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Application of ecological technology for removal of COD, nitrogen and phosphorus from piggery wastewater after biogas production technology

Ứng dụng công nghệ sinh thái để xử lý COD, Nitơ và Phôtpho trong nước thải chăn nuôi lợn sau công nghệ Biogas

Research article

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Despite a positive contribution to economic – social development, the growth of piggeries has caused heavily environmental pollution. Currently, treated wastewater of pig farms unfortunately does not meet the national discharge standards yet. This paper presents some research results on the removing COD, nitrogen and phosphorus in piggery wastewater after anaerobic (biogas) process at pilot scale by the combined system using *Phragmites australis, Cyperus alternifolius, Vetiveria zizanioides* and *Eichhornia crassipes*. The experimental results showed that the wastewater loading rate of 47.35 l/m^2.day with initial concentrations of 203.24 mg COD/l, 111.94 mgTN/l and 13.61 mgTP/l gave removal efficiency of 71.66 %, 79.26 % and 69.65 %, respectively. Thus, the removed quantity of total nitrogen (TN) and total phosphorus (TP) was of 4201.35 mg TN/m^2.day và 448.76mg TP/m^2.day. The obtained results indicated that the flow wetland system, using *Phragmites australis, Cyperus alternifolius, Vetiveria zizanioides* and *Eichhornia crassipes* has a rather high COD, TN and TP removal efficiency with simple operation so that it could be feasible if applied for treating pig wastewater. However, the system should be functioned longer for taking data and for evaluating its stability.

Mặc dù có những đóng góp tích cực cho sự phát triển kinh tế - xã hội, việc phát triển chăn nuôi lợn đã gây ô nhiễm môi trường nghiêm trọng. Hiện nay, nước thải chăn nuôi lợn từ các cơ sở chăn nuôi sau xử lý vẫn chưa đáp ứng được các tiêu chuẩn thải của quốc gia và tiêu chuẩn ngành. Bài báo này trình bày kết quả nghiên cứu về khả năng loại bỏ COD, nitơ (N) và phôtpho (P) trong nước thải chăn nuôi lợn đã qua xử lý bằng hầm biogas của hệ thống phối hợp cây Sậy, Thủy Trúc, cỏ Vetiver và Bèo Tây ở qui mô pilot. Kết quả thực nghiệm ở tải lượng 47,35 l/m^2.ngày, với COD, tổng nitơ (TN) và tổng phôtpho (TP) đầu vào trung bình là 203,24 mg/l, 111,94 mg/l và 13,61 mg/l, tương ứng, thì hiệu suất xử lý lần lượt là 71,66 %; 79,26 % và 69,65 %. *Như vậy lượng TN và TP loại bỏ là 4201*,35 mgN/m2.ngày và 448,76 mgP/m2.ngày. *Kết quả nhận được cho thấy hệ thống sử dụng cây Sậy, Thủy Trúc, cỏ Vetiver và Bèo Tây có hiệu quả loại bỏ COD, TN và TP khá cao trong khi vận hành đơn giản nên* có triển vọng áp dụng trong điều kiện thực tế để xử lý nước thải chăn nuôi lợn. Tuy nhiên *để đánh giá tính ổn định, hệ thống cần được hoạt động với thời gian lâu dài hơn.*

Keywords: ecotechnology, *Phragmites australis, Cyperus alternifolius, Eichhornia crassipes, Vetiveria zizanioides,* piggery wastewater

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1. Introduction

In Vietnam, the piggeries are considered to be the strength of the agricultural sector. Currently, the household pig farming tends to fall while livestock farms increase rapidly and create competitiveness in the market. However, the waste generated from pig farming operations is a matter of concern.

Currently, popular treatment of farm animal waste is through biogas system, but this system can treat only 50-70% of farm waste [6]. Some farms have biogas and waste treatment systems but the systems operate ineffectively, waste has not been treated thoroughly. According to Vincen Porphyre et al (2006) [9], the use of biogas tank in the farms is convenient for using waste and exploiting energy sources but wastewater after Biogas tanks has still many pollutants such as N and P and needs to be treated before being discharged into the environment.

To solve the above-mentioned problem, the combination of methods for livestock wastewater treatment with ecological technology using aquatic plants was studied, applied and obtained positive results by many authors. Ecological technology using aquatic plants as *Eichhornia crassipes*, *Pistia stratiotes*, *Ipomoea aquatica*, *Phragmites australis*, *Vetiveria zizanioides*... for piggery wastewater treatment has many advantages compared to the general wastewater treatment systems, including reduction of COD, nitrogen and phosphorus to acceptable levels in terms of the environment. This method is very environmentally friendly, inexpensive, easy to operate and in accordance with the actual conditions of Vietnam [2, 7].

The experimental combination of *Phragmites australis, Cyperus alternifolius, Eichhornia crassipe and Vetiveria zizanioides* to remove COD, TN, TP from piggery wastewater after biogas technology was conducted to assess the effectiveness of the process and creates the scientific basis for applying these aquatic plants in pollution treatment at pilot scale.

2. Materials and research methods

2.1. Research plants

Reed (*Phragmites australis* Cav.) is a large perennial grass belonging to family *Poaceae*, distributed in wetlands throughout temperate and tropical regions of the world. Reed used for the experiment was collected from the Red River bank and planted in the Co Nhue experimental base, Tu Liem, Hanoi. Plants used for experiments were juvenile with plant density of 15 cm x 20 cm.

Umbrella plant *(Cyperus alternifolius* Linn) lives in tropical, subtropical and temperate regions with optimal ambient temperature from 12 - 30^{o}C, pH 4 - 8. The plants used for experiments were with strong growth, and planted at a density of 15 cm x 20 cm.

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms), belongs to *Pontederiaceae* [1]. *Eichhornia crassipes* used for experiments were juvenile with strong growth, occupying 4/5 of experimental water surface.

Vetiver grass (*Vetiveria zizanioides)* belonging to *Graminae*, is widely distributed in the tropics. The grass used for experiments were grown in the Co Nhue experimental base, Tu Liem, Hanoi. Strongly growing vetiver grass were collected for experiment and planted at a density of 15 cm x 20 cm.

2.2. Piggery wastewater

Wastewater after anaerobic digestive processes was collected from Thuy Phuong Pig Research Center, Tu Liem, Hanoi. The characteristics of the wastewater varied in a range of pH 7.83 - 8.2; TSS 5460 mg/l - 9450 mg/l; COD 775.53 - 1985.98 mg/l; TN 744.59 - 1114.24 mg/l; TP 50.04 mg/l - 115.24 mg/l. Among various forms of nitrogen, NH_4^+ was main form (703.82 mg/l -892.11mg/l) while NO_3^- was negligible (0.65 mg/l to 1.68 mg/l). We conducted analysis of wastewater quality and based on resistance of investigated plants, treatment efficiency and the required output water quality, we adjusted the amount of N and P in the range of 10-15 mg/l and 90-120 mg/l., respectively.

The experiments were conducted in 2015 at the Department of Environmental Hydrobiology, Institute of Environmental Technology, Vietnam Academy of Science and Technology.

2.3. Pilot scale experiments

The experiment consisted of 4 tanks with alternative systems having *Phragmites australis* (surface flow system, Tank 1); *Cyperus alternifolius* and *Vetiveria zizanioides* (Floating plant system, Tank 2); *Eichhornia crassipes* (Floating plant system, Tank 3); *Vetiveria zizanioides* (submerged flow system. Tank 4) (Fig.1.1). The duration of the experiment was of 6 weeks.

The size of each tank was:

D x W x H = 44 cm x 30 cm x 30 cm

Where:

- Volume of *Phragmites australis* growing tank 1: (Hs x Ds x Rs) = 28 cm x 44 cm x 30 cm, equivalent to 36.96 liters. In this tank soil was added with a height of 15 cm, so the volume of remaining water was only of 17.16 liters.

- Volume of *Cyperus alternifolius* and *Vetiveria zizanioides* growing tank 2 was of 26 cm x 44 cm x 30 cm, equivalent to 34.32 liters.

- Volume of *Eichhornia crassipes* growing tank 3 was of 26 cm x 44 cm x 30 cm, equivalent to 34.32 liters.

- Volume of *Vetiveria zizanioides* growing tank 4 (submerged flow) was of 28 cm x 44 cm x 30 cm, equivalent to 36.96 liters. Gravel was added so the volume of final water was 10.3 liters.

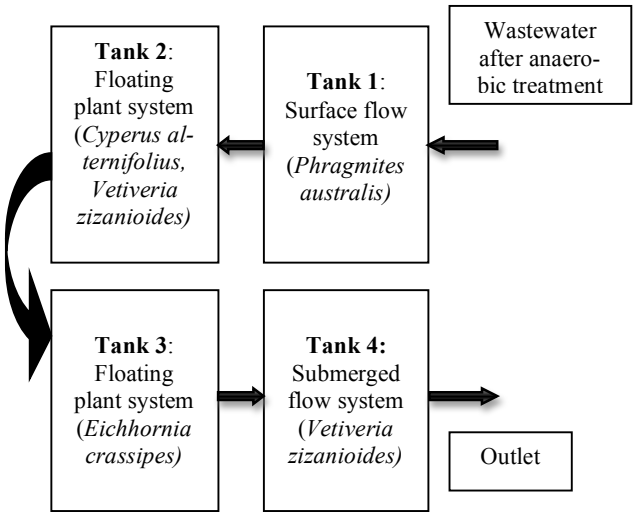

Figure 1. Experimental diagram of the combined system of reed, umbrella plant, water hyacinth and vetiver grass at pilot scale.

Operation of the system: Wastewater was pumped from the storage tank into the system and flows through 4 tanks step by step like in Figure 1.

2.4. Analysis method

The parameters NH_4^+, NO_3^-, NO_2^- , PO_4^{3-} , TP, TN and COD were determined according to the Standard methods (APHA, 1995) and measured on Spectrophotometer UV-Vis 2450, Shimadzu-Japan.

3. Results and discussions

3.1. COD removal efficiency

COD removal efficiency from piggery wastewater in the combined system of *Phragmites australis*, *Cyperus alternifolius*, *Eichhornia crassipes* and *Vetiveria zizanioides* with the wastewater load of 47.35 l/m^2.d is shown in Figure 2.

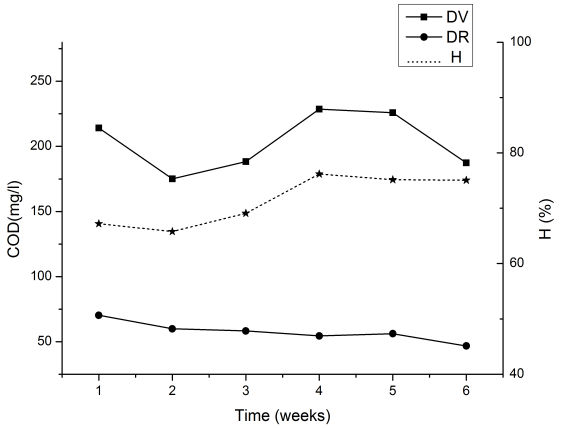

Figure 2. COD removal of the combined system of *Phragmites australis, Cyperus alternifolius, Eichhornia crassipes* and *Vetiveria zizanioides* with the wastewater load of 47.35 l/m^2.d. {DV-inlet, DR-outlet, H -treatment efficiency}.

The initial average COD concentration was of 203.24 mg/l (in the range of 175.05 mg/l to 228.56 mg/l) and it reduced to 140.44 mg/l after discharging from *Phragmites australis* tank. So the COD removal efficiency of *Phragmites australis* tank was of 30.9%. When flowing through the floating plant system 2, the average COD remained 104.1 mg/l. After tank 3, the average COD was of 78.4 mg/l. Thus, separately floating plant system removed 25.88% COD, *Eichhornia crassipes* system (tank 3) removed 24.68% COD and the whole combined system removed 71.66% COD (ranging from 65.79% to 76.19%). So when wastewater went out of the tank 4, the remaining average COD was of 57.61 mg/l (ranging from 46.73 to 70.25 mg/l). The final COD met the level A of National technical regulation on industrial wastewater, QCVN 40:2011/MONRE.

3.2. Nitrogen removal efficiency

Nitrogen removal efficiency from piggery wastewater of the combined system of *Phragmites australis*, *Cyperus alternifolius*, *Eichhornia crassipes* and *Vetiveria zizanioides* with the wastewater load of 47.35 l/m^2.d is shown in Figure 3.

The inlet average TN concentration was 111.94 mg/l (in the range of 107.58 mg/l to 116.23 mg/l) and it was 72.76 mg/l after out of *Phragmites australis* tank 1. So the TN removal efficiency of *Phragmites australis* tank was 35.07%. When flowing through the tank 2, the TN remained 52.41 mg/l, equivalent to treatment efficiency of 27.9%. After the tank 3, the average TN was 35.12 mg/l and the treatment efficiency achieved 32.99%. The average TN after going out of the combined treatment system was 23.21 mg/l (ranging from 21.09 mg/l to 24.82 mg/l). So the TN removal efficiency of the whole treatment system reached 79.26% (ranging from 77.26 mg/l to 80.31 mg/l %). The outlet TN met the level B of QCVN 40:2011/MONRE.

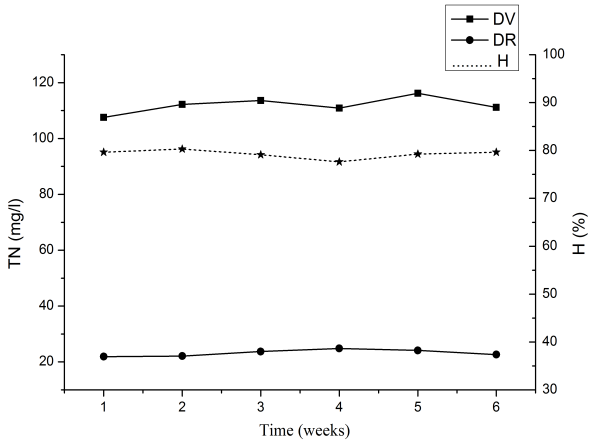

Figure 3. Nitrogen removal of the combined system of *Phragmites australis, Cyperus alternifolius, Eichhornia crassipes* and *Vetiveria zizanioides* with the wastewater load of 47.35 l/m^2.d. {DV-inlet, DR- outlet, H -treatment efficiency}.

3.2. Phosphorus removal efficiency

Phosphorus removal efficiency from piggery wastewater of the combined system of *Phragmites australis*, *Cyperus alternifolius*, *Eichhornia crassipes* and *Vetiveria zizanioides* with the wastewater load of 47.35 l/m^2.d is presented in Figure 4.

The average TP concentration of inlet wastewater was 13.61 mg/l (ranging from 11.54 mg/l to 15.83 mg/l). After *Phragmites australis* tank, the remaining TP concentration was 9.53 mg/l, equivalent to the treatment efficiency of 30.0%. After flowing through tank 2, the TP concentration was 7.18 mg/l, equivalent to treatment efficiency of 24.6%. After tank 3, the TP concentration was 5.36 mg/l and the treatment efficiency got 25.3%. The TP concentration in outlet wastewater was 4.13 mg/l (ranging from 3.7 mg/l to 4.58 mg/l). The TP removal efficiency of the whole treatment system reached 69.65% (ranging from 67.94% to 72.61%). The treated wastewater met the level B of QCVN 40:2011/MONRE.

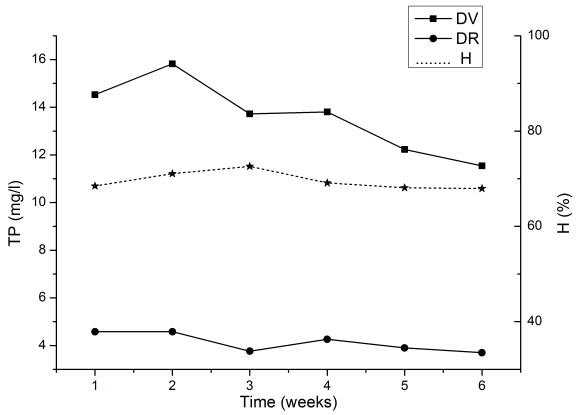

Figure 4. Phosphorus removal of the combined system of *Phragmites australis, Cyperus alternifolius, Eichhornia crassipes* and *Vetiveria zizanioides* with the wastewater load of 47.35 l/m^2.d. {DV-inlet, DR -outlet, H -treatment efficiency}

Generally, the combination of the surface flow system (*Phragmites australis*) – tank 1, the floating plant system (*Cyperus alternifolius, Vetiveria zizanioides* and *Eichhornia crassipes*), tank 2 and 3, and the submerged flow system (*Vetiveria zizanioides*), tank 4 had good treatment efficiency. The treated wastewater met the level B of QCVN 40:2011/MONRE in terms of COD, TN and TP.

The obtained results were similar to that of domestic and international publications. So, Prapa Sohsalam et al (2008) studied possibility of seafood processing wastewater treatment by the surface flow system using sedge, canna, and typha. The treatment system was loaded 2 times with diluted wastewater. The system with retention time 5 days removed 91 – 99% BOD, 52–90% SS, 72–92% TN and 72–77% TP [5].

Rory Harrington and Robert McInnes (2009) used ecological technology with aquatic plants in combination with other technologies in livestock wastewater management achieved social, economic and environmental targets. Eight-year operating results of 12 such systems in Ireland demonstrated the effectiveness and sustainability of this type of technology. Total phosphorus and ammonium removal efficiency was of 95 and 98%, respectively [6].

In Vietnam, Dang Nhu Xuyen et al (2005) studied piggery wastewater treatment at pilot scale by combined system of UASB with aquatic plant *Eichhornia crassipes*. The system removed 70% N- NH_4^+, 58-65 % PO_4^{3-} and maintained pH stable in range from 6.8 to 6.9 [4].

Truong Thi Nga et al (2010) studied livestock wastewater treatment by *Enydra fluctuans* Lour and *Eichhornia crassipes* in Hau Giang. The results showed that *Enydra fluctuans* Lour removed 53.60% TN, 33.56% TP while *Eichhornia crassipes* reduced 64.36% TN and 42.54% TP. The author also showed that these plants have been adapted to this wastewater environment [3].

Tran Van Tua et al (2013) investigated the piggery wastewater treatment by surface flow technology. The obtained results showed that the *Phragmites australis* removed 53.52% TN and 42.83% TP at the load rate of 50 l/m^2.d [8], while Vu Thi Nguyet et al (2015) studied the piggery wastewater treatment by surface flow technology using *Eichhornia crassipes*. The results indicated that at the load rate of 50l/m^2.d, *Phragmites australis* treated 65.79% TN and 55.19% TP [10].

4. Conclusion

The obtained research results concerning the application of the combined system using 4 aquatic plants for removing COD, N and P from piggery wastewater after biogas production technology have shown:

The combined system of *Phragmites australis*, *Cyperus alternifolius*, *Eichhornia crassipes* and *Vetiveria zizanioides* proved to be highly efficient in removing COD, N and P. At the load rate of 47.35 l/m^2.d, inlet COD, TN and TP concentration were 203.24 mg/l, 111.94 mg/l and 13.61 mg/l, respectively, the treatment efficiency of COD, TN and TP got 71.66%, 79.26% and 69.65%, respectively. TN and TP loaded in the system with 5300.49 mgN/m^2.d and 644.32 mgP/m^2.d, respectively, and the system removed 4201.35 mgN/m^2.d and 448.76 mgP/m^2.d. The treated wastewater quality met the level B of QCVN 40:2011/MONRE in terms of COD, TN and TP.

The application of the combined system using *Phragmites australis*, *Cyperus alternifolius*, *Eichhornia crassipes* and *Vetiveria zizanioides* to remove COD, N and P from piggery wastewater is feasible and promising to be enlarged in practice conditions.

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