RESTORATIVE POTENTIAL OF AN IN-CAMPUS ECOLOGICAL WETLAND: BIODIVERSITY AND WATER QUALITY ASSESSMENT

by

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APPROVAL PAGE

This is to certify that I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation submitted in partial fulfillment for the degree of Bachelor of Health Sciences (Hons) (Environmental and Occupational Health).

DECLARATION PAGE

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS

AN	Ammonical Nitrogen
APHA	American Public Health Association
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CW	Constructed wetlands
DID	Drainage and Irrigation Department
DO	Dissolve Oxygen
DOE	Department of Environment
EPA	Environmental Protection Agency
et al.	Et alia (and others)
FWS	Free Water Surface
HFS	Horizontal Flow System
HRT	Hydraulic Retention Time
HTC	Humid Tropic Centre
INWQS	Interim National Water Quality Standard for Malaysia
MSMA SME	Manual Mesra Alam Stormwater Management Ecohydrology
NAHRIM	National Hydraulic Research Institute of Malaysia
NAHRIM	National Hydraulic Research Institute of Malaysia
OSD	On-Site Stormwater Detention
R&D	Research and Development
SF	Surface Flow
SI	Sub-Indices
SS	Suspended Solids
SSF	Subsurface Flow
TDS	Total Dissolved Solid
TKN	Total Kjehldahl Nitrogen
TNB	Tenaga Nasional Berhad
TSS	Total Suspended Solids
UNEP	United Nations Environment Programme
UNEP	United Nations Environment Programme
USEPA	United State Environmental Protection Agency
USM	Universiti Sains Malaysia
UV	Ultra-Violet
VFS	Vertical Flow System
WERF	Water Environment Research Foundation
WQI	Water Quality Index
a.m.	Ante Meridiem
cm	Centimetres
ex:	Example
ha	Hectare

km	Kilometres
L	Litters
mg/L	Milligram per Litter
ml	Millilitres
mm	Millimetre
m	Meter
m^2	Meter square
m^3	Meter cubic
p.m.	Post Meridiem
%	Percentage
<	Less than
>	More than
$^{\circ}C$	Degree Celsius
μm	Micrometre

POTENSI PEMULIHAN EKOLOGI TANAH LEMBAB BUATAN: BIODIVERSITI DAN PENILAIAN KUALITI AIR

ABSTRAK

Tanah lembap buatan adalah ekologi tanah lembap direkabentuk untuk menyingkirkan pelbagai bahan pencemar dalam sisitem air semula jadi, dan meningkatkan kepelbagaian biodiversiti pada ekosistem. Kajian ini dijalankan dari Disember 2013 hingga Februari 2014 untuk memeriksa potensi ekologi tanah lembap dalam kampus untuk peningkatan kualiti air dan pemuliharaan biodiversiti. Persampelan kualiti air telah dijalankan secara terus dan analisis di makmal, manakala potensi pemuliharaan biodiversiti dilakukan dengan cara pemantauan dan mengenal pasti burung , tumbuhan, ikan dan fitoplankton. Keputusan menunjukkan bahawa kualiti air yang dilepasankan ke Sungai Kerian dikelaskan kepada kelas I atau kelas II di mana sesuai untuk spesies akuatik sensitif. Kajian ini mendedahkan bahawa tanah lembap buatan menyingkirkan 63.29%, 59,19%, 30.84% dan 24.28% daripada jumlah pepejal terampai (TSS), nitrogen ammonia (AN), permintaan oksigen biokimia (BOD_5) dan keperluan oksigen kimia (COD). Nilai kualiti indeks air (WQI) menunjukkan bahawa prestasi untuk peningkatan kualiti air mengikut musim kering > musim pertengahan > musim hujan. Enam spesies tumbuhan telah dikenalpasti di tanah lembap buatan. *Lepironia articulata* > *Phragmites Karka* > *Scirpus grossus* > *Eleocharis variegata* > *Typha angustifolia* > *Hanguana malayana*, dengan pengagihan sebanyak 45%, 25 %, 15 %, 7 %, 6%, dan 2% untuk setiap spesis. Dua puluh satu spesies burung daripada 12 keluarga yang berbeza telah dikenal pasti. Lapan kelas fitoplankton ditemui, dengan *Chlorophyceae* > *Cyanophyceae* > *Zygnematophyceae* > *Zygnemophyceae* > *Scenedesmaceae* > *Coscinodiscaeae* > *Bacillariophyceae* > *Tribonemataceae* dengan taburan 35%, 27%, 11%, 8%, 7%, 5%, 4% dan 3% untuk setiap kelas. Sembilan spesies ikan yang ditemui, dengan komposisi tertinggi ialah *Oreochromis niloticus*, yang menyumbang sebanyak 27.27% kawasan tanah lembap buatan. Spesies yang terendah adalah *Channa striata* dan *pangasius* spp., sebanyak 2.27% daripada keseluruhan spesies ikan. Banyak spesies ikan dijumpai di micropool. Kajian ini membuktikan bahawa tanah lembab buatan dalam kampus adalah sesuai untuk rawatan air dan pemuliharaan biodiversiti.

RESTORATIVE POTENTIAL OF AN IN-CAMPUS ECOLOGICAL WETLAND: BIODIVERSITY AND WATER QUALITY ASSESSMENT

ABSTRACT

Constructed wetlands are ecological wetlands designed for the removal of a wide range of pollutants in the natural water bodies, and enhance the abundance of biodiversity on the ecosystem. This study was conducted from December 2013 till February 2014 to examine the potential ecological wetland in in-campus for water quality improvement and biodiversity conservation. Water quality samplings were carried out via in-situ and lab analysis, while the potential for biodiversity conservation was evaluated by on-site monitoring and identification of bird, plants, fish and phytoplankton. Results showed that the water quality discharge to the Kerian River was classified into class I or class II classification that is suitable for sensitive aquatic species. Result revealed that the constructed wetland removed approximately 63.29%,59.19%, 30.84% and 24.28% of the total suspended solid (TSS), ammonical nitrogen (AN), biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD), respectively. The value of water quality index (WQI) indicated that the performance for water quality improvement followed the order dry season> wet-dry season > wet season. Six plant species were identified on the constructed wetland, *Lepironia articulata*> *Phragmites karka*> *Scirpus grossus*> *Eleocharis variegata*> *Typha angustifolia*> *Hanguana malayana*, with the distribution of 45%, 25%, 15%, 7%, 6%, and 2%, respectively. Twenty-one bird species from 12 different families were identified. Eight classes of phytoplankton was found, with order *Chlorophyceae*> *Cyanophyceae*> *Zygnematophyceae*> *Zygnemophyceae*> *Scenedesmaceae*> *Coscinodiscaeae*> *Bacillariophyceae*> *Tribonemataceae*, and distributions of 35%, 27%, 11%, 8%, 7%, 5%, 4% and 3%, respectively. Nine fish species was found, with the highest composition of *Oreochromis niloticus*, which constituted 27.27% of constructed wetland. The lowest species was *Channa striata* and *Pangasius* spp., with 2.27% of the fish species. These fish species were abundantly found at the micropool. This study proved that the in-campus constructed wetland is suitable for the water treatment and biodiversity conservation.

CHAPTER ONE

INTRODUCTION

1.1 The concept of ecological wetland

Wetlands are transitional environments between dry land and open water. In an ecological context, wetlands are intermediate between terrestrial and aquatic ecosystems. Wetland is one of the most important ecosystems on earth and is described as 'kidneys of the earth', because it provides many ecological functions such as cleaning the atmosphere, improving water quality, adjusting the floodwaters, recharging groundwater aquifers, protecting shorelines and provides various important habitats for wildlife, especially for threatened and endangered species. Wetlands are critical for species conservation, biogeochemical cycling as well as hydrological management, although they occupy only 6–8 % of the Earth's surface (Ma et al., 2012). Purposefully planned, designed and operated human-made wetlands may provide a range of services well beyond the primary aim for their construction. Ancillary benefits of wastewater treatment wetlands may include, for instance, provision of habitat and wildlife diversity, support of recreational activities such as walking, bird and wildlife watching, water storage during periods of shortage and excess and aesthetic value in urban environments (Andrea et al., 2009).

In recent years, the selection of treatment methods for wastewater discharge from both municipalities and industrial sources has opened wider options to include natural and constructed wetlands (Wang et al., 2009). Wetland ecosystem is one the most productive and most diverse ecosystems (Ma et al., 2012). The increasing capital and operation costs associated with modern mechanical treatment processes are a major driving force that calls for rethinking of using natural systems to solve river pollution problems. Constructed wetlands are "designed and man made complex of saturated substrates, emergent and submergent vegetation, animal life, and water that simulates natural wetlands for human use and benefits" (Idris et al., 2010).

Constructed wetlands are considered to be a low-cost system for treating wastewater discharged from municipal, agricultural, and industrial sources. A schematic process flow for a constructed wetland system is shown in Figure 1 (Idris et al., 2012). Constructed wetlands represent an emerging eco-technological treatment system in which they are designed to overcome the disadvantages of natural wetlands (Vymazal, 2013). They have the qualities of reliability, cost effectiveness, and versatility on top of the conventional engineering measures. Constructed wetlands have a great potential in treating wastewater as they can tolerate higher organic loading rate and shorter hydraulic retention time (HRT) (Wang et al., 2009). In addition, they also have the capability of treating more than one type of pollutants simultaneously to some satisfactory levels as compared to other conventional treatment systems. Constructed wetlands can be created from existing marshlands or built at any land with limited alternative uses (Idris et al., 2012).

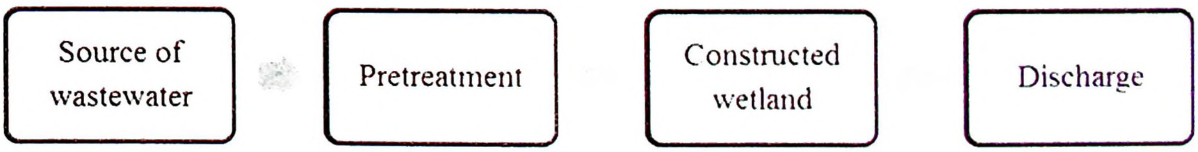

Figure 1.1: The schematic process flow of a constructed wetland system (Idris et al., 2012)

1.2 The progress of ecological wetland in Malaysia

Wetlands are transitional areas between land and water. The boundaries between wetlands and uplands or deep water are, therefore, not always distinct. The term "wetlands" encompasses a broad range of wet environments, including marshes, bogs, swamps, wet meadows, tidal wetlands, floodplains, and ribbon (riparian) wetlands along stream channels. All wetlands (natural or constructed) have one characteristic in common, i.e., the presence of surface or near-surface water, at least periodically (Idris et al., 2010). In most wetlands, hydrologic conditions are such that the substrate is saturated long enough during the growing season to create oxygen-poor conditions in the substrate. The lack of oxygen creates oxygen poor conditions within the substrate and limits the vegetation to those species that are adapted to low-oxygen environments (Wang et al., 2009).

Wetlands contribute significantly to the economy of Malaysia, firstly through agricultural production, forestry and fisheries; second, and increasingly, for water supply (for domestic use as well as for irrigation). Other economic and ecological benefits of wetlands include groundwater replenishment, maintenance of water tables for agriculture, flood control, shoreline protection and stabilization, climate change mitigation, sediment and nutrient retention, water purification and habitats for biodiversity. Tourism in wetlands is also becoming increasingly important (Shukor, 2002). Constructed wetlands are wetlands that are artificially created or modified by humans. If designed well, these wetlands can be very nice and useful. The vegetation and soil can work as a natural filter and in that way the wetland can help to improve the quality of the in and out flowing water. This use of constructed wetlands for water quality improvement is being recognized all over the world due to growing demands to reuse water and the need to compensate for the loss of natural wetlands (Shutes, 2001). Constructed wetlands can also play an important role in the storage of water. During heavy rainfall and storms, wetlands can help to store the extra water, thereby preventing or reducing (the impact of) flooding. In addition to water purification and storage, constructed wetland also signifies the aesthetic value and can serve as a home for birds and other wildlife. High biodiversity values can make them valuable sites for nature education and research (Islam & Kitazawa, 2013).

In Malaysia, constructed wetlands are gaining popularity for the treatment and storage of storm waters, urban runoffs and agricultural effluents and also because they provide pleasant surroundings to live and work in. There a few constructed wetlands such as in Putrajaya, Kota Kemuning, National Hydraulic Research Institute of Malaysia (NAHRIM), Humid Tropic Centre (HTC), and an on campus constructed wetland at Universiti Sains Malaysia (USM), Penang. Firstly, constructed wetland for wastewater treatment was located in Putrajaya. The use of constructed wetlands started in Malaysia in 1999 with the creation of the 200 hectares of the Putrajaya Wetlands at the seat of the administrative capital of Malaysia which is believed to be one of the largest constructed freshwater wetlands in the tropics (USEPA, 2000).

Putrajaya Wetlands is considered a pioneer venture in constructed wetland treatment system in Malaysia (Khor, 2002). Wetlands International-Malaysia Office was engaged as the technical and scientific advisor to the Putrajaya project especially on the biological aspects of plant selection, fish stocking, water quality monitoring and some aspects of engineering and hydrology (Khor, 2002). Putrajaya has international networks and have ready access to pool of international specialists with various expertise on wetlands where by a pollution control specialist and wetland botanist were once called upon to assist in the Putrajaya wetlands project (Cheng et al., 2008). Putrajaya Wetlands about 200 ha constructed wetland system consisting of 24 cells, was created from 1997–1998 to treat surface runoff caused by development and agricultural activities from an upstream catchment before entering Putrajaya lake (400 ha) (Idris et al., 2010). It was designed for stormwater treatment, flood control and amenity use. Putrajaya Wetlands were created in the valley of the Chuau and Bisa Rivers from agricultural lands of oil palm and rubber plantations, within a period of 17.5 months in 1997 and 1998. The wetland system and lake were fully inundated in January 1999 (Idris et al., 2010). The wetlands were created mainly to restore the The polluted Chuau and Bisa river systems caused by agricultural activities in the upstream catchment; and also to play a role in stormwater treatment and flood control. Putrajaya wetlands are a vegetated horizontal surface flow multi-cell wetland system, designed with different water levels in each of the cells that are separated by a weir (Ariffin, 1998).

Water flows through these wetland cells and finally discharges into Putrajaya Lake (Plate 1). The wetland cells were planted with 27 types of emergent wetland plants, such as Common Reed *Phragmites karka* and the Tube *Sedgewhich lepironia articulata* play a role in sediment retention and in nutrient and toxicant removal. Another 35 species of herbaceous plants were planted in the zone of intermittent inundation fringing the marsh area as a border of the wetland system, and these species assist in erosion control and bank stabilization (Cheng et al., 2008).

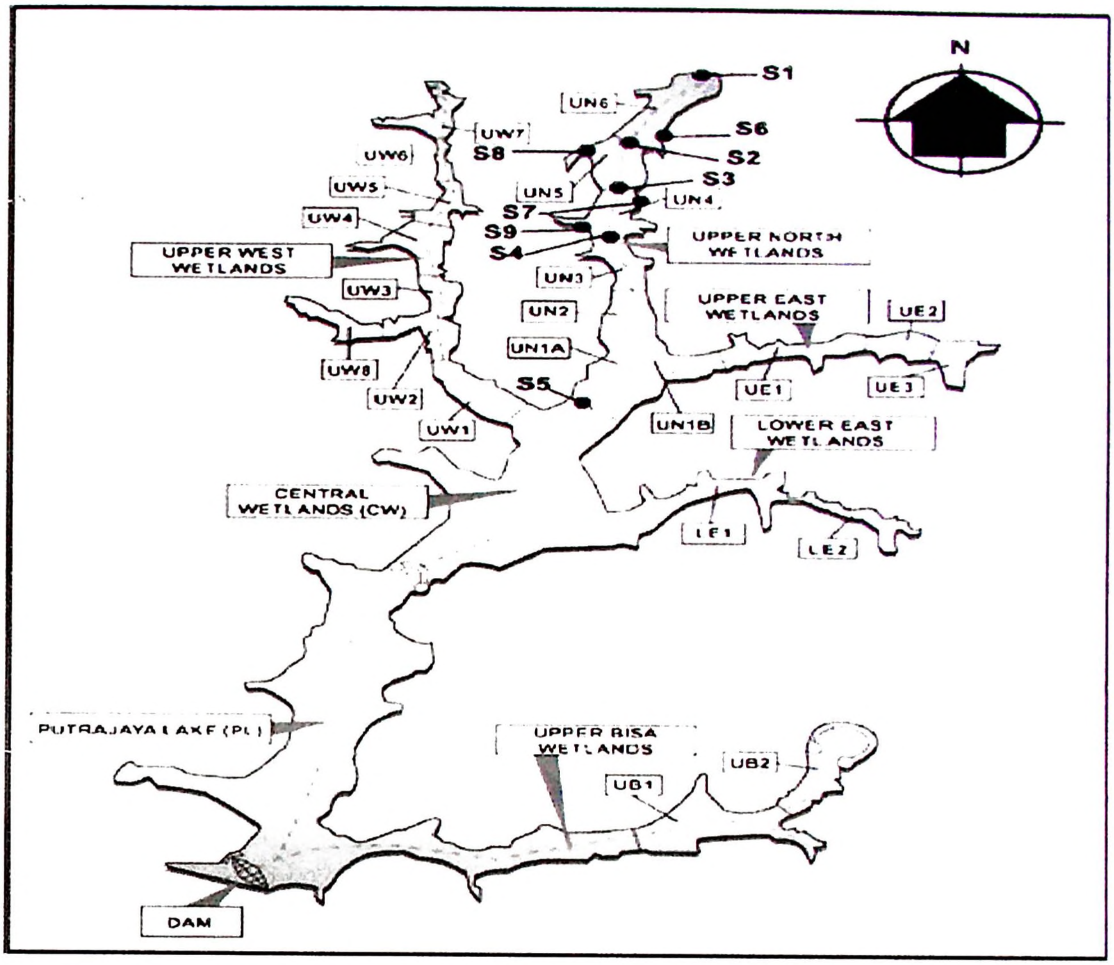

Plate 1.1: Putrajaya Lake and Wetland system, Malaysia (Ariffin, 1998)

Twenty two small islands were created in open water areas, which are vegetated and provide isolated habitats for birds and other fauna. These islands also serve to facilitate water filtration, divert water flow to avoid stagnation and help in the flow to the fringes of wetland cells (especially the planting areas). The system that found on Putrajaya is to increase the availability of water quality treatment and biodiversity conservation (Table 1.1). The ornamental ponds were planted with colourful flower species, such as water lilies, to increase their aesthetic value. These wetland plants were sourced locally and they possess high adaptability conditions of intermittent Inundation (Cheng et al., 2008).

Table 1.1: Location of the six wetland systems, size and storage capacity on Putrajaya wetlands (Khor, 2002).

Wetland system	Upper north	Upper west	Upper east	Lower east	Central Wetlands
Catchment Area (Km^3)	11.54	5.53	3.34	1.73	24.7
Wetland Area (hectares)	54.1	38.5	15.8	14.3	50.9
Wetland Inundated Area (hectares)	38.3	27.0	10.8	9.5	48.3

Kota Kemuning Wetland was created from an existing low-lying water logged area gazetted as reserve land belonging to Tenaga Nasional Berhad (TNB), the Drainage and Irrigation Department (DID) and Kesas Highway. It is a long narrow strip of wetland, covering an area of 8.8 ha. It is situated near the main entrance of the Kota Kemuning Township and Kesas Highway (Wetlands International, 2007). The creation of the wetland was started in June 2002 and it was completed early September 2003. The main purpose of this man-made wetland is to provide a solution for drainage problems occurring in this low-lying area. The wetland receives a large volume of stormwater from its catchment area. The wetlands and rooted vegetation function as pollutant filter, sediment trap and ensure the uptake of nutrients while dissipating water velocity before it is discharged into Klang River. The wetland also controls the occurrence of flash floods due to backflow from the Klang River during heavy downpour (Wetlands International, 2012). A total of 157 thousand local indigenous wetland plants belonging to 15 species have been introduced to the wetland. These include 13 marsh species and 2 ornamental species. The marsh species are important in nutrient removal and in preventing the wetland from eutrophication. These plants are hardy and can withstand long periods of waterlogged and eutrophic conditions. A total of 31 species of shrub and woodland species have been planted at the wetland fringes to create a buffer from human activities and to increase aesthetic values to the area (Wetlands International, 2007). In urban stormwater management systems, the stormwater quantity facilities can be classified by function as either detention or retention facilities.

The detention concept is most often employed to limit the peak outflow rate for a specific range of flood frequencies to that which existed from the same catchment before development (Zainal Abidin & Hassan, 2003). The primary function of detention facilities is to reduce peak discharge by temporary storage and gradual release of stormwater runoff by way of an outlet control structure or other release mechanism. Retention facilities reduce runoff volume and peak discharge by the temporary storage of stormwater runoff, which is subsequently release via evaporation and infiltration only (Zainal Abidin & Hassan, 2003).

Recently in April 2004, a mini wet pond was constructed by National Hydraulic Research Institute of Malaysia (NAHRIM), at the National School Section 2 Puchong, Selangor for research work to control the quantity of water at the source, for water quality monitoring and for the school co-curriculum activities. The mini wet pond area provide educational and some recreational benefits. It has a high visual appeal, and adds to the natural landscape (Zainal Abidin & Hassan, 2003). The concept of mini wetlands cum OSD constructed by NAHRIM in the school is to provide certain views and opportunities for students to learn and experience the richness of the natural habitat of wetland (Zainal Abidin & Hassan, 2003). Generally, the wetland is an example of a rich ecosystem. It is a natural filtration system in removing nutrients and pollutants by using a variety of aquatic plants (Zainal Abidin & Hassan, 2003). This mini wet pond is classified as an on-site storage (small storages constructed on public area) with off-line storage facilities that intercept flow from a conveyance system and functions as a detention pond i.e. the on-site stormwater detention (OSD) (Wetlands International, 2007).

The concept of wetland is included in the construction of the OSD. With these broad objectives in mind, one of the R&D project carried out by NAHRIM is in the design and construction of mini wetland cum OSD pond. The objectives include carrying out research on suitability of mini constructed wetlands; on to reduce flow from developed area (i.e. school), to promote ecological environment in school compound, and to be part of the landscape enhancement area (Wetlands International, 2007). In Malaysia, constructed wetland has been suggested in Manual Mesra Alam Stormwater Management Ecohydrology (MSMA SME). The site is located at Humid Tropic centre (HTC) Jalan Redang Kuala Lumpur, near to the DID

Headquarters, Kuala Lumpur. Below are the criteria of HTC (Mohd Noor et al., 2012). The number of plant species that might be suitable for treatment wetland is large and evaluation studies are a few to date. Species of choice are certain to vary with the design and purpose of the wetland and with the inflowing water quality. Water plays a major reason why macrophytes do not become well established in constructed wetland (Mitch and Gosselink, 2000). Constructed wetland intend to imitate the function of natural wetland which can effectively remove larger quantities of pollutant using natural filtration, sedimentation and other processes of the wetland plants through absorption and assimilation (Mohd Noor et al., 2012). Basically constructed wetland should consist of vegetation that can adapt to the local climate and soil, tolerate pollutants in water or wastewater, with higher biomass production and rapid growth and avoid the usage of noxious species such as *Mimosa pigra, Eichornia crassipes and Limnocharis flava* (Mohd Noor et al., 2012). The design criteria that had been used by HTC is important for the suitability on maintaining the function of wetland itself (Table 1.2). The selection of species is varying with the design and purpose of the wetland, and with the inflowing water quality (Mitch and Gosselink, 2000).

Water plays a major reason why macrophytes do not become well established in constructed wetland. When the plants are first establishing themselves, the optimum condition are moist soil or very shallow (<5 cm) water depth. If the water is too deep, the new macrophytes will be flooded out. If there is inadequate water and topsoil dries out, the macrophytes will not survive. Macrophytes species that planted in HTC constructed wetland are Hanguana malayana, Phragmites karka, Lepironia articulata and Typha latifolia (Mohd Noor et al., 2012). The summary about the constructed wetland that found on Malaysia and the basic characteristic that found on USM constructed wetland (Table 1.3).

Table 1.2: Design criteria for Humid Tropic Centre constructed wetland (Mohd Noor et al. 2012)

Catchment area	5,800 m^2
Length	41 m
Width	14 m
Wetland surface area	574 m^2
Volume	355.73 m^3
Depth:	
Forebay / Pool	1.2 m
Low Marsh	0 m – 0.3 m
High Marsh	0.6 m – 1.0 m
Micro Pool	1.8 m
Mean residence time (d)	1.2
Bed depth	0.6 m

Table 1.3: Summary constructed wetlands in Malaysia

Name	Location	Area (ha)	Reference
Wetland park	Putrajaya . Wilayah Perseketuan	200	Perbadanan Putrajaya, (2006)
Kota Kemuning Wetland	Kota Kemuning, Selangor	8.8	Wetlands International Malaysia, (2007)
NAHRIM (National Hydraulic Research Institute of Malaysia)	Seri Kembangan, Selangor	0.0012	Ministry Of Natural Resources And Environment, (2013)
Humid Tropic Centre (HTC)	Jalan Redang, Kuala Lumpur	0.0005	Mohd Noor et al., (2012)
USM Constructed wetland	Nibong Tebal, Penang	121.4	Zakaria et al., (2003)

1.3 Problem statement

Wetlands are located between the dry terrestrial systems and permanent flooded deep water aquatic systems such as rivers, lakes, estuaries and coastal zone. Wetlands are very important and productive ecosystems; and play an important role for the environment sustainability such as regulating water level within watershed, help to improve water quality level, control and reduce flood and storm damage and provide healthy habitat for wildlife to live (Cheng et al., 2008). Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (USEPA, 2004). Constructed wetlands are artificial wetlands designed to intercept wastewater and remove a wide range of pollutants before discharged into natural water bodies (Kadlec and Wallace, 2008). Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Wetlands are found from the tundra to the tropics and on every continent except Antarctica (USEPA, 2004). The value of a wetland is an estimate of the importance or worth of one or more of its functions to society; for example, a value can be determined by the revenue generated from the sale of fish that depends on the wetland, by the tourist dollars associated with the wetland, or by public support for protecting fish and wildlife (USEPA, 2001).Constructed wetlands are wastewater treatment systems composed of one or more treatment cells in a built and partially controlled environment, designed and constructed to provide wastewater treatment (USEPA, 2000). While constructed wetlands have been used to treat many types of wastewater at various levels of treatment, the constructed wetlands provide treatments to municipal wastewater. These are treatment systems that receive primary effluent and treat it to secondary effluent standards or better, in contrast to enhancement systems or polishing wetlands, which receives secondary effluent and treat it further prior to discharge to the environment. Constructed wetlands provide secondary treatment in a community's wastewater treatment system; this technology also can be used in combination with other secondary treatment technologies (Figure 1.2).

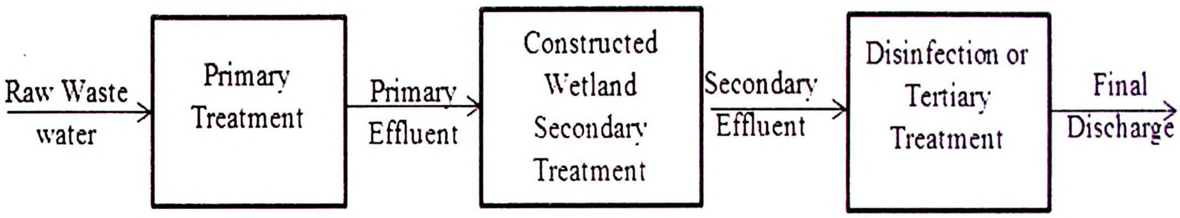

Figure 1.2: Constructed wetlands in wastewater treatment train (USEPA, 2000)

Constructed wetland could be placed upstream in the treatment train from an infiltration system to optimize the cost of secondary treatment. In other uses, constructed wetlands could discharge secondary effluent to enhancement wetlands for polishing. Constructed wetlands are not recommended for treatment of raw wastewater (USEPA, 2000). Figure 1.2 portrays a hypothetical wastewater treatment train utilizing constructed wetlands in series. Constructed wetlands are highly complex systems that separate and transform contaminants by physical, chemical, and biological mechanisms that may occur simultaneously or sequentially as the wastewater flows through the system (USEPA, 2000). Researchers have demonstrated that constructed wetlands are effective for the on site management of municipal and agricultural wastewater and can remove various nutrients, including total suspended solids (TSS), bio logical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen, phosphorus, trace elements, and microorganisms contained in the wastewater (Mitsch and Gosselink, 2007; Kadlec and Wallace, 2008). The treatment of wastewater using constructed wetland is one of the treatment systems which are used in many parts of the world. This system seems to have the potential to be one of the solutions to discharge huge amount of waste and getting access to safer drinking water. Along with treating wastewater, there is an increasing trend in designing constructed wetlands to restore degraded habitats for wildlife (Verhoeven et al., 2006). Wetlands are well known as one of the most productive ecosystems in the world (Mitsch and Gosselink, 2007). Countless species of birds, mammals, reptiles, amphibians, fishes, and invertebrates depend on the water and vegetation in wetland habitats (Mitsch and Gosselink, 2007; Kadlec and Wallace, 2008). Based on the study by Zedler, (2003) &Hansson et al., (2005), a positive relationship between the area of a constructed wetland and the biodiversity and abundance of birds, which is in accordance with other studies on wetlands was suggested. In addition to wetland area, bird biodiversity was found to be affected by adjacent and regional land uses, such as road density and connectedness (Amezaga & Santamaría, 2000). In the study conducted by Shiu et al., (2005) the authorsuggested that bird communities were mainly determined by seasonal patterns, as well as food availability and nesting requirements for brood rearing.

Members of the *Ardeidae* such as Little Egrets and Black-crowned Night Herons, and the *Recurvirostridae* like Black-winged Stilts were found to be associated with the species richness and abundance of fishes. Study by Hansson et al., (2005) showed that fish biodiversity was low in these young (<5 years) constructed wetlands and Hansson et al., (2005) found similar results and indicated that natural wetlands aged more than 100 years showed considerably higher fish species richness than young constructed wetlands. In constructed wetlands, possible sources of the fish are limited to those from nearby streams during floods and mercy releases, and, therefore, the biodiversity of fish is unlikely to increase over a short time period. Gee et al. (1997) suggest close relationships of the richness and density of aquatic macro invertebrates with the coverage of aquatic macrophytes. The abundance and diversity of aquatic invertebrates were found to be associated with the vegetated area of wetlands. In South East Asia, limited study was conducted on constructed or natural wetland to show the effectiveness of wetland in south east. The main purpose to conduct this study is to ensure the water quality discharged to the Kerian River is in appropriate quality level and also to understand restorative potential of constructed wetland in aspect of biodiversity towards nature such as plants, phytoplankton, fish and birds.

1.4 Research objectives

1.4.1 General

To examine the restorative potential of constructed wetlands for Water Quality (WQ) improvement and biodiversity conservation.

1.4.2 Specific

1. To evaluate the feasibility of ecological wetland for the improvement of biochemical oxygen demand (BOD_5), chemical oxygen demand, pH, temperature, total suspended solid, ammonical nitrogen and dissolve oxygen.
2. To identify the diversity of plants species in the constructed wetland.
3. To examine the unique function of ecological wetland to serve as the habitat for birds, fish and phytoplankton.

1.5 Research hypothesis

Hypothesis 1

H_0: There is no significant association between feasibility of ecological wetland to the improvement of biochemical oxygen demand (BOD_5), chemical oxygen demand, pH, temperature, suspended solid, ammonical nitrogen and dissolve oxygen.

H_A: There is a significant association between feasibility of ecological wetland to the improvement of biochemical oxygen demand (BOD_5), chemical oxygen demand, pH, temperature, suspended solid, ammonical nitrogen and dissolve oxygen.

Hypothesis 2

H_0: There is no significant association between identification of diversity of plants species in the constructed wetland.

H_A: There is a significant association between identification of diversity of plants species in the constructed wetland.

Hypothesis 3

H_0: There is no significant association between the unique function of ecological wetland to serve as the habitat for birds, fish and phytoplankton.

H_A: There is a significant association between the unique function of ecological wetland to serve as the habitat for birds, fish and phytoplankton.

CHAPTER TWO

LITERATURE REVIEW

2.1 Ecological wetland

Wetland is defined as the area that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil condition (Ibrahim et al., 2012). In general, wetlands mean those areas of the state that are flooded by surface or ground water with a enough characteristic to support significant vegetation or aquatic life which depends on saturated soil conditions for growth and reproduction (Idris et al., 2010). Wetland has been used for treating municipal, industrial, and mining wastewater for decades (Vymazal, 2013). Some of the wetland systems are called micro-wetlands or rock filters because they have a media filter such as a plants (Faulwetter et al., 2009), and grown to enhance treatment and create a pleasant landscape. These systems also provide safe treatment of wastewater with low maintenance. Despite the benefits and services that they provide for humans, wetlands all over the world are threatened (Schuyt, 2005). The main causes for wetland loss and degradation are human activities (e.g. sewage influx, waste dumping, intensive grazing, overharvesting, and drainage for agriculture) and climate change (Mereta et al., 2013). High population growth rate and expansion of urban and suburban areas has increased the need for more fertile agricultural land, thereby increasing the loss of wetland resources (Schuyt, 2005).

2.1.1 Definition classification, natural functions and unique value of ecological wetland

Natural wetlands are sometimes called swamps, marshes, bogs, fens, wet meadows, or sloughs. Natural wetland definitions are not necessarily the same. Plant types and species, water, and geographic conditions vary, creating different kinds of wetlands in many different countries (Idris et al., 2010). Natural wetlands are important for maintaining aquatic ecosystem biodiversity and should be considered as part of an effective ecosystem management strategy (Amezaga et al., 2002). Natural wetlands appear to perform all of the biochemical transformations of wastewater constituents that take place in conventional wastewater treatments plants, septic tanks, drain fields and other form of land treatment. Submerged and emerged plants, associated microorganisms and wetland soils are responsible for the majority of the treatment affected by the wetland. Generally, natural wetland treatment system is used to provide further treatment of secondary effluent to meet downstream water quality standard (Shutes, 2001). Natural wetland is more suitable to treat non point sources of pollution, such as urban storm water and other diffuse sources of runoff.

United Nations Environment Programme (UNEP) divided natural wetland into four major groups based on where this natural wetland occurs and they are fringe wetlands, riverine wetlands, depressional wetlands and peatlands (Dordio & Carvalho 2013). Fringe wetlands include salt marshes and lakeside marshes in which water typically flows in two opposite directions, influenced by lunar and/or storm tides, riverine wetlands, which occupy floodplains, are usually characterized by water flowing in one direction, depressional wetlands, such as prairie potholes, which usually receive much of their water from runoff and/or groundwater seepage rather than from surface water bodies, so that water residence times are longer and peatlands that have long water residence times, but the accumulated peat creates a unique hydrologic regime that differs from the previous three types of wetlands (Finlayson, 2005). The disadvantage of natural wetland is that the treatment capacity is unpredictable due to wetland performance that changes overtime as a consequence of changes in species composition and accumulation of pollutants in wetland (Haberal et al., 2003). The organic and inorganic materials within a wetland form a complex mass (Idris et al., 2010). This mass along with the occurrence of gas/water interchanges promotes a varied community of microorganisms to break down or transform a wide variety of substances. Dense growths of vascular plants adapted to saturated conditions often thrive in wetlands and contribute to its treatment capacity (Idris et al., 2010). Along with slowing the flow of water, the vegetation creates microenvironments and provides the microbial community enormous attachment sites. Furthermore, plants die in some seasons and tend to accumulate as litter (EPA, 2000). This phenomena creates additional material and exchange sites as well as providing a source of carbon, nitrogen, and phosphorous to fuel microbial processes (EPA, 2000).

Wetland functions are the inherent processes occurring in wetlands; wetland values are the attributes of wetlands that society perceives as beneficial. Many values that wetlands provide result from their functions (hydrological, biogeochemical, and ecological) (Idris et al., 2010). Here a function can be defined as an activity that results from the interactions that occurs between natural processes (physical, chemical, and biological) and the structural components such as geomorphology, hydrology, soil, flora, fauna, and microbes of the ecosystems (Wang et al., 2009).

Hydrological functions may include floodwater retention, groundwater recharge and discharge, and sediment retention. Biogeochemical functions may include nutrient retention/removal and in-situ carbon retention (Idris et al., 2010). Ecological functions may also include ecosystem maintenance and food web support. Under appropriate circumstances, constructed wetlands can provide extremely effective water quality improvement, flood storage and the desynchronization of storm, rainfall and surface runoff, cycling of nutrients and other materials, habitat for fish and wildlife, passive recreation, such as bird watching, and photography, active recreation, such as hunting, education and research, aesthetics, and landscape enhancement (Wang et al., 2009).

2.2 Constructed wetland

Constructed wetland can be defined as an engineered system designed to simulate natural wetland, to exploit the water purification functional value for human use and benefit (Mohd Noor, 2012). Mohd Noor et al., (2012) defined the constructed wetland as a special designed system of production process in which the principle of the species symbiosis, the cycling and regeneration of substances in an ecological system are applied with adopting the system engineering technologies and introducing new technologies and excellent traditional production measures. Constructed wetland represents an emerging eco-technology for water treatment by mimicking the original functions and improving the limitation factors of the natural wetland (Chong et al., 2009). With proper engineering, the hydraulic conductivity can be improved as well as the efficiency of the treatment system (Shutes, 2001). Constructed wetlands are popular systems that efficiently treat different kinds of polluted water and are therefore sustainable environmentally friendly solutions. In general; two types of constructed wetlands systems are most commonly designed and used; the Free Water Surface (FWS) systems, the Subsurface Flow (SSF) systems including horizontal or vertical flow (Langergraber, 2013). SFW systems are similar to natural marshes as they tend to occupy shallow channels and basins through which water flows at low velocities above and within the substrate. In SSF systems, wastewater flows horizontally or vertically through the substrate, which is composed of soil, sand, rock or artificial media (Mohd Noor et al., 2012). The key component of constructed wetland can be classified into several purposes such as aquatic vegetation, microscopic organisms and maintaining water column (Figure 2.1).The role of wetland in water resource management is fast gaining ground resulting in the construction wetland in most developed countries. This trend has evolved because wetlands have been added to wastewater facilities that provide only basic levels of primary or secondary treatment (Idris et al., 2010).

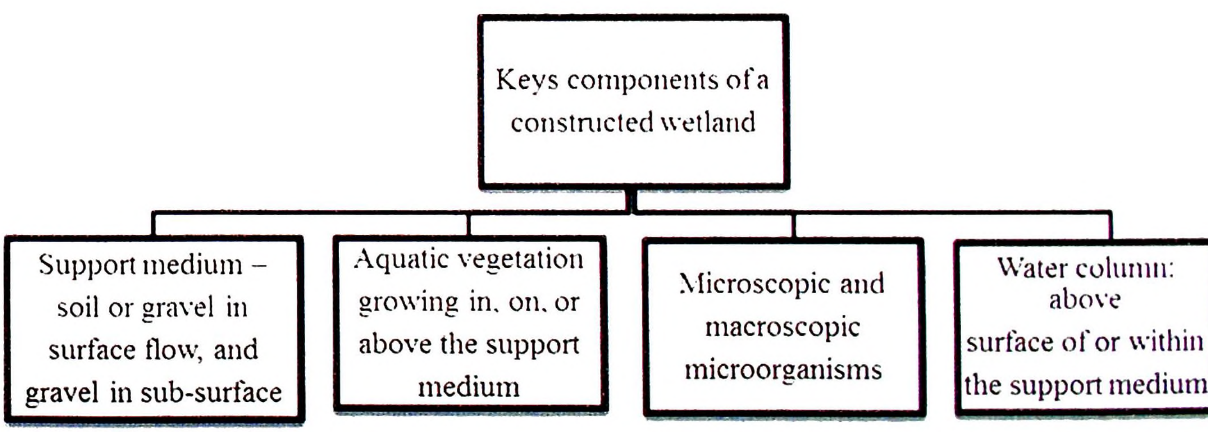

Figure 2.1: Key components of the constructed wetlands (Idris et al., 2010).

Constructed wetlands are man-made system that involves altering the existing terrain to simulate wetland conditions. They primarily attempt to replicate the treatment that has been observed to occur when polluted water enters the natural wetland. These wetlands have been seen to purify water by removing organic compounds and oxidizing ammonia, reducing nitrates, and removing phosphorus. The mechanisms are complex and involve bacterial oxidation, filtration, sedimentation, and chemical precipitation (Idris et al., 2010). Most constructed wetland attempts to imitate the ecosystem's biochemical function as filtration and cleansing agents, followed closely by the hydrological function that is centered on flood mitigation (Wang et al., 2009). These constructed wastewater treatments may include swamps and marshes (Wang et al., 2009).

Most of the constructed wetland systems are marshes. Marshes are shallow water regions dominated by emergent herbaceous vegetation including cattails, bulrush, reeds, rushes, and sedges (Idris et al., 2010). The life span of constructed wetlands has been demonstrated as being approximately 20 years for organic waste treatment (Shutes, 2001). They can be designed to form an aesthetically pleasing and functional landscape which can be incorporated into residential developments. In addition, they provide a valuable ecological habitat for wildlife. The performance of these systems is influenced by their area, length to width ratio, water depth, rate of wastewater loading and the time for it to pass through the wetland (Shutes, 2001).

2.2.1 Constructed wetland design

Constructed wetland systems are classified into two general types that are the horizontal flow system (HFS) and the vertical flow system (VFS) (Idris et al., 2010). HFS has two general types: surface flow (SF) and subsurface flow (SSF) systems. It is called HFS because wastewater is fed at the inlet and flows horizontally through the bed to the outlet. VFS are fed intermittently and drains vertically through the bed via a network of drainage pipes (Idris et al., 2010). SSF are similar to natural marshes as they tend to occupy shallow channels and basins through which water flows at low velocities above and within the substrate. The basins normally contain a combination of gravel, clay or peat-based soils and crushed rock, planted with macrophytes (Shutes, 2001). In SSF, wastewater flows horizontally or vertically through the substrate, which is composed of soil, sand, rock or artificial media. The purification processes occur during contact with the surface of the media and plant rhizospheres (Shutes, 2001). Subsurface flow systems are more effective than surface flow systems at removing pollutants at high application rates. However, overloading, surface flooding and media clogging of the media of subsurface systems can result in a reduced efficiency (Shutes, 2001).

2.2.1.1 Surface flow system (SF)

Constructed wetland designs include horizontal surface and subsurface flow, vertical flow and floating raft systems (Shutes, 2001). The SF system is designed with a shallow layer of surface water (Plate 2.1). This water will flow over mineral such as sand or organic soils (Shutes, 2001). Vegetation for these types of wetland is more to floating and submerged aquatic plants as well as wetland shrubs and trees