UNIVERSITI PUTRA MALAYSIA

EFFECTS OF SEWAGE SLUDGE ON TREE GROWTH, SOIL PROPERTIES AND GROUNDWATER QUALITY

ARIFIN ABDU.

EFFECTS OF SEWAGE SLUDGE ON TREE GROWTH, SOIL PROPERTIES AND GROUNDWATER QUALITY

By

ARIFIN ABDU

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

June 2005

DEDICATION

This thesis is dedicated to:

My beloved wife and son

Nooreriyanie Simon

and

Muhammad Afiq Farhan Arifin

Father, mother and grandmother in ever loving memory

Abdu Andaki, Zaharah Bachok

and

'Nenek Indo'

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

EFFECTS OF SEWAGE SLUDGE ON TREE GROWTH, SOIL PROPERTIES AND GROUNDWATER QUALITY

By

ARIFIN ABDU

June 2005

Chairman : Mohamad Azani Alias, PhD

Faculty : Forestry

Effect of sewage sludge on the growth of plants is well documented for many agricultural and horticultural crops but limited research has been conducted on forest trees. The organic matter in sewage sludge can improve the soil physical and chemical properties but it also contains varying amounts of heavy metals that may cause toxicity and potentially can contaminate the groundwater.

Thesis reports two studies on the effects of sewage sludge on tree growth, foliar nutrients, soil properties and groundwater quality. The first study was conducted in the greenhouse with using two timber species viz *Dyera costulata* and C*innamomum iners.* Factorial experiments of 10 x 2 x 4 were conducted to study the effect of sewage sludge on the growth performance and foliar nutrient concentrations at the 10 levels of treatment. After six months of treatment, the results showed that T7 (70% of sludge by volume) and T6 (60% of sludge by

volume) gave the highest height and growth diameter for *D. costulata* and *C. iners,* respectively. The use of sewage sludge at the rate of more than 70% for *D. costulata* and 60% for *C. iners* did not gave the significant different in terms of height, diameter and foliar nutrient concentrations. The study also indicates that the critical nutrient levels for *D. costulata* and *C. iners* were correspond to treatments 6 and 7, respectively.

The second study was a field experiment with comprising of five tree species viz *S. leprosula, D. costulata, A. mangium, C. iners* and *H. odorata* using t-test comparing two main treatments; plots treated with sewage sludge at the rate of 4050 m^3/ha and a control (untreated). The results showed that all the species treated with sewage sludge were significantly higher in terms of height and growth diameter compared than the corresponding species in the control plot.

The concentrations of foliar nutrients in the five species were significantly higher ($P \leq 0.05$) in the treated than the corresponding trees in the control plots. This implies that sewage sludge significantly affected the concentration of foliar nutrients uptake. The fertility of the soil for both macronutrient (N, P, K, Ca, Mg and Na) and micronutrients (Mn, Zn, Fe and Cu) in the treated plot were also higher than the control plots. However, the concentration of micronutrients and other heavy metals in the foliar and soil did not exceed the maximum permitted concentrations (MPC) of the European Community Standard (ECS).

Water quality monitoring showed that the groundwater within the experimental area was contaminated with organic contaminants and nutrient compounds. The concentrations of arsenic, manganese, ammoniacal-nitrogen, phenol, BOD_5 and COD exceeded the limits recommended by the national guidelines for drinking water quality. The presence of *E. coli* in the groundwater samples indicated that the samples had been contaminated with this organism. Generally, this study indicates that sewage sludge significantly affects tree growth, foliar nutrient concentrations, soil properties and groundwater quality. Disposal of sewage sludge therefore has to be thoroughly monitored to avoid soil and groundwater contaminations.

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

KESAN ENAP CEMAR KUMBAHAN (SEWAGE SLUDGE) TERHADAP PERTUMBUHAN POKOK, CIRI-CIRI TANAH DAN KUALITI AIR BAWAH TANAH

Oleh

ARIFIN ABDU

Jun 2005

Pengerusi : Mohamad Azani Alias, PhD

Fakulti : Perhutanan

Kesan enap cemar kumbahan terhadap pertumbuhan pokok pertanian dan hiasan telah banyak dilaporkan secara meluas tetapi kesan terhadap pertumbuhan pokok hutan dan ciri-ciri tanah adalah terhad. Bahan organik daripada enap cemar kumbahan dapat meningkatkan ciri pisikal dan kimia tanah tetapi ia mengandungi logam berat yang boleh menyebabkan ketoksidan kepada tanaman dan berpotensi menyebabkan pencemaran air bawah tanah melalui proses resapan.

Tesis ini akan melaporkan dua kajian ke atas kesan enap cemar kumbahan terhadap pertumbuhan pokok, kepekatan nutrien daun, ciri-ciri tanah dan air bawah tanah. Kajian pertama dijalankan di tapak semaian dengan menggunakan dua species iaitu Jelutong (*D. costulata)* dan Medang Teja (*C.*

iners). Experimen faktorial digunakan adalah 10 x 2 x 4 untuk mengkaji kesan enap cemar kumbahan ke atas prestasi pertumbuhan dan kepekatan nutrien daun dengan menggunakan 10 paras rawatan. Selepas enam bulan rawatan, keputusan menunjukkan bahawa T7 (70% enap cemar kumbahan mengikut isipadu) dan (60% enap cemar kumbahan mengikut isipadu) masing-masing telah memberikan ketinggian dan ukuran lilitan diameter yang tertinggi pada pokok *D. costulata* dan *C. iners*. Kajian juga mendapati tahap kritikal nutrien untuk *D. costulata* dan *C. iners* adalah masing-masing merujuk pada rawatan 6 dan 7.

Kajian kedua ialah kajian di lapangan melibatkan lima spesis iaitu Akasia *(A. mangium*), Medang Teja (*C. iners*), Merawan Siput Jantan (*H. odorata*), Meranti Tembaga (*S. leprosula*) dan Jelutong (*D. costulata*) dengan menggunakan ujian purata min (t-test) sebagai perbandingan bagi dua rawatan utama iaitu blok yang dirawat dengan enap cemar kumbahan pada kadar 4050 m^3/ha dan blok kawalan (tanpa rawatan). Keputusan menunjukkan bahawa semua spesis yang dirawat dengan enap cemar kumbahan memberikan perbezaan yang sangat bererti pada pertumbuhan ketinggian dan ukur lilitan diameter berbanding dengan spesis yang sama di plot kawalan.

Kepekatan nutrient daun pada lima spesis yang dirawat dengan enap cemar kumbahan adalah lebih tinggi berbanding dengan kepekatan nutrien bagi species yang sama di plot kawalan. Ini menunjukkan bahawa enap cemar kumbahan telah memberi kesan terhadap pengambilan nutrien daun.

Kesuburan kawasan tanah bagi makronutrien (N, P, K, Ca, Mg dan Na) dan mikronutrien (Mn, Zn, Fe dan Cu) dengan rawatan enap cemar kumbahan adalah lebih tinggi berbanding dengan plot kawalan. Walaubagaimanapun, kepekatan mikronutrien dan logam berat di dalam daun dan tanah adalah tidak melebihi tahap yang dibenarkan bagi limit konsentrasi maksimum (MPC) oleh Garis-panduan Komuniti Eropah (ECS).

Kualiti air bawah tanah yang dipantau di kawasan kajian mendapati bahawa ianya telah tercemar dengan bahan pencemar. Kepekatan arsenic, manganese, ammoniacal-nitrogen, phenol, BOD_5 dan COD adalah melebihi tahap kepekatan yang disyorkan oleh garis panduan untuk air minuman di Malaysia. Pencemaran air bawah tanah adalah terbukti dengan kehadiran organisma *E. Coli.* Secara umunya, kajian mendapati bahawa enap cemar kumbahan memberi kesan terhadap pertumbuhan pokok, kepekatan nutrient daun dan air bawah tanah. Walaubagaimanapun, pembuangan enap cemar kumbahan perlu dipantau secara terperinci bagi mengelakkan pencemaran ke atas tanah dan kualiti air bawah tanah.

ACKNOWLEDGEMENTS

I am very grateful to the chairman of my supervisory committee, Dr. Mohamad Azani Alias for his helpful and valuable advice, comments, guidance and encouragement throughout my research study at UPM. I am also grateful and sincerely thankful to the other committee members, Prof. Dato' Dr. Nik Muhamad Nik Ab. Majid and Dr. Mohd. Zaki Hamzah for their valuable advice, suggestions and constructive comments.

I would like to thank Universiti Putra Malaysia for granting me study leave. I also would like to acknowledge Indah Water Konsortium Malaysia Sdn. Bhd for their permission and funding to conduct this study.

I would like to express my thanks and gratitude to Mr. Muzammal Johan, Mr. Zahari Ibrahim and Mrs. Norsafaizah Jaafar for their help throughout my study. Thanks are also due to all of my colleagues for their assistance, particularly Marzuki Ag. Jamaludin, Ku, Ijan, Usop, Awie, Badrul, Anan and Navin.

Finally, I express my deepest appreciation to my wife Mrs. Nooreriyanie Simon and my son Muhammad Afiq Farhan for their continued support and patience during the entire study period.

I certify that an Examination Committee met on June, 13 2005 to conduct the final examination of Arifin Abdu on his Master of Science thesis entitled "Effects of Sewage Sludge on Tree Growth, Soil Properties and Groundwater Quality" 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:

Jamaluddin Basharuddin, PhD
Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mohd. Kamil Yusoff, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Internal Examiner)

Syed Omar Syed Rastan, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Cahyono Agus Dwi Koranto, PhD
Associate Professor
Faculty of Forestry
Gadjah Mada University Bulaksumur
(External Examiner)

GULAM RUSUL RAHMAT ALI, PhD
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of the Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Mohamad Azani Alias, PhD
Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Dato' Nik Muhamad Nik Ab. Majid, PhD
Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)

Kapt. Mohd. Zaki Hamzah, PhD
Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

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

ARIFIN ABDU

Date: 26 June 2005

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ATSDR	Agency Toxic Substances and Disease Registry
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CWMI	Cornell Waste Management Institute
DO	Dissolved Oxygen
EC	Electrical Conductivity
ECS	European Communities Standard
EPA	Environment Protection Agency
FRIM	Forest Research Institute Malaysia
IWK	Indah Water Konsortium
MPC	Maximum Permitted Concentration
NAS	National Academy of Science
NRC	National Research Centre
POTW	Public Owned Treatment Works
USEPA	United State Environment Protection Agency

CHAPTER 1

INTRODUCTION

Sewage sludge is the solid waste accumulated during primary, secondary and tertiary wastewater treatment. It is organic-rich material (usually greater than 50 percent organic matter by volume) and contains sufficient N (2-7 percent) and P (1-5 percent) to make them potentially useful as an organic fertilizer and a source of organic matter (Brady and Weil, 1996; Kelling *et al.,* 1997). Sewage sludge has the potential to boost production of crops while addressing the environmental hazards from the large amount of waste generated and the growing scarcity of sewage disposal area. Sewage sludge is the concentrated settleable solid fraction of wastewater that has been subjected to some form of treatment and originates mainly from domestic sources. The projected increase in production of sewage sludge is indirectly proportional to the increase in domestic wastewater that has to be treated. It is also indirectly proportional to the population growth rate of any particular country.

In 1993, the Government of Malaysia handed over the national sewerage management to Indah Water Konsortium, a private company, to manage a more modern and efficient sewerage system for the country under Sewerage Services Act, 1993. In this country, sewage sludge is mainly produced from domestic and light industrial areas. It has been estimated that about 3 million metric tones (wet basis) of sewage sludge is produced annually. The quantity of sewage sludge is expected to increase with increase in population (Indah Water Consortium, 1997) and by the year 2020 it is estimated that it will increase to 7 million metric tones (wet basis). The total cost of managing sewage sludge is estimated at RM 1 billion per year (Abdulkadir, 1998).

The use of chemical fertilizers in Malaysian forestry started since the beginning of enrichment planting carried out by the Forestry Department. The high cost of previous rehabilitation project is not only from planting stock and labour but also the high cost of fertilizers. Normally, the agricultural sectors regularly use chemical fertilizers to promote plant growth. Heavy application of commercial fertilizers can build up toxic concentrations of salts in the soil. It will make the soil hard and difficult to plough and the moisture retention capability of the soil may be reduced. It can also cause damage to plants by scorching. In addition, chemical fertilizers also lead to environmental problems such as pollution of the water system (Abdul *et al.,*, 1996).

Using organic waste as a fertilizer has been practiced for a long time even before chemical fertilizers became widely available (Adriano, 1986). The use of sewage sludge as a fertilizer for forest trees has not been reported in Malaysian forestry practices. The application of sewage sludge on both agriculture and forestry areas are generally the most economical means of wastewater treatment and also provide an opportunity to recycle beneficial plant nutrients and organic matter for tree growth (Pescod, 1992). The high concentration of plant nutrients in domestic sewage sludge makes it a suitable alternative as fertilizers. However, sewage sludge also contains components that are considered to be harmful to the environment. There are three constituents of environmental concern in sewage sludge: heavy metals, organic pollutants and pathogenic organisms.

The value of sludge, both as a fertilizers and soil conditioner, depends largely on the extent of sewage and sludge treatment and this affects how the user best utilizes the different types of sludge. The substantial amounts of N and P in sludge make it a useful fertilizer material and its organic constituents generate beneficial soil conditioning properties. The improved aeration and drainage following sludge amendments can also have indirect effects on the soil-plant relationships through affecting growth, nodulation in leguminous plants and other properties (Chaney, 1988).

Inspite of the beneficial uses of sewage sludge it also has some potential problems. It has been reported that the growing amount of sewage sludge can cause adverse effects on the environment (Chaney, 1994). The issues of sewage sludge management have been highlighted at both national and international levels and Malaysia is taking part to manage sewage sludge properly either dumping to disposal sites or through incineration process. Meanwhile, incineration and biodegradation processes are costly compared to disposal of sewage sludge at landfill site which also require large tracts of land and can cause major problems to the groundwater system and contaminate the