UNIVERSITI PUTRA MALAYSIA

NUTRIENT REMOVAL IN FLOATING WETLAND USING DIFFERENT PLANT SPECIES (Eleocheris variegate (Poir.) C. PRESL, Scirpus mucronatus L. and Phylidrum lanuginosum BANKS EX GAERTN) AND FLOATING MAT COVERAGE

MUHAMMAD SANUSI IBRAHIM

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By

MUHAMMAD SANUSI IBRAHIM

Thesis submitted to School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

August 2017

DEDICATION

To the gentle souls of my first guides and teachers; my late father Alhaji Ibrahim Dan Amfana, and my late mother Rabi`atu, may Allah SWT shower His infinite mercy on them, reward them abundantly and join them with His chosen servants in Divine communion, amen.

To all those pure ones who dedicated their lives to the guidance of humanity, exposition of the Divine paradigm and realization of the civilizational goals of Islam.

Abstract of the thesis presented to the senate of Universiti Putra Malaysia in fulfilment of the requirement for degree of Master of Science

NUTRIENT REMOVAL IN FLOATING WETLAND USING DIFFERENT PLANT SPECIES (*Eleocheris variegate* (Poir.) C. PRESL, *Scirpus mucronatus* L. and *Phylidrum lanuginosum* BANKS EX GAERTN) AND FLOATING MAT COVERAGE

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August 2017

Chairman : Mohd Yusoff Ishak, PhD
Faculty : Environmental Studies

Nutrients such as ammonia, nitrate, nitrite and phosphorus are the common contaminants discharged into the water bodies. Most of Malaysian wetlands were polluted through nutrient discharge from agricultural runoff and anthropogenic activities. Studies on floating treatment wetland efficiency using native plant species to reduce the nutrient were lacking in Malaysia. The potential of floating treatment wetland in water purification using three plant species of Spike rush (*Eleocheris variegata*), Bug bulrush(*Scirpus mucronatus*) and Fan grass (*Phylidrum lanuginosum),* and floating mat coverage as well as plant species combinations was examined. The result showed the plant species performed better in ammonia, nitrate and phosphorous removal. Spike rush exhibited significantly higher ammonia-nitrogen removal in high nutrient concentration water ($p = 0.013$) compared to low nutrient concentration water. While in nitrate, the plant exhibited significantly higher removal in low nutrient concentration water ($p = 0.000$) compared to high nutrient concentration water. Similarly, the plant showed significantly higher phosphorus removal in low nutrient concentration water ($p = 0.000$) compared to high nutrient concentration water. However, Bug bulrush was also exhibited significantly higher ammonia- nitrogen removal in higher nutrient concentration water ($p = 0.021$) compared to low nutrient concentration water. Conversely, the plant showed significantly higher nitrate removal in low nutrient concentration water ($p = 0.000$) compared to high. Similarly, the plant exhibited significantly higher phosphorus removal in low nutrient concentration water ($p = 0.000$) compared to high. However, Fan grass exhibited significantly higher ammonia- nitrogen removal in low nutrient concentration water ($p = 0.021$) compared to high nutrient concentration water. While, in nitrate removal, the plant showed higher in high nutrient concentration water ($p = 0.000$) compared to low nutrient concentration water. Similarly, the plant exhibited significantly higher phosphorous removal in high nutrient concentration ($p = 0.000$) compared to low nutrient concentration. In BOD removal, the result showed

only significant differences in low nutrient concentration water between the plant species ($p = 0.046$). However, The result showed no significance differences in nutrient removal between the floating mat coverage, except for nitrate in 20% floating mat coverage which showed significantly higher removal ($p = 0.031$) compared to 60% floating mat coverage. Furthermore, the result showed two plant species in 60% floating mat coverage was significantly higher in nitrate removal ($p = 0.041$) compared to control. However, three plant species showed significantly higher phosphorus removal ($p = 0.006$) compared to two plant species and control. Moreover, the control of 40% floating mat coverage exhibited significantly higher Biochemical oxygen demand removal ($p = 0.001$) compared to three and two plant species combinations.

Conversely, three plant species in 20% floating mat coverage showed significantly higher BOD removal ($p = 0.008$) compared to two plant species. The result showed increase in Chemical oxygen demand in all the experiment. The plant species showed good performance in nutrient removal for both high and low nutrient concentration water. Floating mat coverage and plant species combination contribute more in nitrate removal. The plant species are good for BOD removal, but they are not desirable for COD removal.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENYINGKIRAN NUTRIENT OLEH SPESIES TANAMAN (*Eleocheris variegata, Scirpus mucronatus, Phylidrum lanuginosum*) DAN LITUPAN TANAMAN YANG BERBEZA PADA WETLAND TERAPUNG

Oleh

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Nutrien seperti ammonia, nitrat, nitrit dan fosforus adalah bahan pencemar yang biasa dilepaskan ke jasad air. Sebahagian besar tanah paya di Malaysia telah tercemar akibat pelepasan nutrien daripada air larian pertanian dan aktiviti manusia. Kajian tentang keberkesanan *floating wetland* yang menggunakan spesies tumbuhan asal dalam mengurangkan nutrien tersebut di Malaysia agak jarang dilakukan. Kajian ini meneliti potensi *floating wetland* dalam rawatan air menggunakan tiga spesies tanaman iaitu Spike rush (*Eleocheris variegata*), Bug bulrush (*Scirpus mucronatus*) dan Fan grass (*Phylidrum lanuginosum*) dan kombinasi litupan lantai serta spesies tumbuhan yang berbeza. Keputusan mendapati spesies tumbuhan mencapai prestasi lebih baik dalam penyingkiran ammonia, nitrat dan fosforus. Spike rush menunjukkan penyingkiran ammonia-nitrogen yang lebih tinggi dalam air berkepekatan nutrien yang tinggi ($p = 0.013$) berbanding dengan air berkepekatan nutrient rendah. Sementara bagi nitrat, tumbuhan ini menunjukkan penyingkiran yang lebih tinggi dalam air berkepekatan nutrient rendah ($p = 0.000$) berbanding dengan air berkepekatan nutrien yang tinggi. Selain itu, tumbuhan itu menunjukkan penyingkiran fosforus yang signifikan dalam air berkepekatan nutrien yang rendah ($p = 0.000$) berbanding dengan air berkepekatan nutrien yang tinggi. Walau bagaimanapun, Bug bulrush juga menunjukkan penyingkiran ammonia-nitrogen yang signifikan dalam air berkepekatan nutrien yang tinggi ($p = 0.021$) berbanding dengan air berkepekatan nutrien rendah. Sebaliknya, tumbuhan tersebut menunjukkan penyingkiran nitrat yang lebih tinggi secara signifikan dalam air berkepekatan lebih rendah ($p = 0.000$) berbanding dengan kepekatan tinggi. Begitu juga, tumbuhan ini menunjukkan penyingkiran fosforus yang jauh lebih tinggi dalam air kepekatan rendah ($p = 0.000$) berbanding dengan kepekatan tinggi. Walau bagaimanapun, *Fan grass* menunjukkan penyingkiran ammonia-nitrogen yang signifikan dalam air berkepekatan rendah ($p = 0.021$) berbanding dengan air berkepekatan nutrien yang tinggi. Sementara itu, dalam penyingkiran nitrat, tumbuhan menunjukkan penyingkiran lebih tinggi dalam air berkepekatan nutrien yang tinggi ($p = 0.000$) berbanding dengan air kepekatan yang rendah. Tumbuhan

itu juga menunjukkan penyingkiran fosforus yang signifikan dalam air berkepekatan nutrien yang tinggi (p = 0.000) berbanding dengan kepekatan nutrien yang rendah. Bagi penyingkiran BOD, keputusan menunjukkan hanya perbezaan yang signifikan dalam air berkepekatan nutrien yang rendah antara spesis tumbuhan (p = 0.046). Keputusan juga menunjukkan tiada perbezaan yang signifikan dalam penyingkiran nutrien antara liputan terapung terapung, kecuali bagi nitrat dalam liputan 20% yang menunjukkan penyingkiran lebih signifikan (p = 0.031) berbanding dengan litupan 60%. Selain itu, keputusan menunjukkan kombinasi dua spesies tumbuhan dalam liputan 60% adalah lebih signifikan dalam menyingkirkan nitrat (p = 0.041) berbanding dengan kawalan. Walau bagaimanapun, kombinasi tiga spesies tumbuhan menunjukkan penyingkiran fosforus yang lebih signifikan (p = 0.006) berbanding dengan kombinasi dua spesies tumbuhan dan kawalan. Selain itu, kawalan bagi experimen liputan 40% menunjukkan peningkatan Permintaan Oksigen Biokimia yang lebih signifikan (p = 0.001) berbanding dengan kombinasi tiga dan dua spesies tumbuhan. Sebaliknya, kombinasi tiga spesies tumbuhan dalam liputan 20% menunjukkan penyingkiran BOD yang lebih signifikan (p = 0.008) berbanding dengan dua spesies tumbuhan. Keputusan juga menunjukkan peningkatan Permintaan Oksigen Kimia dalam kesemua eksperimen. Spesies tumbuhan menunjukkan prestasi penyingkiran nutrien yang baik dalam kedua-dua kepekatan nutrien yang tinggi dan rendah. Litupan tumbuhan dan gabungan spesies tumbuhan menyumbang lebih banyak dalam penyingkiran nitrat. Spesies tumbuhan adalah baik untuk penyingkiran BOD, tetapi tidak untuk COD.

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I certify that a Thesis Examination Committee has met on 21 August 2017 to conduct the final examination of Ibrahim Muhammad Sanusi on his thesis entitled "Nutrient Removal in Floating Wetland using Different Plant Species (*Eleocheris variegate* (Poir.) C. Presl, *Scirpus mucronatus* L. and *Philydrum lanuginosum* Banks ex Gaertn.) and Floating Mat Coverage " in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CEC	Cat ion Exchange Capacity
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
FSS	Fine Suspended Solid
FTW	Floating Treatment Wetland
L	Litter
N	Nitrogen
NTU	Nephelometric Turbidity Unit
P	Phosphorous
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solid
WQI	Water Quality Index

CHAPTER 1

INTRODUCTION

1.1 Introduction Background

Nutrients discharging into rivers, lakes, and ponds are becoming an issue worldwide as a result of high loading rate to the ending sources. This is due to the increase of anthropogenic activities, which is detriment to human health and aquatic life. Nutrients such as ammonia, nitrate, nitrite and phosphorous in storm water effluent are common contaminants in water bodies threatening public health and ecosystem integrity (Wanielista et al., 2012). This has caused acute and chronic outcomes, both directly and indirectly. For example, without proper treatment, ammonia in wastewater effluent has been shown to stimulate phytoplankton growth, which exhibits toxicity to aquatic biota, and exerts an oxygen demand in surface waters (Beutel, 2006). The non-disassociated ammonia found to be extremely volatile which is either ionized or volatized in aqueous solution, and becomes toxic to fish species (Tarazona et al., 2008). Thus, fish mortality, health, and reproduction have all been affected by the presence of minute amount of ammonia-N (Servizi and Gordon, 1990).

Nitrate has also caused many health problems mainly in human. It has been proven to be responsible for health issues such as liver damage and even some cancers (Huang et al, 1998). However, it was also been discovered that when nitrite react with amino, chemically or enzymatically, it forms nitrosamines which are very potential carcinogens (Sawyer et al, 2003). Phosphorous on the other hand can be an important nutrient in regulating primary productivity in lakes and it is a major contributor to eutrophication in aquatic system (Belmont and Metcalfe, 2003). Thus, by the presence of eutrophication in water body, it could lead to deterioration in water quality and undesirable disruption to the balance of aquatic ecosystem, such as decreased biodiversity, adverse community reaction and changes in biomass of dominant species (Yin Wang et al, 2015). This is recognized as an important and widespread global environmental problem.

The need to reduce such nutrients level in wastewater is increasingly critical as rivers, lakes and coastal waters become more nutrient loaded worldwide (Reinsel, 2012), and consequently becoming detrimental to human health and aquatic ecosystem destruction. Conventional storm water detention ponds were built essentially for the pollution control, providing aesthetic and recreational benefit as well as a flood and downstream erosion control (Wanielista et al., 2012). Nevertheless, increase in human activity and surface runoff that consists fertilizer, animal excrete and organic debris leads to eutrophication that conventional ponds cannot handle, which resulted in new environmental issue and concern. This harmful cycle in ponds creates an algae bloom which gradually covers the water surface there by hindering the sunlight from penetrating the water column, which thus hindered the oxygen transfer in the water column thereby restrains a healthy aquatic ecosystem (Wanielista et al, 2012).

The use of constructed and well managed natural wetlands served as a means of remediating waste water runoff from various sources (Boets et al., 2011). Constructed wetlands are used extensively for water quality improvement by reducing pollutant loads, as well as for ecological reasons (Wood and Shelley, 1999; Schulz and Peall, 2001). It was initially employed mainly to treat point sources waste water, but more recently an increased concern has been on urban and agricultural storm water runoff (Carleton et al, 2001; Schulz and Peall 2001; Page et al, 2002). Moreover, wetlands have frequently been established to remove pollutants from contaminated water. Studies have addressed their removal and fate of pollution control (Goulet et al, 2001; Boets et al., 2011).

Plants play a vital role in nutrient recycling in wetland due to uptake, storage and release process (Arthur et al, 2002). Specifically, plants with potentially high annual primary production can extract large amount of nutrient from their environment, and store these nutrient in biomass and litter. For this reason many wetland plants are being used to reduce the nutrient content of domestic, industrial and agricultural waste water (Hammer, 1989). Microphyte based wetland system has been reported to be effective for water quality improvement by reducing water velocity, thereby allowing suspended particle to settle, and their direct uptake of the nutrients as well as the work of microbial population such as nitrifying and denitrifying bacteria (Chimney & Pietro, 2006; Taylor et al, 2011; Zhu et al., 2012).

Floating treatment wetlands were among the recent green technology that promise best management practices in remediating the waste water and storm water from various sources, which overcome the constructed wetland problems. A floating treatment wetland offers an innovative naturally harmonious solution in pollutant removal by directly assimilating them into their microphyte, and it provides a suitable environment for microorganisms to decompose or transforms the pollutant to gas phase which reduce their concentration (Wanielista et al., 2012).

In conventional treatment wetlands, the duration of inundation, water depth, frequency of flooding and drought are known to affect the plant growth, establishment and survival as well as the land area requirement for establishing the conventional treatment wetlands is a limitation to their applicability. Floating treatment wetlands is an innovative variant on this system and a possible solution to this problem (Wanielista et al., 2012).

As the plants on the floating mat grow, the roots penetrate through the water level and absorb the nutrients in the water column rather than being rooted in the sediments, as in the case of constructed and natural wetlands. As a result, the water depth is not a concern issue and the mat may not be affected by the water level fluctuation. The plants on floating mat are forced to acquire nutrition directly from the water column (Headly et al., 2006; Vymzal, 2007). Thus, nutrients and other elements uptake into biomass rate increases as physiological growth continues (Wanielista et al., 2012).

1.2 Research Problem

Environmental problems associated with deterioration of water quality are becoming a worldwide major environmental issue in present and coming years. Deterioration of water quality is not only considered for drinking water supply, but also related to recreation and aquaculture activities (Pratt, 2005). Major nutrient polluting water bodies such as nitrogen and phosphorous are coming from the point source such as sewage and industrial discharge along tributaries, leachate from waste disposal site, runoff from animal feed lots. The nonpoint sources of agricultural areas rich in nitrogen and phosphorus through the drainage basin or shores, pollution from aquaculture or marine culture zones, external loads from precipitation, and internal loads release from sediment bed are also contributing to the deterioration (Yin Wang et al, 2015). Sewage discharge into aquatic systems is one of the major contributors to the deterioration of water bodies. This is due to the organic or nutrient content of the sewage itself as well as specific contaminants that are associated with the discharge (Mudge and Duce, 2005).

Anthropogenic activities within urban catchment generate pollutants consisting nitrogen and phosphorus, which are transported from street surfaces by storm water runoff, and are discharged into adjacent water bodies (Birch et al, 2004). Such pollutants carried out by urban storm water contribute substantially to the degradation of water quality of receiving water areas (Davis et al, 2001).

Eutrophication as it is triggered by human activities, give rise to variety of environmental problem, by extremely rapid growth of phytoplankton in water bodies which led to deterioration of water quality. As a result it leads to several potential carcinogenic and mutagenic byproducts which have adverse effect on health, thorough damaging the liver, intestine and nervous system. It also leads to severe oxygen depletion in a water body which may result in the decreased in biodiversity (Yin Wang et al, 2015).

Eutrophication is the main water quality issue in Malaysia. Drainage ditches, irrigation channels, ponds and other water ways are polluted by agricultural runoff from fertilizer-rich land such as vegetable farms, fruit and flower nurseries, golf courses and animal farms (Sim, 2003). These sources cause the pollution of wetland areas as a result of nutrient discharge which is becoming an alarming risk in most Malaysian wetlands. This is due to the nutrient discharge and other anthropogenic activities within the urban catchment. According to Sim et al., (2007) 63% of the rivers in Malaysia are classified as moderately to high polluted.

Country Villa, is a residential area located in Kajang, Selangor, and has lakes that have their tributaries from upstream. The lakes are within the residential neighborhood and become a recreational resort of the area as well as leisure and fishing area for the residents. The lakes become polluted as a result of eutrophication and absence of any treatment mechanism. The pollution was mainly caused by the polluted water coming from upstream and high sedimentation due to the erosion from the construction work done adjacent to the lakes which blocked the water ways. The lake reaches the deteriorating condition and developed algae mat on the surface.

The water turns to greenish in color and emits foul odor, which indicate the extensity of the pollution (Figure 1.1). The lake does not exhibit the characteristic of good wetland to purify water in terms of retention time, water flow (inlet) and specific plants to use for water purification as a result of absence of treatment mechanism.

Figure 1.1 : Deterioration of the Lake in Country Villa, a) Sources of polluted water from upstream b) erosion that caused sedimentation c) algae mat bloom and d) water color change into greenish due to high nutrient concentration

Phytoremediation is the best environmental friendly technology and cost effective for remediating waste water compared to conventional treatment system. The floating treatment wetland is recent potential green technology which overcomes the problems facing the constructed wetlands (Wanielista et al., 2012). It is a novel treatment concept that employ rooted emergent macrophytes growing on floating mat on the water surface rather than rooted in sediment (Tanner and Headley, 2011; Fonder and Headley, 2011), and absorbed dissolved nutrients in the water column by using the removal benefit of the vegetation planted on the mat (Headley and Tanner, 2006; Vymazal, 2007).

Numerous studies were carried out on water purification using different wetland plant species. For example White and Cousins (2013) used *Canna flaccida* and *Juncus effuses* in two different nutrient loading rates to examine the remediation efficiency of floating treatment wetland, and found it is effective in low nutrient environment with *Juncus effuses* perform better than *Canna flacida*. Keizer-vlek, et al., (2014) used *Typha angustifolia* and *Iris pseudacorus* to examine the contribution of plant in nutrient uptake to the total removal capacity of FTW as well as Chang et al., (2012), Van De moortel et al., (2010) and Headley and Tinner, (2012). Most of plant species used was *Phragmite autralist*, *Typha latifolia, Canna flaccida, Juncus effuses*, and little trace on *Vetiveria zizanicide* and *Zizania caduciflora,* but no work has been done using *Eleocheris vareagata*, *Scirpus mucronatus* or *Phylidrum lanuginosun*. However, there is no work done on floating treatment wetland in Malaysia using these plant species. Therefore, the study focused on the use of these plants as they are native plant species with high biomass and able to degrade the organic matter presence in the water as well as able to grow in high polluted water.

The study also used different floating mat coverage of 60%, 40% and 20% as the work concerning the floating mat coverage was mostly conducted using 5% and 10% by Chang et al., (2012), 95% by Li et al., (2011) and 100% by Steward et al., (2002). The study was conducted in two phases of microcosm and mesocosm studies. Figure 1.2 below illustrates the flow of the experiment.

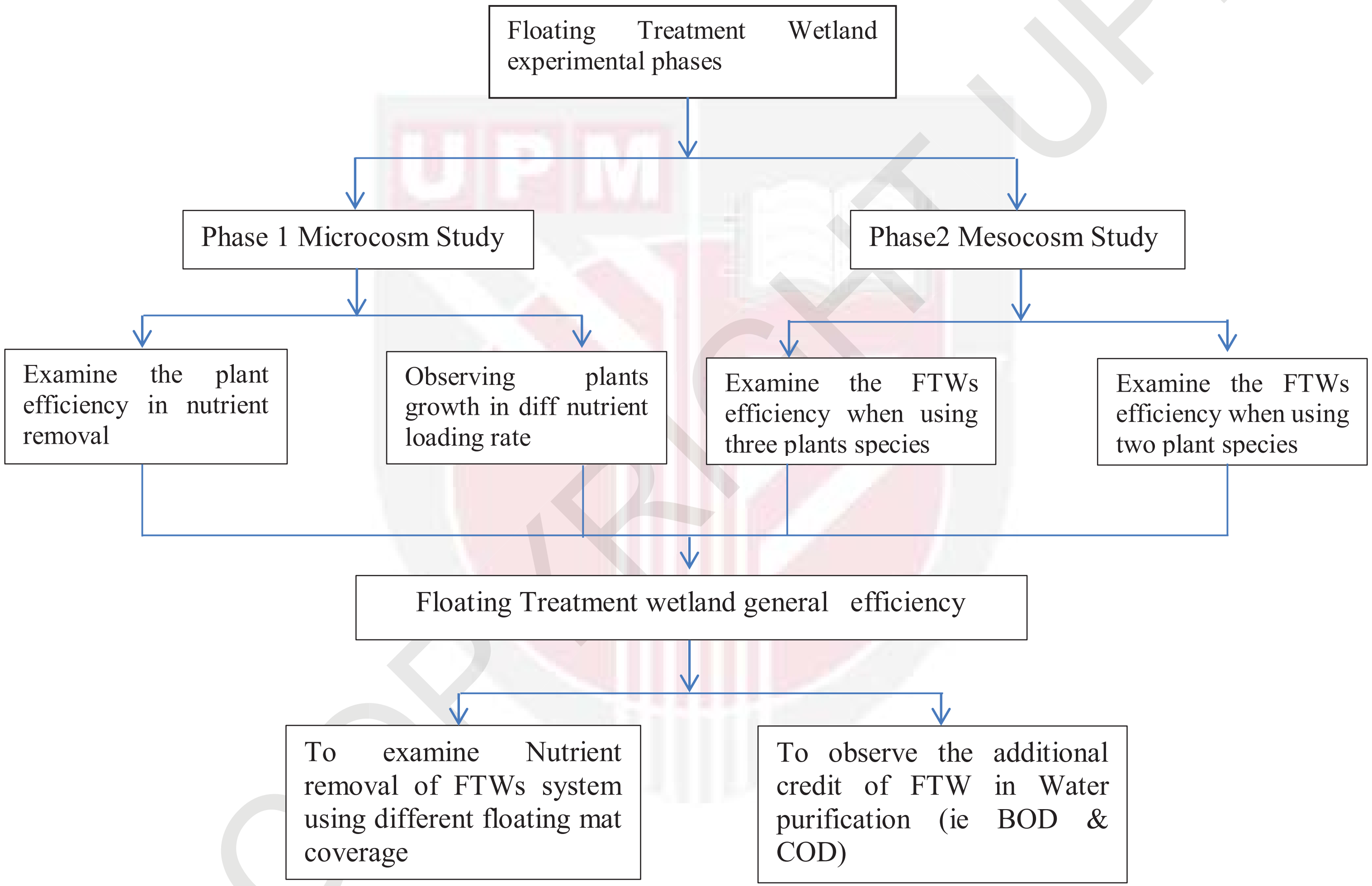

Figure 1.2 : Flow chart of the experimental work

1.2.1 Research question

1) Are the plant species Spike rush (*Eleocheris vareagata*), Bug bulrush (*Scirpus mucronatus*) and Fan grass (*Phylidrum lanuginosun*) efficient to be used in floating wetland for nutrient removal in high and low nutrient concentration water?
2) Does the plant species combination and floating mat coverage influence the floating treatment wetland performance in terms of nutrient removal?
3) Does the floating treatment wetland work efficient in water purification for COD and BOD removal?

1.3 Research Objective

The primary objective of this study is to examine the performance of floating treatment wetlands in water quality improvement via nutrient removal, in a small scale (microcosm) using different plant species and nutrient concentrations (high and low), and large scale (mesocosm) studies using different floating mat coverage and plant species combinations. The specific objectives to be achieved are as follows;

1) To determine the capacity of floating treatment wetland for treating water with high and low nutrient concentrations using three different plant species (in microcosm) study.
2) To assess the efficiency of floating treatment wetland in nutrient removal using different floating mat coverage and plant species combination in a large scale (mesocosm) study over time.
3) To identify the floating treatment wetland performance in BOD and COD removal in both microcosm and mesocosm studies.

1.4 Significance of the Study

The study seeks to provide the alternative green technology of floating treatment wetland in controlling the pollution problem in a lake due to its nature of cost effectiveness, and environmentally friendly technology which efficiently remove the contaminants. By utilizing the macrophyte means of water purification in wetland, the cost of management will be minimized and water purification target could be achieved. Floating treatment wetlands technology is the promising problem solving which overcomes the challenges of duration of inundation, water depth, frequency of flooding and draught facing the constructed wetland in terms of plant growth and establishment, and the problem of land requirement for establishing the treatment wetland (Wanielista et al., 2012).

1.5 Scope of the Study

The study was focused on identifying the floating treatment wetland performance in ammonia-nitrogen, nitrate, nitrite and phosphorus removal as well as it is performance on Biochemical oxygen demand, Chemical oxygen demand removal. The in situ water quality parameters such as temperature, pH, Dissolved oxygen, Electrical conductivity, Total suspended solid and water turbidity was also determined as they may positively or negatively influence the nutrient removal.

The experiment was carried out at Faculty of Environmental Studies, Universiti Putra Malaysia, using the Country Villa Lake water located at Kajang as high nutrient concentration water due to the high pollution. The water from lake behind Faculty of Environmental Studies was used as low nutrient concentration due to the less nutrient content in the water.

REFERENCES

Arthur, F.M. Meuleman., Beekman, J., & Verhoeven, J.T.A. (2002). Nutrient retention and nutrient-use efficiency in *Phragmites australis* stands after wastewater application. *Wetlands*, 22 (4): 712-721.

Auckland Regional Council,(2004). Management and Treatment of Storm water Quality Effects in Estuarine Areas: ARC Technical Publication No. 237. *Auckland Regional Council, Auckland*. New Zealand.

Austin, D., Lohan, E., & Verson, E. (2003). Nitrification and denitrification in a tidal vertical flow wetland pilot. National Conference, 7th Annual Conference and exhibition, Alexandria, Virginia. *Proceedings of the Water Environment Federation*, *2003*(9), 333-357.

Baker, L. A. (1998). Design consideration and applications for wetland treatment of high nitrate waters. *Water Science and Technology*, *38*(1), 389–395.

Barko, J., & Smart, R. (1986). Sediment-related mechanisms of growth limitation in submersed macrophytes. *Ecology*, 67: 1328-1340.

Barrow, N.J. (1983). On the reversibility of phosphate sorption by soils. *Journal of Soil Science*. 34: 751-758.

Bartram, J., & Ballance, R. (1996). *Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes*. Chapman & Hall, London.

Belmont, M. A., White, J. R., & Reddy, K. R. (2009). Phosphorus Sorption and Potential Phosphorus Storage in Sediments of Lake Istokpoga and the Upper Chain of Lakes, Florida, USA. *Journal of Environment Quality*, *38*(3), 987.

Belmont, M., & Metcalfe, C.D. (2003). Feasibility of using ornamental plants (Zantedeschia aethiopica) in subsurface flow treatment wetlands to remove nitrogen, chemical oxygen demand and nonylphenol ethoxylate surfacants in laboratory scale study. *Ecological Engineering*. 21: 233-247. Retrieved from http://www.sciencedirect.com.

Bernet, B. N., Dangcong, P., Delgene, J.P., & Moletta, R. (2001). Nitrification at low Oxygen Concentration in biofilm reactor. *Journal of Environmental Energy*, *127*(3), 266–271.

Beutel, M. W. (2006). Inhibition of ammonia release from anoxic profundal sediments in lakes using hypolimnetic oxygenation. *Ecological Engineering*. 28: 271-279. Retrieved from http://www.sciencedirect.com.

Billore, S., Prashant, K., Sharma, J.K., Singh, N., Ram, H., Dass, P., (2008). Restoration and Conservation of stagnant water bodies by gravel-bed treatment and artificial floating reed bed in Tropical india. In De Stefani, G., Tocchetto, D., Salvato, M., & Borin, M. (2011). Performance of a floating treatment wetland for in-stream water amelioration in NE Italy. *Hydrobiologia*, *674*(1), *157–167.*

Birch, G. F., Carsten, M., Muhammad, S., Fazeli, M., & Jeongyul, S. (2004). Efficiency of a constructed wetland in removing contaminants from stormwater. *Wetlands*. 2 (24): 459-466.

Borne, K. E., Fassman, E. A., & Tanner, C.C. (2013). Floating treatment wetland retrofit to improve stormwater pond performance for suspended solids, copper and zinc. *Ecological Engineering*. *54: 173-182.*

Brisson, J., & Chazarenc, F. (2009). Maximizing pollutant removal in constructed wetlands: Should we pay more attention to macrophyte species selection? *Science of The Total Environment*, *407*(13), 3923–3930.

Brix, H., & Schierup, H.H. (1989). The use of aquatic macrophytes in water-pollution control. *Ambio. Stockholm*. 18: 100-107.

Brown, P. A ., Gill, S. A ., & Allen, S. J . (2000). Metal removal from wastewater using peat. *Water Research*, *34*(16), 3907–3916.

Carleton, J. N., Grizzard, T. J, Godrej, A.N., & Post, H. E. (2001). Factors affecting the performance of stormwater treatment wetlands. *Water Research*, 35: 1552-1562.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., & Smith, V.H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, *3*(8), 559–568. Retrieved from http://www.esajournals.org.

Chang, N. B., Xuan, Z., Marimon, Z., Islam, K., & Wanielista, M. P. (2013). Exploring hydrobiogeochemical processes of floating treatment wetlands in a subtropical stormwater wet detention pond. *Ecological Engineering*, *54*, 66–76.

Chang, N.B., Hossain, F., & Wanielista, M. (2010). Filter media for nutrient removal in natural systems and built environments: I—Previous trends and perspectives. *Environmental Engineering.Science*. 27: 689-706.

Chapman, D. (1996*). Water quality assessment-Guide to use of Biota, sedment and Water in Environmental monitoring (2nd ed)* in colabration with UNESCO, WHO & UNEP. E & FN spoon, Chapman & Hall, London.

Chimney, M.J., & Pietro, K.C. (2006). Decomposition of macrophyte litter in a subtropical constructed wetland in south Florida (USA). *Ecological Engineering*, 27: 301-321.

Chiras, D.D. (2011). *Environmental science* (8th ed.). Jones and Bartlett. London, UK.

Chong, N.M., Chen, Y.C., & Hsieh, C.N. (2012). Assessment of the quality of stormwater from an industrial park in central Taiwan. Environmental *Monitoring and Assessment*, *184*, 1801–1811.

Clark, M.W., & Reddy, K.R. (1998). *Analysis of floating and emergent vegetation formation in orange lake. Vol 1, Final Report.Centre for wtlands, University of Florida, Gainesville,Florida 33pp. St. johns River water management District, platka. F.L.*

Cooper, P.F., Job, G.D., Green, M.B., Shutes, R. B. E. (1996). *Reedbeds and Constructed Wetlands for waste water treatment. Medmenham, Marlow, UK;* WRC Publishers.184 pp.

Cowardin, L.M., Carter, V., Golet, F.C., & LaRoe, E.T. (1979). Classification of wetlands and deepwater habitats of the United States, 103pp. Washington DC. U.S.

Craig, L.S., Palmer, M.A., Richardson, D.C., Filoso, S., Bernhardt, E.S., Bledsoe, B.P., Doyle, M.W., Groffman, P.M., Hassett, B.A. & Kaushal, S.S. (2008). Stream restoration strategies for reducing river nitrogen loads. *Frontiers in Ecology and Environment*, *6*(10), 529–538.

Cronk, J.K., & Fennessy, S. . (2001). *Wetland Plants: Biology and Ecology.* Lewis Publishers. Boca Raton, London, New York, Washington DC. PP3-15.

Duzer, C.V. (2004). Floating Islands; A Global Bibliography. Cantor press, california, U S A.

Davis, A.P., Shokouhian, M., Sham, H. & Minami, C. (2001). Laboratory study of biological retention for urban stormwater management. *Water Environment Research*,73: 5-14.

De Stefani, G., Tocchetto, D., Salvato, M., & Borin, M. (2011). Performance of a floating treatment wetland for in-stream water amelioration in NE Italy. *Hydrobiologia*, *674*(1), 157–167.

Delucia, E.H., & Schlesinger, W. H. (1995). Photosynthetic Rates and Nutrient-Use Efficiency Among Evergreen and Deciduous Shrubs in Okefenokee Swamp on JSTOR. *International Journal of Plant Sciences*, *156*(1), 19–28.

Ding, Y., Song, X., Wang, Y., & Yan, D. (2012). Effects of dissolved oxygen and influent COD/N ratios on nitrogen removal in horizontal subsurface flow constructed wetland. *Ecological Engineering*, *46*, 107–111.

Dodkina and Mendzil. (2014). *Enterprise Assist : Floating Treatment Wetlands* (*FTWs*) *in Water Treatment : Treatment efficiency and potential benefits of* *activated Carbon*. Sustainable expansion of applied costal and marine sctor (SEACAMS) Abertawe Swansea University, Wales.

DOE 2008. Malaysia Environmental Quality Report 2008. Department of Environment, Ministry of Natural Resources and Environment Malaysia, Kuala Lumpur. P. 86. In Suratman, S., Muh`d Sultan, M.I., Hee, Y.Y., Bedurus, E.A., & Latif, M.T. (2015). *A* Priliminary study of Water quality index in Terengganu River basin (Malaysia). *Sains Malaysiana, 44 (1): 67-73.*

Fonder, N., & Headley, T. (2011). Water and Nutrient Management in Natural and Constructed Wetlands. *Media*, 191–213.

Goulet, R.R., Pick, F.R., & Droste, R.L. (2001). Test of the first-order removal model for metal retention in a young constructed wetland. *Ecological Engineering*, 17: 357-371.

Greenway, M., and Woolley, A. (2001). Changes in Plant biomass and nutrient removal over 3 years in constructed wetland in Cairns, Austrelia. *Water Science and Technology,* 44: 11 - 12, 303 – 310.

HACH., (1989). Water Analysis Handbook. HACH Company, Loveland, Corolado, U.S.

Hammer, D.A. (1989). *Constructed wetlands for wastewater treatment: municipal, industrial and agricultural*. Boca Raton, Florida; CRC Press.

Haslam, S.M., & Wolseley, P. A. (1978). *River Plants*.The macrophyte vegetation of water course. Cambridge University Press, Cambridge, London.

Headley, T. R., & Tanner, C. C. (2008). Floating Treatment Wetlands : an Innovative Option for Stormwater Quality Applications. *11th International Conference on Wetland Systems for Water Pollution Control*, 1101–1106.

Headly, T.R., & Tanner, C.C (2006). Application of Floating Wetlands for Enhanced Storm Water Treatment: A Review NIWA Client Report, *Auckland Regional Council, Newziland.*

Hossain, F., Chang, N.B., & Wanielista, M. (2010). Modeling kinetics and isotherms of functionalized filter media for nutrient removal from stormwater dry ponds. *Environmental Progress & Sustainable Energy,* 29: 319-333.

Huang, C.P., Wang, H.W., & Chiu, P.U. (1998). Nitrate reduction by metallic iron. *Water Research*, 32, 2257-2264.

Jette, M.S.M., Logemann, S., Muyzer, G.M., Robertson, L.A., De Vries, S., Van Loosdrecht, M.C.M., & Kuenen, J. G. (1997). Novel principles in the microbial conversion of nitrogen compounds. *Antonie Van Leeuwenhoek International Journal Of General And Molecular Microbiology*, *71,*75-93.

Kadlec, R., & Wallace, S. (2009). *Treatment wetlands*. Secound edition, CRC Press, Boca Raton, Florida.

Kadlec, R.H., & Knight, R. L. (1996). *Treatment Wetland* (1st ed). CRC Press, Boca Raton. Florida.

Kavanagh, L. J., & Keller, J. (2007). Engineered ecosystem for sustainable on-site wastewater treatment. *Water Research*, *41*(8), 1823–1831.

Keizer-vlek, H. E., Verdonschot, P. F. M., Verdonschot, R. C. M., & Dekkers, D. (2014). The contribution of plant uptake to nutrient removal by fl oating treatment wetlands. *Ecological Engineering*, *73*, 684–690.

Kim-Shapiro, D.B., Gladwin, M.T., Patel, R.P., & Hogg, N. (2005). The reaction between nitrite and hemoglobin: the role of nitrite in hemoglobin-mediated hypoxic vasodilation. *Journal of Inorganic Biochem, 99, 237-26.*

Knox, A. S., Dunn, D., Nelson, E., Specht, W., & Paller, M. & Seaman, J. (2004). Metals Retention in Constructed Wetland Sediments, Report WSRC-MS-2004, Oak Ridg, Tennesse (865).

Kyambadde, J., Kansiime, F., Gumaelius, L., Dalhammer, G., (2004). A comparative study of *cyperus* and *Miscanthidium violaceum*- based constructed wetland for waste water treatment in Tropical climate. *Water Science 38, 475 - 485.*

Lamers, L.P.M., Falla, S.J., Samborska, E.M., Van Dulken, I.A.R., Van Hengstun, G. & Roelots, J.G.M. (2002). Factors controlling the extent of eutrophication and toxicity in sulfate-polluted freshwater wetlands. *Limnology and Oceanology*,47: 585-593.

Line, D.E., Jennings, G.D., Shaffer, M.B., Calabria, J. & Hunt, W.F. (2008). Evaluating the effectiveness of two storm water wetlands in north Carolina. American Sociaty of Agriculture and Biological Engineers, 51, 521–528.

Li, Y., & Migliaccio, K. (2010). *Water quality concepts, sampling, and analyses*. CRC Press, Boca Raton, FL, USA.

Lu, H.L., Ku, C.R., Chang, V.H., (2015). Water Quality improvement with artificial floating island. *Ecological Engineering*, *74*, 371–375.

Ma, J., Ding, Z., Wei, G., Zhao, H., & Huang, T. (2009). Sources of water pollution and evolution of water quality in the Wuwei basin of Shiyang river, Northwest China. *Journal of Environmental Management*, *90*(2), 1168–77.

Mander, U., Kuusemets, V., Oovel, M., Ihme, R., Sevola, P., & Pieterse, A. (2000). Experimentally constructed wetlands for wastewater treatment in Estonia. *Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering*, *35*(8), 1389–1401.

Masters, B. (2010). Water quality improvements from vegetated floating islands. *Environ 2010*, 1–18.

Masters, B. (2012). The ability of vegetated floating islands to improve water quality in natural and constructed wetlands: a review. *Water Practice & Technology*, *7: 1-9*.

Matheson, F. E., Nguyen, M. L., Cooper, A. B., Burt, T. P., & Bull, D. C. (2002). Fate of 15N-nitrate in unplanted- planted and harvested riparian wetland soil microcosms. *Ecological Engineering*, *19*(4), 249–264.

Mine, M.A., Sune, N., Hadad, H. & Sanchez, G. (2005). Spatial Variation of Phosphate distribution in sediment of an artificial Wetland. In Serrano L, & H.L., Golterman(eds),. In G. Serrano L, & H.L. (Ed.), *proceeding of the 4th international phosphate in sediment symposium*. Backhuys publishers, The Netherland.

Mouri, G., Takizawa, S., & Oki, T. (2011). Spatial and temporal variation in nutrient parameters in stream water in a rural-urban catchment, Shikoku, Japan: effects of land cover and human impact. *Journal of Environmental Management*, *92*(7), 1837–1848.

Mudge, S., & Duce, C. (2005). Identifying the source, transport path and sinks of sewage derived organic matter. *Environmental Pollution*,136 (2): 209-220.

Oleszkiewicz, J. (2015). Options for improved nutrient removal and recovery from municipal wastewater in Canadian context. Canadian water network. Pp 7.

Page, C.A., Bonner, J.S., McDonald, T.J., & Autenrieth, R.L. (2002). Behavior of a chemically dispersed oil in a wetland environment. *Water Research*, 36: 3821-3833.

Pant, H.K., Reddy, K.R., Lemon, E., (2001). Phosphorus retention capacity of root bed media of sub-surface flow constructed wetland. *Ecological Engineering*, 17, 345–355.

Panagopoulos, Y., Makroponlos, C., & Mimikon, M. (2011). Diffuse surface water pollution: driving factors for different geoclimatic regions. *Water Resources Management 25(14): 3635-3660.*

Paul, E.A. & Clark, F.E . (1996). *Soil micrbiology and biochemistry.* Acadamic Press, San Diego, California, 340pp.

Peirce, J.J., Vesilind, P.A., & Weiner, R.F. (1998). *Environmental pollution and control*. A Betterworth-Heinemann.

Reinsel, M.A., (2012). Floating Wetland help boost nitrogen removal in lagoons, water world. http://www.waterworld.com/articles/volume-28/issue-6.

Revitt, D.M., Worral, P., Brewer, D., (2001). The integration of Constructed wetlands into a treatment system for airport runoff. *Water Science and Technology, 44; 469 - 476.*

Reddy, K.R., & Patrick, W.H. (1984). Nitrogen transformations and loss in flooded soils and sediments. *Critical Reviews in Environmental controle* 13: 273-309.

Reddy, K. R., & D'Angelo, E. M. (1997). Biogeochemical indicators to evaluate pollutant removal efficiency in constructed wetlands. *Water Science Technology*. 35 (5): 1-10.

Rhue, R., & Harris, W.G. (1999).Phosphorous Sorption/Desorption Reactions in Soils and Sediments. In Reddy, K.R., O`conner, G.A. & Schelske, C.L. (ed) *Phosphorus Biogeochemistry of Subtrofical ecosystm*.CRC Press, Boca Raton, Florida: 187-206.

Richardson, C. J., Qian, S., Craft, C. B., & Qualls, R. G. (1996). Predictive models for phosphorus retention in wetlands. *Wetlands Ecology and Management*, *4*(3), 159–175.

Sawyer, C.N., McCarty, P.L., & Parkin, G.F. (2003). Chemistry for Environmental Engineering and Science(5th ed). McGrawHill. *New York*.

Schindler, D. W., Hecky, R. E., Findlay, D. L., Stainton, M. P., Parker, B. R., Paterson, M. J., Beaty, K.G. & Kasian, S. E. M. (2008). Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-years whole-ecosystem experiment. *Proceedings of the National Academy of Sciences*, *105*(32), 11254–11258.

Schmidt, I., Sliekers, O., Schmid, M., Bock, E., Fuerst, J., Kuenen, J. G., Strous, M. (2003). New concepts of microbial treatment processes for the nitrogen removal in wastewater. *FEMS Microbiology Reviews*, *27*(4), 481–492.

Schulz, R., & Peall, S.K.C. (2001). Effectiveness of a constructed wetland for retention of nonpoint-source pesticide pollution in the Lourens River catchment, South Africa. *Environmental Science & Technology*, 35: 422-426.

Servizi, J.A., & Gordon, R.W. (1990). Acute lethal toxicity of ammonia and suspended sediment mixtures to chinook salmon (Oncorhynchus tshawytscha). *Bulletin of Environmental Contamination and Toxicology,* 44, 650-656.

Shammas, N.K., Liu, Y., & Wang, L.K. (2009). *Principles and kinetics of biological processes*. In Wang, L.K., Shammas, N.K., & Hung, Y.T. (ed) Advance biological treatment process. Humana press, New Yourk. USA.

Silva Alves, R. I., Oliveira Caradoso, O., Abreu Tonani, K. A., Julião, F.C., Trevilato, T.M.B., and Muñoz, S. I. (2013). Water quality of the Ribeirão Preto Stream, a watercourse under anthropogenic influence in the southeast of Brazil. *Environmental Monitoring and Assessment*, 2(185), 1151–1161.

Sim, H. C. (2003). The use of constructed wetlands for wastewater treatment for waste water treatment. Wetland International, Selangor, Malaysia.

Sim, H.C., Yusoff, M.K., Shutes, B., Ho, S.C., Mansor, M. (2007) Nutrient removal in a pilot and full scale constructed wetland. Putrajaya city, Malaysia. *Journal of Environmental Management. 88, 307 – 317.*

Sooknah, R.D., & Wilkie, A. C. (2004). Nutrient removal by floating aquatic macrophytes cultured in anaerobically digested flushed dairy manure wastewater. *Ecological Engineering*, *22*(1), 27-42.

Stewart, F. (2007). *Biomimetic floating islands that maximize plant and microbial synergistic relationship to revitalize degraded fisheries, wildlife habitats, and human water resources.* Final report to Montana Board of Research and Commercialization Technology. Floating Island International, pp4.

Stewart, F. M., Mulholland, T., Cunningham, A. B., Bruce, G., Kania, B. G., & Osterlund, M. T. (2008). Floating islands as an alternative to constructed wetlands for treatment of excess nutrients from agricultural and municipal wastes - results of laboratory-scale tests. *Land Contamination & Reclamation*, *16*(1), 25–33.

Suratmans, S., Awang, M., Loh, A.L., & Muh`d Tahir, N. (2009). Water quality index study in Paka River basin, Terengganu (Malaysia). *Sains Malaysiana, 38, 125-131.*

Suratman, S., Muh`d Sultan, M.I., Hee, Y.Y., Bedurus, E.A., & Latif, M.T. (2015). *A* Priliminary study of Water quality index in Terengganu River basin (Malaysia). *Sains Malaysiana, 44 (1): 67-73.*

Svengsouk, L.J., & Mitsch, W.J. (2001). Dynamics of mixtures of Typha latifolia and Schoenoplectus tabernaemontani in nutrient-enrichment wetland experiments. *The American Midland Naturalist*.145: 309-324.

Tanner, C. C., & Headley, T. R. (2011). Components of floating emergent macrophyte treatment wetlands influencing removal of stormwater pollutants. *Ecological Engineering*, *37*(3), 474–486.

Tanner, C. C., Kadlec, R. H., Gibbs, M. M., Sukias, J. P. S., & Nguyen, M. L. (2002). Nitrogen processing gradients in subsurface-flow treatment wetlands - Influence of wastewater characteristics. *Ecological Engineering*, *18*(4), 499–520.

Tarazona, J.V., Munoz, M.J., Ortiz, J.A., Nunez, M.O. & Camargo, J.A. (2008). Fish mortality due to acute ammonia exposure. *Aquaculture Research,* 18, 167-172.

Taylor, C.R., Hook, P.B., Stein, O.R., & Zabinski, C.A. (2011). Seasonal effects of 19 plant species on COD removal in subsurface treatment wetland microcosms. *Ecological Engineering*.121: 4 01-406.

Van De Moortel, A. M. K., Meers, E., De Pauw, N., & Tack, F. M. G. (2010). Effects of vegetation, season and temperature on the removal of pollutants in experimental floating treatment wetlands. *Water, Air, and Soil Pollution*, *212*(1-4), 281–297.

Vogel, J.A. (2011). The Effects of Artificial Floating Wetland Island Construction Materials on Plant Biomass. University of South Florida, st. Peterburg, pp131.

Vymazal, J. (1995). *Algae and element cycling in wetlands.* CRC Press,Lewis Publishers, Boca Raton, Florida.

Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands. *Science of the Total Environment*, *380*(1-3), 48–65.

Vymazal, J. (2009). *Water and Nutrient Management in Natural and Constructed Wetlands*. Springer Dordrecht Heidelberg, London.

Vymazal, J. (2001). Transformations of nutrients in natural and constructed wetlands | Clc. Backhuys publishers, The Netherland.

Wanielista, M.P., Chang, N.B., Xuang, M.C.Z., Islam, K. & Marimon, Z. (2012). Floating Wetland Systems for Nutrient Removal in Stormwater Ponds. Storm water management academy. Civil, environmental & construction eng, University of central Florida, Orlando.

Weragoda, S. K., Jinadasa, K. B. S. N., Zhang, D. Q., Gersberg, R. M., Tan, S. K., Tanaka, N., & Jern, N. W. (2012). Tropical Application of Floating Treatment Wetlands. *Wetlands*, *32*(5), 955–961.

Wetzel, R. G. (2001). The Phosphorus Cycle. *Limnology: Lake and River Ecosystems*, 242–50. San Diego Academic press.

Whitton, B.A., & Potts, M. (2002). The ecology of cyanobacteria. their diversity in time and space. (Whitton,B.A and Potts,M.(Ed.))klewer Acadamic publishers (Vol. 1). Klewer Acadamic publishers, New york, 669pp.

White, S. A., & Cousins, M. M. (2013). Floating treatment wetland aided remediation of nitrogen and phosphorus from simulated stormwater runoff. *Ecological Engineering*, *61*, 207–215.

WHO (1993). *Guidelines for drinking Water quality. Recommendations, volume 1 (2nd ed),* World Health Organisation, Geneva, 188pp.

Wickham, J.O., O'Neill, R.V., Riitter, K.H., Smith, E.R., Wade, T.G. & Jones, K.B. (2002). Geographic targeting of increases in nutrient export due to future urbanization. *Ecological Application, 12*(1), 93–106.

Wood, T. S., & Shelley, M. L. (1999). A dynamic model of bioavailability of metals in constructed wetland sediments. *Ecological Engineering*, *12*(3-4), 231–252.

Wu, W., Song, X., Jin, Q., Ying, H., & Zou, G. (2000). Study on soilless cuture of *Canna* on fish pond. *Chinese Journal of Applied and Environmental Biology ,*6: 206-210.

Yang, Z., Zheng, S., Chen, J., & Sun, M. (2008). Purification of nitrate-rich agricultural runoff by a hydroponic system. *Bioresource Technology*, *99*(17), 8049–8053.

Yin Wang, Z., Lee, J.H.W. & Melching, C. S. (2015). *River Dynamics and Integrated River Management*. Tsinghua University Press, Beijing & Springer Verlag Berling Heidelberg.

Zeller, N.S. (2006). *Floating Islands – an Innovative Natural Treatment System for Enhanced Wastewater* through lagoons.

Zhu, J., Hu, W., Hu, L., Deng, J., Li, Q., & Gao, F. (2012). Variation in the efficiency of nutrient removal in a pilot-scale natural wetland. *Wetlands*. 32: 311-319. Retrieved from http://link.springer.com