A Practical System for Pig Farm Wastewater Treatment

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Abstract : High rate of pig farm growth has been observed during these recent years. In 2017, 10.19 million head count of pig was raised in Thailand. In the same year, about 57 odor and 10 wastewater complaints were filed against pig farm owners. This prompted concerns from government and the Internal Security Operations Command (ISOC) to look into this problem seriously. Piggery wastewater is known to be high in organics, solids, as well as rich nutrient content such as nitrogen and phosphorus. In this study, we investigated the performance of a system consisting of a presettling tank and a three-compartment anaerobic baffled (ABR) reactor to treat pig farm wastewater under low and high flow rate condition. An experiment was run for 80 days at a demonstration farm of the Faculty of Veterinary Science in Nakhon Pathom province. The performance for total COD removal was between 50-78 percent and majorities of organics and solids removal was by sedimentation. The efficiencies of sedimentation process, however, can be very sensitive to solids accumulation and washout. The average TKN removal was only 25 percent. The low removal efficiency was due to the fact that majority of TKN was soluble and the soluble part of TKN cannot be removed properly in anaerobic process. When considering the PCD standard for pig farm, the system still needed an improvement, with respect to total COD and TSS concentrations in the effluent. Enlargement of a presettling tank or an additional presettling unit with solids drainage ports could be a practical option for better solids and organics treatment.

Keywords : Pig Farm Wastewater, Anaerobic Baffle Reactor, Organic Removal, TKN Removal

1. Introduction

High rate of pig farm growth has been observed during these recent years due to an increase in domestic demand for pork in Thailand. In 2017, 10.19 million head count of pig was raised in Thailand [1]. Such expansion inevitably impaired surrounding environmental quality ranging from odor, flies, methane emission, and possible leakage of wastewater to nearby receiving water bodies. In 2017, there were at least formal 57 odor and 10 wastewater complaints against farm owners [2]. This prompted both government and the Internal Security Operations Command (ISOC) to look into this problem seriously. In April 2018, the Chief of the Army and the deputy Secretary of the ISOC has ordered all provincial units of ISOC to coordinate with local government to monitor and manage all forms of farm-related pollution according to the regulatory requirement. Proper pig farm wastewater treatment system would lead to lesser degree of pollutant emission to water and air resources.

2. Objectives

In this study, we investigated performance of a practical treatment system consisting of a presettling tank and an ABR reactor to treat pig farm wastewater under low and high flow rate condition, corresponding to high and low hydraulic retention time (HRT), respectively.

3. Literature review

To date, wastewater treatment system for large pig farms in Thailand is dominated by fixed dome, channel digester, and covered lagoon that aim to produce biogas along with organic waste stabilization [1]. However, small farms with less than 50 pigs are high in number and many of them have no treatment system for their wastewater.

Pig farm wastewater is generated from a wide spectrum of activities such as flushing of farm, animal cleaning, discharges and solids from pigs, etc., and therefore often possesses high organics, high ammonia, high solids, as well as rich nutrient content such as nitrogen and phosphorus [3]. High solids in an influent stream can result in a system failure since solid accumulation could deplete useful space required for reaction. Nitrogen, if not treated or transformed within the system, can result in excessive blooming of aquatic plants [4].

Anaerobic baffle reactor (ABR) is a treatment technique that currently receives lots of attention for high strength wastewater treatment worldwide. Advantages of the ABR are such as low energy consumption, easy operation and maintenance, no moving parts, no mixing required, high resistance to clogging, and high adaptation to shock loading [5]. For an ABR system, baffles were placed vertically, in an alternate manner, to form compartment and to direct the flow of wastewater, from an inlet to an outlet point. In this respect, wastewater is forced to go through floating anaerobic sludge blankets, where major organic stabilization takes place. Significant benefit of this reactor type is an ability to separate different phases of the AD system longitudinally, allowing the reactor to behave as a 'phase separated' system, which would theoretically offer high efficiency removal rates [6, 7]. Of all the strong points, low clogging potential is very appealing when it comes to treating high solid stream like pig farm wastewater.

In this study, we investigated performance of a practical treatment system consisting of a presettling tank and an ABR reactor to treat pig farm wastewater under low and high flow rate condition, corresponding to high and low hydraulic retention time (HRT), respectively. The high flow condition can be expected during daily farm cleaning or if more pigs are added. The performance indicators used were chemical oxygen demand (COD) and TKN removal efficiencies. This system can be made in modules and is relative easy to make and should fit for most small pig farms. The knowledge gained can be applied to solve pig farms complaints throughout the countries, including military establishments.

4. Materials and Methods

4.1 Pig farm wastewater input

The system was set in a demonstration farm of the Faculty of Veterinary Science, Chulalongkorn University, in Nakhon Pathom province. There were approximately fifteen pigs in the farm at the time of study (November 2016 to March 2017). Wastewater samples were obtained from outlet of the farm and were generated from all activities inside.

4.2 Configuration of the system

The treatment system, consisting of a presettling tank and a three-compartment anaerobic baffled reactor (ABR), is given in Figure1. Both were made from acrylic. A settling tank was 5 liters in volume. The effective volume of the ABR reactor was 10 liters. The first compartment of the ABR accounted for half of the volume while the last two compartments accounted for the rest. Input and output wastewater samples were obtained at the point before entering the settling tank and after exiting from the ABR reactor, respectively.

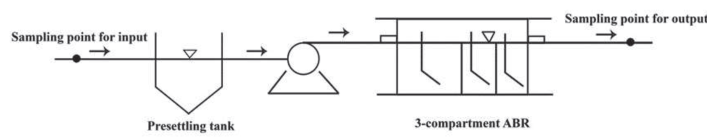

Fig.1 Presettling Tank and an ABR Reactor

4.3 Startup and operation

The system employed the pig farm wastewater as a seed, itself. On Day 1 of the experiment, the wastewater was fed to the system at the rate of 2 L/day (equivalent to 5-day hydraulic residence time for an ABR reactor). From Day 5, the wastewater input rate was increased to 5 L/d (equivalent to 2-day hydraulic residence time for an ABR reactor) until Day 35 where excessive solids accumulation was obviously detected in the presettling tank and in the ABR. Removal of solids was then performed. The flow rate was reduced to 2 L/day from Day 36 to Day 80, which was the last day of the experiment. The Pollution Control Department

(PCD) effluent standard for the farms with 50-500 pigs would be used for performance assessment.

4.4 Analytical procedures

Important parameters under investigation included total suspended solids (TSS), chemical oxygen demand (COD), soluble COD, total Kjeldahl nitrogen (TKN) and soluble TKN. The analytical procedures were outlined in Table 1.

Table 1 Parameters and analytical procedures used

Parameter	Method
pH	pH meter
ORP	ORP meter
Total suspended solids	Standard Method #2540D
COD	Standard Method #5220C
TKN	Digestion Distillation and then Titrimetric Method

5. Results and Discussions

5.1 Total and soluble COD

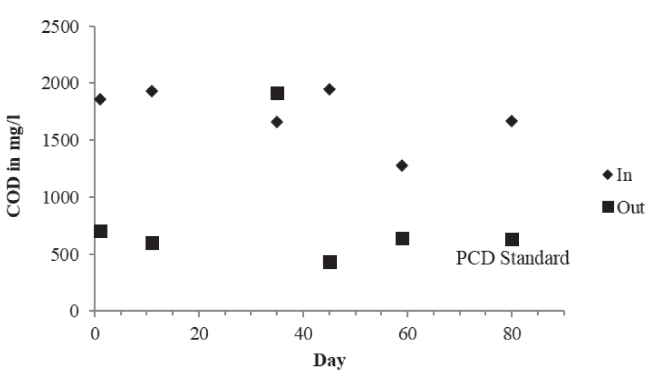

Fig.2 Influent and Effluent Total COD Concentration in mg/L

From Figure 2, initial influent total COD concentration on Day 1 was 1,860 mg/L and remained in the range of 1,670-1,930 mg/L, with an average of 1,725 mg/L, throughout the experiment. The effluent total COD was in the range of 430-1,920 mg/L with an average of 520 mg/L (excluding an outlier) which was still a little bit higher than the PCD standard for COD of 400 mg/L. During the first 20 days, average COD removal efficiency was about 67-75 percent and was directly related to the solids removal ability. Biological reaction played lesser role here since hydraulic retention time (HRT) used here was significantly shorter than ordinary ABR's (2-5 days as compared to 14-15 days) [8, 9]. As solids accumulated and started to wash out, a total COD of 1,920 mg/L was found in an effluent sampling on Day 35. After cleaning and lowering the flow rate of input wastewater to 2 L/day, the system efficiency for total COD reduction came back to the range of 50-78 percent until Day 80. These efficiencies were, however, similar to those of Boopathy and Sievers [8] at 70-80 percent.

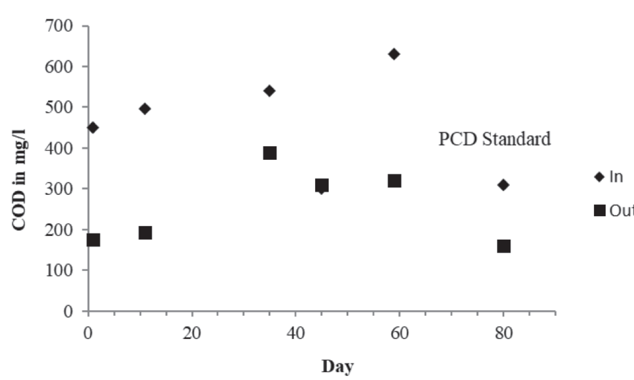

Fig.3 Influent and Effluent Soluble COD Concentration in mg/L

From Figure 3, influent and effluent soluble COD concentrations were in the range of 310-540 mg/L and 160-390 mg/L, respectively. As expected, the removal efficiencies for soluble COD were only 27-61 percent as compared to 50-78 percent for the total COD reduction. Thus, the major mechanism responsible for COD reduction was probably not a biological means, which needed longer HRT. Fortunately, soluble COD contributed approximately only 19-27% of the total COD for the influent stream from the pig farm. An effect of soluble COD increase during the washout on Day 35 was not as significant as compared to the total COD results in Figure 2.

5.2 Total suspended solids (TSS)

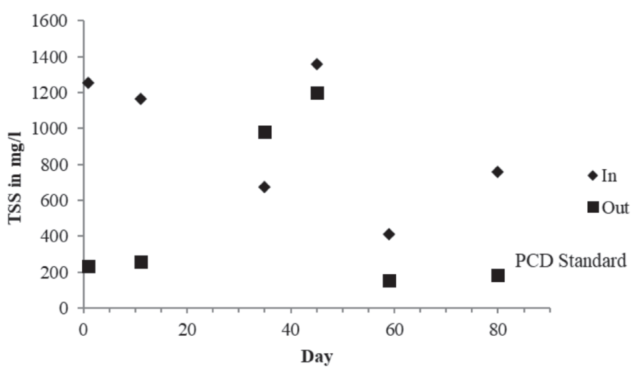

Fig.4 Influent and effluent total suspended solids concentration in mg/L

From Figure 4, influent and effluent TSS concentrations were in the range of 410-1,360 mg/L and 152-1,200 mg/L, respectively. The treatment efficiency for TSS fluctuated widely from 11-81 percent and was almost within the PCD standard for TSS at 200 mg/L, for most of the time. On Day 35, an effluent concentration was found to be more than an influent concentration and was an obvious sign of washout. Cumulative solids in the system contributed to solids wash-out from the system. Strong correlation between total COD and TSS in Figure 5 (R2= 0.82) has indicated that majority of organics in the input wastewater was in solid form. Therefore, treatment of the total COD in Figure 2 was confirmed to be from solid sedimentation with removal efficiencies of approximately 50-78 percent.

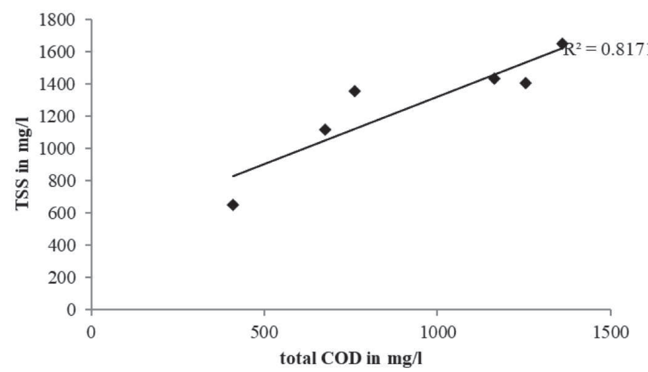

Fig.5 Correlation of TSS vs. Total COD

5.3 Total Kjeldahl nitrogen (TKN)

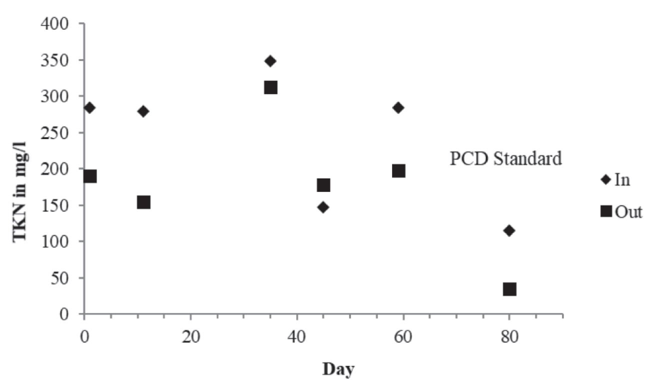

Fig.6 Influent and Effluent TKN Concentration in mg/L

From Figure 6, influent and effluent TKN concentrations were in the range of 115-348 mg/L and 35-313 mg/L, respectively. The TKN samples here included both solid and liquid portions. The treatment efficiency for TKN was found in the range of 10-70 percent with an average of 25 percent. The effluent concentrations were, for most of the time, below the PCD standard of 200 mg/L. Therefore, the TKN removal in the system was adequate as far as the influent TKN concentration was not high. From Figure 6, not much reduction between input and output of TKN was observed. Therefore, solid separation, which was expected to be the main nitrogen removal mechanism, could not reduce majority of TKN entering into the ABR system during the 80 days of experiment. This was perhaps because soluble TKN, which accounted for 45-85 percent of the total TKN, was almost unaffected by the process that was suitable for total COD and TSS removal. The findings were similar to the result from Suthinarakorn [10] and Rattanakowin [11] that majority of TKN could not be biologically transformed or removed in the three- and the five-compartment ABR regardless of the input TKN concentrations.

6. Conclusion

The system of a presettling tank and a three-compartment ABR can treat high solids and high organic wastewater from a pig farm to a certain extent. The performance for total COD removal was between 50-78 percent and majorities of organics and solids removal was by sedimentation. This was because the HRT used here was significantly shorter than the conventional ABR (2-5 days as compared to 14-15 days). The efficiencies of sedimentation process, however, can be very sensitive to solids accumulation and washout. On the other hand, average TKN removal was only 25 percent. The low removal efficiency was due to the fact that majority of TKN was soluble and the soluble part of TKN cannot be removed properly in anaerobic process. When considering the PCD standard for pig farm, the system still needed an improvement, with respect to total COD and TSS concentrations in the effluent. Enlargement of a presettling tank or an additional presettling unit with solids drainage ports could be a practical option for better solids and organics treatment of small size pig farm wastewater.

7. Acknowledgement

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