UNIVERSITI PUTRA MALAYSIA

APPLICATION OF SEWAGE SLUDGE ON AN ACID TROPICAL SOIL: CROP RESPONSE AND HEAVY METALS UPTAKE BY MAIZE AND THEIR ACCUMULATION IN THE SOIL

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By

ROSAZLIN BINTI ABDULLAH

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

July 2002

DEDICATION

This thesis is dedicated to:

My beloved parents

Abdullah Md Noh

and

Junidah Hamid

Brother and sisters,

Rozaidey and Norhayati
Rosazura
Rosazlinda
Rosazleza
Rosazliyana

Who always supported and encouraged me to do the best

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

APPLICATION OF SEWAGE SLUDGE ON AN ACID TROPICAL SOIL: CROP RESPONSE AND HEAVY METALS UPTAKE BY MAIZE AND THEIR ACCUMULATION IN THE SOIL

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Chairman : Dr. Che Fauziah Binti Ishak

Faculty : Agriculture

At present, Malaysia produces about 5 million m^3 sludge per year (wet weight basis). Land application of sewage sludge is considered the most economical and also provides an opportunity to recycle beneficial plant nutrients and organic matter to soil for crop production. However, sewage sludge also contain varying amounts of heavy metals which may pose a hazard of metal toxicity to crops and the consumer of these crops. Thus the uptake of heavy metals by crops and the fate of these heavy metals in soils need to be monitored.

The first study, which involved ten sewage sludges, were collected from different wastewater treatment plants and classified into domestic sludge (type A) and light-industry sludge mixed with domestic sludge (type B). The chemical properties of sewage sludge with emphasis on heavy metal content were determined. In general, type

B sludge has higher heavy metal content than type A sludge. The concentration of heavy metals in these sludges did not exceed the maximum permitted concentrations (MPC) of the European Community Standard (ECS), for land application, except for Zn (7110.10 mg kg^{-1}). Also, the Cu concentration is rather high in type B sludge. Therefore, type B sludge can be characterized as quite hazardous and unsuitable for agricultural use.

The second study was a field experiment conducted at the share farm Universiti Putra Malaysia from 1999 till 2001. The study was to investigate the crop response and uptake of heavy metals from sewage sludge by maize, and, to correlate heavy metals in the soil with content in the maize. The treatments carried out were inorganic N (ammonium sulfate) at 140 kg N ha^{-1}, control (no N application) and sludge application rates at 140, 280, 420 and 560 kg N ha^{-1} equivalent with five replications. Application of sewage sludge and inorganic fertilizers produced significantly higher yield than the control. The rate of 420 kg ha^{-1} sewage sludge gave the highest dry matter yield for the 1st cycle and 720 kg N ha^{-1} sewage sludge for the 3rd cycle. It can be concluded that sewage sludge was able to perform just as good as inorganic fertilizer. Sewage sludge application seemed to have little effect in increasing heavy metals concentrations in the soil and grain after the third maize cycle. The concentration of heavy metals in the soil were below the MPC of the ECS, which ranged: Zn (12.44-35.44 mg kg^{-1}), Cu (5.00-9.80 mg kg^{-1}), Cd (0.60-2.44 mg kg^{-1}), Pb (7.16-24.04 mg kg^{-1}), Ni (7.44-11.36 mg kg^{-1}), Mn (29.76-41.32 mg kg^{-1}), Cr (19.72-44.00 mg kg^{-1}) and Fe (1.47-2.23 %), respectively. The concentrations of heavy metals in maize grain were below the MPC values of Malaysian Food Act 1983 and Food Regulation 1985 (fresh weight basis) which ranged : Zn (4.95-19.18 mg

kg^{-1}), Cu (0.56-2.60 mg kg^{-1}), Cd (0.037-0.052 mg kg^{-1}), Pb (0.034-0.052 mg kg^{-1}), Ni (0.66-1.22 mg kg^{-1}), Mn (1.56-8.53 mg kg^{-1}), Cr (0.12-0.44 mg kg^{-1}) and Fe (8.16-24.93 mg kg^{-1}), respectively. There were significant correlations between total heavy metals in soil and content of heavy metals in leaves and stems.

The third study is to determine the forms of Cd, Cu, Ni, Pb and Zn in the sewage sludge, and in the soils applied with sewage sludge, after the 1st and 3rd maize cycle. The correlations between different forms of heavy metals in the soil and content in maize grain were also investigated. Fractionation of heavy metals in sewage sludge showed that the dominant form of all heavy metals were residual form except Cu. Leaving the residual fraction out, Cd and Pb were dominant in exchangeable form, Ni in carbonate form and Zn in Fe-Mn oxide form. The organic form is dominant for Cu in sludge treated soil. Cd and Pb were predominant in the exchangeable form. Ni was predominant in the carbonate form and Zn was predominant in the Fe-Mn oxide form. In general, the percentage of water soluble content was less than 5%. Significant correlations were only obtained between Cd content in maize grain and the organic forms in soil, Ni content in grain with total metal in the soil and between Cu content in maize grain and the carbonate, Fe-Mn oxide and organic forms in soils.

For conclusion, domestic sewage sludge produced in Malaysia can be safely as fertilizer applied on agricultural land, in three continuous applications, for crop production. However, the Cu and Zn concentrations in grain and soil need to be monitored.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi keperluan penganugerahan ijazah Master Sains Pertanian

PENGGUNAAN ENAP CEMAR KUMBAHAN PADA TANAH ASID TROPIKA: HASIL PERTUMBUHAN DAN PENGAMBILAN LOGAM BERAT OLEH JAGUNG DAN PENGUMPULANNYA DI DALAM TANAH

Oleh

ROSAZLIN BINTI ABDULLAH

Julai 2002

Pengerusi : Dr. Che Fauziah Binti Ishak

Fakulti : Pertanian

Setiap tahun Malaysia menghasilkan lebih daripada 5 juta tan enap cemar kumbahan (berdasarkan berat basah). Penggunaan enap cemar kumbahan tersebut pada tanah dapat mengurangkan kos dan ia juga mengandungi nutrien dan bahan organik untuk tanaman. Walaubagaimanapun, enap cemar kumbahan juga mengandungi logam berat yang menyebabkan ketoksikan kepada tanaman dan kepada pengguna tanaman. Jadi, pemantauan pengambilan logam berat oleh tanaman dan tindakbalas logam berat dalam tanah perlu dilakukan.

Kajian pertama melibatkan sepuluh jenis enap cemar kumbahan yang diambil daripada pelbagai loji rawatan dan dibahagikan kepada enap cemar domestik (jenis A) dan enap cemar industri ringan bercampur dengan enap cemar domestik (jenis B). Komposisi kimia enap cemar kumbahan dengan penekanan kepada kandungan logam

berat dikenalpasti. Pada umumnya, enap cemar kumbahan jenis B adalah lebih tinggi berbanding kandungan logam berat enap cemar jenis A. Kepekatan logam berat di dalam enap cemar kumbahan tidak melebihi tahap yang dibenarkan (MPC) oleh garis panduan Kesatuan Eropah (ECS) untuk penggunaannya ke atas tanah kecuali Zn (7110 mg kg^{-1}). Juga, kepekatan Cu yang agak tinggi di dalam enap cemar kumbahan jenis B. Oleh itu, enap cemar jenis boleh diklasifikasi agak merbahaya dan tidak sesuai untuk digunakan pada tanah pertanian.

Kajian kedua ialah kajian di ladang yang telah dijalankan di Ladang Kongsi Universiti Putra Malaysia dari tahun 1999 hingga tahun 2001.Kajian ini adalah untuk mengenalpasti kesan pertumbuhan oleh tanaman dan pengambilan logam berat daripada enap cemar kumbahan oleh jagung, dan, korelasi antara logam berat di dalam tanah dengan kandungannya di dalam jagung. Rawatan yang digunakan ialah baja tak organik N (ammonium sulfat) pada kadar 140 kg N ha^{-1}, kawalan (tiada penggunaan N), dan penggunaan enap cemar kumbahan pada kadar setara 140, 280, 420 dan 560 kg N ha^{-1} dengan 5 replikasi. Penggunaan enap cemar kumbahan dan baja tak organik menunjukkan hasil yang tinggi berbanding kawalan. Kadar enap cemar 420 kg N ha^{-1} memberikan hasil yang tertinggi pada tanaman pertama dan 720 kg N ha^{-1} enap cemar pada tanaman ketiga. Ini boleh disimpulkan bahawa enap cemar kumbahan mampu membekal N seperti baja tak organik. Penggunaan enap cemar kumbahan ke atas tanaman memberi kesan ke atas tanah dan bijirin selepas tiga kali penanaman. Kepekatan logam berat dalam tanah masih di bawah tahap yang dibenarkan(MPC) oleh ECS iaitu : Zn (12.44-35.44 mg kg^{-1}), Cu (5.00-9.80 mg kg^{-1}), Cd (0.60-2.44 mg kg^{-1}), Pb (7.16-24.04 mg kg^{-1}), Ni (7.44-11.36 mg kg^{-1}), Mn

(29.76-41.32 mg kg^{-1}), Cr (19.72-44.00 mg kg^{-1}) dan Fe (1.47-2.23 %). Kepekatan logam berat di dalam biji jagung masih di bawah tahap yang dibenarkan (MPC) menurut Akta Makanan Malaysia 1983 dan Peraturan Makanan 1985 (berdasarkan berat basah) iaitu :Zn (4.95-19.18 mg kg^{-1}), Cu (0.56-2.60 mg kg^{-1}), Cd (0.037-0.052 mg kg^{-1}), Pb (0.034-0.052 mg kg^{-1}), Ni (0.66-1.22 mg kg^{-1}), Mn (1.56-8.53 mg kg^{-1}), Cr (0.12-0.44 mg kg^{-1}) dan Fe (8.16-24.93 mg kg^{-1}). Terdapat perkaitan yang signifikan di antara logam berat di dalam tanah dan kandungan logam berat di dalam daun dan batang.

Kajian ketiga ialah untuk mengenalpasti bentuk Cd, Cu, Ni, Pb dan Zn di dalam enap cemar kumbahan dan juga di dalam tanah yang dirawat oleh enap cemar kumbahan selepas tanaman pertama dan ketiga. Korelasi di antara bentuk logam berat yang berbeza dengan kandungannya di dalam biji jagung juga dikaji. Kajian pemeringkatan di dalam enap cemar kumbahan menunjukkan semua logam berat yang dikaji adalah dominan di dalam bentuk sisa baki kecuali Cu. Jika bentuk sisa baki tidak di ambil kira, Cd dan Pb adalah dominan dalam bentuk tukarganti, Ni dominan dalam bentuk karbonat dan Zn dalam bentuk Fe-Mn oksida. Cu adalah dominan dalam bentuk organik bagi tanah yang di rawat dengan enap cemar kumbahan, Cd dan Pb adalah dominan dalam bentuk tukarganti, Ni dominan dalam bentuk karbonat, dan Zn dalam bentuk Fe-Mn oksida. Pada umumnya, didapati peratus bentuk larut air yang diekstrak dengan air suling adalah kurang daripada 5%. Terdapat hanya perkaitan positif di antara kandungan Cd di dalam biji jagung dengan bentuk organik di dalam tanah, kandungan Ni di dalam biji jagung dengan bentuk

jumlah di dalam tanah dan di antara kandungan Cu di dalam biji jagung dengan bentuk karbonat, bentuk Fe-Mn oksida dan bentuk organik di dalam tanah.

Kesimpulannya, enap cemar kumbahan domestik yang dihasilkan di Malaysia adalah selamat apabila digunakan sebagai baja untuk tanah pertanian setelah tiga penanaman yang berterusan. Walaubagaimanapun, kepekatan Zn dan Cu dalam bijirin dan tanah hendaklah sentiasa dipantau.

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I certify that an Examination Committee met on 22nd July 2002 to conduct the final examination of Rosazlin Binti Abdullah on her Master of Agricultural Science thesis entitled "Application of Sewage Sludge on an Acid Tropical Soil: Crop Response and Heavy Metals Uptake by Maize and Their Accumulation in the Soil" in accordance with Universiti Putra Malaysia (Higher Degree) Act 1980 and Universiti Putra 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 has been accepted as fulfillment of the requirement for the degree of Master of Agricultural Science. The members of the Supervisory Committee are as follow:

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C	=	Carbon
CEC	=	Cation Exchange Capacity
EC	=	Electrical Conductivity
ECS	=	European Communities Standard
IWK	=	Indah Water Konsortium
MPC	=	Maximum Permitted Concentration
N	=	Nitrogen
P	=	Phosphorous
UK	=	United Kingdom
UPM	=	Universiti Putra Malaysia
USDA	=	United State Department of Agriculture
USEPA	=	United States Environmental Protection Agency