COPYRIGHT© INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DEVELOPMENT OF LANDSCAPE ECOLOGICAL MODEL SYSTEM USING *Glossostigma elatinoides* AND *Hemianthus callitrichoides* TO REMEDIATE AQUACULTURE POND CONTAMINANTS

BY

FARAH AYUNI BT MOHD HATTA

A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Built Environment)

Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia

SEPTEMBER 2015

ABSTRACT

The aquaculture industry has contributed significantly to the economic development of Malaysia. However, the large volume of water consumption and the effluent discharged into water sources has caused significant environmental problems that require urgent management and the introduction of more effective controls. For instance, water pollution caused by excess contaminants, rapid loss of natural habitats such as mangrove lands as well as degradation of ecosystems cause innumerable damage far beyond damage to the environment. Phytoremediation, which is the application of plant-based technologies, has become more acceptable as a means to examine the problems and provide sustainable solutions for such environmental issues. Accordingly, this research explores the efficacy of a landscape ecological model system to remediate aquaculture pond contaminants specifically heavy metals using selected aquatic plant species. To achieve this aim, we examine the contaminants available in shrimp and catfish aquaculture ponds in Perak. The results revealed that nutrients like nitrogen and phosphorus and heavy metals concentration varied dependent upon several factors such as the size of the farm, the quantity of food given, the chemicals added, and the cycles and periods of cultivation. In addition, the environmental condition itself like pH, salinity, conductivity, and dissolved oxygen also influence the toxicity of the heavy metals available. Through water sampling, heavy metals that exceed the limit of water quality standard for aquaculture, which are cadmium (Cd), copper (Cu), chromium (Cr), and lead (Pb) were assessed. The efficiency of potential aquatic plants which are *Glossostigma elatinoides* and *Hemianthus callitrichoides* to sequester Cd, Cu, Cr and Pb were also investigated. This model system was conducted over four different periods ranging four weeks and at the following three different concentrations:1 mg/L, 2 mg/L, and 3 mg/L. The findings suggested that the capability to sequester different concentrations of heavy metals for certain periods varied between different species. The results indicated that *Glossostigma elatinoides* was a good phytoremediator for Cd and Cr with the bioconcentration factor (BCF) values 5436.7±16.70 and 6070.4±3.98 respectively, whereas *Hemianthus callitrichoides* was a good phyoremediator for Cu and Pb with the BCF values 5291.1±30.19 and 1787.1±27.43 respectively. This highlights that aquatic plants have different capabilities to sequester different heavy metals since various factors are involved during the phytoremediation process. The expected outcome of this research is to introduce cost-effective and eco-friendly technologies to mitigate environmental pollution from a landscape ecology perspective. The plants used as phytoremediators can enhance the visual aesthetics of underwater gardens, create new habitats, improve the soil structure, and provide ecology restoration and revitalisation. Thus, phytoremediation should be recognised as a 'tool' in landscape ecological development especially in contaminated sites. This knowledge may push the boundaries of the landscape architecture profession as well as promoting the concept of sustainability.

Keywords: Aquaculture; Phytoremediation; Landscape ecology; Heavy metals; *Glossostigma elatinoides*; *Hemianthus callitrichoides*; In vitro model system.

خلاصة البحث

لقد شاركت صناعة تربية الأحياء المائية بشكل واضح في تطوير الاقتصاد الماليزي. ومع ذلك فإن استخدام المياه بكثرة وطرح فضلاتها في مصادر المياه أدى الى حدوث مشاكل بيئية تحتاج إلى إدارة وسيطرة كبيرة. على سبيل المثال، تلوث المياه الناتج من زيادة الملوثات، مثل: النتروجين، والفسفور، والمعادن الثقيلة، والخسارة السريعة للمحميات الطبيعية للأشجار الاستوائية، وتحطم البيئة المائية سببت دماراً شديداً للبيئة. إن استخدام علاج النباتات كعلاج لتطبيق التقنية النباتية، قد أصبح أكثر قبولاً كطريقة اختبار المشاكل، وتهيئة الحلول الملائمة لها. وفقا لذلك، فإن هذا البحث يحاول أن يكشف نهجاً بيئياً فعالاً عن طريق تطوير نظام نموذجي لعلاج النباتات لغرض معالجة الملوثات اللاعضوية الناتجة من البحيرات. ولتحقيق هذا الهدف، فقد أُختيرت المعوقات من ناحية نوعية المياه، والملوثات اللاعضوية، وعلى وجه الخصوص المعادن الثقيلة. بينت النتائج أن التركيز العالي للمواد الغذائية، مثل: النتروجين، والفسفور، وكذلك كمية المعادن الثقيلة تعتمد على عوامل عدة: مساحة المزرعة، وكمية الغذاء المعطاة، وكمية المواد الكيميائية المضافة، وإعادة عمليات الحرث. فضلا عن ذلك، فإن العوامل البيئية، مثل: درجة الحموضة، والملوحة، والأكسجين المذاب تؤثر في تسميم المعادن الثقيلة. ومن خلال أخذت عينات للنفايات السائلة، وقد تمّ تقدير المعادن الثقيلة التي تتجاوز الحد المسموح من مستوى جودة المياه لتربية الأحياء المائية، وهي: الكادميوم، والنحاس، والكروم، والرصاص. وتمّ استقصاء كفاءة النباتات المائية المرجحة، وهي: الكلوسوتيكماليتينويدس والهيميانثاسكالليترويدس (*Glossostigma elatinoides* و *Hemianthus callitrichoides*) لعزل النحاس، والكادميوم، والكروم، والرصاص. وتمّ إجراء هذا النموذج على أربعة أزمنة مختلفة بحدود أربعة أسابيع، وبالتركيز على الآتي: 1، و2، و3 مغ/لتر. اقترحت النتائج أن قابلية عزل تركيز المعادن الثقيلة المختلفة، وبأزمنة مختلفة تختلف باختلاف الفصائل. أوضحت النتائج أن الكلوسوتيكماليتينويدس معالج جيد للكادميوم، والكروم بقيمة "BCF 5436.7±16.70 و 6070.4±3.98" على التوالي. بينما الهيميانثاسكالليترويدس معالج جيد للنحاس، والرصاص بقيمة " BCF 5291.1±30.19 و 1787.1±27.43" على التوالي. وهذا يبين أن النباتات المائية لها قابلية مختلفة لعزل المعادن الثقيلة، حيث إن العوامل العديدة تعتمد عليها في عملية المعالجة النباتية. من منظور جمال البيئة فإن المعالجة النباتية تعزز المنظور الجمالي للحدائق تحت مائية، وإيجاد محميات، وتطوير عناصر تركيب التربة، وترميم وتنشيط علم البيئة. لذلك فإن المعالجة النباتية تعد أداة لتطوير المناظر الطبيعية في المناطق الملوثة على وجه الخصوص. وهذه المعرفة قد تدفع العاملين إلى تحديد مناطق المناظر الطبيعية فضلاً عن تشجيعها لمفهوم قوة المساندة الدائمة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

………………………………………..….
Rashidi Othman
Supervisor

I certify that I have read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

……………………………….............
Maheran Yaman
Internal Examiner

…………………………………….....
Mhd. Radzi Abas
External Examiner

This thesis was submitted to the Department of Landscape Architecture and is accepted as a fulfilment of the requirement for degree of Master of Science (Built Environment).

……………………………….........
Zainul Mukrim Baharuddin
Head,
Department of Landscape Architecture

This thesis was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for degree of Master of Science (Built Environment).

………………………………………..
Alias Abdullah
Dean, Kulliyyah of Architecture and Environmental Design

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Farah Ayuni bt Mohd Hatta

Signature……………………………… Date …………………………………

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

DEVELOPMENT OF LANDSCAPE ECOLOGICAL MODEL SYSTEM USING *Glossostigma elatinoides* AND *Hemianthus callitrichoides* TO REMEDIATE AQUACULTURE POND CONTAMINANTS

I declare that the copyright holder of this thesis are jointly owned by the student and IIUM.

Copyright © 2015 by Farah Ayuni bt Mohd Hatta and International Islamic University Malaysia. All rights reserved.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may only be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purpose.

3. The IIUM library will have the right to make, store in a retrieval system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Farah Ayuni bt Mohd Hatta

……………………………	……………………….
Signature	Date

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

DEVELOPMENT OF LANDSCAPE ECOLOGICAL MODEL SYSTEM USING *Glossostigma elatinoides* AND *Hemianthus callitrichoides* TO REMEDIATE AQUACULTURE POND CONTAMINANTS

I declare that the copyright holder of this thesis is
Farah Ayuni bt Mohd Hatta

Copyright © 2015 by Farah Ayuni bt Mohd Hatta. All rights reserved.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may only be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purpose.

3. The IIUM library will have the right to make, store in a retrieval system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Farah Ayuni bt Mohd Hatta

…………………………… ……………………….
Signature Date

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and The Most Merciful.

First and foremost, I would like to express my special appreciation to my supervisor, Assoc. Prof. Dr. Rashidi Othman, for the guidance and support which broadened my knowledge in landscape architecture. I am very grateful to be under his supervision as his enthusiasm was a constant source of encouragement throughout this research.

My deepest thanks to my family who have been very supportive, especially my beloved parents Mohd Hatta Yahya, Robitoh Hassan, Hamzah Said and Nor Hashimah Alias. Thanks for raising me as a good caliph on Earth. Not to forget, my deepest thanks to my wonderful and supportive husband, Muhammad Ammar Hamzah, who is always there when I need him and is a source of inspiration and happiness. Thanks for being my best friend. I am also grateful to Allah for blessing me with such a wonderful daughter, Munaa ‘Umairah. Many thanks to my beloved sister, Maziati Akmal who has supported me throughout my research. The invaluable encouragement and love of these wonderful people continues to motivate me to excel.

I would also like to take this opportunity to acknowledge all my friends, Razanah Ramya, Fatimah Azzahra Mohd Zaifuddin, Nurul Azlen Hanifah, Qurratu Aini Mat Ali, Nur Hanie Mohd Latiff, Anis Fatihah Abu Yazid, and Wan Syibrah Hanisah Wan Sulaiman for assisting me during the sample collection for this research and for the knowledge we shared. Special thanks to the Science Officer of Herbarium Lab, Nur Hafizana who assisted me in completing this research. I am grateful to Allah for the opportunity to meet such wonderful people. May Allah bless all of you with His Rahmah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

^{o}C	degree
=	equal
>	more than
%	percent
±	standard deviation

LIST OF ABBREVIATIONS

μg/L	microgram per litre
μmol	micromolar
Al	aluminum
As	arsenic
ASEAN	Association of Southeast Asian Nations
BCF	bioconcentration factor
BOD	biological oxygen demand
Cd	cadmium
Co	cobalt
COD	chemical oxygen demand
Cr	chromium
Cu	copper
DO	dissolved oxygen
EMS	Early Mortality Syndrome
EPP6	sixth Entry Point Project
FAO	Fisheries and Aquaculture Department
Fe	iron
Hg	mercury
IMWQS	Malaysia Interim Marine Water Quality Criteria and Standards
mg/kg	milligram per kilogram
mg/L	milligram per litre
Mn	manganese
Mo	molybdenum
N	Nitrogen
NCIA	Northern Corridor Implementation Authority
NH_3	ammonia
NH_4	ammonium
Ni	nickel
NKEA	National Key Economic Area
NGO	non-governmental organization
NO_2	nitrite
NO_3	nitrate
NWQS	National Water Quality Standards
P	Phosphorus
PAHs	polycyclic aromatic hydrocarbons
pH	power of hydrogen
Pb	lead
PO_4	phosphate
Pt	platinum
Ra	radium
Rn	radon
TOC	total organic carbon
TDS	total dissolved solid
TSS	total suspended solid
U	uranium
ZIA	Aquaculture Industrial Zone
Zn	zinc

CHAPTER ONE

INTRODUCTION

1.1 RESEARCH BACKGROUND

Contaminated sites arenormally cleared and restored by environmental engineers and specialists. Landscape architects only involved when there is an area that needs to be developed as a green area.Their role only begins after site remediation has completed. Phytoremediation should be recognised as a landscape design tool and approach as it may help enhance sites restoration and revitalization through appropriate plant selection in problematic areas, for example, ecological restoration in the ex-mining area, landfill area, agricultural and aquaculture areas among others.As mentioned by Sleegers (2010), in the context of landscape architecture, phytoremediation is a 'green tool' that pushes the boundaries of the landscape profession.

This research focuses on the phytoremediation approach by developing a landscape ecological model system using aquatic plant species in order to remediate heavy metal contaminants produced by aquaculture ponds. To achieve the aim of this research, we first provide an overview of the aquaculture industry in Malaysia and its impacts onthe environment. The poor aquaculture pond management, which led to serious environmental degradation, will be a major issue in this research. This ecological approach will be studied in order to contribute towards introducing new knowledge and technology, consequently improving the management of aquaculture pond without harming the surrounding environment. This research may also help promote the concept of sustainability in the aquaculture industry. The Messenger of

Allah, Muhammad (PBUH) said, "*There should be neither harming [darar] nor reciprocating harm [diraar]"* (Imam Nawawi, Hadith no.32, 2002).

To accomplish the goal, site sampling at aquaculture pond areas in Perak, Peninsular Malaysia will be performed. The water sample will be collected and analysed in order to identify the concentration of the heavy metals available. Then, the efficiency of potential aquatic plants to sequester identified contaminants available in the pond will be investigated. The phytoremediation model system using selected aquatic plant species will be run over several periods to remediate several heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr), and lead (Pb) in different concentrations.

The research is expected to contribute tothe landscape field as it introduces cost-effective and eco-friendly technology to remedy environmental pollution. Moreover, the phytoremediation approach is a scientific and technological knowledge which could be beneficial (*ilmnafi'*) to the community (*Ummah*) as well as future generations.

1.2 ISSUES

Globally, almost half of total fish supplies for human consumption is contributed by the aquaculture industry (FAO, 2010) and 90% of global aquaculture production was is from Asia (Thorpe, Reid, and Smith, 2014). In late 1970s, shrimp aquaculture was practiced in many ASEAN countries and it begun to develop in the early 1980s through governmentincentives (Senarath, and Visvanathan, 2001). As reported by Integratedfarm (2009), during 1997, total global production of shrimp aquaculture was 0.95million tons, while in 2004, the production increased to 1.8 million tons.

Although this industry contributed significantly toeconomic growth, however, the large volume of water consumption and the effluent discharged into the water sources caused significant environmental problems that must be properly controlled (Read and Fernandes, 2003; Akinbileand Yusoff, 2012). The aquaculture waste may decrease dissolved oxygen levels, accumulate bottom sediments, and load high nutrients that would cause water deterioration due to excessive phytoplankton growth (Tilley et al., 2002; Ghaly,Kamal,and Mahmoud,2005). Other negative impacts of the aquaculture in relation to the environment were mentioned by the Fisheries and Aquaculture Department (FAO, 2006) as below:

i. Natural habitats and the related ecological destruction as a result of ecosystem functions alteration.
ii. Water demand competition.
iii. Health and environmental issues increase due to improper use of chemicals.
iv. Aquatic animal diseases transmission through improper regulated translocations.

The rapid establishmentof this industry has increased the attention among researchers and legislators to mitigate the environmental problems based on the principles of “Ecosystem- based Approach to Aquaculture” introduced by the FAO. The principles emphasized the holistic approach in managing ponds produced by the aquaculture industry by considering the capacity of the ecosystem to assimilate the effluent released. Many researches have focused on the aquaculture and its environmental impact (Fishery et al., 2008), assummarised below:

i. Mangrove loss;

Mangrove forest destruction is the mostsignificant effect resulting from the aquaculture industry. Evidently, mangrove forests play an important role in terms of ecologically and socioeconomically, which should be highly recognised on conservation agendas (International Union for Conservation of Nature [IUCN], 1996; Baran and Hambrey, 1998; Nickerson, 1999; Islam and Wahab, 2005). However, the mangrove areas of many countries such as Sri Lanka, China, Thailand, India, Indonesia, Philippines, Malaysia, Ecuador, Mexico, Honduras, Panama, and Nicaragua have been cleared for aquaculture activities (Clough, 1993; Jayasinghe and De Silva, 1993; Ong, 1995; Field 1996; Macintosh, 1996; Primavera, 1997; Delgado et al., 2003).

Shrimp farming was reported as a main contributor of mangrove forest destruction over the past few decades (Delgado et al., 2003). There were reports that 1-1.5 million ha of coastal lowlands of the mentioned countries have been converted for shrimp aquaculture (Rosenberry, 1998; FAO, 1999) and globally, it is estimated that more than a third of mangrove forests have been degraded (Azad, Jensen and Lin, 2009). Specifically, in Thailand, a study reported that 16–32% of the total mangrove areas lost from 1979 to 1993 were due to shrimp aquaculture (Dierberg and Kiattisimkul, 1996). In Ecuador, Boyd (2002) reported that between 1969 and 1992, 15-20% of the total destruction was caused by the aquaculture industry. Peninsular Malaysia also suffered from the same problem where it lost 18700 ha from 1980 to1990 (Chan et al., 1993).The destruction of the mangrove ecosystem affected from poor aquaculture management has led to several problems such as degrading the existing natural populations and habitats, expose the coastlines to storm and tidal surges (Azad et al., 2009) a cause of soil acidification (Mitra and Bhattacharyya, 2003), and water pollution (Martin, 2011).

ii. Waterconsumption and effluent;

Since the last two decades, large scale shrimp aquaculture has boomed (Allsopp et al., 2009). Although this industry contributes significantly to the economic growth of the country, however, the large volume of water consumption and the large amount of effluent discharged into the water source cause a significant environmental problem that must be controlled (Read and Fernandes, 2003; Akinbileand Yusoff, 2012). Studies have shown that coastline areasare most affected by shrimp aquaculture ponds (Corea et al., 1995). Eflluents areproduced from fertilizers, uneaten feeds, faecal and other excretory wastes (Delgado et al., 2003; Nora'aini, Nurbaitiand Ahmad Jusoh, 2011) that consist of nutrients like nitrogen and phosphorus which are discharged into drains without any or minimal treatment, subsequently contaminating water sources (Bernhard et al., 2004; Senarath and Visvanathan, 2001).

Consequently,the effluentwould cause eutrophication and disturb aquatic life due to blooms of algal and increasing of water toxicity (Correll, 1998; Delgado et al., 2003; Singkran and Sudara, 2005). Moreover, the aquatic ecosystem is threatened by the chemicals and antibiotics used during the pond treatment process (Tendencia and de la Pena, 2001).

iii. Improper pond management;

Many approaches such as settling systems, centrifugal systems and mechanical filters have been introduced to treat wastes, however they seem ineffective because they produce large amounts of sludge deposits, consume high energy,are expensive, and need frequent maintenance (Barceló and Poschenrieder, 2003; Evans and Furlong, 2003; Nora'aini et al., 2005;Mudhoo, Garg, and Wang, 2012). The sand filtration approach had also been practiced, but it could only remove suspended solid in aquaculture pond (Porrello et al., 2003).

1.3 PROBLEM STATEMENTS

As a whole, the problems regarding aquaculture industry are:

i. Improper effluent management of aquaculture pondswhichproduced in large amounts.
ii. Water pollution caused by excess contaminants such as, nitrogen, phosphorus, and heavy metals.
iii. Rapid loss of natural habitat such as mangrove land and degradation of ecosystem.
iv. Distract visual impact on landscape scenic and aesthetic quality.

Due to awareness about the loss of mangrove ecosystems and its environmental and societal effects, many researchers have initiated studies on rehabilitation and restoration strategies to achieve sustainable aquaculture practices and long-term conservation and management of natural resources (Paez-Osuna, 2001; Lebel et al., 2002; Allsopp et al., 2009; Azad et al., 2009; Bosire et al., 2008). As emphasised by Akinbile and Yusoff (2012), in order to sustain the development of aquaculture in Malaysia, a proper water pond treatment should be practiced.