LEACHATE TREATMENT BY FLOATING PLANTS IN CONSTRUCTED WETLAND

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Dedicated to God;
He makes everything possible and
confirms once again His grace is sufficient…

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ABSTRACT

Leachate generation was one of the major concerns of a landfill. Leachate contained high levels of organic and inorganic matters. As the landfill leachate was highly contaminated, leachate could not be discharged directly into the surface water bodies. Therefore, leachate treatment was essential before it was discharged into receiving water. Constructed wetland emerged as one of the potential treatment alternative that employed floating plants to remove pollutants form leachate. In this research, a constructed wetland was developed by using *Eichhornia crassipes* to treat landfill leachate. Different leachate concentration (100%, 50%, 25%) was studied in the constructed wetland to compare the treatment efficiency in terms of pollutants removal in leachate and the heavy metal uptake by *Eicchornia crassipes*. The treated leachate was analyzed for nutrient and heavy metal removal. The growth of *Eichhornia crassipes* was observed and the plants were digested at the end of experiment to study the heavy metal uptake by plant. The results showed that the wetland with 100% leachate concentration was the most efficient in removing BOD (74.04%) and Fe (100%) while wetland of 50% leachate concentration was the most efficient in removing NO_3^--N (64.51%) and Mn (53.13%) compared to 25% wetland. The higher the concentration of leachate, the more the plants wilt and this resulted in less accumulation of heavy metal in plants. *Eichhornia crassipes* had a higher capacity to accumulate Fe and Mn in the roots than in the leaves. At the end of experiments, the pH of the leachate decreased in all wetland regardless of the leachate concentration. pH decrease was due to heavy metal uptake by plants and nitrification process by microorganisms. As a conclusion, this study showed that wetland was efficient in removing BOD and NO_3^--N in high leachate concentration. The wetland also posed a great role in removing Fe and Mn through plant uptake.

ABSTRAK

Penghasilan air larut lesap adalah salah satu isu yang penting di tapak pelupusan sampah. Air larut lesap mengandungi kepekatan bahan organik dan inorganik yang tinggi. Oleh sebab air larut lesap adalah sangat tinggi kontaminasinya, air larut lesap tidak boleh dialirkan secara terus ke permukaan air. Oleh itu, rawatan air larut lesap adalah penting sebelum ia dikeluarkan ke sumber air. Tanah bencah buatan merupakan satu rawatan alternatif yang berpotensi dengan menggunakan tumbuhan terapung untuk menyingkirkan bahan tercemar daripada air larut lesap. Dalam kajian ini, tanah bencah buatan dibangunkan dengan menggunakan *Eichhornia crassipes* untuk merawat air larut lesap. Kepekatan air larut lesap yang berlainan (100%, 50%, 25%) dikaji di tanah bencah buatan untuk membandingkan keefisienan rawatan dari segi penyingkiran bahan pencemar dalam air larut lesap dan pengambilan logam berat oleh *Eicchornia crassipes*. Air larut lesap yang dirawat dianalysis untuk penyingkiran nutrien dan logam berat. Pertumbuhan *Eicchornia crassipes* diperhatikan dan tumbuhan dicernakan setelah eksperimen habis untuk mengkaji pengambilan logam berat oleh tumbuhan. Keputusan menunjukkan tanah bencah buatan dengan 100% kepekatan air larut lesap adalah paling efisien dalam penyingkiran BOD (74.04%) dan Fe (100%) manakala tanah bencah buatan dengan 50% kepekatan air larut lesap adalah paling efisien dalam penyingkiran NO_3^--N (64.51%) dan Mn (53.13%) berbanding dengan 25% tanah bencah buatan. Semakin tinggi kepekatan air larut lesap, semakin banyak tumbuhan layu dan ini mengakibatkan lebih sedikit pengumpulan logam berat dalam tumbuhan. *Eicchornia crassipes* mempunyai kapasiti yang lebih tinggi untuk mengumpul Fe dan Mn dalam akar berbanding dalam daun. Setelah eksperimen habis, pH air larut lesap didapati menurun dalam semua tanah bencah buatan tanpa mengambil kira kepekatan air larut lesap. Penurunan pH adalah disebabkan oleh pengambilan logam berat oleh tumbuhan dan proses nitrifikasi oleh mikroorganisma. Sebagai kesimpulan, kajian ini menunjukkan tanah bencah buatan adalah efisien dalam menyingkirkan BOD dan NO_3^--N bagi kepekatan air lesap yang tinggi. Tanah bencah buatan juga memainkan peranan yang penting untuk menyingkirkan Fe dan Mn melalui pengambilan tumbuhan.

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Af	-	Accumulation factor
Al	-	Aluminum
AN	-	Ammonia Nitrogen
BOD	-	Biochemical Oxygen Demand
BOD_5	-	5-day Biochemical Oxygen Demand
Ca	-	Calcium
Cd	-	Cadmium
COD	-	Chemical Oxygen Demand
Cr	-	Chromium
Cu	-	Copper
DMS	-	Dimethyl sulphide
DO	-	Dissolved Oxygen
Fe	-	Ferum
FWS	-	Free Water Surface
HLR	-	Hydraulic Loading Rate
HRT	-	Hydraulic Retention Time
Mg	-	Magnesium
Mn	-	Manganese
Ni	-	Nickel
P	-	Phosphorus
Pb	-	Publum
S	-	Sulfur
SOP	-	Soluble orthophosphate
SS	-	Suspended Solid

SSF	-	SubSurface Flow
TKN	-	Total Kjeldahl Nitrogen
TOC	-	Total Organic Carbon
TP	-	Total Phosphorus
TSS	-	Total Suspended Solids
VFA	-	Volatile Fatty Acids
Zn	-	Zinc

CHAPTER 1

INTRODUCTION

1.1 Introduction

The change from an agro-based to an industrial nation, the good health care, education and better employment opportunities in Malaysia has led to an increase in the population. Our population has increased rapidly from 6 278 800 in 1957 to an estimated 25 050 000 in 2005 (DSM, 2005). Thus, the amount of solid wastes generated in Malaysia also increases rapidly. Kuala Lumpur and Selangor produced 7922 tonnes/day in year 2000, and this will increase to 11 728 tonnes/day in year 2010. For the states of Negeri Sembilan, Melaka and Johor, waste generated for 2000 was 2633 tonnes/day and 3539 tonnes/day are expected by year 2015 (Maseri, 2005). There are different alternatives to reduce, treat and dispose the solid wastes. However, landfill is still the most common practice for solid waste management. Sanitary landfill for solid waste management is defined as an engineered method of disposing of solid wastes on land by spreading them in thin layers, compacting them to the smallest practical volume, and covering them with soil each working day in a manner that protects the environment (Brunner and Keller, 1972). There are 230 official dumping sites in Malaysia, the majority of which are crude landfills, with only 10% providing leachate treatment ponds and gas ventilation systems and with most having no control mechanisms and supervision (Zaman, 1992).

However, the landfill method causes generation of leachate (Galbrand, 2003). Leachate is defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials (EEA, 2005). Leachate occurrence is by far the most significant threat to ground water. Once it reaches the bottom of the landfill or an impermeable layer within the landfill, leachate either travels laterally to a point where it discharges to the ground's surface as a seep, or it will move through the base of the landfill and into the subsurface formations (El-Fadel *et al.*, 1997). Depending upon the nature of these formations and in the absence of a leachate collection system, leachate has reportedly been associated with the contamination of aquifers underlying landfills which resulted in extensive investigations for the past four decades (Albaiges *et al.*, 1986; Mann and Schmadeke, 1986).

Leachate contains high concentration of organic matter, inorganic matter (sodium chloride and carbonate salt) and heavy metal (Trebouet *et al.*, 2001). Organic matter in leachate results in decomposition by microorganisms and causes oxygen depletion in surface water bodies (Schwartz, 2005). This favours anaerobic conditions which are detrimental for the aquatic life. The anaerobic microflora is responsible for putrefactive processes which are characterized by the production of different types of toxic and noxious compounds (ammonia, hydrogen sulfide and phosphine) as final products of the organic matter degradation. Oxygen deficiency and toxic substance from anaerobic metabolism cause fish death and impairment of aquatic life. Heavy metals that are present in leachate are toxic to aquatic and human lives. Heavy metals are hazardous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment (Lenntech, 2005). The most common heavy metals pollutants in leachate are mercury, iron, manganese and copper. Large doses of heavy metal can be detrimental to human health. For example, ingestion of inorganic mercury salts may cause acute effect in terms of gastrointestinal disorders such as abdominal pain, vomiting, diarrhea, and hemorrhage (ATSDR, 1989). Repeated and prolonged exposure of inorganic mercury will result in severe disturbances in the central nervous system, gastrointestinal tract, kidneys, and liver. Meanwhile, large doses of manganese cause apathy, irritability, headaches, insomnia, and weakness of the legs while the acute toxicity for ingested copper is characterized by abdominal pain, diarrhea, vomiting, tachycardia and a metallic taste in the mouth. Continued ingestion of copper compounds can cause cirrhosis and other debilitating liver conditions (Mueller-Hoecker *et al*., 1989). Therefore, since leachate can affect aquatic ecosystems and human health, proper leachate treatment is needed before leachate is discharged into receiving water (Paredes, 2003).

1.2 Problem Statement

The conventional leachate treatment systems are physical-chemical treatment, recirculation of leachate through landfill and biological treatment (El-Gendy, 2003). Physical-chemical treatment includes chemical precipitation, chemical oxidation, ion exchange and reverse osmosis, activated carbon adsorption and ammonia stripping (Ehrig, 1989). Precipitation in physical-chemical treatment is based on the addition of some chemicals to remove suspended solids, nitrogen, phosphorus and metal (Paredes, 2003). Meanwhile, chemical oxidation is effective in removing COD, iron and colour (Ho *et al.*, 1974). The physical-chemical treatment processes can produce high quality effluents, adapt to wide variations in flow and chemical composition and have the ability to remove toxic substances from leachate (Shams-Khorzani *et al.*, 1994). However, these treatment systems are difficult to operate and require highly skilled labor besides high capital and operating costs. Some of these processes even require extensive pretreatment process (Britz, 1995).

As a conclusion, the conventional treatment systems are effective in treating leachate. However, they require highly skilled labor and involve both high capital and operating costs. Therefore, constructed wetland was developed for floating platns (*Eichhornia crassipes*) as an alternative to treat leachate in this research since constructed wetland has low cost of construction and maintenance (El-Gendy, 2003). The type of wetland developed in this research was Free Water Surface (FWS) wetland with leachate concentration factor being studied.

1.3 Objectives of the Study

The objectives of the study are:

(i) To investigate the removal efficiency of BOD, COD, NH_4-N, NO_3^--N, PO_4^{3-} and heavy metal (Fe and Mn) for different leachate concentration (100%, 50%, 25%);

(ii) To study the heavy metal (Fe and Mn) uptake by *Eichhornia crassipes* in roots and leaves;

(iii) To study the effect of leachate concentration in the growth of *Eichhornia crassipes*.

1.4 Scope of the Study

The scope of study includes set-up of lab-scaled wetland to treat leachate. The leachate was collected from landfill and initial water quality of the leachate was analyzed. Then, experiments were conducted separately in constructed wetland: leachate only as control, 100% leachate, 50% leachate and 25% leachate. All the experiments in the constructed wetland were aerated and the amount of leachate in each tank was 7 liters. The efficiency of treatment for different leachate concentrations was evaluated in terms of water quality parameters (pH, DO, BOD, COD, NH_4-N, NO_3^--N, PO_4^{3-}) and heavy metal analysis. The heavy metal (Fe, Mn) by plant uptake was also studied by looking at the heavy metal concentration in plant leaves and roots. Besides, the effect of leachate concentration on plant growth was determined in terms of the leaf diameter and the physical appearance of the leaves throughout the experiments.

1.5 Importance of the Study

The research is conducted to evaluate the efficiency of plants to treat leachate. Phytoremediation is a potential method to treat leachate naturally in low cost. It is an environmentally friendly approach to remove pollutants from leachate. Therefore, phytoremediation can be used practically in landfill site to improve the water quality of leachate. The pretreated leachate in the landfill can be treated with *Eichhornia crassipes* before it is discharged into the river.

This research also determines the best leachate concentration for optimum removal of pollutants through analysis of the parameters. The leachate concentration plays an important role to ensure that the leachate concentration will neither be too high nor too low to interfere the efficiency of treatment in constructed wetland.

Besides, the research provides essential information for heavy metal removal by *Eichhornia crassipes*. A common method of removing heavy metals from wastewater has been to mix it with sewage, where conventional primary, secondary and tertiary treatment would then remove heavy metals (Matagi *et al*., 1998). However, secondary and tertiary processes require high input of technology, energy and chemicals (Tchnobanoglous, 1999). The costs of establishing and maintaining them with skilled personnel are also very high. Therefore, these treatment processes are not very attractive or economic. As a result, plant such as *Eichhornia crassipes* can provide less costly and environmental friendly method to remove heavy metal from wastewater. Besides, *Eichhornia crassipes* can remove and concentrate heavy metal from large volume of wastewater.

compared to the initial concentration (Crites and Tchobanoglous, 1998). Growth of the plants was only observed in 25% leachate concentration wetland where heavy metal concentration was not high to affect plant growth. The pH changes in all the constructed wetland were due to the heavy metal uptake by plants and nitrification by microorganisms.

5.2 Recommendations

For future work, plant harvesting could be done in the wetland to promote active growth of the plants, avoid mosquito proliferation and to improve the efficiency of treatment performance (Mbuligwe, 2005).

Besides, more extensive studies could be conducted for future research in order to understand more clearly the processes/mechanisms that happen in constructed wetland. Below are some recommendations for future research:

(i) To study nitrogen, carbon and hydrogen concentration in plant tissues for different leachate concentration wetlands;

(ii) To use more than one type of plants to treat leachate in constructed wetland;

(iii) To study leachate treatment efficiency when different number of plants is introduced in the constructed wetland.

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