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Comparing the potential treatment of biogas effluent by two artificial wetland wastewater treatment systems

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ABSTRACT

Nowadays, environmental pollution treatment is one of the most concerning subjects in many countries. Especially the breeding waste treatment has to be taken as a priority. Besides, biogas technology sets up and operates primarily to treat breeding waste. However, this technology formed a considerable amount of wastewater the effluent quality is still poor and the concentration of pollutants is higher than the required national technical regulation (QCVN 62-MT:2016/BTNMT). The study was conducted on two units of horizontal flow constructed Wetland (HFCW) and vertical flow constructed wetland (VFCW). Both of these units were planted with Cyperus involucratus. The study aimed to compare the potential treatment of two artificial wetland systems and find out an appropriate wetland system to reduce environmental pollution from biogas effluent. The results indicated that vertically Flow Constructed Wetlands exhibited a higher treatment efficiency than horizontally Flow Constructed Wetlands with the average removal efficiency for COD, BOD_5, TSS, N-NH_3, and P-PO_4^{3-} were 55.2%, 75.3%, 82.3%, 75.9%, and 70.1%, respectively. The results of this study should provide insight into using wetland systems to treat wastewater and show vertical flow constructed wetland potential for improving the quality of biogas wastewater.

***Keywords:** biogas, breeding waste, constructed wetlands, cyperus involucratus*

1. Introduction

In accordance with the continuous development of industries, breeding branches are also drastically changing. In recent decades, breeding in Vietnam has had considerable improvement, that is ensuring either quantity or quality for the survival needs of people in the country. The breeding branch is supplying humans with a large amount of essential food, solving jobs, raising income, and improving the living standards for breeders. It cannot be denied that the breeding branch has brought many economic benefits to humans, however, this also makes the environment more seriously polluted with breeding waste. A large amount of breeding waste discharged into the environment brought about serious pollution to soil, water, and air and harmed the beautiful landscape, diminishing humans' health.

To treat the breeding waste, most breeding farms are using biogas technology which was regarded as the most practical solution to allow the breeding branch to develop sustainability. Energy arising from biogas reactors was used as fuel for human activities. This has economized on cost and cut down air pollution from fossil fuel use. Besides, waste from biogas reactors can be also salvaged to make organic fertilizer serving agriculture production. However, this technology created a considerable amount of wastewater that the effluent quality is still poor and the concentration of pollutants surpasses the required national technical regulation (QCVN 62-MT:2016/BTNMT). The concentration of organic pollutants in wastewater was up to five times as much as the required national technical regulation (QCVN 62-MT:2016/BTNMT) towards BOD_5 and six times as much as towards COD. The concentration of other pollutants in wastewater is also fairly profusely. Biogas wastewater reservoirs made the environment more polluted. Unfortunately, most of the swine farms did not have an effective solution for the treatment of this wastewater. Some swine farms directly used biogas wastewater for agriculture cultivation or let wastewater run out to canals or rivers. This action polluted groundwater, rivers had eutrophication, and food was not safe. Therefore, suitable technologies for biogas wastewater treatment should create new models with simple designs, a cost-effective and of course, technical effective.

Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewater (Vymazal, 2010). Constructed wetlands for wastewater treatment may be classified into various types (Brix & Schierup, 1989). Horizontal and vertical flow-constructed wetlands could be classified according to the flow direction (Ministry of Environment and Resources, 2016). The first constructed wetland was carried out in Germany in the early 1950s (Seidel, 1995). Since then, the constructed wetlands have evolved into an effective wastewater treatment technology for various types of wastewater such as hospital wastewater, paper and pulp wastewater, landfill leachate, and domestic wastewater (Vymazal, 2010). However, the constructed wetlands have not been applied for biogas wastewater yet.

The study was conducted on two units of horizontal flow constructed Wetland (HFCW) and vertical flow constructed wetland (VFCW). Both of these units were planted with *Cyperus involucratus*. The overall objectives of this research were: (1) to compare the potential treatment of two artificial wetland systems; (2) to find out an appropriate wetland system to reduce environmental pollution from biogas effluent.

2. Materials And Methods

Technical details of constructed wetlands

Two different types of constructed wetlands were used in this research including Horizontal flow constructed wetlands (figure 1) and Vertical flow constructed wetlands (figure 2). Horizontal and vertical flow-constructed wetlands comprising a flatbed with a dimension of 30cm width, 40cm length, and 26cm depth, were constructed in Tan Uyen district, Binh Duong province, under realistic conditions as shown in Figure 1 and Figure 2.

Figure 1 shows a schematic cross-section of a horizontal flow constructed wetland. It is called a horizontal flow constructed wetland because the wastewater is fed in a containable zone and flows slowly through the porous substrate under a horizontal path until it reaches the outlet zone.

Figure 2 shows a schematic cross-section of a vertical flow constructed wetland. It is called horizontal flow constructed wetland because the wastewater is fed from the top and then gradually percolates down through the porous in substrate until it reaches the outlet zone.

Types of substrates in bed (sand, rock 1 x 2cm, and rock 4 x 6cm) disposed from top to bottom. An 8cm layer of sand was disposed of at the top. After that was a 3cm layer of rock 1 x 2cm. The last layer was a bed of rock (4 x 6cm) with a 5cm thickness. This substrate supports the root system of *Cyperus involucratus*, which was planted at the top of the substrate. Both the wetlands were planted with six *Cyperus involucratus* trees. They reached equal growth and size. *Cyperus involucratus* was about one year old after rising from seeds. *Cyperus involucratus* was selected for the experiment by several factors such as its ability to grow and develop rapidly, and its massive root biomass.

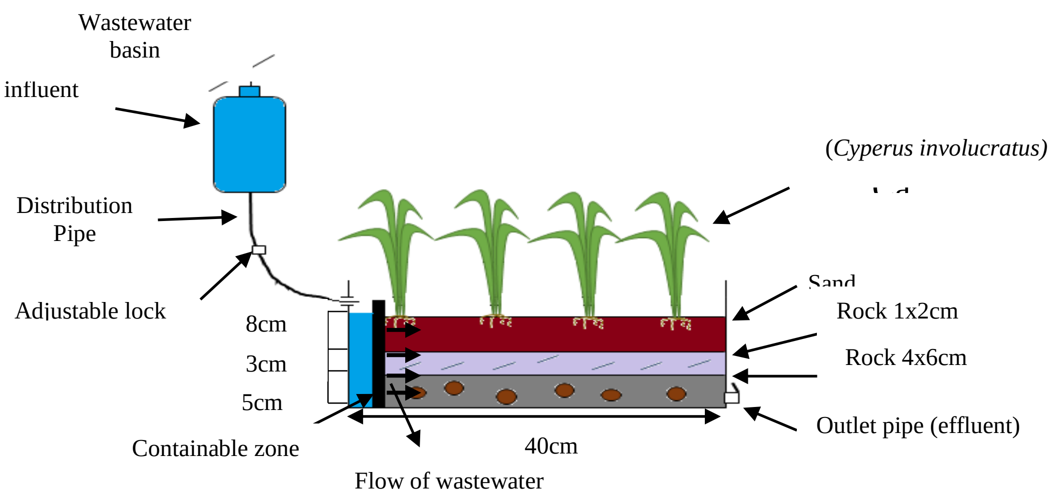

Figure 1. Schematic cross-section of a horizontal flow constructed wetland

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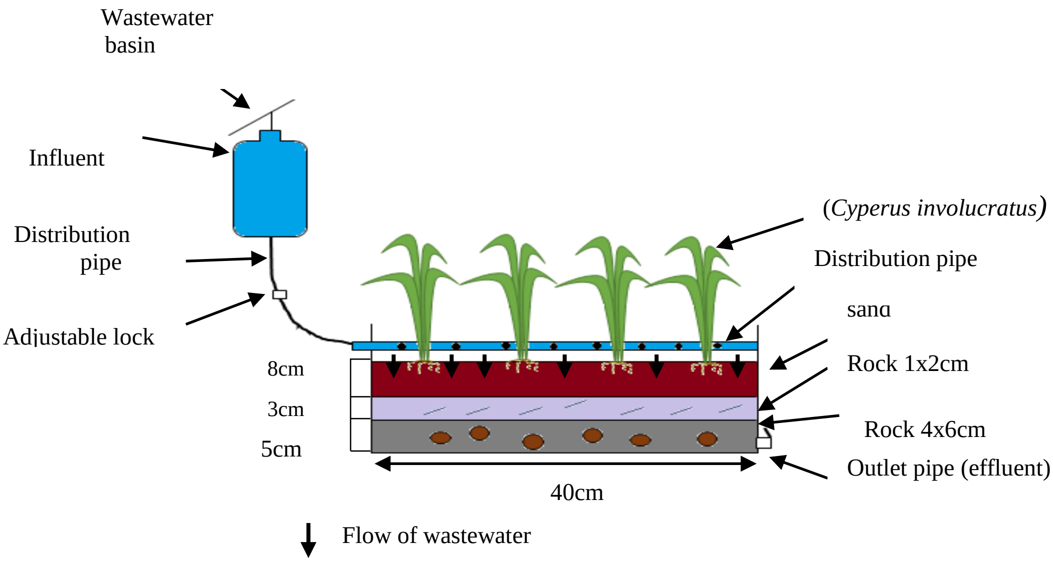

Figure 2. Schematic cross-section of a vertical flow constructed wetland

Experiment

The experiment consisted of 2 treatments corresponding to 2 systems of Horizontal Flow Constructed Wetland and Vertical Flow Constructed Wetland 3 investigated species of *Dracaena* with 3 replicates. Total number of experimental systems: 2 x 3 = 6.

Biogas wastewater from swine was collected in a swine farm in the Tan Uyen district of Binh Duong province. Wastewater was fed into the wetland units at an average volume of 10 L/day.

The wastewater characteristics were 490mg/l, 259mg/l, 68mg/l, 30.77mg/l, and 80.6mg/l for COD, TSS, BOD, $N\text{-}NH_3$, and $P\text{-}PO_4^3$, respectively.

Collection and analysis of samples

Effluent samples were collected from outlets of wetland units. Each effluent sample was collected and kept in a well-cleaned polyethylene bottle. pH of the sample was immediately measured, then the samples were stored at 4°C for further analysis.

After every 10 days of treatment, an effluent sample was collected from the outlet pipe of the wetland. The effluent sample was also kept in a well-cleaned bottle. Analysis was immediately conducted in a laboratory with parameters included as COD, TSS, BOD, $N\text{-}NH_3$, and $P\text{-}PO_4^3$.

3. Results And Discussion

Removal of water quality parameters such as COD, BOD_5, TSS, $N\text{-}NH_3$, and phosphate showed the differences between various wetlands as follows:

Chemical oxygen demand (COD) (mg/l)

COD removal from biogas wastewater in wetland units was monitored for one month. Table 1 shows the concentration of COD in treated wastewater in both of wetlands reduced continuously depending on the treatment time. In HFCW, the concentration of COD reduced from 490mg/l to 268.8mg/l. While, in VFCW, the concentration of COD reduced from 490mg/l to 219.7mg/l. The removal efficiency of COD by HFCW was 45.1 %, while the removal of COD by VFCW was 55.2 %. Therefore, it indicated that during the experimental period, the VFCW reached a higher removal efficiency of COD as compared with that of the HFCW.

Aerobic microorganism plays an important role in the decomposition of organic matter in wastewater. Aerobic microorganisms decompose organic contaminants in the rhizosphere. Oxidation of organic matter takes place in hypoxic regions. Vertical flow constructed wetland creates a more aerobic environment than horizontal flow constructed wetland, thus it created ideal conditions for microorganisms to decompose substances (Vymazal & Kröpfelova, 2008).

The Effluent Standards of Vietnam specified COD in effluent at 150mg/l (column B). It was clear that both experimental units could not meet this regulation.

TABLE 1. COD concentration before and after 30 days of treatment of two wetlands

Experimental unit	HFCW	VFCW
Influent	490± 4.58	490± 4.58
After 10 days of treatment	484.1 ± 1.44	460.6 ± 2.72
After 20 days of treatment	321.97 ± 1.3	311.1 ± 1.86
After 30 days of treatment (Effluent)	268.8 ± 0.40	219.7 ± 0.37
QCVN (Column B)	300	
QCVN (Column A)	100	
Removal efficiency (%)	45.1	55.2

Note: Mean ± SD

Suspended solid total (TSS) (mg/l)

The results as presented in figure 2 show TSS varied with treatment time for both of the wetlands. A treatment period of 30 days reduced the TSS concentration to 50.7mg/l for HFCW, while the TSS concentration was reduced to 45.7 mg/l for VFCW. The experiments proved that the wetlands are capable to reduce up to 80 % of TSS. The vertical flow of wastewater could affect a higher TSS removal efficiency than the horizontal flow perhaps because TSS concentrations easily settled in slow water flow in the VFCW unit. The concentration of TSS satisfies the requirement of national technical regulation (QCVN 62-MT:2016/BTNMT) (column A).

The thick suspended solids of the filter layer determine the removal of TSS content in the wastewater. The removal process of the TSS content increases with the size of the filter layer. For this reason, the vertical flow gives a higher TSS removal capacity (Oppelt Timothy, 1999).

TABLE 2. TSS concentration before and after 30 days of treatment of two wetlands

Experimental unit	HFCW	VFCW
Influent	259 ±2.08	259 ±2.08
After 10 days of treatment	156.33 ± 1.53	154.67 ± 1.53
After 20 days of treatment	102.33 ± 1.15	97.33 ± 1.15
After 30 days of treatment (Effluent)	50.7 ± 0.45	45.7±0.26
QCVN (Column B)	150	
QCVN (Column A)	50	
Removal efficiency (%)	80.4	82.3

Biochemical oxygen demand (BOD_5) (mg/l)

TABLE 3. Results of BOD_5 removal from experimental units

Experimental unit	HFCW	VFCW
Influent	68 ± 0.93	68 ± 0.93
After 10 days of treatment	63.4 ± 0.50	57.2 ± 0.57
After 20 days of treatment	45.05 ± 0.35	37.05 ± 0.78
After 30 days of treatment (Effluent)	24.5 ± 0.21	16.8 ± 0.14
QCVN (Column B)	100	
QCVN (Column A)	40	
Removal efficiency (%)	63.9	75.3

According to the requirement of the national technical regulation (QCVN 62-MT:2016/BTNMT), BOD_5 in effluent must be lower than 30mg/l (column A). As shown in Table 3, both HFCW and VFCW units could meet this regulation. The results showed that the wetland with the vertical flow was superior to those with the horizontal flow. The average removal efficiency of BOD_5 in the HFCW unit (63.9 %) was lower than in the VFCW unit (75.3 %). This occurrence might be the effect of the flow of wastewater in the wetland unit.

Ammonia nitrogen (N_NH_3) (mg/l)

TABLE 4. Results of $N\text{-}NH_3$ removal from experimental units

Experimental unit	HFCW	VFCW
Influent	30.77 ± 0.21	30.77 ± 0.21
After 10 days of treatment	12.86 ± 0.49	11.66 ± 0.56
After 20 days of treatment	9.94 ± 0.07	7.42 ± 0.06
After 30 days of treatment (Effluent)	9.94 ± 0.07	7.42 ± 0.06
Removal efficiency (%)	67.7	75.9

From Table 4, it indicated that the concentration of $N\text{-}NH_3$ in treated wastewater in both HFCW wetland and VFCW reduced considerably according to the treatment time. So if treated biogas wastewater lets run out to rivers or lakes, both algal bloom and eutrophication will be reduced. The average $N\text{-}NH_3$ removal efficiency was higher in the VFCW unit (75.9 %) and slightly less in HFCW (67.7 %).

Nitrogen is removed in wetlands primarily through nitrification and plant uptake. The vertical flow filter creates a more aerobic environment than the horizontal flow filter, so it facilitates the nitrification process more leading to higher treatment capacity (U.S. EPA., 1993). The nitrogen removal efficiency in the vertical flow filter tank above 80% gave similar results to studies on other types of wastewater such as domestic wastewater, hospital wastewater, and leachate (UN-HABITAT, 2008).

Phosphate ($P\_PO_4^{3-}$) (mg/l)

TABLE 5. Results of $P\_PO_4^{3-}$ removal from experimental units

Experimental unit	**HFCW**	**VFCW**
Influent	80.6 ± 0.67	80.6 ± 0.67
After 10 days of treatment	50.77 ± 0.41	49.47 ± 0.50
After 20 days of treatment	41.4 ± 0.46	34.12 ± 0.36
After 30 days of treatment (Effluent)	31.6 ± 0.46	24.1 ± 0.36
Removal efficiency (%)	60.8	70.1

Phosphate has been recognized as a pollutants sources that is responsible for algal bloom and eutrophication in lakes and slow flowing water. Reduction of phosphorus in wastewater is important for new technology. The concentration of both the two constructed wetlands met this requirement. As seen in Table 5, phosphate removal efficiency in wetland units was very high ranging from 60.8 to 70.1 percent. For phosphate removal, the VFCW unit showed higher efficiency than the HFCW units. Phosphate removal mechanisms are related to plant uptake ability, and chemical adsorption and precipitation in the soil (Crites & Tchobanoglous, 1998). It could be explained that in the wetland with vertical flow, the plants had a long time to uptake of phosphate for their growth.

4. Conclusion

Based on the results presented, it can be concluded that the VFCW system showed higher removal efficiency for pollutant removal in biogas wastewater than the HFCW system with the average removal efficiency for COD, BOD_5, TSS, $N\text{-}NH_3$, and $P\text{-}PO_4^{3-}$ were 55.2%, 75.3%, 82.3%, 75.9%, and 70.1%, respectively. VFCW system might be suitable for biogas wastewater treatment.

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