrogen and phosphorus. This research studies the efficiency of swine farm effluent treatment using a laboratory-scale continuous reactor without alkali and Mg^{2+} addition to promote struvite precipitation and crystallization processes. The study investigates the effect of aeration rate and hydraulic retention time (HRT) on struvite crystallization. The swine farm effluent pH is increased due to CO_2 stripping processes by added air in the reactor. The struvite formation was determined by SEM, SEM-EDS and XRD. The result shows that solution pH was increased with increasing aeration rate. At the 23 hours HRT experiment, the equilibrium solution pH was 8.43, 8.56, 8.71, 8.98 and 9.41, respectively. The efficiency of phosphorus removal was 64 – 69 percent and nitrogen removal was 36 – 74 percent. The struvite precipitated was found when effluent pH was 8.5 – 9.0.**

Keyword: Struvite, Swine Farm Effluent, Chemical Precipitation, Continuous Flow Reactor, CO_2 Stripping, Nitrogen and Phosphorus Removal

Thongchai Umpornpanga[1] is with the Department of Environmental Engineering, Chulalongkorn University, Thailand.

Ramnaree Netvichien[2] is with the Department of Environmental Engineering, Chulalongkorn University, Thailand.

Sutha Khaodhiar[3] is with the Department of Environmental Engineering, Chulalongkorn University, Thailand.

I. Introduction

Swine farm is increasing continuously every year in Thailand. This resulted in a large quantity of swine wastewater. Since the swine wastewater contains high concentration of nitrogen and phosphorus, if it is released into the natural sources without treatment, it can contribute to eutrophication problem. With proper treatment and recovery process, nitrogen and phosphorus can be transformed to fertilizer for agriculture application.

Most of swine farm treats their wastewater by anaerobic process which can reduce concentration of organic substance in the wastewater and produce biogas as valuable byproduct [2]. However, this biological anaerobic process can't reduce concentrations of phosphorus and nitrogen in the wastewater so the swine effluent normally contains phosphorus and nitrogen in high concentration. Post treatment is needed in order to reduce phosphorus and nitrogen to meet the effluent standard.

There are several popular processes uses for removing nutrients from swine wastewater farm [3]. Chemical precipitation processes, such as magnesium-ammonium -phosphate, struvite, precipitation is of interest because it can simultaneously reduce the concentration of phosphorus and nitrogen as well as produce useful by product [4].

II. Materials and methods

A. Swine farm effluent

Swine farm effluent used in this research was from medium size swine farm in Nakhon Pathom Province. The effluent was collected after it was treated by the anaerobic filter. The effluent was filled into effluent tank and then was pumped to the reactor. Effluent from anaerobic process normally contains contained phosphorus and nitrogen in the form of phosphate and ammonia that can be removed by struvite crystallization process.

B. Reactor design and operational conditions

The continuous flow reactor use in this research was a cylindrical column with a pyramid at the bottom made by clear acrylic plastic, and had the volume of 0.023 m^3. The reactor consist of a reaction zone (interior column) 0.006 m^3 and settling zone 0.017 m^3. The dimension of the reactor is 1.2 m height, 0.2 m diameter and 0.125 m interior column diameter. Interior column was aerated with air (1.32, 2.78, 7.98, 16.02 and 32 liters of air per hour) to raises pH value by CO_2 stripping. Wastewater was added at the top of reactor inside the reaction zone as the hydraulic retention time at defined hydraulic retention time (23, 15.33 and 7.7 hours). The effluent was collected every day for pH, chemical oxygen demand (COD), total kjeldahl nitrogen(TKN), total suspended solids (TSS), total phosphorus (TP) and metals (magnesium, calcium and portassium) measurement. The schematic of reactor using in this research is shown in Figure 1.

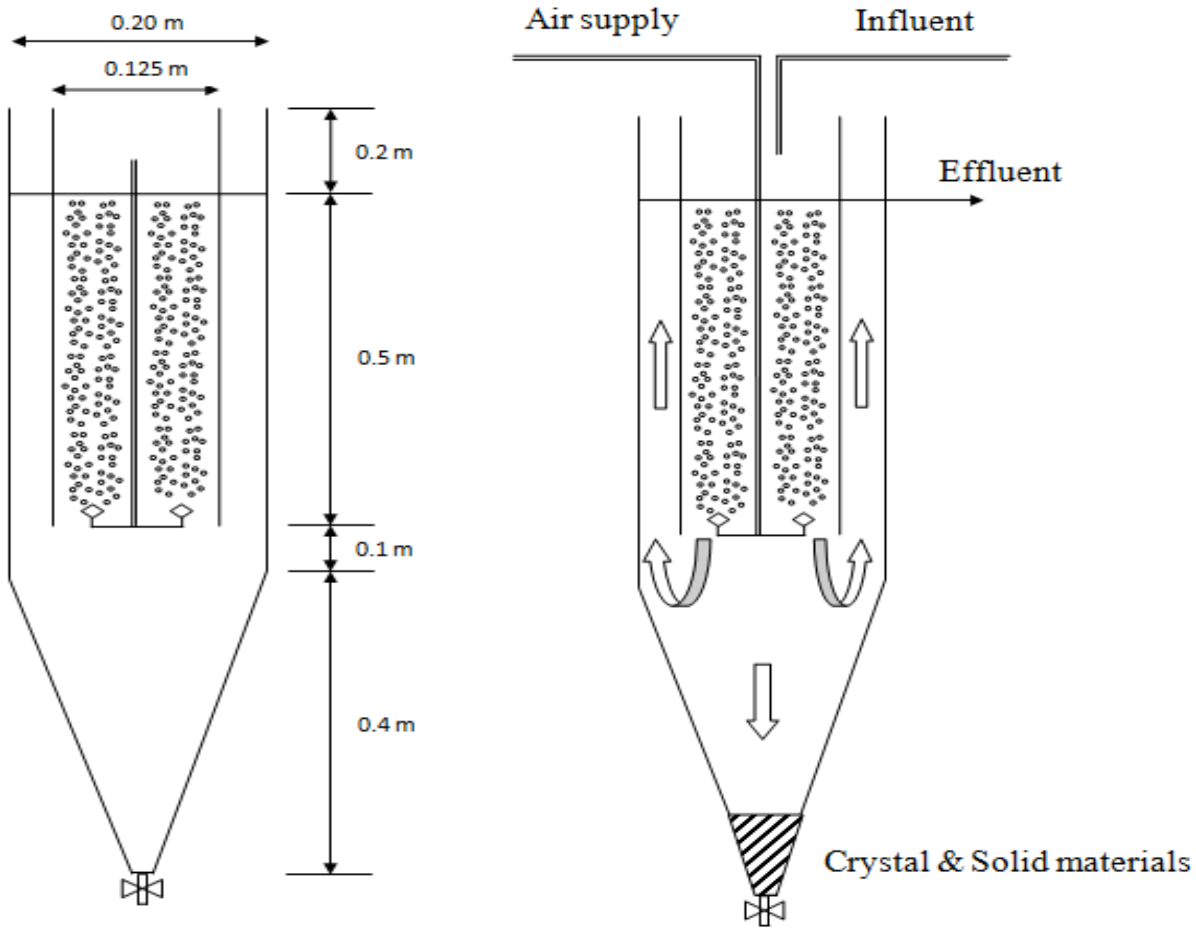

Figure 1. Layout of continuous flow reactor

C. Analytical methods

The parameters of the effluent were measured using standard methods APHA, AWWA and WEF. 2005 [1] as shown in table I.

Table I PARAMETER AND MEASUREMENT METHOD

Parameters	Measurement methods
pH	pH meter
Chemical oxygen demand (COD)	Closed reflux/titrimetric
Total Kjeldahl nitrogen (TKN)	Macro Kjeldahl
Total suspended solids (TSS)	Gravimetric
Total phosphorus (TP)	Vanadomolybdophosphoric acid
Metals	Atomic absorbtion spectrophotometer (AAS)

III. Results and discussion

A. Swine farm effluent characteristics.

The swine farm effluent from anaerobic process was collected for 10 days for analysis. The physicochemical properties of the swine effluent used in the experiments are summarized in Table 2. The mole ratio of magnesium, phosphorus and nitrogen of the effluent is 1.92: 1: 15.17. Swine farm effluent has inappropriate pH value for struvite crystallization because most of magnesium and phosphorus existed as soluble form. Aeration is used to raise pH to the optimum conditions (8.5 – 9.0) in order to promote struvite crystallization.

Table II PHYSICOCHEMICAL COMPOSITIONS OF SWINE FARM EFFLUENT USED IN THE EXPERIMENTS

Parameter	Mean		S.D.
pH	7.23	-	0.15
COD	476	mg/L	25.85
Total suspended solids	125.53	mg/L	14.7
Total Kjeldahl nitrogen	254.5	mg/L	8.64
Total phosphorus	37.73	mg/L	6.35
Metal			
Magnesium	55.47	mg/L	3.13
Calcium	68.76	mg/L	1.64
Potassium	225.32	mg/L	19.26

B. Effect of aeration rate

Table III summarized the results of the effect of the aeration rate on effluent characteristics after chemical precipitation. Effluent solution pH was increased with increasing aeration rate. At the 23 HRT, aeration rate 1.32, 2.78, 7.98, 16.02 and 32 L/Min, the pH value was 8.43, 8.56, 8.71, 8.98 and 9.41, respectively. The precipited was characterized by SEM, the struvite was found in pH 8.5 – 9.0. The formation of calcium hydroxyapatite crystallization was also observed.

The total phosphorus and nitrogen decreased after chemical precipitation in all experiments. The efficiently of phosphorus and nitrogen removal was 64-69 and 36 – 74 percent, respectively. The total COD, Total suspended solids and metals concentration was decreased as well.

C. Effect of HRT

Table IV summarized the effect of Hydraulic Retention Time (HRT) on effluent characteristics after chemical precipitation. At constant aeration rate of 1.32 L/Min, the longer HRT provided the longer contact time between effluent and bubble, the effluent pH was increased with increasing HRT. The efficiently of phosphorus, nitrogen COD, TSS and metals removal was also increased with increasing HRT.

Table III CHARACTERISTICS OF EFFLUENT AFTER CHEMICAL PRECIPITATION; OPERATIONAL CONDITION AT HRT 23 HOURS AND AERATION RATE OF 1.32, 2.78, 7.98, 16.02 AND 32 L/MIN

Parameter		Operational condition at HRT 23 hours				
		Air 1.32 L/Min	Air 2.78 L/Min	Air 7.98 L/Min	Air 16.02 L/Min	Air 32 L/Min
pH		8.43±0.01	8.56±0.02	8.71±0.02	8.98±0.02	9.41±0.07
COD	mg/L	222±20	253±14	240±3.27	274±7.44	281±8.23
Total suspended solids	mg/L	55.5±11.59	41.5±5.26	49±5.77	52.5±8.41	68±4.12
Total Kjeldahl nitrogen	mg/L	190.±3.85	191±9.53	192±6.67	199±7.29	203±7.04
Total phosphorus	mg/L	11.74±3.23	12.17±0.15	12.17±0.54	13.53±0.92	12.44±0.61
Metal						
Magnesium	mg/L	5.07±0.47	11.22±1.01	12.35±0.18	10.80±0.64	10.90±0.28
Calcium	mg/L	13.24±2..33	19.62±1.40	17.32±0.45	18.41±0.65	17.56±0.88
Potassium	mg/L	154.21±4.98	137.42±4.06	141.06±1.51	131.66±8.42	140.47±3.51

Table IV CHARACTERISTICS OF EFFLUENT AFTER CHEMICAL PRECIPITATION; OPERATIONAL CONDITION AT AERATION RATE OF 1.32 AND HRT 23, 15.33 AND 7.7 HOURS

Parameter		Operational condition at Aeration Rate 1.32 L/Min		
		HRT 23 hours	HRT 15.33 hours	HRT 7.7 hours
pH		8.43±0.01	8.41±0.01	8.32±0.02
COD	mg/L	222±20	311±36	342±2.31
Total suspended solids	mg/L	55.5±11.59	76.5±14.27	82.5±10.23
Total Kjeldahl nitrogen	mg/L	190.±3.85	210±5.45	212±7.25
Total phosphorus	mg/L	11.74±3.23	12.01±3.79	13.43±0.11
Metal				
Magnesium	mg/L	5.07±0.47	11.86±1.19	11.73±1.38
Calcium	mg/L	13.34±3.23	14.16±1.67	14.83±1.31
Potassium	mg/L	154.21±4.98	147.02±10.40	149.92±14.23

IV. Conclusions

Swine farm effluent contains significant amount of nutrients and magnesium. Magnesium Ammonium Phosphate, Struvite, precipitation can be used to improve swine farm effluent quality. In this study, continuous reactor was used to treat swine farm effluent and promote struvite formation. Aeration is sufficient for adjusting pH to 8.5-9 which is the appropriate pH for struvite formation. The longer HRT, the better quality of the treated effluent. Effluent through continuous reactor have quality meet swine effluent standard.

Acknowledgment

Financial support for this work under the Graduate School, Chulalongkorn University, Thailand and the Department of Environmental Engineering, Chulalongkorn University, Thailand. Finally, thank to Mr. Chaiwat Theeranuwat, the owner of prachafarm swine for kindly help, good advice and take place for doing this research.

References

[1] APHA, AWWA and WEF. 2005. Standard methods for the examination of water & wastewater. 21st Ed. American Public Health Association. American Public Health Association. Washington D.C.

[2] Liu, Y-H., Kwag, J-H., Kim, J-H. and Ra, C-S. 2011. Recovery of nitrogen and phosphorus by struvite crystallization from swine wastewater. Desalination. 277: 364-369.

[3] Song, Y-H., Qiu, G-L., Yuan, P.,Ciu, X-Y., Peng, J-F., Zeng ,P., Duan, L., Xiang, L-C. and Qian, F. 2011. Nutrients removal and recovery from anaerobically digested swine wastewater by struvite crystallization without chemical additions. Journal of Hazardous Materials 190: 140-149

[4] Suzuki, K., Tanaka, Y., Kuroda, K., Hanajima, D., Fukumoto, Y., Yasuda, T. and Waki, M. 2007. Removal and recovery of phosphorous from swine wasterwater by demonstration crystallization reactor and struvite accumulation device. Bioresource Technology 98: 1573-157

About Author (s) :

This research was done to study the effect of aeration rate and hydraulic retention time to the struvite crystallization form, this crystallization process was the promise way to treats swine farm effluent due to this process can simultaneuosly reduce the concentration of phosphorus and nitrogen as well as produce useful by product .