Sustainable Environmental Insight

Research Article
Volume 2(2), 2025, 113–123
https://doi.org/10.53623/sein.v2i2.796

Evaluation of the Treatment Performance Over Time of Constructed Wetlands for Wastewater from Rice Noodle Handicraft Village after Biogas Process

Nguyen Van Thanh[1], Pham Thuong Giang[2,3]*, Bui Thi Kim Anh[1], Nguyen Thi Thu Thuy[4]

[1]Institute of Science and Technology for Energy and Environment, Vietnam Academy of Science and Technology, Hanoi, Vietnam
[2]Faculty of Applied Sciences, University of Transport Technology, Hanoi, Vietnam
[3]Graduate University of Science and Technology, Vietnam Academy of Science and Technology, Hanoi, Vietnam
[4]Institute of Tropical Biomedicine, Joint Vietnam-Russia Tropical Science and Technology Research Center, Hanoi, Vietnam

*Correspondence: Thuonggianglc911@gmail.com

SUBMITTED: 8 August 2025; REVISED: 4 September 2025; ACCEPTED: 7 September 2024

ABSTRACT: Constructed wetlands (CWs) offer a low-cost and sustainable treatment option. However, their performance strongly depends on hydraulic retention time (HRT), which also influences land use and construction requirements. This study aimed to determine the minimum HRT required for treating wastewater from rice noodle handicraft villages after the biogas process to meet the National Technical Regulation on Industrial Wastewater (QCVN 40:2025/BTNMT), Column B. The CW system was set up in a glass tank (50 × 30 × 50 cm) with a 40 cm substrate layer consisting of yellow sand mixed with crushed stone, limestone (1 × 2 cm), and gravel (3 × 5 cm), and was planted with *Cyperus alternifolius* at a density of 18 plants per CW unit. The system was operated for 70 days with daily sampling. Results showed that effluent quality met QCVN 40:2025/BTNMT, Column B standards after 4 days, with average treatment efficiencies of 89.2% for total suspended solids (TSS), 82.4% for chemical oxygen demand (COD), 54.7% for total nitrogen (TN), and 78.1% for total phosphorus (TP). Although longer HRTs improved treatment efficiencies, removal rates plateaued after the fourth day. Therefore, a 4-day HRT is recommended as an optimal balance between treatment performance and construction cost. These findings provide practical implications for scaling up CW systems to improve wastewater management in Vietnamese handicraft villages.

KEYWORDS: Constructed wetland; rice noodle handicraft village wastewater; hydraulic retention time, nutrient removal, sustainable sanitation.

1. Introduction

The processing of rice-based products provides greater economic benefits for farmers. In addition, traditional craft villages offer substantial cultural and historical value. However, due to small-scale operations and limited or absent funding for environmental protection, environmental problems, particularly wastewater pollution, are becoming increasingly severe in rice noodle handicraft villages in Vietnam [1]. It is estimated that the production of one ton of finished rice noodles generates approximately 8.5 cubic meters of wastewater. This wastewater is characterized by a high concentration of organic matter and nutrients, as it is often mixed with other waste streams from the craft village. Currently, the most commonly used treatment technology is anaerobic digestion (biogas tanks). However, the quality of the treated effluent still exceeds the permissible limits set by QCVN 40:2011/BTNMT, Column B [2, 3]. Therefore, it is necessary to adopt alternative or supplementary treatment technologies to ensure that the wastewater meets the required standards, while maintaining low cost, ease of operation, and suitability for application in rice noodle handicraft villages.

CW technology has demonstrated effective treatment capabilities for wastewater rich in organic matter and nutrients, similar to the effluent from rice noodle handicraft villages after biogas tank treatment [4, 5]. It is low-cost and environmentally friendly, as its treatment mechanism is based on natural transformation processes [6, 7]. For example, nitrogen in the wastewater undergoes nitrification and ammonification to form NO_3^- and NH_4^+, which are subsequently assimilated into the biomass of plants and microorganisms [8]. Hydraulic retention time (HRT) is a critical factor influencing treatment performance in CW systems. A longer HRT allows for greater contact between the wastewater, microorganisms, and filter media, thereby enhancing biochemical processes such as nitrification and denitrification. Depending on the characteristics of the wastewater and treatment requirements, CW systems are designed with varying retention times [9]. The study by Shruthi and Shivashankara (2021) demonstrated that an optimal HRT of approximately 6 days is effective for rural wastewater treatment [10]. For dairy processing wastewater, a retention time of more than 2 days resulted in nitrogen removal efficiency exceeding 80% [11]. For wastewater similar to that generated in rice noodle handicraft villages, but with higher pollutant concentrations as in the present study, an HRT of 6 days is required to meet the discharge standards specified in QCVN 40:2011/BTNMT, Column B [2].

Although increasing HRT generally enhances treatment performance, it must be balanced with hydraulic loading and system stability to avoid clogging and long-term performance degradation. A study on piggery wastewater found that treatment efficiency was optimal after 3 days; extending the retention time to 4 days did not result in significant improvement, as the system had reached a saturation point where longer retention no longer contributed to additional pollutant removal [5]. On the other hand, extending HRT increases construction costs. Therefore, it is essential to determine an appropriate retention time that ensures both economic and environmental efficiency. Studies related to wastewater from rice noodle handicraft villages after the biogas process are still limited in Vietnam.

In this study, a laboratory-scale CW system was designed, and wastewater samples were collected at different time intervals. The results provide data on the variation in pollutant concentrations and treatment efficiency over time. Based on these findings, a suitable retention time is proposed for CW design to treat effluent from rice noodle handicraft villages after biogas treatment, ensuring compliance with discharge standards. The experiment was conducted under Vietnamese climatic conditions, and the quality of the treated effluent met the requirements of the new QCVN 40:2025/BTNMT, Column B standard.

2. Materials and Methods

2.1. Materials.

The wastewater was collected at the outlet of a biogas tank in a rice noodle handicraft village located in Da Mai Ward, Bac Ninh Province, Vietnam (21°16′49.23″N, 106°9′26.56″E). Among the analyzed parameters, pH was within the permissible range, whereas the concentrations of TSS, COD, TN, and TP exceeded the QCVN 40:2025/BTNMT, Column B standards by factors of 1.7 to 5.1 (Table 1).

Table 1. Characteristics of biogas effluent from the rice noodle handicraft craft village in Da Mai, Bac Ninh.

Parameter	Unit	Value (mean ± SD)	QCVN 40:2025/ BTNMT Column B
pH	-	6.8 ± 0.3	6 - 9
COD	mg/l	457.1 ± 23.6	90
TSS	mg/l	249.6 ± 7.5	80
TN	mg/l	67.6 ± 2.4	40
TP	mg/l	12.0 ± 0.6	6

Note: QCVN 40:2025/BTNMT, Column B refers to the national technical regulation on industrial wastewater, applied to wastewater discharged into receiving water bodies that are not intended for domestic water supply.

2.2. Methods

2.2.1. Experimental setup.

The experiment was conducted on a laboratory scale. The CW system used is a vertical subsurface flow constructed wetland, which was installed in a rectangular glass tank with dimensions of 50 × 30 × 50 cm (length × width × height) (Figure 1). The 40 cm substrate layer was vertically arranged from top to bottom as follows: the top layer consisted of a 10 cm mixture of yellow sand and crushed stone, which has small, porous particles favorable for plant growth; the middle layer was 10 cm of limestone (1 × 2 cm), capable of neutralizing acidity in the wastewater; and the bottom layer was 20 cm of gravel (3 × 5 cm), a highly porous material that helps minimize clogging risks. *Cyperus alternifolius* was used, as it has been proven to grow well in rice noodle handicraft village wastewater and demonstrates high efficiency in removing organic matter and nutrients [3]. The plants were pre-cultivated on the substrate for two months before the experiment to allow for stable development, with a planting density of 18 plants per experimental unit. The environmental conditions included temperatures from 28 - 34 °C, humidity from 81 – 87 %, and average sunlight hours from 12.8 to 13.2 hours per day. The experiment was conducted in batch mode, with wastewater added to completely submerge the substrate layers (32 l). Samples of 100 mL were collected at different time intervals (1, 2, 3, 4, 5, 6, and 7 days) to analyze changes in the concentrations of TSS, COD, TN, and TP. The daily water loss due to evaporation and sampling was replenished using distilled water. The experimental setup was maintained for 100 days. During the 30-day startup phase, wastewater was added with gradually increasing concentrations of 0, 25, 50, and 75% of the actual wastewater in order to allow the plants to adapt and grow. The operational and sampling phase lasted for 70 days, corresponding to 10 cycles, with each cycle lasting 7 days, and samples were collected once per day.

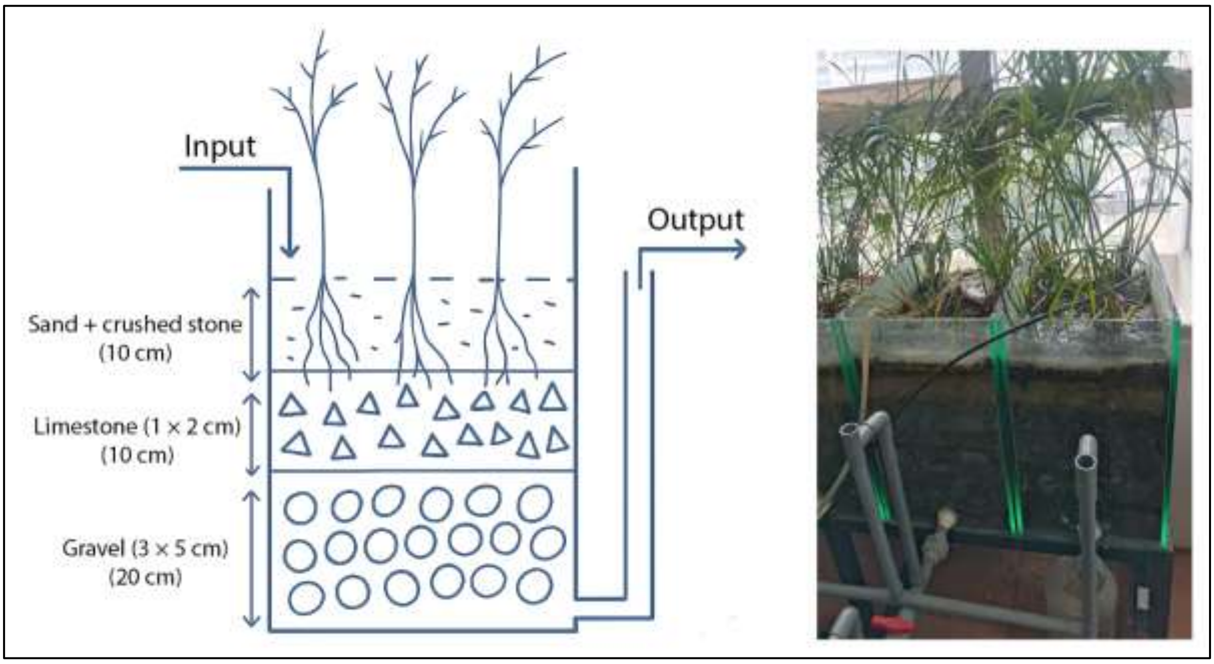


Figure 1. Experimental design of the constructed wetland.

2.2.2. Data analysis.

Treatment efficiency was calculated using the following formula:

$$H = \frac{C_0 - C_i}{C_0} \times 100\% \tag{1}$$

where H is the treatment efficiency on day i, C_0 is the initial pollutant concentration (mg/L), and C_i is the effluent concentration on day i (mg/l).

Removal rate, representing the amount of pollutant removed per unit area of the CW per day, was calculated using the following formula:

$$R_i = \frac{(C_{i-1} - C_i) \times V_0}{S} \tag{2}$$

where R_i is removal rate on day i (g m^{-2} d^{-1}), C_{i-1} and C_i are the pollutant concentrations on day i–1 and i, respectively (mg/l); V_o is the daily treatment flow rate (32 $l.d^{-1}$), and S is the fixed surface area of the CW (0.015 m^2).

Experimental data were compiled and analyzed using Microsoft Excel 2016 for Windows. SPSS 20 (Windows) software was used to perform one-way ANOVA, with p-values < 0.05 considered statistically significant. The average values of pollutant indicators in the treated effluent were compared with the corresponding limits in QCVN 40:2025/BTNMT, Column B (TSS: 80 mg/l; COD: 90 mg/l; TN: 40 mg/l; TP: 6 mg/l).

2.2.3. Water quality analysis.

To assess water quality, the following wastewater parameters were analyzed using standard methods for water and wastewater testing in Vietnam. COD was determined by the colorimetric method using potassium dichromate [12], and TSS were measured by filtration through a glass fiber filter [13]. TN was analyzed using the catalytic digestion method after reduction with Devarda's alloy [14]. TP was determined by spectrophotometry using the ammonium molybdate method [15].

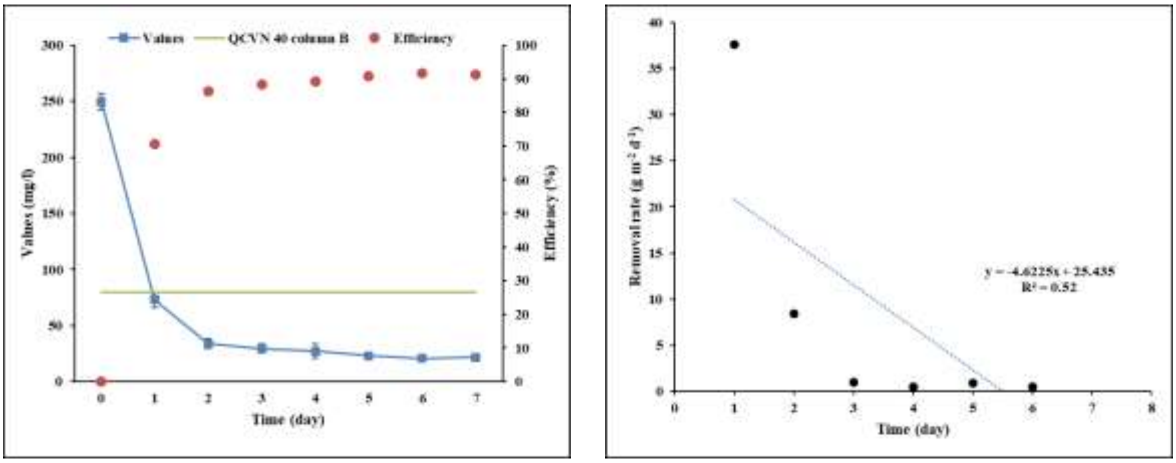
2.2.4. Linear regression analysis.

The relationship between removal rate and HRT was evaluated using linear regression analysis. Experimental data points representing removal rate (g m^{-2} d^{-1}) at different retention times (days) were plotted, and a linear regression model was fitted to the data. The regression equation was expressed in the form y= ax+b, where a is the slope and b is the intercept. The coefficient of determination (R^2) was calculated to quantify the proportion of variance in the removal rate explained by retention time. A higher R^2 value indicates a stronger correlation between the two variables. This approach allows for the identification of trends in removal performance over time and supports the determination of optimal HRT for the CW system.

3. Results and Discussion

3.1. TSS removal.

The removal mechanism of TSS primarily relies on sedimentation and filtration within the substrate layer [16]. The rate and efficiency of filtration depend on the properties of the substrate (e.g., particle size, shape, and adsorption capacity) [4, 16]. In the CW system used in this study, the filtration media were arranged to simulate a vertical filter column with increasing particle size along the flow path, thereby significantly enhancing filtration performance. Experimental results revealed distinct changes during different phases of the study. The TSS removal efficiency and daily TSS removal load increased markedly during the first 1–2 days; after just one day of operation, the TSS concentration already met the Column B standard of QCVN 40:2025/BTNMT (Figure 2).



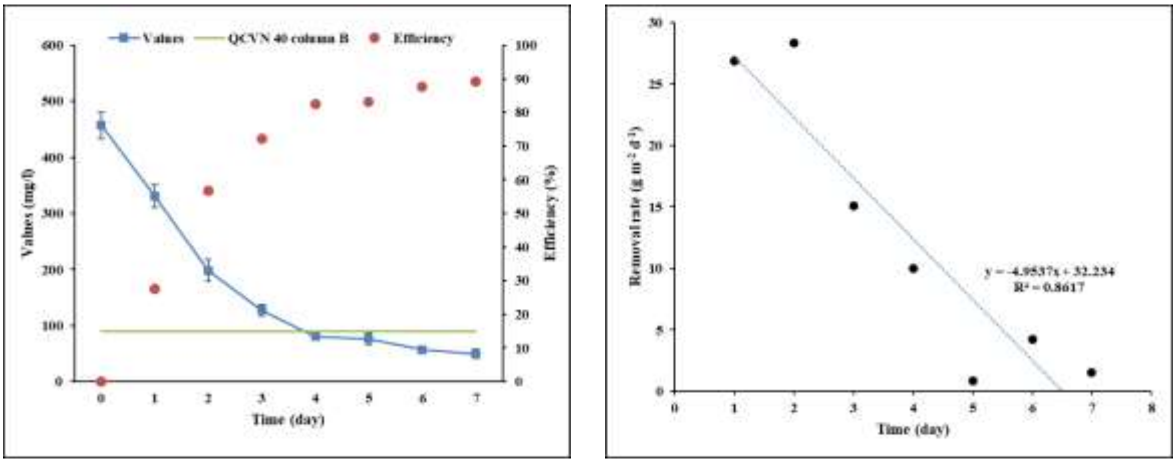
(a) **(b)**

Figure 2. TSS removal efficiency (a) and removal rate (b) over time.

The CW achieved a TSS removal efficiency of up to 92% after seven days. Previous studies have reported an increase in TSS removal efficiency from 80.2% to 98.8% when the HRT was extended from 1 to 4 days [11]. Sirianuntapiboon et al. observed a sharp increase in TSS removal efficiency between 0.75 and 1.5 days of HRT, followed by a decline when HRT was extended to 3 days [17]. Similarly, Lee et al. suggested that longer retention times could enhance sedimentation but should be optimized to prevent system overload [18]. In the present study, the coefficient of determination ($R^2 = 0.52$) indicated a moderate correlation between treatment duration and removal rate, suggesting that HRT was not a critical determinant of TSS removal efficiency. Therefore, extending the retention time did not yield substantial performance gains. The TSS removal rate showed no significant difference from the third day onwards ($p > 0.05$). For wastewater from rice noodle handicraft villages, an HRT of one day was sufficient to meet regulatory standards, with corresponding removal efficiency and removal rate values of 70.7% and 37.6 g m^{-2} d^{-1}, respectively.

3.2. COD removal.

Extending the HRT in CWs enhances COD removal efficiency by providing optimal conditions for biological, chemical, and physical processes. A longer HRT allows microorganisms more time to degrade organic matter, thereby improving treatment performance. The experimental results also demonstrated a gradual decrease in COD concentration over time, accompanied by a progressive increase in removal efficiency (Figure 3).



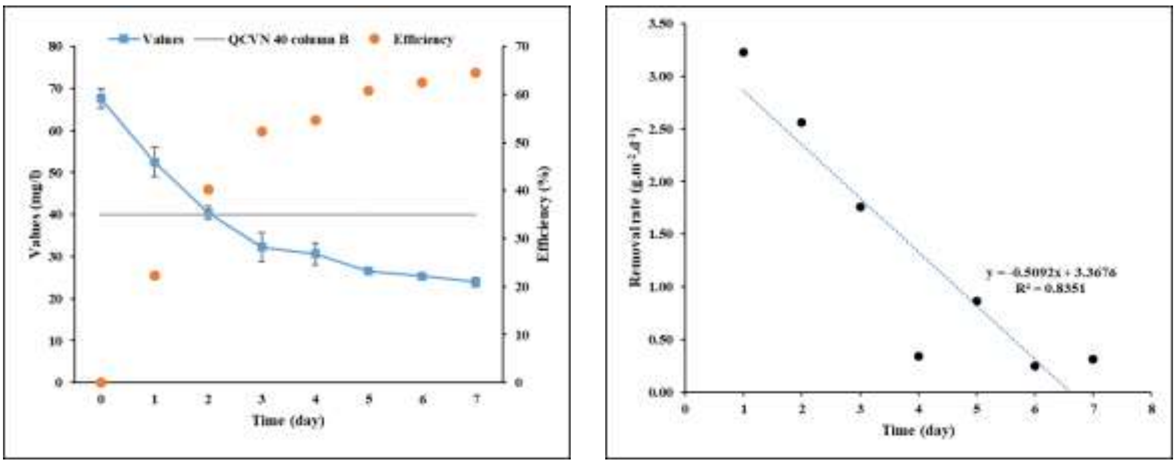
(a) **(b)**

Figure 3. COD removal efficiency (a) and removal rate (b) over time.

Initially, COD removal occurred predominantly through filtration, resulting in a high removal rate of 26.9 g m^{-2} d^{-1}; however, the removal efficiency after one day was only 27.6%. In the subsequent days, natural transformation processes mediated by microorganisms and plants became the primary mechanisms for COD removal, leading to a gradual decline in removal rate, while removal efficiency continued to increase ($p < 0.05$). Ghosh et al. (2010) similarly reported low COD removal efficiency on the first day (30.8%), which increased to 85% by the third day [11]. The coefficient of determination ($R^2 = 0.8617$) and the slope of the correlation equation (-4.84) indicate a negative correlation between COD removal load and experimental duration. This finding demonstrates that, although COD removal efficiency increases over time, the amount of COD removed per day tends to decrease. Therefore, it is essential to determine an optimal removal threshold to maximize COD treatment efficiency in CWs. The results showed that, after 4 days, the COD concentration was 80.4 ± 4.3 mg/L, meeting the Column B standard of QCVN 40:2025/BTNMT, with a corresponding removal efficiency of 82.4%. Previous studies have reported shorter HRTs of only 30 - 36 hour to achieve removal efficiencies of 61.4 - 82%. However, the influent in those studies was domestic wastewater with significantly lower COD concentrations than in the present study [17, 19]. Another report indicated that with influent COD concentrations ranging from 725.8 to 882.4 mg/L, an HRT of six days was required to meet the Column B standard of QCVN 40:2011/BTNMT, with a COD removal efficiency of 86% [2]. Clearly, COD removal efficiency and hydraulic retention time depend on the characteristics of the wastewater. To achieve the permissible discharge standard, the required HRT for COD removal in the wastewater examined in this study was 4 days.

3.3. TN removal.

The removal of TN in CWs depends significantly on treatment duration. During the first four days, TN concentration decreased rapidly, with removal efficiency reaching 54.7%. In the initial stage, nitrogen compounds may be retained through adsorption onto the substrate and subsequently released into the water for microbial utilization - a process that generally occurs quickly. Consequently, a substantial amount of TN is removed within a short period. In the following days, nitrogen transformation processes such as nitrification and denitrification take place, and a considerable portion of bioavailable nitrogen is taken up by plants as a nutrient source, thereby removing nitrogen from the wastewater. However, these processes require a longer retention time [8]. Prolonging the treatment period led to continued improvement in removal efficiency. From the fourth day onwards, the efficiency increased more slowly but still showed a statistically significant difference ($p < 0.05$). Nevertheless, the coefficient of determination ($R^2 = 0.8351$) indicated a clear correlation between retention time and removal rate (Figure 4). The results demonstrated that a longer retention time was associated with a lower removal rate. Therefore, determining the optimal HRT is essential to reduce construction costs. Previous studies have reported TN removal efficiencies of 84% after three days for domestic wastewater [17]; an increase from 35.4% to 94.6% when HRT was extended from one to four days for dairy-processing wastewater [11]; and 56.5% after three days for swine wastewater [5]. Depending on influent TN concentration and the discharge requirements specified in Column B of QCVN 40:2025/BTNMT, for post-biogas effluent from rice noodle handicraft villages, an HRT of 2–3 days is considered necessary for CWs to achieve optimal TN removal efficiency.

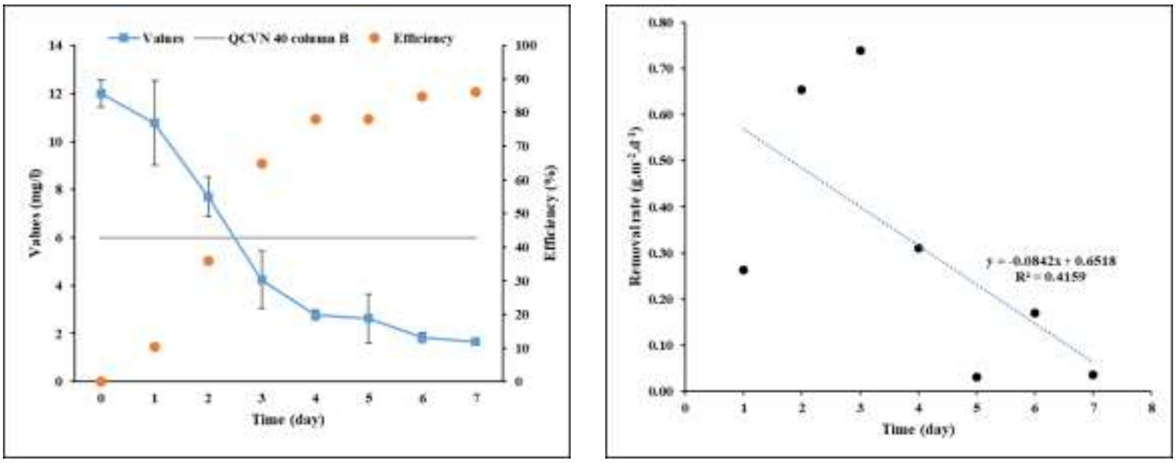


(a) **(b)**

Figure 4. TN removal efficiency (a) and removal rate (b) over time.

3.4. TP removal.

Phosphorus removal can occur rapidly through precipitation or over longer periods via natural transformation processes. Similar to nitrogen, phosphorus in wastewater can also serve as a nutrient source for plants and microorganisms [8], therefore prolonged treatment times can lead to increased phosphorus removal. In addition, precipitation reactions between phosphorus and filter media, particularly carbonate-based materials such as limestone, play an important role [4]. In the present study, HRT was not a determining factor for TP removal efficiency in the CW. The coefficient of determination (R^2 = 0.4159) indicated a low to moderate correlation between treatment time and removal rate, suggesting that factors other than HRT also influence TP removal performance. TP removal efficiency increased rapidly during the first four days, reaching 78.1%, while the removal rate rose during the first three days from 0.26 to 0.74 g m^{-2} d^{-1}. Thereafter, efficiency continued to increase but at a slower pace, and the removal rate began to decline from day 4 onward, yet the difference remained statistically significant ($p < 0.05$) (Figure 5). After 7 days, the removal rate had dropped to only 0.04 g m^{-2} d^{-1}. These findings suggest that the optimal period for TP removal from post-biogas effluent of rice noodle handicraft villages in the CW system is within the first 3–4 days. When retention time is extended, phosphorus removal slows as the filter media gradually become saturated and phosphorus concentrations decrease, which reduces the rates of biological processes such as assimilation and precipitation [8]. G. Baskar et al. (2014) reported that increasing HRT from 2 to 8 days enhanced TP removal efficiency from 25% to 75%, with a recommended HRT of six days [20]. Another study showed that TP removal efficiency reached 77% with an HRT of three days [21]. In the present study, TP concentrations met the Column B standard of QCVN 40:2025/BTNMT after three days of treatment, with a corresponding removal efficiency of 64.7%.



(a) **(b)**

Figure 5. TP removal efficiency (a) and removal rate (b) over time.

HRT is a parameter that can be easily adjusted in CW design to modify treatment efficiency [22]. This study demonstrated the influence of retention time on the treatment performance of CWs. The general trend observed was a decrease in pollutant concentrations and an increase in removal efficiency over time. Therefore, it can be concluded that a longer HRT is a viable approach to improving the treatment efficiency of post-biogas wastewater from rice noodle handicraft villages. However, extending HRT requires increasing the construction area, which raises the overall cost of the technology and may not be affordable for village-scale operations. Thus, it is necessary to determine an appropriate HRT that ensures compliance with discharge standards while optimizing costs. This can be established by considering the differences in the removal patterns of individual pollutants. The results showed that TSS met the regulatory limit after only one day, whereas other pollutant parameters reached the standard after 3 - 4 days. In addition, the removal rate tended to decrease, particularly from the fourth day onward, indicating a gradual decline in treatment performance. To ensure that the treated wastewater meets the Column B standard of QCVN 40:2025/BTNMT while minimizing construction costs, the recommended HRT was 4 days. At this retention time, the removal efficiencies of TSS, COD, TN, and TP were 89.2%, 82.4%, 54.7%, and 78.1%, respectively, and the corresponding removal rates were 47.5 g m^{-2} d^{-1}, 80.4 g m^{-2} d^{-1}, 7.9 g m^{-2} d^{-1}, and 2.0 g m^{-2} d^{-1}. A previous study using CWs reported comparable removal efficiencies for TSS and COD, at 81.2% and 86.0%, respectively, but with an HRT of up to 6 days and a lower TP removal efficiency [2]. Another study reported a TN removal efficiency as high as 84% in low-strength wastewater [17]. Overall, in addition to HRT, the influent pollutant concentration also affects the treatment efficiency of CW systems. Furthermore, in practical applications, plant growth and weather conditions significantly influence the performance of the technology.

4. Conclusions

Hydraulic retention time has a decisive influence on the treatment performance of CWs. While TSS met the regulatory standard after one day, COD, TN, and TP required 3 - 4 days. Extending the retention time beyond this point further improved removal efficiency but resulted in a decline in removal rate, particularly from the fourth day onward. Based on these findings, an HRT of 4 days is recommended as the optimal balance for CWs treating post-biogas wastewater from rice noodle handicraft villages to comply with the Column B standard of QCVN 40:2025/BTNMT. At this retention time, removal efficiencies for TSS, COD, TN, and TP were 89.2%, 82.4%, 54.7%, and 78.1%, respectively. These results demonstrate the potential of CWs as a cost-effective and sustainable approach for improving wastewater management in Vietnamese handicraft villages.

Acknowledgments

This study was conducted within the framework of project KC.08.02/21-30.

Author Contribution

Nguyen Van Thanh: Conceptualization, Methodology, Data Analysis, Writing; Pham Thuong Giang: Methodology, Data Collection, Data Analysis, Writing; Bui Thi Kim Anh: Writing, Supervision, Funding; Nguyen Thi Thu Thuy: Methodology, Data Collection.

Competing Interest

The authors declare no competing interests.

References

[1] Nguyen, X.C.; Chang, S.W.; Tran, T.C.P.; Nguyen, T.T.N.; Hoang, T.Q.; Banu, J.R.; Al-Muhtaseb, A.A.H.; La, D.D.; Guo, W.; Ngo, H.H.; Nguyen, D.D. (2019). Comparative study about

the performance of three types of modified natural treatment systems for rice noodle wastewater. *Bioresource Technology*, *282*, 163–170. https://doi.org/10.1016/j.biortech.2019.02.117.

[2] Thanh, N. V.; Anh, B. T. K.; Thuy, N. T. T.; Yen, N. H.; Chuyen, N. H.; Kim, D. D. (2024). Study Filter Materials for Vertical Subsurface Flow Constructed Wetland to Treat Wastewater from the Da Mai Noodle Handicraft Village in Bac Giang Province. *VNU Journal of Science: Earth and Environmental Sciences*, *40*, 93–104. https://doi.org/10.25073/2588-1094/vnuees.5078.

[3] Thanh, N. V.; Hai, D. T.; Thuy, N. T. T.; Anh, B. T. K.; Khanh, T. V. (2022). Evaluating the treatment efficiency of the subsurface constructed wetlands system and free floating plants system for the wastewater from noodle handicraft village in Hiep Hoa commune, Quang Yen town, Quang Ninh province. *Thai Nguyen University Journal of Science and Technology*, *227*, 367–375. https://doi.org/10.34238/tnu-jst.5926.

[4] Anh, B. T. K.; Thanh, N. V.; Phuong, N. M.; Ha, N. T. H.; Yen, N. H.; Lap, B. Q.; Kim, D. D. (2020). Selection of Suitable Filter Materials for Horizontal Subsurface Flow Constructed Wetland Treating Swine Wastewater. *Water, Air, & Soil Pollution*, *231,* 88. https://doi.org/10.1007/s11270-020-4449-6.

[5] Sarmento, A. P.; Borges, A. C.; De Matos, A. T. (2013). Effect of cultivated species and retention time on the performance of constructed wetlands. *Environmental Technology*, *34*, 961–965. https:/doi.org/10.1080/09593330.2012.724210.

[6] Taha, D. S.; al-Qadisiya, B. (2023). Using of Constructed Wetlands in The Treatment of Wastewater: A Review for Operation and Performance. *Journal of Engineering*, *29*, 169–188. https://doi.org/10.31026/j.eng.2023.07.11.

[7] Waly, M. M.; Ahmed, T.; Abunada, Z.; Mickovski, S. B.; Thomson, C., (2022). Constructed Wetland for Sustainable and Low-Cost Wastewater Treatment: Review Article. *Land*, *11*, 1388. https://doi.org/10.3390/land11091388.

[8] Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands. *Science of the Total Environment, 380*, 48-65. https://doi.org/10.1016/j.scitotenv.2006.09.014.

[9] Dotro, G.; Langergraber, G.; Molle, P.; Nivala, J.; Puigagut, J.; Stein, O.; Von Sperling, M. (2017). Treatment Wetlands. *Water Intelligence Online*, *16*, 9781780408774. https://doi.org/10.2166/9781780408774.

[10] Shruthi, R.; Shivashankara, G. P. (2022). Investigation on the performance evaluation of vertical subsurface flow constructed wetland for the treatment of rural wastewater. *Water Science and Technology*, *85*, 16–26. https://doi.org/10.2166/wst.2021.507.

[11] Ghosh, D.; Gopal, B. (2010). Effect of hydraulic retention time on the treatment of secondary effluent in a subsurface flow constructed wetland. *Ecological Engineering*, *36*, 1044–1051. https://doi.org/10.1016/j.ecoleng.2010.04.017.

[12] MOST. (1999). Water quality - Determination of the chemical oxygen demand (Vietnamese National Standards (TCVN) – Ministry of Science and Technology, 6491:1999).

[13] MOST. (2000). Water quality Determination suspended solids by filtration through glass-fibre filters (Vietnamese National Standards (TCVN) – Ministry of Science and Technology, 6625:2000).

[14] MOST. (2000). Water quality - Determination of nitrogen - Catalytic digestion after reduction with Devarda's alloy (Vietnamese National Standards (TCVN) – Ministry of Science and Technology, 6638:2000).

[15] MOST. (2008). Water quality - Determination of phosphorus - Ammonium molybdate spectrometric method (Vietnamese National Standards (TCVN) – Ministry of Science and Technology, 6202:2008).

[16] Ji, Z.; Tang, W.; Pei, Y. (2022). Constructed wetland substrates: A review on development, function mechanisms, and application in contaminants removal. *Chemosphere*, *286*, 131564. https://doi.org/10.1016/j.chemosphere.2021.131564.

[17] Sirianuntapiboon, S.; Kongchum, M.; Jitmaikasem, W. (2006). Effects of hydraulic retention time and media of constructed wetland for treatment of domestic wastewater. *African Journal of Agricultural Research, 1*, 027–037. https://doi.org/10.5897/AJAR.9000253.

[18] Lee, S.; Maniquiz-Redillas, M. C.; Kim, L.-H. (2014). Settling basin design in a constructed wetland using TSS removal efficiency and hydraulic retention time. *Journal of Environmental Sciences*, *26*, 1791–1796. https://doi.org/10.1016/j.jes.2014.07.002.

[19] Neetu, R.; Karuna Narayan, P. (2021). Assessment of Hybrid Subsurface Flow Constructed Wetland Planted with Arundo Donax for the Treatment of Domestic Wastewater at Different Hydraulic Retention Time. *Journal of Water Chemistry and Technology*, *43*, 178–183. https://doi.org/10.3103/S1063455X21020107.

[20] Baskar, G.; Deeptha, V.; Annadurai, R. (2014). Comparison of treatment performance between constructed wetlands with different plants. *International Journal of Research in Engineering and Technology*, *3*, 210–214. https://doi.org/10.15623/ijret.2014.0304037.

[21] Du, L.; Chen, Q.; Liu, P.; Zhang, X.; Wang, H.; Zhou, Q.; Xu, D.; Wu, Z. (2017). Phosphorus removal performance and biological dephosphorization process in treating reclaimed water by Integrated Vertical-flow Constructed Wetlands (IVCWs). *Bioresource Technology*, *243*, 204–211. https://doi.org/10.1016/j.biortech.2017.06.092.

[22] Minakshi, D.; Sharma, P. K.; Rani, A. (2021). Effect of filter media and hydraulic retention time on the performance of vertical constructed wetland system treating dairy farm wastewater. *Environmental Engineering Research*, *27*, 200436–200430. https://doi.org/10.4491/eer.2020.436.