INDUSTRIAL WASTEWATER TREATMENT: REMOVAL OF AMMONIA-NITROGEN AND ORTHOPHOSPHATE IN PALM OIL MILL EFFLUENT USING CONSTRUCTED WETLAND

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A dissertation submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Chemical Engineering (Biotechnology)

Faculty of Chemical & Natural Resources Engineering
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MAY, 2009

DECLARATION

I declare that this dissertation entitled ***"INDUSTRIAL WASTEWATER TREATMENT: REMOVAL OF AMMONIA-NITROGEN AND ORTHOPHOSPHATE IN PALM OIL MILL EFFLUENT USING CONSTRUCTED WETLAND"*** is the result of my own research except as cited in references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :……………………………………….

Name of Candidate : Siti Nurbaya binti Mustafa Kamal

Date : 2nd May 2009

DEDICATION

Special Dedication to my beloved mother (Fatimah bt Yusoff) and father (Mustafa Kamal bin Ahmad), for their love and encouragement.

And,

Special Thanks to my friends, my fellow course mates and all faculty members. For all your care, support and best wishes.

Sincerely,
Siti Nurbaya binti Mustafa Kamal

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere appreciation to my supervisor, Pn. Noor Ida Amalina bt. Ahamad Nordin, for constantly guiding and encouraging me throughout this study. Thanks a lot for giving me a professional training, advice and suggestion to bring this project to its final form.

I am very thankful to the staff of Chemical & Natural Resources Engineering Faculty, Universiti Malaysia Pahang for their cheerfulness and professionalism in handling their work.

In particular, my sincere thankful is also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. Not forgotten a special thanks to my parents and my sister for their continuous support while completing this project. Last but not least, I appreciate the support and encouragement from Asrul Basri bin Azmi.

ABSTRAK

Sisa buangan kawasan perindustrian sangat kompleks dan menyumbang kepada pencemaran air jika tidak dirawat dengan sebaiknya kerana mengandungi bahan organik yang tinggi. Sisa buangan kelapa sawit adalah cecair berwarna coklat yang mengandungi nitrogen dan fosforus terhasil daripada kilang pemprosesan minyak kelapa sawit. Rawatan sisa buangan seperti tanah bencah buatan diperlukan untuk mengurangkan kesan buruk akibat daripada pencemaran. Tanah bencah buatan ialah tanah bencah yang dibina untuk pengurusan pencemaran dan sisa buangan. Objektif kajian ini adalah untuk mengetahui tahap kecekapan tanah bencah buatan untuk merawat sisa buangan kelapa sawit. Parameter kajian adalah ammonia-nitrogen (NH_3-N) dan orthophosphate (PO_4^{3-}). Di dalam kajian ini, kaedah rawatan tanah bencah jenis permukaan air bebas berskala makmal telah dibina dengan pokok kiambang (*Pistia stratiotes*) dan batu kerikil. Eksperimen ini mengandungi dua sistem iaitu kaedah rawatan berulang dan tanpa ulangan. Setiap sistem mempunyai empat peringkat dimana peringkat pertama dan ketiga menggunakan batu kerikil sebagai penapis manakala peringkat kedua dan keempat menggunakan pokok kiambang untuk menyingkirkan bahan pencemar. Eksperimen ini dijalankan berdasarkan kepekatan sampel yang berbeza iaitu 100% dan 80% kepekatan. Bagi sistem yang pertama (tanpa ulangan)iaitu 10 hari rawatan, 93.36% NH_3-N dan 79.54% PO_4^{3-} disingkirkan dari 100% sampel kepekatan manakala 90.95% NH_3-N dan 78.52% PO_4^{3-} disingkirkan dari 80% sampel kepekatan. Untuk sistem yang kedua (berulang) iaitu 20 hari rawatan, 98.39% NH_3-N dan 83.12% PO_4^{3-} disingkirkan dari 100% sampel kepekatan manakala 96.37% NH_3-N dan 80% PO_4^{3-} disingkirkan dari 80% sampel kepekatan. Ini menunjukkan penyingkiran NH_3-N lebih tinggi berbanding PO_4^{3-}. Kesimpulannya, tanah bencah buatan boleh digunakan sebagai kaedah rawatan untuk industri dan mempunyai kadar kecekepan yang tinggi dalam penyingkiran bahan pencemar di dalam sisa buangan kelapa sawit.

ABSTRACT

Wastewaters from industrial places are very complex and lead to water pollution if discharged untreated, especially due to its high organic loading. Palm oil mill effluent (POME) is a brownish liquid that contain high amount of nitrogen and phosphorus that has been produced from the palm oil processing plants. Therefore, wastewater treatment such as constructed wetland is needed to decrease the effect of contamination. Constructed wetland is a wetland that specifically constructed for pollution and waste management. The objective of this research is to study the efficiency of constructed wetland to treat pollutant in POME. Parameters concerns are ammonia-nitrogen (NH_3-N) and orthophosphate (PO_4^{3-}). In this study, lab scale of free water surface had been constructed by using water lettuce (*Pistia stratiotes*) as wetland plant and gravel as filter. This experiment consists of two systems which are without and with cycle. Each system was conducted on four stages; first and third stage used gravel as a filter whereas second and fourth stage used constructed wetland to remove the pollutant. This experiment was conducted with different concentrations of sample which are 100% concentration and 80% concentration. For the first system (without cycle)which is 10 days of treatment, 93.36% of NH_3-N and 79.54% of PO_4^{3-} had been removed from 100% sample concentration while 90.95% of NH_3-N and 78.52% of PO_4^{3-} removed from 80% of sample concentration. For the second system (with cycle) which is 20 days of treatment, the optimum days of treatment was 15 days which give the optimum results of 98.39% of NH_3-N and 83.12% of PO_4^{3-} from 100% sample concentration whereas 96.37% of NH_3-N and 80% of PO_4^{3-} removed from 80% sample concentration. From the results, they show that the percent removal of NH_3-N is much higher than PO_4^{3-}. As a conclusion, constructed wetland can be used as industrial waste treatment and also gives high efficiency in removal of contaminant in POME.

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LIST OF SYMBOLS

NH_3	Ammonia
POME	Palm Oil Mill Effluent
CH_4	methane
SO_2	sulphur dioxide
BOD	biochemical oxygen demand
COD	chemical oxygen demand
FWS	free water flow
SF	surface flow
mg	miligram
L	liter
DNA	Deoxyribonucleic Acid
FFB	full fruit bunch
EFB	empty fruit bunch
%	percentage
CPO	crude plam oil
RM	Ringgit Malaysia
PPF	palm pressed fibres
$HgCl_2$	mercuric chloride
^oC	degree Celcius
km	kilometre
Sdn Bhd	sendirian berhad
nm	nanometre
NH_3-N	ammonia-nitrogen
PO_4^{3-}	orthophosphate

CHAPTER 1

INTRODUCTION

1.1 Background of Study

A constructed wetland is a designed and man-made complex of saturated substrates, emergent vegetation, animal life and water that simulates natural wetlands for human use and benefits (Hammer, 1990; 1997). This system is the designs of ecotechnological treatment system that can overcome the disadvantages of natural wetland. Two most popular designs that have been used nowadays are surface flow also called as free-water system and subsurface flow system. In the beginning of usage of constructed wetland, it is used to improve the ability of plant biodegradation.

Nowadays, constructed wetland is used to treat a lot of industrial wastewater, aquaculture wastewater and urban runoff. Wastewater may contain heavy metal such as magnesium and nutrients such as nitrogen and phosphorus. The removal of nitrogen and phosphorus species in constructed wetland can be done with 3 mechanisms which are 1) nitrification 2) volatilization of ammonia, NH_3 3) uptake by wetlands plant. The removal of nutrients by uptake by wetland plants can be achieved by using various aquatic plants such as cattail (*Typha*), water grass (*Stapf*), Asia crabgrass (*Digitaria bicornis*) and water lettuce (*Pistia stratiotes*).

Constructed wetlands are marshes built to treat contaminated and have four key components which are soil and drainage material such as pipes and gravel, water, plants and microorganisms.

Constructed wetlands differ from natural wetlands in several ways such as they remain constant in size, they are not directly connected with groundwater, they accommodates greater volumes of sediment and more quickly develop the desired diversity of plants and associated organisms. The advantages of these systems include low construction and operating costs and they are appropriate both for small communities and as a final stage treatment in large municipal system (Cooper *et al*., 1996). This will give benefits to industrial in order to minimize the cost on treating waste over conventional engineering measures.

Recent studies show that constructed wetlands have big potential because they can tolerate higher organic loading rate and shorter time needed. Furthermore, less space required for construction wetland. This will decrease the cost of treatment. Moreover, plants also assimilate nutrients via their growth metabolism (Reddy *et al*., 1982; Hammer, 1992; Kadlec and Knight, 1996; Brix, 1997).

1.2 Problems Statement

Palm oil is one of the two most important vegetable oils in the world's oil and fats market. The environmental impact of Palm Oil Mill Effluent (POME) cannot be over emphasized; hence the need for treatment measures to reduce these impacts before discharge. Effluent water is defined as water discharged from industry, which contains materials that are injurious to the environment. Such soluble materials may be gases such as CH_4, $S0_2$, NH_3, halogens or soluble liquids or solids which contain ions of either organic or inorganic origin and with their concentration above the threshold value. Since these compounds are harmful to the environment, it becomes necessary that effluents water should be treated or purified before discharged into the environment. (Igwe and Onyegbado, 2007)

In Malaysia, the enforcement of strict laws promulgated under the Environmental Quality Act has led to the development of several innovative technologies for the utilization of POME. Many methods for POME treatment to attained the required standards and utilizing the effluent to advantage have been tried by many researchers including Davis (1978), Chan *et al.* (1980), Dolmat et al. (1987), Bek-Nielsen *et al.* (1999) and more recently, Ahmad *et al.* (2003).

People know that heavy metals are harmful but not many know that nutrients also can give big impact if it is exist in excess amount. Nitrogen and phosphorus are the essential for microorganisms such as to form proteins, cell wall development of teeth and bones and metabolisms of carbohydrate but in the excess amount, nutrients will contribute to a lot of problems for living things. In example, the accumulation of feed residue and fish excreta during cultivation often cause deterioration in fishponds resulting toxic to fish. The removal of ammonia-nitrogen from wastewater is important since it will cause the ammonia's toxicity to river or sea living things if discharged into them.

The exposures of these excess nutrients can effects human through drinking water. Human will get infect by the excessive level of nitrogen and cause methemoglobinemia which transportation of the oxygen to the blood decreases. Excess nutrients led to the eutrophication phenomena and in many cases deterioration in public health (Dorsheimeret *et al*., 1997; Banens and Davis, 1998; Mackie, 2001). The lakes, rivers and artificial reservoirs are increasing in the amount of nitrogen and phosphorus that lead to decreasing of oxygen in water. This will pollute the water and create the problem of clean water supply will occur.

The technology in treating excess nutrients has been developed and it must be effective enough in order to overcome this problem. The use of constructed wetland technologies is rising rapidly for waste treatment because of its positive greenhouse effect yet it is low in cost and energy-efficient. This natural means of treating POME also offers the potential of multiple benefits such as source of recreational systems providing aesthetic qualities, wildlife habitats and the superior quality effluents that can be recycled for landscape irrigations (Higgins *et al*., 1993; Campbell and Ogden, 1999; Wise *et al., 2000*).

1.3 Objective

The purpose of this study is to determine the removal of ammonia-nitrogen and orthophosphate percentage in different concentration of water sample.

1.4 Scope of Study

This study focused on treating the water sample from Palm Oil Mill Effluent, Lepar Hilir Satu. The water sample was taken from the several places from cooling pond and was treated using constructed wetland. In this experiment, the same plant was used in every design of constructed wetland. The treatment was monitored everyday. The scopes of this study were:

a) To design the constructed wetland with diluted water sample and non-dilute wastewater sample
b) To determine the effect on variation of concentration and cycle of treatment
c) To evaluate the efficiency of constructed wetland by determine the concentration of nitrogen and phosphorus in industrial wastewater

1.5 Rationale and Significant of Study

The objective of this study is to determine the removal percentage of ammonia-nitrogen and orthophosphate in wastewater sample using constructed wetlands. In this study the plant that will be used is water lettuce and a environmentally friendly approach study. The waste sample is taken from Palm Oil Mill Effluent (POME), Lepar Hilir Satu. At an average, about 0.1 tons of raw Palm Oil Mill Effluent (POME) is generated for every tons of fresh fruit bunch processed. POME consists of water soluble components of palm fruits as well as suspended materials like palm fiber and oil. Despite its biodegradability, POME cannot be discharged without first being treated because POME is acidic and has a very high biochemical oxygen demand (BOD). The purpose of collecting the waste sample is to monitor the waste quality and to treat the waste before it can be discharged safely or it can be used again for the factory as any other useful components. If the wastewater discharges to the river without any treatment, it will harm people around as POME contains highly acidic components and gives critical conditions to health conditions. The proposed treatment will also ensure the industry to meet a more stringent discharge standard in terms of the BOD, COD and nutrients values. Most people know about metal can harm human but they do not know about excess nutrients contribute deterioration to public. In a few years come if anyone or any student wants to do the wastewater treatment of POME he/she can refer this study as reference or make the comparison between them. Besides, if this study success Universiti Malaysia Pahang can build and have its own human-created lake like lake at Putrajaya, Universiti Malaya and Universiti Kebangsaan Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Wetland

A wetland is simply area where water covers soil and transitional area between land and water. Wetland encompasses broad range of wet environment. Wetlands have long before been under-rated for their values and people thought that wetlands should be avoided or better yet be eliminated. Most people thought wetlands are the place mosquito to breed. But nowadays, they are just becoming more understood as more studies have been conducted regarding the useful and effectiveness of wetlands in removing contaminants and excess of nutrients. In the other hand, wetlands maintain wild life and other water microorganisms' habitats while serving as treatment system. Wetlands always served as natural environmental water treatment.

Wetlands are natural wonderland of great value. Over hundred of years, natural wetlands have been used to treat water. Natural wetlands are those not added with wastewater. Although constructed wetlands have dominated the water treatment nowadays but the old age of natural wetlands give a lot of advantages for water purification as it ways too much on cost saving. Natural processes have always cleansed water as it flows through rivers, streams and lakes. The hydrology of wetlands generally slow flows and shallow or saturated substrate. Slow flows will give more contact time or retention time between water and surface within the wetlands. There are a lot of plants that grow and get adapted to wetlands saturated condition. The plant slows the flow and provides more attachment for microbial community in water. As plants die and fall back in water. They accumulate and create additional material and provide source of carbon, nitrogen and phosphorus to fuel microbial processes.

2.2 Constructed Wetlands

Constructed wetlands are engineered system that have been design to utilized the natural function of wetlands vegetation, soil and specifically constructed for the purpose of pollution control plus waste management. Constructed wetlands have grown in popularity for wastewater treatment since early 1980s (Reed *et.* al, 1995). The role of wetlands as a passive approach in improving water quality has give the idea to researchers such as Janjit Iamchaturapatr, Su Won Yi, Jae Seong Rhee (2007) to study constructing wetlands system for wastewater treatment while preserving natural wetlands. The concern over potential harmful effects of toxic constituents, pathogen and degradation of wetlands due to added of nutrients have given the benefits and promotes growing interest in the use of constructed wetlands for wastewater treatment. Constructed wetlands are designed to take advantages of chemical and biological processes of natural wetlands to remove contaminants from the wastewater (Skousen, 2004). These popular treatment system use rooted wetlands plants and shallow, flooded or saturated soil to provide wastewater treatment. Constructed wetlands are very effective in terms of cost and energy saving since it is using less equipment and electrical power. They are also involved in recycling and facilitate water reuse. In addition, constructed wetlands have many advantages compared to conventional treatment techniques such as:

i) Have significantly lower total lifetime costs and often lower capital costs than conventional treatment systems.
ii) Tolerate fluctuate in flow and pollutant concentrations
iii) Are capable of treating multiple or mixed contaminants
iv) Provide flood protection
v) Have lower air and water emissions and secondary wastes
vi) Can be built to fit into the landscapes

vii) Provide habitat for plants and wildlife
viii) Provide recreational and educational opportunities
ix) Are environmental friendly

2.3 Types of Constructed Wetlands

There are several types of constructed wetlands which are surface flow wetlands, subsurface flow wetlands, vertical flow and hybrid systems that incorporate surface and subsurface flow wetlands. But the two main types of constructed wetlands there are very well known and have been used widely are surface flow and subsurface flow. Surface flow wetland also known as free-water flow wetlands. Surface wetlands consist of shallow basins partially filled with soil, peat or any other media that will support plant roots. It is generally have a soil bottom, emergent vegetation, and a water surface above the substrate. The design may or may not include areas of open water in addition to the vegetated areas. The water surface in FWS wetlands is exposed to the atmosphere, and intended flow path through the system is horizontal. Pretreated wastewater is applied continuously to such system and treatment occurs as the water flows through the stems and roots of emergent vegetation. FWS system may also be designed with the objective of creating new wildlife habitats or enhancing nearby existing natural wetlands. Figure 2.1 shows the surface flow while in Figure 2.2 shows the subsurface flow.

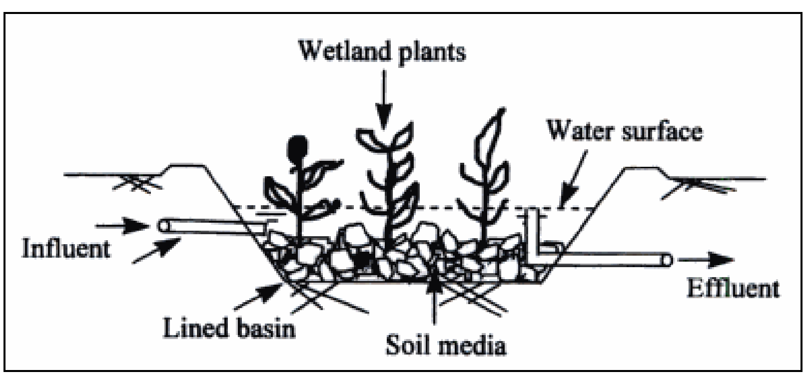

Figure 2.1: Surface flow (free-water flow wetland)

In the other hand, subsurface water wetland is subsurface flow wetlands are generally constructed with a porous material such as oil, sand, or gravel as a substrate for growth of rooted wetland plants in addition to various microbes. Subsurface flow wetlands are also known as reed beds, rock-reed filters, gravel beds, and vegetated submerged bed. Flow is maintained by either a sloping bottom or an adjustable outlet structure which allows the water level to be lowered at the end of the bed, producing the pressure head required to overcome flow resistance through the substrate media.

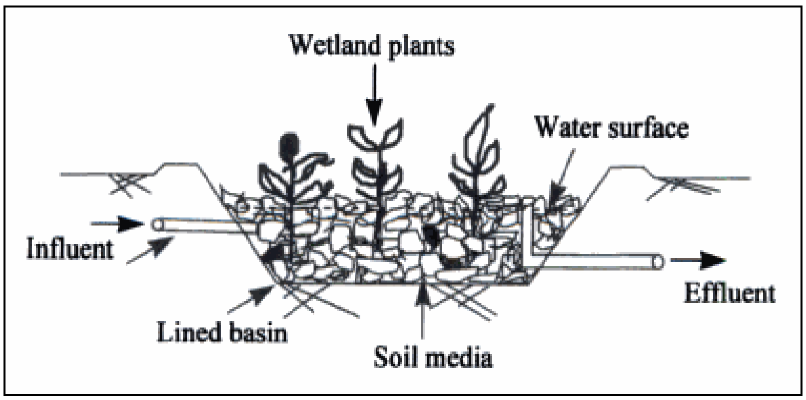

Figure 2.2: Subsurface flow

Comparing the two types of constructed wetlands systems, the SF types of wetlands offers several advantages over FWS type. If the water surface is maintained below the media surface, there is little risk of odors, public exposure or insect vectors. In addition, it is believed that the medium provides a larger available surface area for attached growth organisms. As a result, the treatment response may be faster and a smaller surface area may be needed for same wastewater condition. Furthermore, the subsurface position of the water and the accumulated plant debris on the surface of the SF bed offer great thermal protection in cold climates as compared to the FWS type (Syed R. Qasim, 1998). Table 2.1 shows advantages and disadvantages of subsurface flow and surface flow

Table 2.1: Advantages and disadvantages of subsurface flow and surface flow

Surface Flow Wetlands	
Advantages	**Disadvantages**
Less expensive to construct	Lower rates of contaminants removal
Can be used for higher suspended solids wastewater	Requires more land than conventional treatment methods
Offer greater flow control than SSF wetlands	May be slower to provide treatment than conventional treatment
Provides habitat for plants and wildlife	
Subsurface Flow Wetlands	
Advantages	**Disadvantages**
Higher rates of contaminant removal	Require more land than conventional treatment methods
Lower total life costs and capital costs than conventional treatment systems	May be slower to provide treatment than conventional treatment
Less expensive to operate than SF system	
Odors and insects not a problem because the water level is below media surface	

2.4 Wetland Plants

Wetlands plants can be divided into four categories which are free floating plants, floating plants, emergent plants and submerged plants. Each wetland has a variety of plants which provide shelter and food for many of the animals living there. Plants add oxygen to the water for underwater species. Some plants, such as the pickerelweed, grow along the water's edge. Emergent plants are the plants that grow out of water while floating plants is where their leaves float on top of the water. This is because some aquatic plants have adapted to the water. Submerged plants are so well adapted to water that they live completely under the surface of the water. Some plants like the water milfoil have roots that anchor them to the bottom of the pond. Figure 2.3 shows common reed on the left and water lettuce on the right.

Figure 2.3: Common Reed (left) and Water lettuce (right)

Figure 2.4 shows an overview and classification of constructed wetlands that has been done by Jan Vymazal in his study titled Removal of Nutrient in Various Types of Constructed Wetlands. While Table 2.2 shows the characteristics of plants for constructed wetlands.

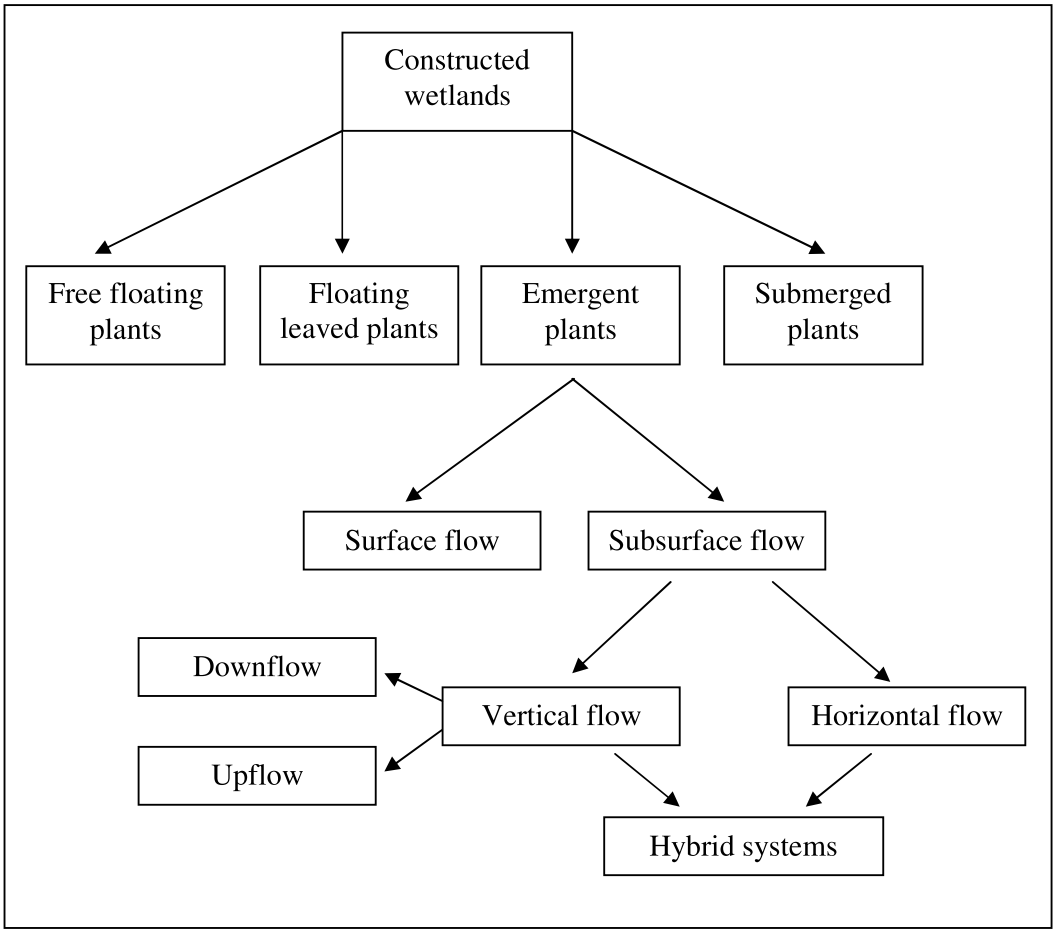

Figure 2.4: Classification of constructed wetlands for wastewater treatment (Vymazal, 2001)

Table 2.2: Characteristics of plants for constructed wetlands

General types of plants	General Characteristics	Function or importance to treatment process	Function or importance for habitat
Free floating habitat	• Roots or root-like structures suspended from floating leaves • Will move about water current • Will not stand erect out of water	• Primary purposes are nutrient uptake and shading to retard algal growth • Dense floating mats limits oxygen diffusion from the atmosphere	• Dense floating mats limit oxygen diffusion from the atmosphere and block sunlight from submerged plants
Rooted floating aquatic	• Usually with floating leaves, but may have submerged leaves • Rooted to bottom • Will not stand erect out of the water	• Primary purposes are providing structure for microbial attachment and releasing oxygen to the water column during day light hours	• Dense floating mats limit oxygen diffusion from the atmosphere and block sunlight from submerged plants
Submerged aquatic	• Usually totally submerged • May have floating leaves • Rooted to bottom • Will not stand erect in air	• Primary purposes are providing structure for microbial attachment and releasing oxygen to the water column during day light hours	• Plants provide shelter and food for animals