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Degradation of Nitrate, Ammonium and Phosphate in Domestic Wastewater by Aquatic Plants, *Actinoscirpus grossus* in Floating Treatment Wetland System (FTWs)

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Abstract. Ecological technologies such as wetlands constructed for wastewater treatment are innovative solutions for environmental protection and restoration. This study examines a Floating Treatment Wetlands System (FTWs), which is a new treating concept using macrophytes rooted in modified growing aquatic plants with floating systems. An aquatic plant, *Actinoscirpus grossus* obtained from rice fields in Banda Aceh. FCWs filled with five plants per shoot with five compartments were fed with domestic wastewater with a flow rate of 7 L/hour. Plant height was varied by 90cm - 150cm in Pond 1 and 50cm - 90cm in Pond 2, and Pond 3 was prepared as a control (without plants). Water quality in influent and effluent was analyzed every two weeks with a duration of 18 weeks and nine times sampling. Results showed a decrease in the concentration of nitrate, ammonium, and phosphate in the effluent flow with degradation efficiency (% DE) on average, NO₃-N: 76.34%; NH₄-N: 97.75%; and PO₄³⁻: 89.45%; respectively. The degradation of domestic wastewater showed very significant results. The periodic harvest management process becomes an important part of aquatic plants, *Actinoscirpus grossus* to achieve optimum results in treating waste, i.e., for 112 days with a maximum plant growth height of 165cm and 173cm for both variations of experimental ponds.

1. Introduction

Nowadays, the most dominant pollutants in water bodies derived from domestic wastewater, which reaches 60 - 70% [1]. The technology of treating wastewater with energy and centralized costs has proven to be ineffective in solving problems related to complex water discharge resulting from rapid urbanization [2], especially the City of Banda Aceh [3]. The idea for artificial wetlands (CWs) has emerged and is currently a viable option for wastewater treatment, which is recognized as an attractive alternative to conventional wastewater treatment methods. This system offers the overall need for low and sustainable operational costs [4][5]. Various types of CWs include (i) surface free water flow (FWS); (ii) subsurface flow (SSF); (iii) hybrid system; and (iv) floating wetlands (FTWs). The selection of all types of artificial wetland constructions above is very dependent on the target needs, especially concerning the maintenance system, geographic, cost, available area, and processing purpose [6]. Today's rapid development in processing domestic waste, one of which is the bioremediation system [7][8] using phytoremediation techniques (Phyto which means plants and



remediation which means cleaning) by utilizing local natural green plants directly to absorb/remove pollutants through roots and translocate to the surface plant parts, various plant species are used [9]. As shown by [10], the plant species used for phytoremediation must be native plants and have a rapid growth rate, many root systems, high yields of biomass, can adapt to various habitats, have a high tolerance and can accumulate pollutants on the top of the land. Some environmental factors such as temperature, pH, solar radiation, and water salinity can affect plant growth and its performance in phytoremediation. From several previous studies conducted by researchers [2], [11], and [12], aquatic plant *Actinoscirpus grossus* is very suitable for phytoremediation systems that superior compared to some other similar plants, both decreasing levels of BOD, COD, $\text{NH}_4^+\text{-N}$, $\text{NO}_3\text{-N}$, Total Phosphate, coliform fecal, and ammonium. Besides, as a local plant, this plant has resistance to the season, weather, many root systems and strong, and also has a large biomass yield which very suitable in the tropics [13]. This study assessed the effectiveness of domestic waste treatment by the aquatic plant *Actinoscirpus grossus* using the FTWs.

2. Materials and Methods

2.1 Materials

Constructed Wetland (CWs) pond was modified from wood and vinyl materials available on the market. Stereoform and wood were used between plants to support plants do not fall and spread in the CWs. Influent was accommodated in a storage tank equipped with a water discharge controller before being distributed to the treatment pond (3 ponds) which were pumped from drainage with a peristaltic pump. The effluent flow was collected in a 600mL bottle container.

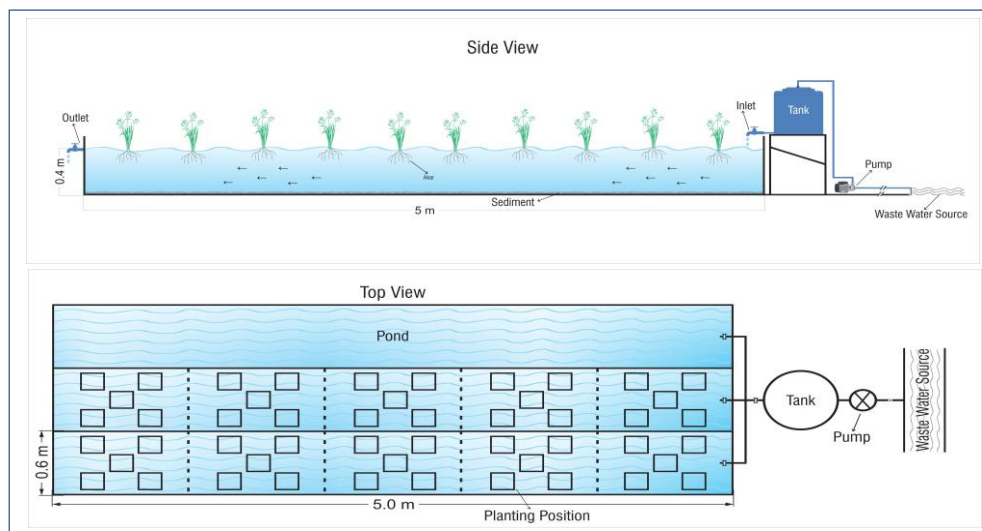


Figure 1 View of Floating Treatment Wetland System (FTWs)

2.2 CWs Design

Three CWs ponds were prepared with a size of 5.0m x 0.6m x 0.4m (long x wide x height) respectively, two ponds for treatment test and one pond as a control (without plants). *Actinoscirpus grossus* plant was taken from the rice fields in Ilie Ulee Kareng Village, Banda Aceh using a manual procedure. The size of plants was grouped into two groups according to the research variable; the first group has an average height of 50-90cm while the second group was 100-150cm high. CWs were filled with domestic wastewater, then each CWs was filled with five plants per shoot with 25 shoots per CWs.

2.3 Wastewater Degradations Process

The plants were acclimated for 1-2 weeks by ensuring the availability of sufficient wastewater in the continuously FTWs. The degradation process occurred when plants have been able to grow and adapt which was indicated by the growth of new roots. This condition proved that plants have been adapted to the new environment and already used to promote phytoremediation in FTWs. The FTWs system could be carried out for the treatment process that flowed continuously with new domestic wastewater with a flow rate of 7 L/hour. Water quality in influent and effluent was observed and analyzed every two weeks with a duration of 18 weeks with nine times sampling analysis. Samples were analyzed using the analysis method of the Indonesian National Standard.

3. Analysis Results

The average temperature and pH of influent were $28 \pm 4^\circ\text{C}$ and 6.69 ± 0.7 , respectively. The effect of plants on water quality was observed as a significant reduction in the parameters of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, and PO_4^{3-} (Table 1). The concentration of the test parameters above, which were significantly degraded indicates that the FTWs system was functioning properly. This condition occurred because of the low Hydraulic Loading Rate (HLR) of 7 L/hour which results in a high Hydraulic Retention Time (HRT) so that it can make good contact between roots with wastewater.

Table 1. Degradation Efficiency (% DE) of domestic wastewater laboratory results on FTWs system with various plant heights (T).

| No. | Parameter | | pH | NH ₄ -N (mg/L) | NO ₃ -N (mg/L) | PO ₄ ⁻³ (mg/L) |
|--------------|-------------------------|-------------------|---------------------|------------------------------|------------------------------|---|
| | | | Indonesian Standard | 6.5 – 8.5 | 0.06 | 10 |
| 1. | Control (without plant) | Average DE (%) | 7.07 | 63.22% | 34.27% | 45.84% |
| 2. | Plants T 50-90cm | | 6.65 | 97.14% | 72.74% | 88.03% |
| 3. | Plants T 90-150cm | | 7.04 | 98.36% | 79.94% | 90.87% |
| % DE Average | | | 6.92 | 97.75% | 76.34% | 89.45% |

The most significant degradation in domestic wastewater with the FTWs system results from the three experimental ponds occurred in ponds with plant heights T90-150cm, $\text{NH}_4\text{-N}$ 98.36%; $\text{NO}_3\text{-N}$ 79.94% and PO_4^{3-} 90.87%, respectively.

3.1 The Relationship Between Degradation of Nitrogen Compound Content (NH_4^+ and NO_3^-) with Phosphate Compounds (PO_4^{3-}) on the Growth of Aquatic Plants *Actinoscirpus grossus*

Nitrogen (N) and Phosphorus (P) are nutrients that are needed by plants in large quantities. Nitrogen was important in the formation of chlorophyll, protoplasm, proteins, and nucleic acids. This element has an important role in the growth and development of all living tissues [14]. Phosphorus (P) was an important component of compounds for energy transfer (ATP and other nucleoproteins), for genetic information systems (DNA and RNA), for cell membranes (phospholipids), and phosphoprotein, P in CWs systems being deposited as microorganism nutrients and absorbed directly by plants and is needed for growth, roots and flowering [15]. Neutral pH conditions between 6.5-7.5 cause the absorption of NH_4^+ to be dominant compared to NO_3^- , the plant itself could reduce the need for nitrate absorption because ammonium compound could be immediately transported to the cell through translocation to other plant organs, starting from stems, leaves, canopy and other parts without the need to undergo the process of nitrification first. Nitrogen compounds (NH_4^+ and NO_3^-) were directly translocated so that they have a significant influence in providing protein for plants; chlorophyll synthesis also increases, which results in a photosynthetic activity that produces assimilates. The assimilate results are then translocated to the more dominant parts, namely shoots or apical. If the results of assimilating have been fulfilled in the shoots, then it is translocated to other organs, especially around the canopy so that the fresh weight of the plant can increase its growth. *Actinoscirpus grossus* adsorb phosphorus in the form of PO_4^{3-} through roots, which will be reduced

through the harvest process, and the presence of microorganisms in the roots can reduce pollutants in the waste [16]. Therefore, the presence of phosphorus will increase plant growth that will also have an impact on the optimal absorption of nitrogen, causing the absorption of phosphor (as nutrients) to be more effective.

Figure 2 reports that the average reduction efficiency of NH_4^+ for treatment plants (T 50-90cm and T 90-150cm) was found to be 96.57% which was more dominant than the average decreasing of NO_3^- (77.04%). Optimal absorption of nitrogen nutrients (NH_4^+ absorption is more dominant than NO_3^-) results in maximum nutrient P being degraded by aquatic plants with an average phosphate absorption ($\text{PO}_4\text{-3}$) of 89.92% for treatment plants and 45.92 % for control plants, respectively.

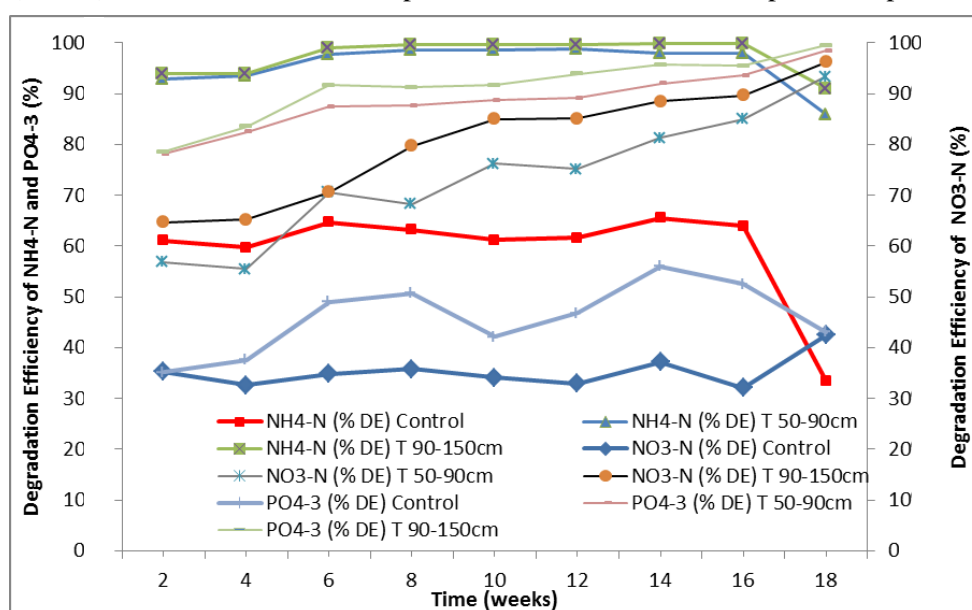


Figure 2 Degradation efficiency of NH_4^+ and NO_3^-

3.2 Periodic Impact of System Sustainability on Harvesting of Aquatic Plants *Actinoscirpus grossus*

Figure 3 shows the growth and development of the *Actinoscirpus grossus* plant when the study begins which is observed regularly every week. It takes about 60 days since the first plant was exposure into the experimental pond to stabilize the first growth until the plant is ready for the first harvest (initial cutting). Based on observations observed, it occurred that the average strand length had been stable with growth. Although macrophyte productivity influenced by the growth rate after the first harvest, however, the growth and development process at this initial stage shows a stable process, this is because the water plant *Actinoscirpus grossus* has undergone a stabilization process before the experiment begins so that every process of research *Actinoscirpus grossus* has gone through its recovery process. From the data, it could be found that the maximum height of this plant was 165 cm for plants with an average height of 50-90cm and 171cm for plant height 90-150cm. When the plant has experienced a maximum height, the first harvesting process begins (Figure 3). When the plant has experienced a maximum height, the first harvesting process begins.

Research data shows that planting and harvesting *Actinoscirpus grossus* could be done periodically and sustainably. Throughout the research, the process of domestic wastewater supply was carried out continuously with a flow rate of around 7 L/hr; this maximum water velocity caused contact between wastewater and plant roots became very maximal. FTWSs systems in floating aquatic plants were planted with *Actinoscirpus grossus* on October 28, 2018, and continue to be given domestic waste until the end of June 25, 2019. Plant growth was observed every week. Variations in shoot height were shown in Figure 3. The average maximum shoot height was 165cm in the initial plants T 50-90cm and 173cm for the initial plants 90-150cm in the first harvest. The growth curve

showed that shoots reach a maximum growth of 120 days during the first harvest. Subsequent growth was expected to be faster, possibly only needing under 120 days to reach maximum shoot height after each harvest [13].

Figure 4 compares the average plant height above the water level in the FTWs that appeared one month to 4 months after the first harvest. [17] reported that harvest can affect nutrient storage in annual plant tissues, depending on harvest time and the type of biomass (leaves, rhizomes, or both) harvested and that it can also reduce carbohydrates available for early season growth and strand strength. Harvesting on land has been reported harm on biomass production, although total productivity was much higher if shoots were moved during the period of growth. It can also be seen the results in Figure 4, which showed that the maximum height achieved in sustainable activities in the harvest of *Actinoscirpus grossus*.

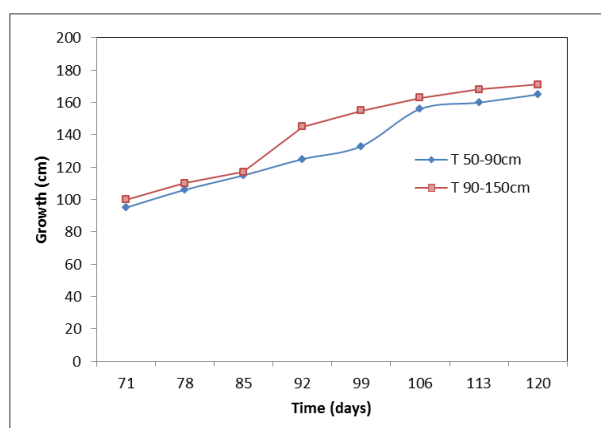


Figure 3. Growth of *Actinoscirpus grossus* before harvesting.

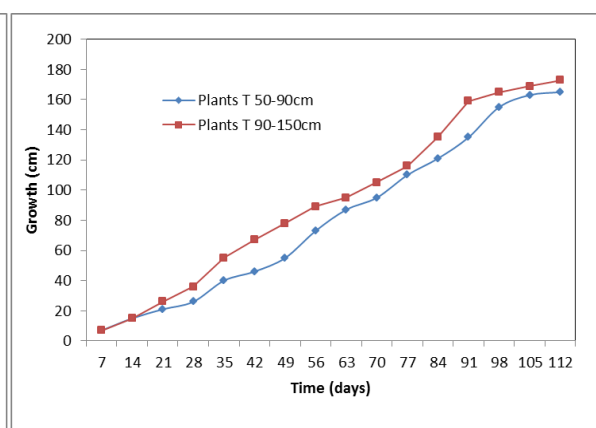


Figure 4. Growth of *Actinoscirpus grossus* after first harvesting.

Harvesting can be considered as an effective management tool for achieving proper vegetation balance (balance between adequate vegetation for recovery while controlling excess detritus formation if needed for optimal processing performance. If excess vegetation is not harvested, most nutrients that have been absorbed into plant tissues will be returned to water through decomposition. The built-up wetland system can act as a reservoir for nutrients during active growth [18], and sustainable harvesting in tropical conditions does not directly encourage active growth throughout the year — high above-ground biomass in wetlands built on situations of general hydraulic and nutritional loading [19].

4. Conclusion

This study concludes that the aquatic plants, *Actinoscirpus grossus* can degrade $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, and PO_4^{3-} from the domestic wastewater with degradation efficiency (%DE) on average, $\text{NO}_3\text{-N}$: 76.34%; $\text{NH}_4\text{-N}$: 97.75%; and PO_4^{3-} : 89.45%; respectively. The system run with the HLR 7 L/hour and HRT 6 days with a pond volume of 1 m³, pond size (5.0m x 0.6m x 0.4m); planting plants; 5 shoot and 25 shoots per ponds, and all of these characteristics can degrade significantly.

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