INTEGRATED USE OF CONSTRUCTED WETLANDS FOR LIVESTOCK WASTEWATER TREATMENT AND FODDER PRODUCTION

By

NGO THUY DIEM TRANG

Thesis Submitted to the School of Graduate Studies, Univeristi Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

I wish to dedicate this work to my beloved parents, Ngo Ngoc Huy and Pham Thi Leo, and respected teachers, supervisors who gave me knowledge and experience and I also wish to dedicate this research to all the tropical farmers

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Associate Professor Liang Juan Boo, Ph.D.

Faculty: Agriculture

Constructed wetlands (CW) are widely used to treat wastewater (WW) because of its high efficiency for removal of pollutants, and low operational and maintenance costs. Plants play an important role in enhancing the WW treatment process in CW. Therefore, selection of the appropriate plant species to be grown in CW is an important criterion to ensure the success of the CW system. The performances of 5 plant species, namely, Typha (*Typha spp*), Dwarf Napier (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*) and 2 varieties of Kenaf (*Hibiscus cannabinus* L) i.e. K 465/118 (K465) and Thai Kenaf grown in cattle WW were evaluated over 4 weeks. The different plant species were ranked using Typha (a widely use plant for phytoremediation) as a control based on their percentage of mortality, rate of growth of the root system, crude protein (CP) content, dry matter yield (DMY), and palatability score. The results showed that Typha had the highest score followed by Napier, K465 Kenaf, Thai Kenaf and Guinea. Based on the results of this study three

plant species (Typha, Napier and K465 Kenaf) were selected for further evaluations in experiment 2.

In the second experiment, the 3 plant species were grown in 3 different concentrations of cattle WW; low (COD 2,000 mg/L), medium (COD 7,000 mg/L) and high (COD 14, 000 mg/L) in a 3 x 3 factorial experiment arranged in a RCBD design. Almost all of the Napier plants died by the end of the 2 weeks adaptation period. Typha and Kenaf had the highest above-surface fraction (stems and leaves) fresh yield (FY) and DMY in the medium WW concentration. The nutrient content of the 2 plants increased with increased WW concentration. The under-surface fraction (roots) FY and DMY of Typha was positively associated with the WW concentration, while negative relationships were obtained for Kenaf. Pollutants removal by Typha from WW was more efficient than Kenaf.

The third experiment was conducted to examine the efficiency of pollutants removal from cattle WW. It consisted of a 3 hydraulic retention times (HRT) (5, 10 and 15 days) x 3 plant types [Typha, Kenaf and no plant (as control)] factorial experiment, arranged in a randomized complete block design (RCBD) with 3 replications. On average, the removal efficiency ranged from 58 to 65 % for Chemical Oxygen Demand (COD) for the various treatments, 77 to 94 % for Total Suspended Solids (TSS), 60 to 79 % for Ammonium Nitrogen (NH^{+}_{4}-N), 51 to 65% for Total Kjeldahl Nitrogen (TKN), 50 to 60% for Dissolved phosphate (DP) and 50 to 61% for Total Orthophosphate (OP). Nitrogen and P removal efficiencies of the cells with plants

were 11-19 and 7-11%, respectively, higher than unplanted cells; however, plants were not effective in COD and TSS removals. HRT contributed on removal efficiency for TSS and COD but not in nutrients removal. Effluent TSS for the 15 days HRT (46.7 mg/L) is within the permissible limit for effluent discharge from livestock WW in Malaysia. However, the average COD of the effluent discharge (684 mg/L) from different treatments was marginally higher than the permissible limit (500 COD mg/L) for effluent discharge from livestock WW in Malaysia.

Typha and Kenaf plants grew well in the CW and exhibited their potential as phytoremediation agents and possibly as a source of animal feed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia dalam memenuhi keperluan untuk Ijazah Master Sains

INTERGRASI PENGGUNAAN TANAH LEMBAB DIBINA UNTUK RAWATAN AIR KUMBAHAN TERNAKAN DAN PENGELUARAN FODER

Oleh

NGO THUY DIEM TRANG

Februari 2004

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Tanah Lembab Dibina (CW) telah digunakan secara meluas untuk merawat air sisa dab kumbahan (WW) disebabkan keberkesanan yang tinggi untuk menyingkir bahan pencemar dan kos operasi dan penyelenggaraan yang rendah. Tumbuhan memainkan peranan yang penting dalam mempercekapkan proses rawatan WW di dalam CW. Oleh sebab itu, pemilihan spesis tumbuhan yang tepat untuk ditanam di dalam CW adalah kriteria yang penting untuk mempastikan kejayaan sistem CW. Prestasi 5 spesis tumbuhan iaitu Typha (*Typha spp*), Napier Kerdil (*Pennisetum purperium*), Rumput Kuda (*Panicum maximum*) dan 2 varieti Kenaf (*Hibiscus cannabinus* L) iaitu K 465/118 (K465) dan Thai Kenaf yang ditanam di dalam WW ternakan lembu telah diteliti selama 4 minggu. Kedudukan mengikut skor tertinggi sepsis berkenaan telah disusun menggunakan Typha (tumbuhan yang digunakan secara meluas untuk

fitoremediasi) sebagai asas kawalan bersandarkan kadar kematian, kadar pertumbuhan sistem akar, kandungan protein kasar (CP) hasil bahan kering (DMY), dan skor kesedapan. Berdasarkan keputusan kajian ini tiga spesis tumbuhan (Typha, Napier dan Kenaf K465) telah dipilih untuk penelitian di dalam eksperimen 2.

Didalam eksperimen kedua, ketiga-tiga spesis telah ditanam dalam konsentrasi WW yang berbeza iaitu konsentrasi rendah (COD 2,000 mg/L), sederhana (COD 7,000 mg/L) dan tinggi (COD 14,000 mg/L) didalam eksperimen faktorial 3 X 3 yang disusun dalam rekabentuk RCBD. Hampir semua tumbuhan Napier mati pada penghujung minggu kedua tempoh penyesuaian. Typha dan Kenaf mempunyai bahagian atas permukaan (batang dan daun), hasil segar (FY) dan DMY tertinggi didalam konsentrasi WW sederhana. Kandungan nutrien didalam 2 tumbuhan ini meningkat dengan pertambahan konsentrasi WW. Hasil segar (FY) bahagian bawah permukaan (akar) dan DMY Typha berkait secara positif dengan konsentrasi WW, manakala hubungan negatif telah diperolehi untuk Kenaf. Penyingkiran bahan pencemar dari WW oleh Typha adalah lebih efisien berbanding Kenaf.

Eksperimen ketiga telah dijalankan untuk memeriksa kecekapan penyingkiran bahan cemar daripada WW ternakan lembu. Eksperimen faktorial, yang terdiri daripada 3 masa retensi hidrolik (HRT) (5, 10 dan 15 hari) X 3 jenis tumbuhan [Typha, Kenaf dan tiada tumbuhan (sebagai kawalan)] disusun dalam rekabentuk RCBD dengan 3 replikasi. Secara keseluruhan, kecekapan penyingkiran bahan berjulat daripada 58 hingga 65% untuk COD, 77 hingga 94% untuk jumlah Pepejal Terampai (TSS), 60

hingga 79% untuk Ammonia nitrogen (NH^{+}_{4}-N), 51 hingga 65% jumlah untuk Nitrogen Kjeldahl (TKN), 50 hingga 60% untuk Fosforus terlarut (DP) dan 50 hingga 61% untuk fosfat (OP). Efisiensi penyingkiran nitrogen dan fosforus oleh tumbuhan adalah masing-masing 11 – 19 dan 7 –11% lebih tinggi daripada sel tak bertanaman (kawalan); walau bagaimanapun, keberkesanan tumbuhan adalah rendah untuk menyingkir COD dan TSS. HRT menyumbang keatas kecekapan pengurangan TSS dan COD tetapi tidak untuk pengurangan nutrien. Effluen TSS untuk 15 hari HRT (46.7 mg/L) adalah di dalam had yang dibenarkan untuk effluen daripada WW ternakan di Malaysia. Walau bagaimanapun, purata COD effluen (684 mg/L) daripada rawatan yang berbeza adalah lebih tinggi daripada had yang dibenarkan (500 COD mg/L) untuk effluen daripada WW ternakan.

Typha dan Kenaf tumbuh dengan baik dalam CW dalam kajian ini dan ia mempamerkan potensi sebagai agen fitoremediasi dan berkemungkinan sebagai sumber makanan haiwan.

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I certify that an Examination Committee met on 6th February 2004 to conduct the final examination of Ngo Thuy Diem Trang on her Master of Science thesis entitled "Integrated Use of Constructed Wetlands for Livestock Wastewater Treatment and Fodder Production" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis 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 the Supervisory Committee are as follows:

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DECLARATION

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

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NGO THUY DIEM TRANG

Date: 22 April 2004

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ABBREVIATIONS

CW	Constructed Wetlands
WW	Wastewater
COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
OM	Organic Matter
TKN	Total Kjeldahl Nitrogen
NH^{+}_{4}-N	Ammonium Nitrogen
OP	Orthophosphate
DP	Dissolved phosphate
TSS	Total Suspended Solids
CP	Crude Protein
DM	Dry Matter
DMY	Dry Matter Yield
FY	Fresh Yield
CPY	Crude Protein Yield
ADF	Acid Detergent Fibre
NDF	Neutral Detergent Fibre
RL	Root Length
SH	Stem Height
N	Nitrogen
P	Phosphorus

AOAC	Association of Official Analytical Chemists
APHA	American Public Health Association
HRT	Hydraulic Retention Time
mg/L	milligram per litter
pH	Hydrogen Ion Concentration
cm	Centimetre
g/m^2	gram per meter square
kg/m^2	kilogram per meter square
SSF	Subsurface Flow
FWS	Free-Water Surface

CHAPTER 1

INTRODUCTION

The trend toward large livestock operations has caused an increase in the volume and concentration of animal wastes on production farms, which can potentially desolate the environment. This is because many large livestock farms do not have the land on which to spread the manure, which is generally considered to be the most common way used to dispose livestock manure. Confined animal operations continually generate huge amounts of animal wastes, and therefore, these establishments must have a proper waste management system to adequately handle the wastes.

The environmental problem from cattle production in Malaysia is associated mainly with the intensive feedlot system where large quantities of cattle waste are produced. Unfortunately, feedlot operators have not invested enough in the treatment of their cattle wastes due to weak and intermittent enforcement of regulations to control the discharge of cattle wastes. Most of feedlot operators conveniently discharge their cattle wastes directly into nearby waterways (Jalaludin and Halim, 1998). Although cattle wastewater (WW) contains nutrients, particular nitrogen (N) and phosphorus (P), which are potential nutrients for crops, the amount of WW produced in intensive livestock farms is often far in excess of agronomic requirements. This has led to repeated WW applications at rates that are greater than crop requirements, leading to