Effect of initial cod concentration and the fraction of N/P on treatment ability of Para grass (Brachiaria mutica) vegetation in the stabilization pond

V T T Ho¹*, M D Pham¹ and T L Van²

¹Hochiminh City University of Natural Resources and Environment (HCMUMRE), Vietnam
²NTT-Hi Tech, Institute, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam

*Corresponding author's e-mail: httvan@hcmunre.edu.vn

Abstract. Stabilization pond which is covered by aquatic plant is a environmentally friendly method to treat wastewater. In this study, stabilization pond using Para grass vegetation is applied to treat industrial wastewater and study the effect of initial COD concentration and the N/P ratio on treatment ability of para grass vegetation in the stabilization. The influent flow rate is controlled at 0.18 m³/h (corresponding to a retention time of 5.3 days). As inflow COD concentration is 203 ± 5.9 mg/L, COD treatment efficiency reaches 59.6 – 61.7%. When COD concentration in the input wastewater is 349.2 ± 4.5 mg/L, COD removal efficiency decreased to 55.7 ± 0.9%. Continue to increase input COD concentration in the input to 512.6 ± 14.7 mg/l, COD treatment efficiency reduce to 47.9±0.6%. However, when increasing the input COD concentration corresponding to increasing the organic loading rate into the model, reached 10.270 kgCOD/ha.day at COD concentration = 512.6 ± 14.7 mg/L, twice higher than the organic loading rate of the model since COD concentration = 203 ± 5.9 mg/L. The result shows strong adaptability and wastewater treatment ability of facultative waste stabilization pond system covered by Para grass, although the input COD concentration or organic load increase more than doubled. The study also showed that the treatment efficiency of total nitrogen (TN) tends to increase when COD concentration in influent increases, with treatment effiency has reached from 57.2 to 76.4%. Besides, the fraction of nitrogen and phosphorus in influent also surveyed in this study. The fraction of N/P selected to survey in the study is approximately 2.26, 4.16 and 6.11. The results show that when increasing the N/P ratio, the efficiency of Total Nitrogen treatment tends to increase. At N/P ratio = 2.26 ± 0.19, even though the concentration of TN in the inlet is low, but nitrogen metabolism still takes place in the experimental model, so outlet TN concentration decrease to very low. The COD treatment efficiency increases gradually when increasing the N/P ratio. The output COD match Vietnam discharge standard QCVN 40:2011/BTNMT. These results show potential for applying the stabilization pond which is covered by Para grass for treating concentrated industrial wastewater.

1. Introduction
The scientific name of Para grass researched in this study is Brachiaria Mutica. Brachiaria Mutica is native to Brazil, Africa and is abundant in tropical countries. Brachiaria Mutica prefer hot and humid temperatures, grow well in summer. The Brachiaria mutica is a perennial grass with a suitable average
growth rate at 21 °C. Growth will be limited when the temperature drops to 15 °C, stops growing at temperatures below 8 °C, is very sensitive to ice, the leaves can be dead but the tree can recover.

In addition, Para grass can form pure stands in low-lying, seasonally-flooded wetlands. When growing along the banks of deep waterways it has stems that float over the water surface [1], as shown in Figure 1.

![Figure 1. Para grass (Brachiaria Mutica).](image)

In Vietnam, Para grass is currently mostly used as a feed source for livestock because of soft leaves and trunk. There are a few of studies about the Para grass in previous work such as Valencia-Gica's research has studied the ability of Para grass to produce biomass and nutrient removal in milk processing wastewater. Results showed that Para grass has a dry biomass yield (4357 tons/ha/year) and its ability to absorb nutrients in wastewater is quite high (Nitrogen (N): 1083–1405 kg/ha/year; Phosphorus (P): 154 –164 kg/ha/year, Potassium (K): 1992–2141 kg/ha/year) [2].

Thanunathan, K. et at. have studied to find out the long-term effects of using wastewater on irrigation and the growth of Para grass. The results show that the Para grass grows quickly when watering the grass with highly polluted wastewater compared to good quality clean water, especially high-nitrogen and phosphorus-rich wastewater [3]. The results of this study open the way to use Para grass as a plant to treat wastewater. However, but these work almost focused on the ability to absorb nutrients of Para grass that have not yet to study in detail the effect of initial COD concentration and the N/P ratio on treatment ability of para grass vegetation in the stabilization.

In Viet Nam, Para grass is distributed in three regions, has the ability to develop well in the winter-spring and is the main feed for cattle because the stem and leaves are soft. Recently, Hoang Dong Nam and colleagues [4] have conducted a study on the treatment of industrial wastewater by microorganisms, using a traditional multi-stage treatment process with anaerobic microbiological reduction of iron (III) pond and the first combination of experiments stabilization ponds planning Brachiaria mutica with algae pond for advance treatment process. Initial results show that the above model of wastewater treatment is quite good, the COD, BOD$_5$ and TN of industrially wastewater type B can be approximated type A according to standards QCVN 40:2011/BTNMT (National Technical Regulation on Industrial Wastewater). From the results above, Para grass is a promising aquatic plant capable of efficiently treating N and P in the domestic wastewater or organic matter, but further study specifically about the treating ability of this flora is needed, especially conduct the survey of technological factors to the efficiency of wastewater treatment.

In this study, a stabilization pond covered Para grass was built in pilot scale to survey treatment ability of industrial wastewater with different input COD parameters and different N/P ratios. The aim of the research is to study the effect of initial COD concentration and the N/P ratio on treatment ability of para grass vegetation in the stabilization that could be found an effective treatment method, environmentally friendly and towards sustainable development.
2. Experimental methods and analysis

2.1 Materials and experimental methods
Facultative waste stabilization pond was built in pilot scale with size LxWxH = 4.0 x 2.0 x 4.0 (m), as shown in Figure 2. Para grass was grown in this model of which wastewater is provided continuously on one side. Influent wastewater is controlled by flow valves with a fixed flow of 0.18 m³/h (corresponding to a retention time of 5.3 days). Wastewater from many factories in the industrial park is centralized in collecting tank and then water is pumped into the wastewater tank to stabilize the concentration. Then, it is pumped into the intermediate tank to convey the wastewater through the distribution system to the stabilization pond.

![Figure 2. Full view of facultative waste stabilization pond system covered with Para grass.](image)

In this study, there are 3 inlet COD concentrations (203, 349.2 and 512.6 mg/l) was studied to examine consequence of wastewater treatment ability on Para grass model. In additional, N/P ratio is one of survey factor which affect on wastewater treatment efficiency. N/P ratio was studied from 2.26, to 4.16 and 6.11.

The chemical used to adjust the COD concentration is Glucozo (C₆H₁₂O₆) and the chemical used to adjust the N/P ratio is Mono potassium phosphate (KH₂PO₄). The sample of waste water is collected at outlet of the Para grass model based on TCVN 5999: 1995 (ISO 5667-10: 1992).

2.2 Analysis
Measurements parameters is pH, COD and TN. Influent sample is collected at S1 point and effluent sample is collected at S2 point (Figure 3).

![Figure 3. Facultative waste stabilization pond covered with Para grass on the pilot scale.](image)
Parameters for water sample were determined by the standard method for water and wastewater testing are shown in Table 1.

| Parameter | Analysis method | Unit |
|-----------|-----------------|------|
| pH        | 4500 – H+ B. Electrometric Method | -    |
| COD       | 5220 C. Closed Reflux, Titrimetric Method | mgO₂/L |
| TN        | 4500 – Norg B. Macro Kjeldahl Method | mgN/L |

3. Results and discussions

3.1. Effect of influent COD concentration on wastewater treatment efficiency by facultative waste stabilization pond system covered with Para grass

As inflow COD concentration is 203 ± 5.9 mg/L, COD treatment efficiency reaches 59.6 – 61.7%, organic loading rate approaches 5.570 kgCOD/ha.day. According to this result, it shows the superior treatment ability of the Para grass model even if the COD concentration in the input wastewater is not too high. It is possible to open the direction of application of biological stabilization pond covered Para grass as a advanced treatment process. When COD concentration in input increases, the treatment efficiency of the model tends to decrease. As COD concentration in the input wastewater is 349.2 ± 4.5 mg/L, COD removal efficiency decreased to 55.7 ± 0.9%. Continue to increase input COD concentration in the input to 512.6 ± 14.7 mg/l, COD treatment efficiency reduce to 47.9 ± 0.6%. However, when increasing the input COD concentration corresponding to increasing the organic loading rate into the model, reached 10.270 kgCOD/ha.day at COD concentration = 512.6 ± 14.7 mg/L, twice higher than the organic loading rate of the model since COD concentration = 203 ± 5.9 mg/L. The result shows strong adaptability and wastewater treatment ability of facultative waste stabilization pond system covered by Para grass, although the input COD concentration or organic load increase more than doubled (input COD concentration: from about 200 mg/L to about 500 mg/L; input organic loading rate: from about 5.570 kgCOD/ha.day to about 10.270 kgCOD/ha.day) but the treatment efficiency is still good.

Facultative waste stabilization pond system covered with Para grass removed organic biodegradable organic matter because it is partially absorbed by Para grass, a part of the remaining organic matter is decomposed by aerobic and anaerobic microorganisms attach to submerged stems,
leaves and roots of grass. These microorganisms play an important role in the treatment of organic pollutants. According Eckenfelder W.W and Connon D.J. (1961), the aerobic decomposition process consists of 3 stages [5]:
- Oxidation of organic compounds
  \[ C_{x}H_{y}O_{z}N + (x + y/4 + z/3 + ¾) O_{2} \xrightarrow{\text{Enzyme}} xCO_{2} + [(y-3)/2]H_{2}O + NH_{3} \]
- Synthesis the construction of a biological structure
  \[ C_{x}H_{y}O_{z}N + NH_{3} + O_{2} \xrightarrow{\text{Enzyme}} C_{5}H_{7}NO_{2} \text{(Microbial cells)} + xCO_{2} \]
- Self-oxidizing cellular material
  \[ C_{5}H_{7}NO_{2} + 5O \xrightarrow{\text{Enzyme}} CO_{2} + H_{2}O + NH_{3} \]

**Figure 5.** TN removal efficiency with different influent COD concentration

Since inflow COD concentration is 203 ± 5.9 mg/L, the total Nitrogen input is 21.5-25.4 mg/L, the effective treatment of Total Nitrogen reaches 56.1 ± 1.1%, the TN output concentration from 10.5±1.1 mg/L. It shows that although the treatment efficiency is not too high, but the biological pond covered by Parag grass is capable of thoroughly treating Total Nitrogen in wastewater even when the input level is relatively low.

As the COD concentration in the input wastewater increased to 349.2 ± 4.5 mg/L, the TN treatment efficiency increased gradually reach 53.4±0.7%. This result could be explained due to the TN treatment efficiency of the system increased because the system began to adapt well to the wastewater environment. [4, 5,6] In addition, organic matter in higher wastewater also helps to increase denitrification:

\[ 6NO_{3}^- + 5CH_{3}OH \rightarrow 5CO_{2} + 3N_{2} + 7H_{2}O + 6OH^- \]

Continue to study at next inflow COD concentration 512.6 ± 14.7 mg/L, respective TN concentration input is: 27.1±2.1 mg/L, the TN treatment efficiency reaches 49.3±1.5%. Even though concentration of total nitrogen input increased, but after treatment through experimental model, it still reaches
Vietnam discharge standards QCVN 40:2011/BTNMT while the retention time was only 7.4 days. The reason is that organic matter in higher wastewater also helps to increase denitrification process, converting NO$_3^-$ into N$_2$ to release to the atmosphere. Moreover, through the process of adapting to high concentration of COD and total nitrogen, wastewater treatment ability of facultative waste stabilization pond system covered with Para grass becomes more stable. It shows that the adaptability is fast and the potential to remove total nitrogen in the pond is very positive. This result is also consistent with the study of Thanunathan et al., since Para grass grows quickly when watering grass with highly polluted wastewater compared to good quality water, especially wastewater high in nitrogen and phosphorus [3].

The total nitrogen removed in the system in the biological pond covered by Para grass is due to the nitrification and denitrification processes:

$$\text{NH}_4^+ + 1.5\text{O}_2 \xrightarrow{\text{Nitrosomonas}} \text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}$$

$$\text{NO}_3^- + 0.5\text{O}_2 \xrightarrow{\text{Nitrobacter}} \text{NO}_2^-$$

$$\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}$$

$$6\text{NO}_3^- + 5\text{CH}_3\text{OH} \rightarrow 5\text{CO}_2 + 3\text{N}_2 + 7\text{H}_2\text{O} + 6\text{OH}^-$$

Besides, nitrogen is also removed through the evaporation of ammonia NH$_4^+$ to NH$_3$ and evaporates into the air and absorption of plants [6]. Para grass in the model plays an important role in the nitrogen removal process in the wastewater, because the plant's roots forming biofilm to remove nitrogen and provide oxygen for nitrogen oxidation by aerobic microorganisms.

This explanation is also consistent with the study in 1981, in Hawaii-America, Para grass was used to remove nitrogen in domestic wastewater. The amount of irrigation water is 98 mm/day, 5 days/week, the average amount of water loss is 4.6 mm/day, the total amount of nitrogen is removed from 130-2600 kg/ha/year. In which, 79% is absorbed by grass, 3% is retained during filtration, 29% is lost due to nitrate reduction. After processing the remaining nitrogen in the water is 10 mg/L [7].

3.2. Effect of N/P ratio to efficiency of wastewater treatment of facultative waste stabilization pond system covered with Para grass

![Figure 6. COD removal efficiency with different ratio between nitrogen and phosphorus.](image-url)
As N/P ratio = 2.26 ± 0.19, the input COD concentration ranged about 205.83 ± 16.48 mg/L. After a retention time of 5.3 days, the output COD concentration ranged about 81.5 ± 5.45 mg/L, COD treatment efficiency reached 60.4 ± 1.09%. As N/P ratio = 4.16 ± 0.12, the input COD concentration ranged about 236.83 ± 12.55 mg/L. After a retention time of 5.3 days, the output COD concentration ranged about 101.9 ± 7.61 mg/L, the COD removal efficiency reduced to 57.0 ± 1.04%. As N/P ratio = 6.11 ± 0.53, the input COD concentration ranged about 204.8 ± 14.34 mg/L. After a retention time of 5.3 days, the output COD concentration ranged about 88 ± 7.19 mg/L, the COD removal efficiency continued to increase to 57.0 ± 1.16%. From the results, COD treatment efficiency increases gradually when increasing the N/P ratio. The output COD match with Vietnamese Standard of Industrial Wastewater Discharge QCVN 40:2011/BTNMT.

As N/P ratio = 2.26 ± 0.19, the input TN concentration ranged about 19.7 ± 0.53 mg/L. After a retention time of 7.4 days, the concentration of TN output ranged from 12.6 ± 0.95 mg/L, the treatment efficiency reached 36.1 ± 0.58%. As N/P ratio = 4.16 ± 0.12, the concentration of TN input fluctuated in the range of 41.6 ± 2.62 mg/L. After a retention time of 7.4 days, the concentration of TN output ranged from 24.5 ± 2.15 mg/L, the treatment efficiency increased to 41.4 ± 1.49%. As N/P ratio = 6.11 ± 0.53, the concentration of TN input fluctuated in the range of 64.2 ± 2.16 mg/L. After a retention time of 7.4 days, the concentration of TN output ranged from about 33.4 ± 1.36 mg/L, the treatment efficiency continued to increase to 48.0 ± 0.75%. When increasing the N/P ratio, the efficiency of Total Nitrogen treatment tends to increase. At N/P ratio = 2.26 ± 0.19, even though the concentration of TN in the inlet is low, but nitrogen metabolism still takes place in the experimental model, so outlet TN concentration decrease to very low.

3.3 pH variation

Figure 8 shows variation of pH of waste water before and after treated by stabilization ponds covered by Para grass. The output pH value fluctuates in the value of 6.8 - 7.3 (6.98 ± 0.14) lower when compared to the input pH in the range of 7 - 7.5 (7.27 ± 0.16). The pH value after treatment is in the value allowed to discharge into the environment according to QCVN 40: 2011/BTNMT and suitable for plant growth. pH after treated by Para model is decrease showing that decomposition processes and
The nitrification process takes place strongly inside the model due to the process could be generated H⁺ ion, and CO₂ so it will be reduced pH of water [8].

Nitrification process:

\[
\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}
\]

Microbial decomposition process:

\[
\text{Enzyme}\quad \text{C}_5\text{H}_7\text{NO}_2 + 5\text{O}_2 \rightarrow x\text{CO}_2 + \text{H}_2\text{O} + \text{NH}_3
\]

**Figure 8.** Variation of pH of waste water before and after treated by stabilization ponds covered by Para grass.

4. Conclusions

The research results show that facultative waste stabilization pond system covered by Para grass in pilot scale is capable of handling industrial wastewater well. The effect of initial COD concentration and the N/P ratio on treatment ability of para grass vegetation in the stabilization have studied in detail in this work. The influent flow rate is controlled at 0.18 m³/h (corresponding to a retention time of 5.3 days) for the model and we found that as inflow COD concentration is 203 ± 5.9 mg/L, COD treatment efficiency reaches 59.6 – 61.7%. Furthermore, the results show that when increasing the N/P ratio, the efficiency of Total Nitrogen treatment tends to increase. At N/P ratio = 2.26 ± 0.19, even though the concentration of TN in the inlet is low, but nitrogen metabolism still takes place in the experimental model, so outlet TN concentration decreases to very low. The COD treatment efficiency increases gradually when increasing the N/P ratio. The N/P ratio in the input wastewater also affects the effluent treatment efficiency of the Para grass model. These findings indicate that the treatment ability of the by facultative waste stabilization pond system covered with Para grass shows that the pond is highly effective for wastewater with high concentration organic pollutants. The success of this work will be a premise to find solutions to treat industrial wastewater with low cost, easy to operate, make use of existing conditions and environment-friendly.
Acknowledgments
This research project has been funded by Ministry of Natural Resources and Environment, Project number: TNMT.2016.04.14. The authors would like to thank Dr. Nam Dong Hoang and Mr. Nguyen Minh Dang, Ms. Nga Bui Thi, Ms. Ngoc To Thi Hong for their strong supports for this work.

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