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Nutrients Removal from Municipal Wastewater Treatment Plant Effluent using *Eichhornia Crassipes*

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Abstract**—**Water hyacinth has been used in aquatic systems for wastewater purification in many years worldwide. The role of water hyacinth (Eichhornia crassipes) species in polishing nitrate and phosphorus concentration from municipal wastewater treatment plant effluent by phytoremediation method was evaluated. The objective of this project is to determine the removal efficiency of water hyacinth in polishing nitrate and phosphorus, as well as chemical oxygen demand (COD) and ammonia. Water hyacinth is considered as the most efficient aquatic plant used in removing vast range of pollutants such as organic matters, nutrients and heavy metals. Water hyacinth, also referred as macrophytes, were cultivated in the treatment house in a reactor tank of approximately 90(L) x 40(W) x 25(H) in dimension and built with three compartments. Three water hyacinths were placed in each compartments and water sample in each compartment were collected in every two days. The plant observation was conducted by weight measurement, plant uptake and new young shoot development. Water hyacinth effectively removed approximately 49% of COD, 81% of ammonia, 67% of phosphorus and 92% of nitrate. It also showed significant growth rate at starting from day 6 with 0.33 shoot/day and they kept developing up to 0.38 shoot/day at the end of day 24. From the studies conducted, it was proved that water hyacinth is capable of polishing the effluent of municipal wastewater which contains undesirable amount of nitrate and phosphorus concentration.

Keywords**—**water hyacinth, phytoremediation, nutrient removal, Eichhornia crassipes

I. INTRODUCTION

HUMAN activities can accelerate the rate at which nutrients enter ecosystems. Runoff from agricultural land and industrial developments, pollution from septic systems and sewers, and other human-related activities increase the flux of both inorganic nutrients and organic substances into terrestrial and aquatic ecosystems. Elevated levels atmospheric compounds of nitrogen can increase nitrogen availability. Phosphorus is often regarded as the main culprit in cases of eutrophication in lakes subjected to point source pollution from sewage [1].

Municipal wastewater is treated by sewage treatment plants (STP) which consist of several treatment processes. Most activated sludge systems operated at low sludge age do not involve nitrification in the treatment. Hence, treated effluent released from these sewage treatment plants may contain undesirable concentrations of nutrients (ammonia, nitrate and phosphorus) [2], which can stimulate growth of microorganisms. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life; when discharged in excessive amounts on land, they can also lead to the pollution of groundwater [3]. Post-treatment of the effluent can be introduced to remove these nutrients. Phytoremediation technology for removing contaminants from wastewater is a good treatment option. It is the least harmful method which preserves the natural state of the environment and can reduce the maintenance cost indirectly.

In freshwater or estuarine systems close to land, nitrate concentration can reach levels that can potentially cause the death of fish. While nitrate is much less toxic than ammonia or nitrite, its concentration over 30 ppm can inhibit growth, impair the immune system and cause stress in some aquatic species [4]. In most cases of excess nitrate concentrations in aquatic systems, the primary source is surface runoff from agricultural or landscaped areas which have received excess nitrate fertilizer. Consequently, as nitrates form a component of total dissolved solids, they are widely used as an indicator of water quality [5].

Global demand for fertilizers led to large increase in phosphate (PO_4^{3-}) production in the second half of the 20th century. Due to the essential nature of phosphorus to living organisms, the low solubility of natural phosphorus-containing compounds, and the slow natural cycle of phosphorous, the agricultural industry is heavily reliant on fertilizers which contain phosphate, mostly in the form of superphosphate of lime [6]. Phosphorus can stimulate growth of algae and other organisms. Because of noxious algal blooms that occur in surface water, there is presently much interest in controlling the amount of phosphorus compounds that enters surface waters via domestic and industrial waste discharges and natural runoff [7].

Phytoremediation is a promising cleanup technology for contaminated soils, groundwater, and wastewater that is both low-tech and low-cost. It is defined as the engineered use of green plants (including aquatic microbes, grasses, forbs, and woody species) to remove, contain, or render harmless such environmental contaminants as heavy metals, trace elements, organic compounds, and radioactive compounds in soil or water. Phytoremediation is a method that can reduce remedial costs, restore habitat, and clean up contamination in place rather than entombing it in place or transporting the problem to another site [8].

The most important factor in implementing phytoremediation is the selection of an appropriate plant. This is often done by considering previous applications and research. The final plant choice will be influenced by the condition of the site which will affect the plant growth. In order to select the most appropriate plant, a list of potentially beneficial plants for remediation should be prepared first [9]. Studies conducted by some researchers show that water hyacinth has the potential to cleanup various wastewaters due to its rapid growth [2], [3], [10], [11] and [12].

This experiment focused on the effectiveness of water hyacinth (*Eichhornia Crassipes)* in removing ammonia, nitrate and phosphorus from the sewage treatment plant (STP) effluent in Universiti Teknologi PETRONAS (UTP), Tronoh, Malaysia. The study was also conducted to provide information on post treatment of municipal wastewater treatment plant effluent.

II. METHODOLOGY

Water hyacinth collected from local lakes in Tronoh, Malaysia was used to treat the STP effluent from Universiti Teknologi PETRONAS, Tronoh, Malaysia. Two reactor tanks were used for the entire experiment with one of the reactors used as a control with no water hyacinth. The tanks were constructed using a 5 mm transparent PVC sheet. The tanks were 90 cm × 40 cm × 25 cm (Length × Width × Height) each. The detention time was varied as 2 days, 4 days and 6 days by constructing the tank into three baffled compartments with sampling points for each compartment placed on the side of the tank. The three sampling points at detention times T1=2 days, T2=4days and T3=6 days, were W-T1, W-T2, W-T3 for the wetland reactor and C-T1, C-T2, C-T3 for the control reactor. The sampling points were attached with 5 mm plastic tubing to ease sampling. Water hyacinths were placed in each compartment in wetland tank while no plants were placed in control tank. Effluent from the STP was pumped using peristaltic pumps (Master Flexx) into the reactor tanks via plastic tubing. Each plastic tube was 6 m in length and they were sprayed with black spray in order to prevent algae growth in the channeling tubes. The flowrate of the pump was set at 12 L/d. A one week acclimatization period was set to stabilize the water hyacinth. At the start of the experiment, three young shoots of water hyacinths of the same size were placed in the compartments of each wetland reactor tank. Influent and effluent samples were monitored for COD, ammonia, phosphorus and nitrate. Sampling from each compartment was collected on alternate days for a 24 day study period.

III. RESULT AND DISCUSSION

A. Characteristic of STP effluent

The STP effluent had an average COD, ammonia, phosphorus and nitrate concentrations of 58 mg/L, 12 mg/L, 5 mg/L and 7 mg/L respectively.

B. Chemical Oxygen Demand (COD)

Figures 1 and 2 show the influent and effluent COD concentrations at different detention times for the wetland and control tanks, respectively. From Figure 1, it can be observed that influent COD was variable throughout the sampling period as this was determined from the operation of the STP. Statistical analysis of effluent COD concentrations at different detention times indicated that at 5% level of significance, there was no significant difference in effluent COD concentrations at the three detention times studied.

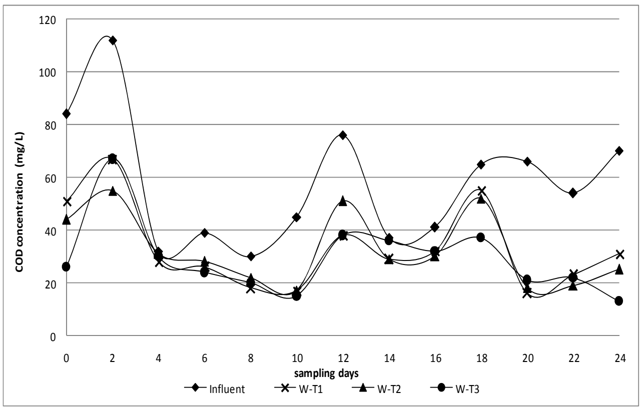

Fig. 1: COD concentration at detention times W-T1 = 2 days, W-T2 = 4 days and W-T3 = 6 days for wetland tank.

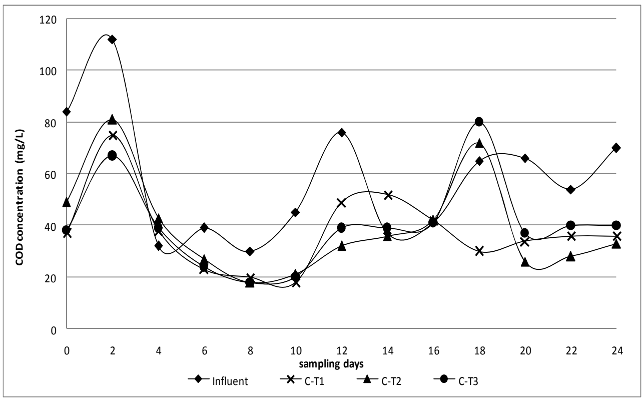

Fig. 2: COD concentration at detention times C-T1 = 2 days, C-T2 = 4 days and C-T3 = 6 days for control tank.

Effluent COD concentrations from the wetland reactor ranged between 13 and 67 mg/L.

Figure 2 shows the COD concentrations vs sampling days for the control tank. Effluent COD concentrations for the control tank ranged from 18-80 mg/L, higher than the wetland tank. The COD removals from the control tanks were mainly due to uptake by algal growth in the tank as there was no water hyacinth in the tank. No algal growth was detected in the wetland tank.

The COD removal efficiency for the wetland tank corresponding to a detention time of 2 days was higher than the control tank at the end of the sampling period. The maximum COD removal efficiency for W-T1 was 75% while the maximum COD removal efficiency for C-T1 was 66%. However, based on statistical analysis it was found that at 5% level of significance, there was no significant difference in COD removal efficiency between the two reactors throughout the sampling period.

At detention time of 4 days, the COD removal efficiency for the wetland tank was higher than the control at the end of the sampling period. The maximum COD removal efficiency for the wetland tank was found to be 63% while the maximum COD removal efficiency for the control was only 50% at a detention time of 4 days. However, even though COD removals in the wetland tank was higher than the control tank at detention time of 4 days, based on the statistical analysis it was found that at 5% level of significance, there was no significant difference in COD removal efficiencies between the reactors throughout the study period.

At detention time of 6 days, the COD removal efficiency for wetland tank was higher than the control at the end of the sampling period. Maximum COD removal efficiency for wetland tank was found to be 80% while the maximum COD removal efficiency for the control is 71%. However, based on statistical analysis conducted at 5% level of significance, there was no significant difference in COD removal efficiencies between the reactors throughout the sampling period.

C. Ammonia

Figures 3 and 4 show influent and effluent ammonia concentrations at different detention times for the wetland tank and the control tank, respectively. Influent ammonia concentration discharged from the sewage treatment plant varied throughout the sampling period and ranged from 9-16 mg/L. Effluent ammonia concentrations from wetland tank ranged from 0.13 to 5.87 mg/L.

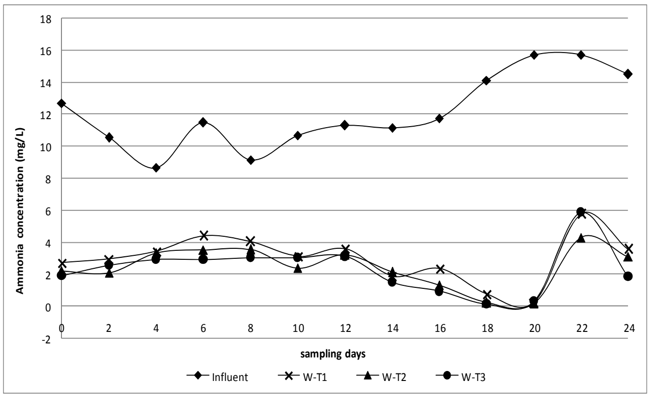

Fig. 3: Ammonia concentration at detention times W-T1 = 2 days, W-T2 = 4 days and W-T3 = 6 days for wetland tank.

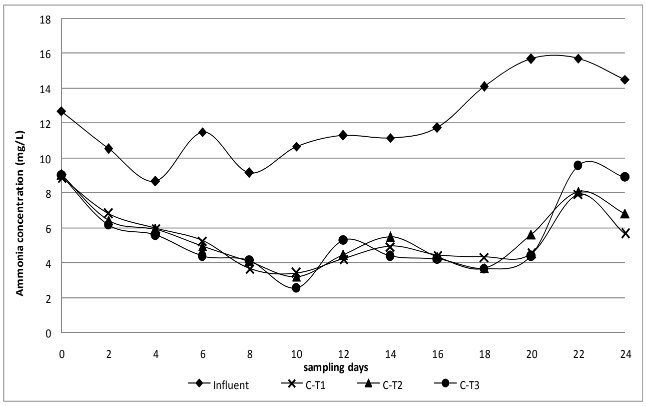

Fig. 4: Ammonia concentration at detention times C-T1 = 2 days, C-T2 = 4 days and C-T3 = 6 days for control tank.

Based on statistical analysis at 5% level of significance, it was found that there was no significant difference in effluent ammonia concentration at all detention times. From Figure 4, it can be observed that effluent ammonia concentrations at all detention times ranged from 2.53 to 9.57 mg/L; higher compared to the wetland tank. The ammonia removal efficiency of the wetland tank was generally higher than the control tank throughout the study period at detention time of 2 days. Maximum ammonia removal efficiency for the wetland tank was 98% while maximum ammonia removal efficiency for the control was 68%. Based on statistical analysis conducted at 5% level of significance, there was a significant difference in ammonia removal efficiency between the wetland and control tanks at detention time of 2 days.

At detention time of 4 days, ammonia removal efficiency for wetland tank was higher than of the control tank throughout the sampling period. Maximum ammonia removal efficiency for wetland tank was 99%, while that for the control was only 62%. Based on the statistical analysis conducted at 5% level of significance, there was a significant difference in ammonia removal efficiency between the reactors.

At detention time of 6 days, ammonia removal efficiency for the wetland tank was higher than that of the control throughout the sampling period. Maximum ammonia removal efficiency for wetland tank was 99% while the maximum ammonia removal efficiency for control was 68% throughout the study period. Based on statistical analysis conducted at 5% level of significance, there is a significant difference in the ammonia removal efficiency between the reactors.

D. Phosphorus

Figures 5 and 6 show influent and effluent phosphorus concentrations at various detention times throughout the study period for the wetland and control tanks, respectively. It can be observed that the phosphorus concentrations discharged from the STP varied throughout the study period and ranged from 2-10 mg/L. Effluent phosphorus concentration at all detention times for the wetland tank ranged from 0.72-6.0 mg/L. However, based on statistical analysis at 5% level of significance, there was no significant difference in phosphorus concentration at all detention times.

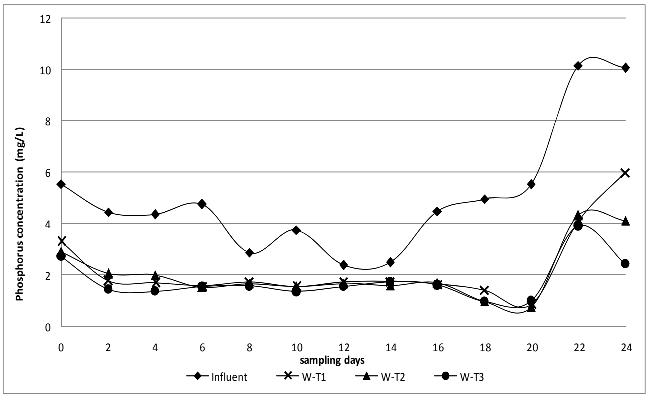

Fig. 5: Phosphorus concentration at detention time W-T1 = 2 days, W-T2 = 4 days and W-T3 = 6 days for wetland tank.

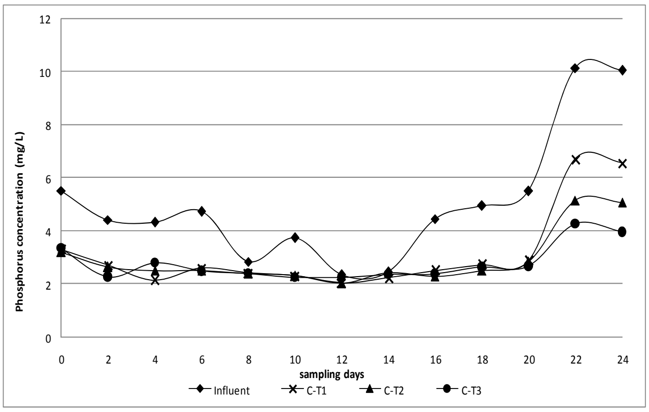

Fig. 6: Phosphorus concentration at detention time C-T1 = 2 days, C-T2 = 4 days and C-T3 = 6 days for control tank.

Effluent phosphorus concentration from the control tank ranged from 2.06 to 6.72 mg/L, higher than the wetland tank. Hence there is some removal of phosphorus by the water hyacinth.

The phosphorus removal efficiency for the wetland tank was higher than that of the control throughout the study period at detention time of 2 days. Maximum phosphorus removal efficiency for the wetland tank was 83% while the maximum phosphorus removal efficiency for the control was 51%. However, this difference is not that significant as based on the statistical analysis conducted at 5% level of significance, it was found that there was no significant difference in phosphorus removal efficiency between the reactors at detention time of 2 days.

The phosphorus removal efficiency for the wetland tank was higher than that of the control throughout the study period at detention time of 4 days. Maximum phosphorus removal efficiency for wetland tank was 84% while the maximum phosphorus removal efficiency for the control tank was 55%. Based on the statistical analysis conducted at 5% level of significance, there was a significant difference in phosphorus removal in the wetland and control tanks.

The phosphorus removal efficiency for the wetland tank was higher than that of the control throughout the study period at detention time of 6 days. Maximum phosphorus removal efficiency for the wetland tank was 72% while the maximum phosphorus removal efficiency for the control was 55%. Based on the statistical analysis conducted at 5% level of significance, it was found that there was a significant difference in phosphorus removal in the wetland tank.

E. Nitrate

Figures 7 and 8 show the influent and effluent nitrate concentrations for the wetland and control reactors, respectively, at various detention times. The nitrate concentration discharged by the STP varied throughout the study period. Influent nitrate concentration varied from 2.7-10.6 mg/L. Effluent nitrate concentrations from the wetland tank ranged from 1.2-6.6 mg/L. However, based on statistical analysis at 5% level of significance, there was no significant difference in effluent nitrate concentration at all detention times. Effluent nitrate concentration from the control tank ranged from 1.9-7.8 mg/L, higher than the wetland tank.

The nitrate removal efficiency for wetland tank was generally higher than that of the control tank throughout the sampling period at detention time of 2 days. Maximum nitrate removal efficiency for wetland tank was 81% while the maximum nitrate removal efficiency for the control was 75%. However, based on the statistical analysis conducted at 5% level of significance, there is no significant difference in nitrate removals for both reactors.

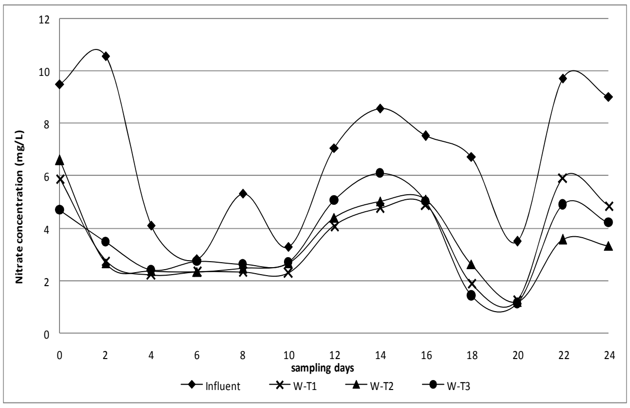

Fig. 7: Nitrate concentration at detention times T1 = 2 days, T2 = 4 days and T3 = 6 days for wetland tank.

The maximum nitrate removal efficiency for the wetland tank was 84% while the maximum nitrate removal efficiency for the control is 75% at detention time of 4 days. However, based on the statistical analysis conducted at 5% level of significance, there was no significant difference in COD removal efficiency between the reactors at detention time of 4 days.

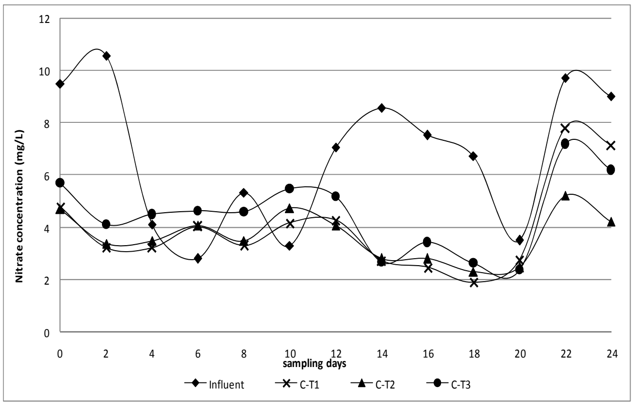

Fig. 8: Nitrate concentration at detention time T1 = 2 days, T2 = 4 days and T3 = 6 days for control tank.

The nitrate removal efficiency for the wetland tank was higher than that of the control tank throughout the study period at detention time of 6 days. Maximum nitrate removal efficiency for the wetland tank was 80% while the maximum nitrate removal efficiency for the control is 63%. However, based on the statistical analysis conducted at 5% level of significance, there was no significant difference in nitrate removals between the reactors at detention time of 6 days.

F. Water Hyacinth growth

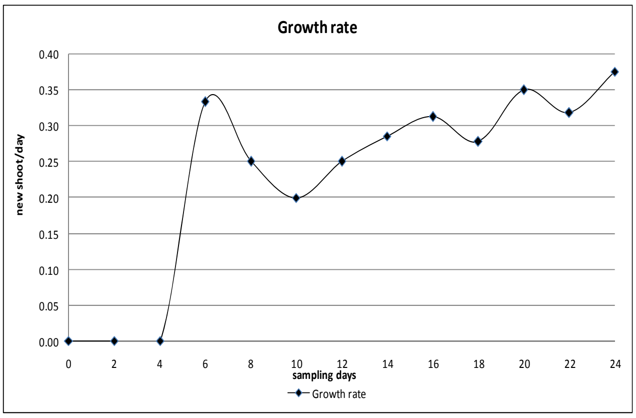

Fig. 9: Growth rate versus sampling days

The wetland tank was initially planted with three water hyacinths in each compartment and no plants in the control tank. After the study period of 24 days, the water hyacinth in the wetland tank had doubled its quantity. Figure 9 shows the growth rate of the water hyacinth throughout the study period. It can be seen that the water hyacinth started to grow steadily from the 10th sampling day at a rate of 0.33 shoot/day. At the end of day 24, water hyacinth continued to grow up to 0.38 shoot/day.

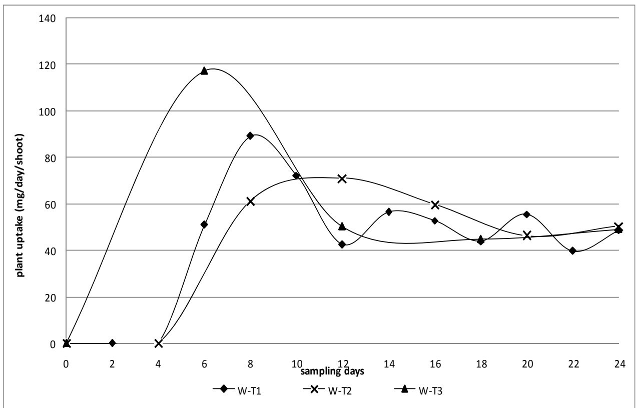

Fig. 10: Ammonia uptake by plant at detention times T1 = 2 days, T2 = 4 days and T3 = 6 days for the wetland tank.

G. Water Hyacinth Plant uptake

From Figure 10, it can be observed that starting from day 10, the ammonia uptake stabilized towards the end of the sampling period. From Figure 11, it can also be observed that starting from day 14, the phosphorus uptake by the water hyacinth stabilized towards the end of the sampling period. It can be observed from Figure 12, from the 10th sampling day uptake of nitrate by the water hyacinth tend to stabilized from day 8 of the sampling period.

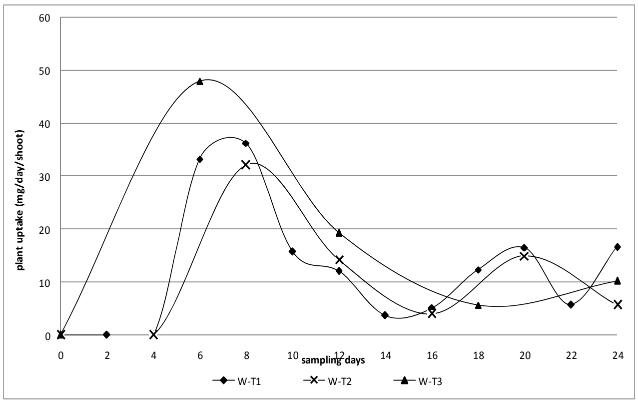

Fig. 11: Phosphorus uptake by plant at detention times T1 = 2 days, T2 = 4 days and T3 = 6 days for the wetland tank.

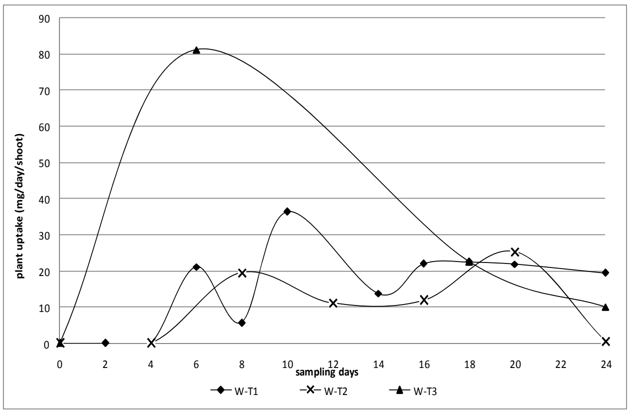

Fig. 12: Nitrate uptake by plant at detention times T1 = 2 days, T2 = 4 days and T3 = 6 days for the wetland tank.

The uptake of ammonia, phosphorus and nitrate are initially higher at detention time of 2 days but decreased throughout the sampling period as the wastewater passed through the first compartment. Therefore, there is an advantage for water hyacinth in compartment 1 as they got to use up the nutrient for their growth development. This is proven as the plant size and root length in compartment 1 is larger than other plants in the other two compartments. Based on the plant uptake graphs for COD, ammonia, phosphorus and nitrate, it is concluded that water hyacinth start to stabilize approximately from day 10.

IV. CONCLUSION

Water hyacinth is capable of removing ammonia, phosphorus and nitrate from the municipal wastewater treatment plant effluent. Water hyacinth showed growth and development from day 6 until day 24 with growth rate 0.33 shoot/day to 0.38 shoot/ day. Moreover, water hyacinth showed its ability to survive in high concentration of nutrients. Significant removals of ammonia and phosphorus, respectively was obtained using the water hyacinth plants. Use of water hyacinths can help reduce eutrophication effects in receiving streams and also improve its water quality.

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REFERENCES

[1] Reddy K. R. (1985). "Nutrient transformations in aquatic macrophyte filters used for water purification". Journal of Proceedings Water Reuse III. American Water Works Association. Page 660 - 678.
[2] Xia H. and Ma X, (2005)."Phytoremediation of Ethion by Water Hyacinth (*Eichhornia Crassipes*) from Water". Journal of Phytoremediation. Volume 6: Page 137 - 148.
[3] Metcalf and Eddy (2004), Wastewater Engineering Treatment and Reuse, Fourth Edition, McGraw-Hill, New York, USA.
[4] Petrucio M.M and Esteves F.A, (2000). "Uptake Rates of Nitrogen and Phosphorus in the Water by *Eichhornia Crassipes* and *Salvinia Auriculata*". Journal of Water Hyacinth for improving eutrophic lake water. Volume 60, No.2: Page 229 - 236.
[5] Black A.P and Babers F.H (1939). "Methyl Nitrate". Journal of Org Synthetic. Vol 2: Page 412.
[6] Anderson JJB (1996). "Calcium, Phosphorus and Human Bone Development". Journal of New Scientist. Page 126.
[7] Freddy K.R and De Busk W.F, (1985). "Nutrient removal Potential of Selected Aquatic Macrophytes 4". Journal of Environmental Quality. Page 459 - 462.
[8] Zynda Todd, April (1994). Michigan State University TAB Program, National Institute of Environmental Health, Phytoremediation fact sheet and guideline.
[9] US EPA, 2000: Manual - Phytoremediation Resource Guide. Office of Research and Department. Page 165.
[10] Jayaweera M.W and Kasturiarachchi J.C, (2004). "Removal of Nitrogen and Phosphorus from industrial wastewaters by phytoremediation using water hyacinth (*Eichhornia Crassipes*)". Journal of Wastewater science and technology. Volume 50, No. 6: Page 217 – 225.
[11] Nesic N. and Jovanovic L. (1996). "Potential Use of Water Hyacinth (*E. Crassipens*) for Wastewater Treatment in Serbia". Journal of Wastewater treatment using Aquatic plant. No.13: Page 1 - 8.
[12] Reddy K. R. & Tucker J. C. (1983). "Effect of nitrogen source on productivity and nutrient uptake of water hyacinth (*Eichhornia crassipes*)". Journal of Economic Botany. No.37: Page 236 - 246.