Nitrogen removal in constructed wetland treating wastewater from the seafood industry

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Abstract

Nitrogen in wastewater causes many problems in receiving water such as eutrophication and algae bloom. Wastewater problems from the seafood industry are a common and wide spread, especially in the south of Thailand. The seafood industry generally generates large quantity of wastewater containing high concentrations of organic, nitrogen, and solid matter. The wastewater needs to be properly treated before disposal. Constructed wetland can be used for tertiary treatment and nutrient recycling. This research studied the nitrogen removal efficiency of a laboratory scale experiment constructed wetland using cattail (Typha augustifolia) at different HRT at 5, 10, and 15 days and another experimental control unit at 10 day HRT without cattail. The constructed wetland units received wastewater from the oxidation pond of a seafood factory located in Songkhla, Southern Thailand. Average Temperature, pH, DO, BOD₅, SS, TKN, NH₃-N, Org-N, NO₃-N and NO₂-N of influent were found to be 28°C, 7.1, 2.3, 92, 457, 64.86, 59.55, 4.71, 1.58 and 26.03 mg/l, respectively. From the experimental results, BOD₅ and SS removal efficiencies of 85 and 95% were achieved even at 5 day HRT. TKN and NH₃-N removal efficiencies of about 60% were found in all experimental units. Furthermore, it was shown that effluent from 5, 10, 15 day HRT constructed wetlands could meet the Industry Effluent Standard enacted by the Ministry of Industry, Thailand. Constructed wetland can be used as tertiary treatment for wastewater from the seafood industry.

Keywords: ammonia nitrogen, constructed wetland, nitrate, nitrite, organic nitrogen, seafood wastewater, Total Kjeldahl Nitrogen (TKN).
1 Introduction

Nitrogen in wastewater causes many problems in receiving water such as biostimulation of plant and algal growth in surface water, as known in term of eutrophication or algae blooms. Depletion of dissolved oxygen (DO) can be occurred by nitrification and ammonia toxicity for aquatic life, public health (EPA [1]). Wastewater problem from seafood industry is a common and wide spread, especially in the South of Thailand. The wastewater from seafood industry is generally large in quantity and contains high concentration of organic, nitrogen, and solid matter. The wastewater needs to be proper treated before disposal. There are many methods to treat wastewater containing high nitrogen concentration i.e. Activated Sludge, Stabilization ponds, Trickling filter, etc. Constructed wetland (CW) is one of compromise techniques to be used as tertiary treatment and nutrient recycling. CW are used for not only to treat wastewater but also to offer other purposes i.e. habitat value for animals, cost-effective treatment potential, an area for public education and outdoor recreation (for walking, jogging, bird watching) (Reed et al [2]; EPA [3]).

CW can be used as wastewater treatment process in many cases. Reed Bed Treatment System (RBTS) was set up to improve effluent from biofilter at the central research organization of UK Water Industry (Cooper et al [4]). Four restore wetlands were used to improve the quality of agricultural runoff that contained nitrogen from rice field in the Delta of Ebro River in 1993 (Comín et al [5]). CWs remove nitrogen with many mechanisms i.e. ammonification, nitrification, denitrification, nitrogen fixation, and plant uptake (assimilation) (EPA [6]). This study investigated nitrogen removal in CW receiving wastewater from seafood wastewater treatment plant as tertiary treatment process.

2 Method

This research was set up with 3-FWS laboratory-scale CWs experimental units using cattails (Typha augustifolia) at about 30 stems per unit. The experiments were conducted at various HRT of 5, 10, and 15 days and another experimental control unit at 10 days HRT without cattail. Each unit was constructed with acrylic plate in dimension of 0.3 m x 1.20 m x 0.7 m in width, length, and depth, respectively. All of CWs and control units were covered with aluminum foil from bottom to gravel level, to mimic the nature of wetland. The wastewater from oxidation pond of selected seafood factory was maintained at 0.20 m above ground level. Wastewater was fed by peristaltic pump to achieved 5, 10, and 15 days HRT. Influent and effluent were collected every 4 days and analyzed for pH, temperature, Dissolved oxygen (DO), Biochemical oxygen demand (BOD₃), suspended solid (SS), Total Kjeldahl Nitrogen (TKN), Ammonia nitrogen (NH₃-N), Organic nitrogen (Org-N), Nitrate (NO₃-N), and Nitrite (NO₂-N) with the methods specified in Standard Methods for the Examination of Water and Wastewater (APHA, AWWA and WEF [7]). The samples were collected and analyzed from July to end of September 2002.
3 Results and discussion

The average results of influent and effluent at 5, 10, 15 day HRT for CWs and another control unit were shown in Table 1. Average pH, temperature and DO of influent were 7.1, 28 °C, and 2.2 mg/l, respectively. For effluent, pH, temperature, and DO at 5, 10, 15 day HRT CWs were ranged between 7.2-7.3, 27-28 °C, and 4-5mg/l, respectively. However, DO in effluent of control unit was different, about 8.0 mg/l. It was shown that the environmental conditions favored both plants and microorganisms livings. From the experimental results, pH, temperature, and DO of all experimental units were similar. Compared with CWs, suspended solid in effluent for control pond was double. Because of strong sunlight in the area, algae were found to be major components of suspended solids.

According to Table 1, all CWs provided similar experimental results. Average BOD₅ in effluent at 5-, 10-, and 15- days HRT were 14 mg/l, 14 mg/l, and 17 mg/l, respectively whereas control unit provided higher result, at about 26 mg/l. From Figure 2, it was found that experiments at 5- and 10- days HRT provided the superior BOD₅ removal efficiency at about 85% whereas BOD₅ removal efficiency for control unit was about 72%. Thailand Industrial Effluent Standard specified the limitation of BOD₅ should be less than 20 mg/l (PCD [8]). For SS, all experimental CWs gave the superior results than control unit. SS in effluent were about 23 mg/l, 28 mg/l and 31 mg/l for 5-, 10-, and 15- days HRT, respectively, whereas in control unit higher concentration of SS at about 53 mg/l was notified. It was shown from Figure 2 that at 5 days HRT, the best SS removal efficiency of about 95% was achieved. However, there was not much different SS removal efficiency within the various HRT conducted. The control unit could remove SS to achieve the removal efficiency at about 88%. According to the Thailand Industrial Effluent Standard (PCD [8]), SS of effluent should be less than 50 mg/l. It can be shown that in term of SS, CWs performed the proper removal efficiency to meet the regulations.

For nitrogen removal as shown in Table1, nitrogen content was mostly in a form of NH₃-N. It can be seen that CWs removed TKN from about 60 mg/l to be lower than 30 mg/l. The best results occurred at 10 days HRT. However, it was found that TKN in effluent from control unit was about 12.20 mg/l. However, all of the experiments agreed with the regulation of the Thailand Industrial Effluent Standard (PCD [8]) that specified limitation of TKN at 100 mg/l. The experimental results of control-unit were in line with NH₃-N, Org-N, NO₃-N, and NO₂-N. The phenomena may result from algae appearance in control unit. In the experimental period, it can be clearly observed that there was high quantity of algae in water of control unit. In addition, the environment of that time enhanced the photosynthesis of algae (warm temperature, high light intensity and lot of nutrient). Darley [9] indicated that nutrient uptake of algae has often stimulated by light. Hence, it is possible that the better nitrogen removal in control unit resulted from nitrogen uptake by algae.

Kantawanichkul et al [10], [11] and Schaafsma et al [12] showed the similar results of increased NO₃-N in effluent of CWs. Nitrification was claimed for
increased NO$_3$-N. Furthermore, Hunter et al [13] reported the apparent NO$_3$-N in effluent caused from incomplete denitrification by lacking organic carbon available to heterotrophic bacteria (Viessman and Hammer [14]).

Table 1: Performances of constructed wetland and control units.

<table>
<thead>
<tr>
<th>(mg/l)</th>
<th>Influent</th>
<th>5 day HRT CW</th>
<th>10 day HRT CW</th>
<th>15 day HRT CW</th>
<th>Control unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Effluent</td>
<td>%RE</td>
<td>Effluent</td>
<td>%RE</td>
</tr>
<tr>
<td>BOD$_5$</td>
<td>92±69</td>
<td>14±6</td>
<td>85</td>
<td>14±6</td>
<td>85</td>
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<tr>
<td>SS</td>
<td>457±840</td>
<td>23±6</td>
<td>95</td>
<td>28±10</td>
<td>94</td>
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<tr>
<td>TKN</td>
<td>64.86±14.31</td>
<td>26.33±10.2</td>
<td>59</td>
<td>23.55±6.02</td>
<td>64</td>
</tr>
<tr>
<td>NH$_3$-N</td>
<td>59.55±11.13</td>
<td>22.97±11.0</td>
<td>61</td>
<td>21.40±5.60</td>
<td>64</td>
</tr>
<tr>
<td>Org-N</td>
<td>5.61±4.49</td>
<td>3.36±2.15</td>
<td>40</td>
<td>2.15±2.10</td>
<td>62</td>
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<tr>
<td>NO$_3$-N</td>
<td>1.58±1.00</td>
<td>2.46±2.29</td>
<td>-56</td>
<td>4.20±3.35</td>
<td>-166</td>
</tr>
<tr>
<td>NO$_2$-N</td>
<td>26.03±28.70</td>
<td>8.03±7.96</td>
<td>69</td>
<td>9.33±6.30</td>
<td>64</td>
</tr>
</tbody>
</table>

Note: Mean± SD, %RE = % Removal efficiency.

From Figure 1, it can be found that the average removal efficiencies of nitrogen were about 59%, 64%, and 61% for TKN for 5-, 10-, and 15- days HRT,
respectively. It was about 61%, 64%, and 63% of NH$_3$-N removal efficiency for 5-, 10-, and 15- days HRT, respectively. For Org-N it were about 40%, 62%, 64% removal efficiencies for 5-, 10-, and 15- days HRT, respectively. Then it was shown that the 10-days HRT CWs experiment provided the best performance in TKN, NH$_3$-N and Org-N.

From experimental results, it was found that NO$_3$-N was increased which could be claimed that nitrification occurred in the experimental units resulted from present of dissolved oxygen in the water. For NO$_2$-N, it was 5-days HRT unit that treated NO$_2$-N best (among CWs). This phenomenon may be from denitrification (in nighttime), plant uptake, and microorganism uptake. However, it can be said that all of CWs provided the satisfactory removal performances employed to treat nitrogen-containing wastewater from seafood factory to meet the Industrial Effluent Standard (PCD [8]), even at 5 days HRT.

4 Conclusion

CWs can be used to treat the wastewater to meet the regulation. From the experimental results, all CWs could further remove BOD$_5$, SS, TKN, NH$_3$-N, Org-N and NO$_2$-N in satisfactorily. The best removal efficiencies at 10 days HRT resulted in average removal efficiency of BOD$_5$, SS, TKN, NH$_3$-N, Org-N and NO$_2$-N about 85%, 95%, 64%, 64%, 64%, and 69%, respectively. Increased NO$_3$-N may result from nitrification and lack of proper condition for denitrification. This study showed the possibility of CWs to treat wastewater from seafood wastewater as tertiary treatment and nutrient recycling. The authors expect that CWs will be one of methods to relieve problems of water bodies and to protect the future environment.

Acknowledgements

The authors would like to thank the Joint Graduate School of Energy and Environment (JGSEE) for grant supporting. Further, this study could not be held by lacking the cooperation of Prince of Songkla University.

References


