UNIVERSITI PUTRA MALAYSIA

SOLID STATE BIOCONVERSION OF DOMESTIC WASTEWATER TREATMENT PLANT SLUDGE INTO COMPOST BY SCREENED FILAMENTOUS FUNGI

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By

MD. ABUL HOSSAIN MOLLA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

June 2002

Dedicated
to
Departed Souls………,

Who always believe once their blossom will flourish

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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June 2002

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Faculty: Engineering

Similar to other countries, Malaysia is facing problems of safe and environmental friendly disposal of domestic wastewater treatment plant (DWTP) sludge. None of the conventional disposal techniques is recognized as safe and environmental friendly. Solid state bioconversion (SSB) is emerging as a natural promising environmental friendly process. This microbial-based technique of organic wastes bioremediation is gaining greater public acceptance. This study has exploited the SSB technique to rejuvenate the composting process as a remedy for safe disposal and reuse of the Indah Water Konsortium (IWK) DWPT sludge. In this study isolation, screening and selection of compatible mixed fungal culture from relevant sources were followed by optimization of the SSB process. The SSB of IWK DWTP sludge into compost was examined and the compost was tested for crop growth. Six fungal strains *Phanerochaete chrysosporium* 2094, RW-Pl 512, *Trichoderma harzianum*^{s}, *T. harzianum*^{c}, *Aspergillus versicolor* and *Mucor hiemalis* were identified as sludge acclimatized and non-phytopathogenic among 33 members. The

T. harzianum[s] with *P. chrysosporium* 2094 (T/P), and *T. harzianum*[s] with *M. hiemalis* (T/M) were selected as the best compatible mixed fungal cultures. Four factors were optimized based on superior production of biomass, total organic carbon (TOC) and soluble protein (SP) for both mixed cultures of SSB of the IWK DWTP sludge. These were C/N ratio 30:1, wheat flour (WF) as a cheap carbon source, pH 4.5 to 5.5 and rice straw (RS) as a bulking material. Higher microbial growth was obtained in RS compared to sawdust (SD) in SSB of the IWK DWTP sludge based on measurement of optical density, soluble protein and glucosamine. Significantly the lowest C/N ratio of 12.14 for T/P and 12.58 for T/M were achieved using RS in composting bin at 75 days. The lowest germination index of 33.43% for T/P and 39.4% for T/M were attained at 30 days. Then it rose to around 90% at 60 days using RS in composting bin. The suitable electrical conductivity (EC dS/m) values of 0.33 for T/P and 0.35 for T/M in SD, 1.41 for T/P and 1.49 for T/M were attained in RS at 75 days. The above facts support the production of stabilized composts. Comparatively, superior composts were produced by T/P around 50-60 days of SSB. Compost could provide 50% N requirement of optimal dose of corn production. Around 65 to 100% higher dry matter production was attained by 50% compost plus 50% N treatment compared to control. Heavy metals uptake were low; whereby the composts of the IWK DWTP sludge contained average 30 times lower than the USA standard limit. The SSB is potentially capable of natural friendly biodegradation of the IWK DWTP sludge into compost with significant reduction of moisture and volume, which have an excellent use for organic farming. It will open a new route of final safe disposal of the IWK DWTP sludge.

Abstrak tesis yang dilkemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

BIO-PENUKARAN KEADAAN PEPEJAL ENAPCEMAR LOJI RAWATAN AIRSISA DOMESTIK KEPADA KOMPOS SECARA PENAPISAN KULAT BERFILAMEN

Oleh

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Malaysia menghadapi masalah pembuangan air sisa enapcemar domestik (DWTP) yang selamat dan mesra alam seperti yang dihadapi oleh negara-negara lain. Tiada teknik pembuangan enapcemar konvensional yang diiktiraf sebagai selamat dan mesra alam. Bio-penukaran keadaan pepejal (SSB) dikenalpasti menjanjikan mesra alam, berdayatahan, dan diterima umum sebagai teknik biorawatan sisa berasaskan mikrob. Satu percubaan telah dibuat untuk mengeksploitasi teknik SSB kepada proses pembuangan yang diubahsuai semula sebagai satu rawatan untuk kaedah pembuangan yang selamat dan diguna semula untuk DWTP Indah Water Konsortium (IWK). Enam jenis fungus yang telah diasingkan iaitu *Phanerochaete chrysosporium* 2094, *Trichoderma harzianum*^{s}, *T. harzianum*^{c}, *Aspergillus versicolor* dan *Mucor hiemalis* telah dikenalpasti sebagai bukan pitopatogenik dan mudah disesuaikan dengan keadaan enapcemar dari kalangan 33 ahli. Fungi *T. harzianum*^{s} dengan *P. chrysosporium* 2094 (T/P) dan *T. harzianum*^{s} dengan *M. hiemalis* (T/M) merupakan kombinasi kultur campuran yang terbaik. Empat faktor dioptimisasikan untuk penguraian airsisa enapcemar domestik IWK telah dilakukan berasaskan kepada kelebihan penghasilan biomas, jumlah karbon organik (TOC), dan protein terlarut (SP) bagi kedua-dua kultur campuran. Faktor tersebut adalah nisbah C/N 30:1, tepung gandum (WF) sebagai punca C termurah, nilai pH 4.5 ke 5.5, dan jerami padi (RS) sebagai bahan pencukup. Pertumbuhan organisma yang tinggi diperolehi pada RS berbanding habuk gergaji (SD) dalam penguraian SSB airsisa enapcemar domestik IWK berasaskan kepada penyukatan ketumpatan optikal, protein terlarut, dan glukosamin. Nilai nisbah C/N terendah bererti 12.14 untuk T/P dan 12.58 untuk T/M dicapai dengan menggunakan tong pembuangan pada hari ke 75. Indeks percambahan terendah 33.43% untuk T/P dan 39.4% untuk T/M dicapai pada hari ke 60 menggunakan tong pembuangan. Manakala, nilai EC (dS/m) mencapai 0.33 untuk T/P dan 0.35 untuk T/M dalam SD, 1.41 untuk T/P dan 1.49 untuk T/M dalam RS. Kesemua fakta tersebut menyokong kepada penghasilan SSB yang stabil. Sebagai perbandingan, keputusan terbaik SSB dicapai oleh T/P dalam masa 50-60 hari. Kompos telah mengurangkan sebanyak 50% keperluan N pada dos optimum pengeluaran jagung. Penghasilan bahan kering sebanyak 65 hingga 100% lebih tinggi dicapai dengan penggunaan campuran 50% kompos dengan 50% N berbanding kawalan. Pengambilan logam berat adalah rendah walaupun kompos mengandungi purata 30 kali lebih rendah daripada nilai piawaian USA. Teknik SSB mempunyai pontensi besar dengan menggunakan kaedah semulajadi mesra alam dalam penguraian enapcemar DWTP IWK kepada kompos, dengan pengurangan isipadu dan lembapan yang mana ia boleh digunakan sebagai baja organik untuk kegunaan penanaman organik. Ini merupakan lembaran baru bagi pelupusan terakhir yang selamat bagi enapcemar DWTP IWK.

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LIST OF ABBREVIATIONS

C	: Carbon
^{c} (Superscript)	: Compost (i.e. source of isolation from compost)
CEC	: Cation exchange capacity
C/N	: Carbon Nitrogen ratio
CaF	: Cassava flour
CoF	: Corn flour
CPMAS	: Cross-Polarization Magic-Angle Spinning
DAS	: Days after sowing
DM	: Dry matter
DMRT	: Duncan's Multiple Range Test
DOE	: Department of Environment
DS	: Dry solid
DWTP	: Domestic Wastewater Treatment Plant
EC	: Electrical conductivity
FBM	: Fungal biomass
FDB	: Fungal dry biomass
FM	: Fungal metabolite
FS	: Fixed solid
FTIR	: Fourier-Transform Infrared
GLOX	: Glyoxal Oxidase
IWK	: Indah Water Konsortium Sdn. Bhd.
LSB	: Liquid State Bioconversion
LSD	: Least Significant Difference
LSF	: Liquid State Fermentation
MEA	: Malt extract agar
MF	: Mesocarp fiber
MLSS	: Mixed liquor suspended solid
MSW	: Municipal solid wastes

N	: Nitrogen
NMR	: Nuclear Magnetic Resonance
PDA	: Potato dextrose agar
PME	: Phosphomonoesterase
POME	: Palm Oil Mill Effluent
POTW	: Publicly owned treatment works
RF	: Rice flour
RS	: Rice straw
S	: Sugar (cane)
^{s} (Superscript)	: Sludge (i.e. source of isolation from sludge)
SC	: Sludge cake
SD	: Sawdust
SF	: Sago flour
SmF	: Submerged fermentation
SP	: Sludge powder or Soluble protein
SSB	: Solid State Bioconversion
SSF	: Solid State Fermentation
STP	: Sewage Treatment Plant
SVI	: Sludge volume index
TDS	: Total dry solid
TOC	: Total organic carbon
T/M	: *Trichoderma harzianum*^{s} with *Mucor hiemalis*
T/P	: *Trichoderma harzianum*^{s} with *Phanerochaete chrysosporium* 2094
TS	: Total solid
TSS	: Total suspended solid
TVDS	: Total volatile dry solid
TVSS	: Total volatile suspended solid
VM	: Volatile Matter
VS	: Volatile solid
WF	: Wheat flour

CHAPTER I

INTRODUCTION

Global environmental hazard is of grave concern all over the world and its remediation is not only complex but also expensive (Cameron et al., 2000). Continuous pollution due to unavoidable every day operations, such as industrial discharges, domestic sewerage and its disposal, municipal wastes, agricultural and animal husbandry farm wastes, motor industries, and burning of wastes are of main concern. Presently, the problem is more acute in developing countries. Among these various global environmental hazards, sewage sludge is top ranked in waste generation. On an average, a typical person generates over 15 L of sewage sludge per week (Cheremisinoff, 1994) and 50 g of dry solids are produced per capita per day (Hudson, 1995). Its volume increases proportionally with the increasing population in urban areas.

Malaysia is not an exception as aquatic pollution in the urban areas is steadily increasing due to sewage disposal. Here the largest share of total waste volume is also contributed by sewage (64.4%), followed by animal husbandry waste (32.6%), agro based (1.7%) and industrial effluent (1.3%) (DOE, 1996). Presently, Malaysia produces approximately 3 million cubic meters of domestic sewage sludge annually throughout the country that need US$ 0.3 billion (RM 1 billion) cost for management (Kadir and Velayutham, 1999). This figure is expected to rise to 7 million cubic meters by the year 2020. The proper management and disposal of this ever-increasing sewage sludge has been treated as one of the prime environmental issues (Zain et al., 2001). As developed countries, Malaysia is also not satisfied with its ongoing management and disposal options such as sludge lagoon, land filling, direct application of liquid slurry and dried sludge to agricultural and forest land, and disposal in swallow trenches, rivers and seas. In Malaysia, existing Sewage Treatment Plants (STP) are far from complete in terms of efficiency and effectiveness if they are evaluated strictly with the Department of Environment (DOE) regulation on sewage generation and disposal. Although no detailed study has been undertaken on the extent of environmental contamination by STP sludge, some information is already available indicating the presence of certain pathogens and bacteria that can adversely impact on the environment. The problem is further compounded by the fact that after few years of operation the quality of the discharge from the STP fails to confirm to the standard of the DOE. It is therefore evident that an alternative treatment system is much needed to replace the existing and conventional ones.

Effective management and environmental friendly disposal of wastewater sludge is a serious problem in every wastewater treatment plant. Environmentally sound and economically viable technology for wastewater sludge management is a great expectation to concerned people. The conventional practices and techniques for wastewater sludge disposal are land filling, dumping, incineration, composting