UNIVERSITI PUTRA MALAYSIA

TREATMENT OF SYNTHETIC WASTEWATER USING HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLAND

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By

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Chairman: Associate Professor Dr. Thamer Ahmed Mohamed, PhD

Faculty: Engineering

Constructed wetland is an effective wastewater treatment technology which is used in worldwide. Nevertheless, the effectiveness of using this wastewater treatment is depending on the selection of the type of design used and other factors. This research was conduced to test the influence of media and vegetation subsurface flow constructed wetlands, designed based on the first-order plug flow kinetics. In this study, four horizontal subsurface flow wetlands (HSSF), each with dimensions of 1.3 m (L) × 0.5 m (W) ×0.4 m (D), were constructed at the Research Station of Tehran University, located in Karaj, Iran. The study was carried out from April to September, 2007. Gravel and *zeoilte* were used in this study as substrate. Gravel-beds with and without plants, and gravel-beds mixed with 10% *zeolite*, with and without plants were examined to investigate the feasibility of treating synthetic wastewater which was specially produced and modified to imitate agricultural wastewater. The average synthetic influent wastewater contained approximately 100

mg l^{-1} Nitrate (NO_3-N), 10 mg l^{-1} total Phosphorous, 10 mg l^{-1} Zn (II), 2 mg l^{-1} Pb (II) and 1 mg l^{-1} Cd (II), while the macrophytes selected were *Phragmites Australis* and *Juncus Inflexus* in combine with each other. Water discharge was 65 l / day for each cell, and retention time (HRT) was 1.4 d. The influent and effluent Zn, Pb, Cd, P and NO_3-N concentrations were monitored and analyzed every 15 days to assess the performance of the wetland units for removal efficiencies based on the statistical analyses. Two intermediate samples were also collected from each cell to evaluate the values of pollutant concentrations, the parameters along the units, and the effect of the HRT. At the end of the study, plants were harvested and analyzed for the same factors (NO_3, P, Zn, Pb and Cd).

The results derived indicated that the system had acceptable and optimal pollutant removal efficiency, and that both plants were found tolerant under the tested conditions. The wetland system could achieve the NO_3-N removal of 79.19% in vegetated cell with gravel and 10% *zeolite* as substrate, and 86.58% in an unvegetated cell with gravel and 10% *zeolite* as substrate, and 82.39% in vegetated cell with gravel as substrate, and finally 87.94% in unvegetated cell with gravel as substrate. As for the P removal, the efficiencies of 93.12%, 89.47%, 81.76% and 76.65% were respectively achieved for the vegetated cell with gravel and *zeolite* as substrate, the vegetated cell with gravel as substrate, unvegetated cell with gravel and *zeolite* as substrate, and unvegetated cell with gravel as substrate. The outflow concentrations of Pb and Cd were found to be under the detection limit; however, as for Zn, the removal efficiencies of 99.9%, 99.76%, 99.71% and 99.52% were concluded for the vegetated cell with gravel and *zeolite*, unvegetated cell with gravel and *zeolite*, vegetated cell with gravel, and unvegetated cell with gravel, respectively.

Keywords:

Constructed Wetland, Nitrate-Nitrogen, Phosphorus, Wastewater, Zeolite, Zn

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

RAWATAN AIR KUMBAHAN SINTETIK MENGGUNAKAN ALIRAN MENDATAR PERMUKAAN BAWAH TANAH LEMBAP

Oleh

SANAZ SARAFRAZ

September 2008

Pengerusi: Profesor Madya Dr. Thamer Ahmed Mohamed, PhD

Fakulti: Kejuruteraan

Pembinaan kawasan tanah lembab adalah teknik yang sangat berkesan untuk rawatan air kumbahan dan telah digunakan dengan meluas diseluruh dunia. Walaubagaimanapun keberkesanan penggunaan teknik ini bergantung kepada pemilihan jenis rekabentuk dan beberapa factor lain. Penyelidikan ini telah dijalankan untuk menguji kesan jenis media dan tumbuhan keatas 4 jenis aliran mendatar bawah tanah bagi rekabentuk tanah lembab berdasarkan *first order plug flow kinetics*. Dalam kajian ini, 4 jenis aliran rekabentuk aliran mendatar bawah tanah untuk tanah lembab (HSSF), 1.3 m (L) x 0.5 m (W) x 0.4 m (D), telah dibina di Pusat Penyelidikan, Tehran University yang terletak di Karaj, Iran. Kajian ini telah dijalankan bermula dari bulan April hingga September 2007. Didalam kajian ini batu kelikir dan *zeoilte* telah digunakan sebagai lapisan bawah. Lapisan batu kelikir dengan tumbuhan dan tanpa tumbuhan, dan juga lapisan batu kelikir yang dicampur dengan 10% zeolite dengan tumbuhan dan tanpa tumbuhan telah dikaji untuk mengkaji kemungkinan merawat air kumbahan sintetik yang dibuat dan diubahsuai khusus supaya serupa dengan cirri-ciri air kumbahan pertanian. Purata sisa air kumbahan mengandungi lebih kurang 100 mg 1-1 Nitrat (No3-N), 10 mg 1-1 jumlah Phosphorous, 10 mg 1-1 Zn (II), 2 mg 1-1 Pb (II) dan 1 mg 1-1 Cd (II), sementara *macrophytes* yang dipilih adalah *Phyragmites Australis* dan *Juncus Inflexus* digabungkan bersama. Luahan air adalah 781 d-1 untuk setiap sel dan masa tahanan hidraulik (HRT) adalah 1.2 d. Kepekatan luahan masuk dan keluar Zn, Pb, Cd, P dan NO3-N diperhatikan dan dianalisa setiap 15d untuk mengakses pencapaian kecekapan setiap unit tanah lembab berdasarkan analisa statistik. Dua sampel perantaraan juga dikutip untuk setiap sel bagi dinilai kadar kepekatan bahan enap cemar, parameter-parameter unit dan kesan masa tahanan hidraulik (HRT). Dipenghujung kajian tumbuh-tumbuhan dituai dan analisa keatas NO3, P Zn, Pb dan Cd dilakukan.

Keputusan yang diperolehi menunjukkan sistem mempunyai tahap penerimaan dan tahap kecekapan penyingkiran bahan enap cemar yang optimum dan kedua-dua tumbuh-tumbuhan didapati mampu bertahan dibawah keadaan dimana kajian dijalankan. Sistem tanah lembab tersebut mampu mencapai tahap penyingkiran NO3-N sehingga 79.9% dalam sel berbatu kelikir yang ditumbuhi tumbuh-tumbuhan, 10% zeolite sebagai lapisan strata bawah dan 86.58% dalam sel berbatu kelikir tanpa tumbuh-tumbuhan serta 10% zeolite sebagai lapisan strata bawah dan 87.94% dalam keadaan tanpa tumbuh-tumbuhan dengan batu kelikir sebagai lapisan strata bawah. Tahap penyingkiran P pula ialah 93.12%, 89.47%, 81.76% dan 76.65% masing-masing diperolehi dari sel dengn tumbuh-tumbuhan dengan batu kelikir dan zeolite sebagai lapisan strata bawah, sel dengan tumbuh-tumbuhan dan batu kelikir sebagai lapisan strata bawah, sel tanpa tumbuh-tumbuhan dengan bati kelikir dan zeolite sebagai lapisan strata bawah dan sel tanpa tumbuh-tumbuhan dengan batu kelikir sebagai lapisan strata bawah. Kepekatan luahan Pb dan Cd pula didapati dibawah tahap yang boleh dikesan, bagaimanapun bagi Zn, tahap kecekapan penyingkiran sebanyak 99.9%, 99.7%, 99.71% dan 99.52% dapat disimpulkan untuk keadaan sel masing-masing dengan tumbuh-tumbuhan dengan batu kelikir dan zeolite, sel tanpa tubuh-tumbuhan dengn batu kelikir dan zeolite, sel dengan tumbuh-tumbuhan dengan batu kelikir, dan sel tanah tumbuh-tumbuhan dengan batu kelikir.

Kata Kunci:

Tanah lembab yang dibina, Nitrat-Nitrogen, Phosfur, Air kumbahan, Zeolite, Zn

DEDICATION

I wish to dedicate this thesis to my beloved country, Iran

And

To my parents, Manouchehr Sarafraz and Afsaneh Parhami

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I am ever grateful to God, the Creator and the Guardian, and to whom I owe my very existence.

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I wish to thank my my brother, Yashar and my sister, Sepideh for providing a loving environment for me.

Most importantly, I wish to thank my parents. They bore me, raised me, supported me, taught me, and loved me. To them I dedicate this thesis.

I certify that an Examination Committee has met on 25th September 2008 to conduct the final examination of **Sanaz Sarafraz** on her **Master of Science** thesis entitled "**Treatment of synthetic wastewater using horizontal subsurface flow constructed wetland**" in accordance with Universiti Pertanian Malaysia (higher degree) act 1980 and Universiti Pertanian Malaysia (higher degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of supervisory committee were as follows:

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Date: 18 December 2008

DECLARATION

I declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institutions.

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SANAZ SARAFRAZ

Date: 12 March 2009

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LIST OF ABBREVIATIONS

Abbreviations	**Meaning**
BOD	5day Biochemical Oxygen Demand
Cd	Cadmium
CW	Constructed Wetland
d	Day
D	Depth
EPA	Environmental Protection Agency
ET	Evapotraspiration
FWS	Free Water Surface
HLR	Hydraulic Loading Rate
HRT	Hydraulic Retention Time
K_t	1^{st} Order Rate Constant
Kg/g	Kilogram/gram
L	Length/Liter
mg	Milligram
N	Nitrogen
NO_3-N	Nitrate- Nitrogen
°C	Degrees Celsius
P	Phosphorus
Pb	Lead
pH	Acidity
ppm	Parts Per Million

PVC	Polyvinyl Chloride
RZE	Root Zone Effect
SSF	Subsurface Flow
TSS	Total Suspended Solids
TP	Total Phosphorus
TKN	Total Kjeldahl Nitrogen
W	Wide
WW	Wastewater
Zn	Zinc

CHAPTER I

INTRODUCTION

1.1 General

There are 80 countries and regions which are experiencing water stress all around the world; out of which 30 countries are suffering water scarcity during a large part of the year, and exploiting reserves which are being not sufficiently replaced (Gleick, 1993).

Iran is also going to experience water scarcity by 2025, based on the availability of less than 1000 m^3 of renewable water per person per year (Kivaisi, 2001). The depletion of reserves and competition for water usage between the nations, as well as among various sectors such as agriculture, industry and municipalities, has imposed the major reasons leading to water scarcity.

Iran is a country with an area of 648,000 km^2, in which arid and semi-arid climate has covered a great area of the lands. The average of its annual precipitation is about 240 mm, which is less than one third of the average precipitation of the world.

1.2 Statement of the problem

Due to the occurrence of draught in 2001, population growth, urbanization and industrial development, the need for water use has been increased in Iran (Hassanoghli, 2003).

On the contrary to the rising needs, the amount of renewable water resources has been reduced in the last few years. Statistics shows that this amount was decreased from 5500 m^3 in 1960 to 2100 m^3 in 1997, to 1750 m^3 in 2005, and this is expected to be only 1300 m^3 in 2020 (Iran Statistical Centre, 2006).

The minimum acceptable renewable water resources demand for a standard life is 2000 m^3 per year per capita (Bouwer, 1994). According to water usage amount and the population increase, the water demand in Iran is expected to be 126×10^{9} m^3 in the year 2010, and this will be 150×10^{9} m^3 in 2020 (Hassanoghli, 2003).

In addition to the natural scarcity of freshwater, the quality of the available freshwater is also getting worse; this is due to pollution which is a result of water shortage. Today, it is reported that more than 5 million people die each year throughout the world from various illnesses because of drinking poor quality water (Kivaisi, 2001).

In Iran, pollution resulting from agricultural wastewater is increased, a scenario which is harmful for both human being and environment. The main sources of agricultural wastewater include silage leachate, manure runoff, pesticide runoff and farmyard runoff. The recognitions of the impacts of these pollutants on the environment have led to the improvement of wastewater treatment systems.

Agricultural and residential wastewaters contain high levels of nutrients and if not treated, they can contaminate surface water and groundwater systems.

During the last two decades, various experiments have been taken to reduce the nutrient transport from agricultural activities. The best identified management practices are increasingly used to reduce the input of nutrients to the agricultural fields and the leakage from the fields. At the same time, different water treatment approaches such as wetlands are also used to decrease the transport of nutrients from land to the sea (Johansson *et al*., 2004). The management for water usage and water demand, using recycled water and wastewater, as well as using water and wastewater treatment programs are some of these solutions.

The treatment of wastewater using constructed wetland is one of the treatment systems which is used in many parts of the world. This system seems to have the potential to be one of the solutions in discharging the huge amount of wastes and getting access to safer drinking water.

Although CWs have not been widely adopted in Iran, they can be preferred system for wastewater treatment due to the existence of many natural wetlands and capability of many areas for constructing artificial wetlands to treat different kinds of wastewaters. They are effective in treating pollutants by combining biological, chemical and physical treatment processes (Crites, 1994).