

**TREATMENT OF MUNICIPAL WASTEWATER USING CONSTRUCTED
WETLAND: REMOVAL OF ORTHOPHOSPHATE AND AMMONIA
NITROGEN**

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I declare that this dissertation entitled “*Treatment of Municipal Wastewater Using Constructed Wetland: Removal of Orthophosphate and Ammonia Nitrogen*” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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*Dedicated to mom, dad and the whole family
Thank you for everything...*

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This is a fulfilling moment when the report has been completed successfully after a few months of hard work.

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ABSTRACT

Municipal wastewater is one of the major concerns of the environment problems. As the wastewater is found to be highly contaminated, it could not be discharged directly into the environment. Therefore, wastewater treatment is essential to minimize the effect of the contaminants to nature. Based on previous studies, constructed wetland system (CWS) was proved to have high efficiency in treating industrial wastewater with low operating and maintenance cost. The industrial wastewater studied was food waste which was taken from UMP's cafeteria drainage system. In this research, lab scale of free water surface constructed wetlands was designed with the water lettuce (*Pistia Stratiotes*) as the wetland plant. The parameter studied including ammonia nitrogen ($\text{NH}_3\text{-N}$) and orthophosphate (Po_4^{3-}). In order to investigate the effectiveness of the systems, three variables were studied which were the number of cycle (1 and 2), the wastewater concentration (dilute and non-dilute) and the physical appearance of the plants during the treatment. The results showed that $\text{NH}_3\text{-N}$ was removed at high removal efficiency meanwhile Po_4^{3-} removal appeared at low removal efficiency. Both $\text{NH}_3\text{-N}$ and Po_4^{3-} removal showed better results in the CWS with 2 cycles. In term of the different municipal wastewater concentration variable, the CWS with non-dilute sample showed the highest removal efficiency for $\text{NH}_3\text{-N}$ and municipal wastewater concentration with dilute sample (DF=20) showed the highest removal efficiency for Po_4^{3-} . For plant growth observation, at the end of the treatment, many of the water lettuces were wilted. As conclusion, this study showed that constructed wetland can remove contaminant in cafeteria wastewater.

ABSTRAK

Sisa buangan domestik merupakan salah satu masalah utama kepada alam sekitar. Sisa buangan ini amat tercemar dan tidak boleh dibuang sewenang-wenangnya ke alam sekitar. Oleh yang demikian, rawatan sisa buangan adalah penting untuk meminimumkan kesan pencemaran kepada alam sekitar. Berdasarkan kajian yang dijalankan sebelum ini, sistem tanah bench buatan menunjukkan kecekapan yang tinggi dalam merawat sisa buangan industri dengan kos operasi dan penyelenggaraan yang murah. Sisa buangan domestik yang dikaji ialah sisa buangan cafeteria yang diambil daripada sistem pembentungan kafe di UMP. Sistem tanah bench buatan ini adalah berskala makmal dan menggunakan pokok kiambang (*pistia stratiotes*) sebagai tumbuhan akuatik. Parameter yang telah dikaji ialah ammonia nitrogen ($\text{NH}_3\text{-N}$) dan orthophosphate (PO_4^{3-}). Untuk mengkaji keberkesanan sistem ini, eksperimen dijalankan berdasarkan bilangan kitaran rawatan (1 dan 2), kepekatan sisa buangan (dicairkan dan tidak dicairkan) dan keadaan fizikal pokok kiambang pada akhir rawatan. Keputusan kajian menunjukkan $\text{NH}_3\text{-N}$ telah disingkirkan pada peratus keberkesanan yang tinggi manakala peratus keberkesanan penyingkiran PO_4^{3-} adalah rendah. Penyingkiran kedua-dua $\text{NH}_3\text{-N}$ dan PO_4^{3-} menunjukkan keputusan yang baik di dalam tanah bench buatan yang mempunyai 2 kitaran rawatan. Untuk kepekatan sisa buangan yang berlainan, didapati tanah bench buatan telah menyingkirkan $\text{NH}_3\text{-N}$ pada jumlah yang tertinggi bagi sisa buangan yang tidak dicairkan berbanding sisa buangan yg dicairkan (factor pencairan=20) manakala bagi PO_4^{3-} , penyingkiran yang tertinggi dicatatkan pada kepekatan sisa buangan yg dicairkan. Pemerhatian kepada keadaan fizikal tumbuhan menunjukkan keadaan daun tumbuhan adalah semakin layu di akhir eksperimen. Secara keseluruhannya, kajian ini menunjukkan bahawa sistem tanah bench buatan boleh menyingkirkan bahan pencemar di dalam sisa buangan cafeteria.

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LIST OF SYMBOLS

CaCO ₃	-	Calcium carbonate
COD	-	Chemical Oxygen Demand
CW	-	Constructed wetland
Fe	-	Ferum
FWS	-	Free Water Surface
mg/g	-	milligram per gram
mg/L	-	milligram per liter
mL/s	-	milliliter per second
Mn	-	Manganese
NH ₄ ⁺	-	Ammonia
NH ₃ -N	-	Ammonia Nitrogen
NO ₃ -N	-	Nitrate Nitrogen
PO ₄ ³⁻	-	Orthophosphate
POME	-	Palm Oil Mill Effluent
SF	-	Sub Surface Flow
SS	-	Suspended solid
TN	-	Total nitrogen
TP	-	Total phosphorus

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays, the number of large cities is increasing. Although small communities can find the necessary water locally water demands of large cities are drawn from extensive drainage areas or aquifers. A lot of large cities have to draw waters from lower quality sources or from long distances. Furthermore, wastewater is discharged usually into a surface water source or to sea. Therefore, in order to prevent water quality degradation wastewaters should be treated properly prior to disposal.

Most of the waste that channel to the river comes from domestic wastes, industrial and agricultural wastes. For domestic wastes the waste comes from human and animal excreta, food bodies and household garbage. Harmful effects of industrial wastes can pollute water and disturb aquatic life. Harmful effects of agricultural pollution can cause hormonal imbalance in human beings because pesticides reaching on bodies taken through water or by consuming pesticide contaminated food.

In general, the major trends of water pollution control have significantly contributed to the development of conventional sanitation approaches in terms of legal and financial frameworks, as well as technological enhancement. Despite advances in the science, engineering and legal frameworks, 95 per cent of the

wastewater in the world is released into the environment without treatment. Only five per cent of global wastewater is properly treated using the standard sanitation facilities, mainly in developed countries. As a result, the majority of the world's population is still exposed to waterborne diseases, and the quality of water resources has been rapidly degraded, particularly in poor developing countries.

So, sewage should be fully treated before releasing in the rivers. All effluents (wastes) from industries should be treated to render them ineffective before release. Protection of public health may be assured by reducing pathogenic bacteria, parasites and viruses, controlling chemicals and limiting public exposure. Wastewater is put to mechanical filtering, biological decomposition and finally chlorination to make it germ free and safe for human consumption.

Constructed wetlands (CW) are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater. They are designed to take advantage of many of the processes that occur in natural wetlands, but do so within a more controlled environment. Constructed wetland systems have been used nationally and internationally with good results. The system should be located on the contour with drainage directed away from the system.

As an appropriate technological system to treat polluted water, constructed wetland is delicately designed and set up with essential ecological function that can be controlled when compared to the natural wetland. For developing countries, CW is usually considered to be one of the most promising technologies to treat wastewater due its low cost, simple operation and maintenance (O/M), little secondary pollution and favorable environment appearance. In general, CW can be grouped into two categories which are free water surface and of subsurface-flow. The subsurface-flow CW can be further divided as of horizontal subsurface-flow and of vertical subsurface-flow based on detail fluent characteristics.

1.2 Problem Statement

Municipal waste water are a complex mixture of human waste, suspended solids, debris and a variety of chemicals that come from residential, commercial and industrial activities. Substances such as pharmaceuticals, therapeutic products and endocrine disrupting compounds have been widely detected in surface water at concentrations that may cause adverse effects in ecosystems and there are concerns over their possible presence in drinking water supplies. It is widely believed that municipal waste water discharges are major contributors of these pollutants.

Nutrients are mineral compounds needed by all living things to grow and thrive. In most land and water systems, the limited availability of certain nutrients reduces growth of plants and animals. As nutrient concentrations increase, surface water quality is degraded through the process of eutrophication. Changes in surface water quality coincide with increasing nutrient concentration such as increased algae growth, reduced water clarity, reduced oxygen in the water, altered fisheries, fish kills. Toxins from cyanobacteria (blue-green algae) affecting human and animal health. It also will give water treatment problems such as odor and bad taste, increased filtration costs, and disinfectant byproduct with potential human health effects.

Increasing input of nitrogen and phosphorus compound in the lakes and artificial reservoirs lead to increase of primary production of water born organisms and finally its consequence is disappearance of oxygen in waters (Kirby, 2002). Therefore, constructed wetland was developed as an alternative method to treat municipal wastewater since it has low cost of construction and maintenance (Verhoeven J.T.A and A.F.M Meuleman, 1999). Constructed wetlands have proven to be a very effective method for the treatment of municipal and industrial wastewater. Due to its high rate of biological activities, the wetland can transform common pollutants into harmless byproduct and essential nutrients (Kadlec and Knight, 1996)

1.3 Scope of Research Work

In each experiment, Lab-scaled constructed wetland was set-up for the municipal waste treatment. The municipal waste was taken from UMP's cafeteria. The same plant species (*Pistia Stratiotes*.) was used and the amount of wastewater for each container was 15 liters. The scopes of study include:

- Parameters of studied are ammonia nitrogen and orthophosphate.
- The experiments were divided into two systems. First system was treatment with one cycle and second systems was wastewater treatment with two cycles.
- The duration for treatment of municipal waste water for one cycle was 10 days (1 day for 1st stage, 4 days for 2nd stage, 1 day for 3rd stage, and 4 days for 4th stage).
- The duration for treatment of municipal waste water for two cycles was 20 days. (Repeat the number of days in one cycle once again)
- For one cycle the treatment was consists of 4 stages. (For 1st stage was the coarse filter using gravel, 2nd stage was the wetland, 3rd stages was fine filter gravel, and 4th stage polishing stage using wetland)
- For two cycle the treatment was consists of 8 stages. (Repeated the stages in one cycle once again).
- Varies the concentration of municipal wastewater sample (First sample was dilute and second sample was non-dilute)
- Two set experiments which consist of dilute and non-dilute waste water sample were treating with one cycle and two cycles.
- The number of plants for each cycle was constant. Wetland plant used were *Pistia Stratiotes*
- The number of containers used was 5.
- One control experiment was set-up for comparison with the variables, with no addition or subtraction to the wastewater sample.

The equipment DR 2800 portable spectrophotometer (HACH) is used for the analysis. All experiment was conducted in open environment condition with day

light source. The experiment was carried out at the Basic Science Laboratory, Chemical Engineering Laboratory, Universiti Malaysia Pahang.

1.4 Objective of the Project

To determine the efficiency of constructed wetland system to treat nutrient (ammonia nitrogen and orthophosphate) in municipal wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Wetland

A wetland is an area of land which soil is saturated with moisture either permanently or seasonally. Such areas may also be covered partially or completely by shallow pools of water. Wetlands include swamps, marshes, bogs, and others. The water found in wetlands can be saltwater, freshwater, or brackish.

Wetlands are considered the most biologically diverse of all ecosystems. Plant life found in wetlands includes mangrove, water lilies, cattails, sedges, tamarack, black spruce, cypress, gum, and many others. Animal life includes many different amphibians, reptiles, birds, and furbearers.

In many locations, such as the United Kingdom, Norway, South Africa and the United States, wetlands are the subject of conservation efforts and Biodiversity Action Plans

Wetlands have been categorized both as biomass and ecosystems. They are generally distinguished from other water bodies or landforms based on their water level and on the types of plants that thrive within them. Specifically, wetlands are characterized as having a water table that stands at or near the land surface for a long enough season each year to support hydrophytes. Put simply, wetlands are lands made up of hydric soil.

2.1.1 Natural Wetland

Natural wetlands are important for maintaining aquatic ecosystem biodiversity and should be considered as part of an effective ecosystem management strategy. There are four major groups of natural wetlands:

- a) Fringe wetlands: Include salt marshes and lakeside marshes in which water typically flows in two opposite directions, influenced by lunar and/or storm tides.
- b) Riverine wetlands: Occupy floodplains, are usually characterized by water flowing in one direction.
- c) 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.
- d) Peatlands wetlands: Have long water residence times, but the accumulated peat creates a unique hydrologic regime that differs from the previous three types of wetlands.

Geomorphic setting, water source, and hydrodynamics generate considerable variation within each of these different categories of wetlands. Water quality improvement is a positive service attributed to wetlands that absorb and recycle nutrients from human settlements. The denitrification potential of wetlands is often surprisingly high. As much as 2,000 to 3,000 kg of nitrate-nitrogen can be denitrified per hectare of wetlands per year, depending on the hydraulic conditions. This is important for the protection of surface waters because a significant amount of nitrate is released by agricultural activities. As much as 100 kg nitrate-nitrogen per hectare may be found in the drainage water from intensive agriculture. Since the denitrification is accompanied by the oxidation of organic matter, this process also removes a significant amount of organic matter.

2.1.2 Constructed Wetland

Constructed wetland (CW) technology was first introduced to treat wastewater in 1952 by K. Seidel in Germany and the first full-scale CW system was built in the Netherlands in late 1960s. In the following decades, the CW technology developed rapidly and the use of CW system to treat wastewater spread widely all across the Europe and North America. Until 2004, there had been about 5000 CWs in operation in Europe and 1000 in the US. A special issue on the technological researches and engineering applications of CW was also published by the Ecological Engineering in 2005. (Chen *etc. al*, 2005).

Constructed wetlands (CW) are engineered systems that have been designed and constructed to utilize natural processes involving wetland vegetation, soils and the associated microbial assemblages to assist in treating wastewaters. They are designed to take advantage of many of the processes that occur in natural wetlands but do so within a more controlled environment. The basic classification is based on the type of macrophytic growth (emergent, submerged, free floating and rooted with floating leaves), further classification is usually based on the water flow regime (surface flow, sub-surface vertical or horizontal flow). Recently, the combinations of various types of CWs (also known hybrid systems) have been used to enhance the treatment effect, especially for nitrogen.

In 1970s and 1980s, constructed wetlands were nearly exclusively built to treat domestic or municipal sewage. Since 1990s, the constructed wetlands have been used for all kinds of wastewater including landfill leachate, runoff (e.g. urban, highway, airport and agricultural), food processing (e.g. winery, cheese and milk production), industrial (e.g. chemicals, paper mill and oil refineries), agriculture farms, mine drainage or sludge dewatering.

2.2 Types of Constructed Wetland

There are two main types of constructed wetlands which are free surface-flow (SF) constructed wetlands, and subsurface-flow (SSF) constructed wetlands. Subsurface-flow (SSF) constructed wetland divided into two types; horizontal and vertical (Tchobanoglous, 1997; Kirby, 2002).

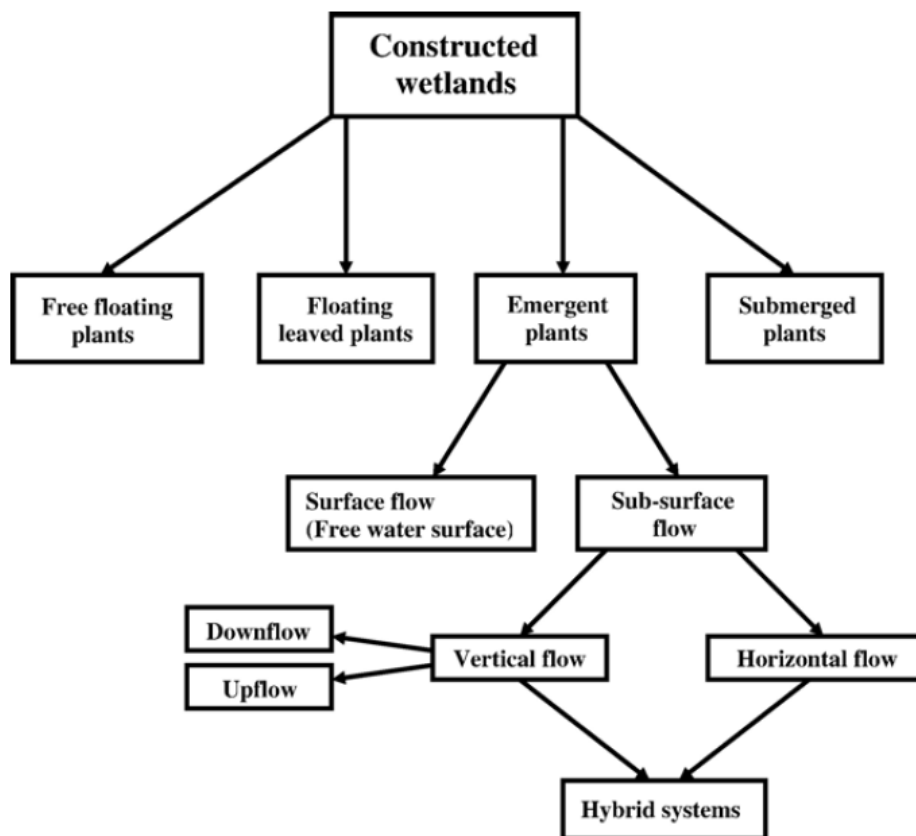


Fig. 1. Classification of constructed wetlands for wastewater treatment (Vymazal, 2001).

Figure 2.1 Typical configuration for types of constructed wetlands

a) **Surface Flow (SF) Systems**

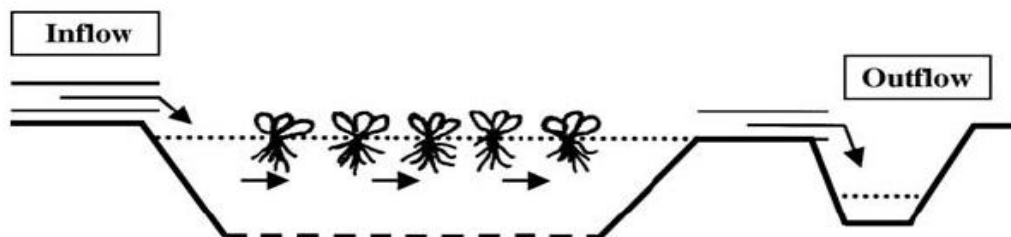


Figure 2.2 Typical configuration of a surface flow wetland system (Kadlec and Knight, 1996)

The first full-scale free water surface (FWS, surface flow) CW was built in the Netherlands to treat wastewaters from a camping site during the period 1967–1969. Figure 2.1 show the typical configuration for a surface flow wetland system. There were about 20 FWS CWs built in The Netherlands even though FWS CWs did not spread throughout the Europe.

Surface flow constructed wetlands and their use in arid and semi-arid areas of Australia showed the development of vegetation succession in relation to hydrology and nutrient retention in created riverine wetlands over a 10-year period. (Greenway, 2005).

Surface flow constructed wetlands is useful for the treatment woodwaste leachate in British Columbia. The system showed promising treatment effect but climatic conditions affected the performance and adjustment of pH is desirable. Also, the results indicate that treatment performance improves with the length of operation. (Masbough *et al*, 2005).

Surface flow constructed wetland can beneficial with plant species composition management. It has been found that the proper vegetation management not only improves treatment effect but also improves substantially wildlife value of the constructed wetland. (Thullen *et al.*, 2005).