UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF SLUDGE SETTLEABILITY AND DEWATERABILITY USING PILOT SCALE LIQUID STATE BIOCONVERSION PROCESS UNDER NON-CONTROLLED CONDITIONS

HIND F. A. BARGHASH

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By

HIND F. A. BARGHASH

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

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DEDICATION

TO MY WOUNDED COUNTRY (IRAQ), MY PARENTS, HUSBAND AND SON

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

OPTIMIZATION OF SLUDGE SETTLEABILITY AND DEWATERABILITY USING PILOT SCALE LIQUID STATE BIOCONVERSION (LSB) PROCESS UNDER NON-CONTROLLED CONDITIONS

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HIND F. A. BARGHASH

June 2008

Chairman: **Professor Fakhru'l-Razi Ahmadun, PhD.**

Faculty: **Engineering**

The study of microbial treatment of domestic wastewater treatment plant (DWTP) sludge, by liquid state bioconversion (LSB) process, was conducted using several approaches under sterilized controlled conditions in a bench scale with co-substrate supplementation. For this purpose, the mixed strains (P/A) of two selected filamentous fungi SCahmA103 (*Aspergillus niger*) and WWZP1003 (*Penicillium corylophilum*) were used to evaluate the performance of the LSB process in the bench scale and pilot scale, under optimized non-controlled conditions without co-substrate in terms of biodegradation, bioseparation, biosolid accumulations, settling and dewatering of the DWTP sludge.

Three numerical parameters, namely sludge concentrations TSS (w/w %), inoculum sizes (v/w %) and inoculum feeding intervals (hrs.), with three levels statistical design under the response surface methodology (RSM), were optimized with and without co-substrate supplementation to evaluate the performance of the process in terms of acclimatization and biodegradation of the DWTP sludge, under non-

controlled (natural) conditions. The optimum process parameters of the TSS (w/w %), inoculum size (v/w%) and inoculum feeding interval (hrs.) were observed to be 1% w/w, 5 %v/w and 11 hrs, respectively, without any co-substrate supplementation to get the maximum predicted values of adaptation, and the COD removal of 98% and 96.7%, respectively, in the fungal-treated sludge by LSB under the non-controlled (natural) conditions in shake flasks.

Another three-level statistical design under RSM was used to optimize the process parameters of aeration rates (vvm) and mixing rate (rpm) in a 100 L pilot-scale using the optimized value obtained from the shake flasks. This design was selected to evaluate the bioconversion performance, using the mixed culture *P/A*, under natural conditions in the pilot-scale in terms of biodegradability and biodewaterability of the DWTP sludge. The optimum aeration rate (vvm) and mixing rate (rpm) of 0 vvm and 10.5 rpm were respectively used to obtain the maximum predicted COD and SRF responses of 98.9% and 98%, respectively in the fungal-treated sludge by the LSB, under the natural conditions in the pilot-scale.

In terms of biodegradation, bioseparation and biosolid accumulations of the DWTP sludge, the validation results gathered from the statistical models in the shake flasks and pilot-scale showed that the LSB efficiency was higher in the pilot-scale than in the shake flasks. Consequently, the optimized values obtained from the two statistical models were used at a 200 L pilot-scale to investigate the settleability and dewaterability characteristics in fungal treated with DWTP sludge, under natural conditions. The results for settleability suggested that 65% of the sludge was settled after one minute of settling period, with a maximum TSS reduction of 99%. The sludge volume index (SVI) reduction of 86% for the treated and untreated sludge was

10 minutes and 180 minutes, respectively. Specific resistance to filtration (SRF) was found to decrease by 98% in the treated sludge after 3 days of fungal treatment, as compared to the untreated sludge. This suggested that the settleability and dewaterability of the DWTP sludge, in the developed LSB process, were highly influenced by the fungal mycelial entrapment under the non-controlled (natural) conditions in the pilot scale.

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

PENGOPTIMAMAN KEBOLEHMENDAPAN DAN KEBOLEHNYAHCAIRAN ENAPCEMAR DENGAN MENGGUNAKAN PROSES BIOPENUKARAN KEADAAN CECAIR (LSB) PADA SKALA LOJI DI BAWAH KEADAAN TIDAK-DIKAWAL

Oleh

HIND F. A. BARGHASH

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Pengerusi: **Profesor Fakhru'l-Razi Ahmadun, PhD.**

Fakulti: **Kejuruteraan**

Kajian ke atas rawatan mikrob bagi enapcemar loji rawatan air sisa domestik (DWTP) oleh proses biopenukaran keadaan cecair (LSB) telah dijalankan dengan beberapa pendekatan di bawah keadaan-keadaan steril terkawal pada skala makmal dengan penambahan substrat-sampingan. Bagi tujuan tersebut, dua jenis fungi berfilamen strain bercampur (P/A) terpilih iaitu SCahmA103 (*Aspergillus niger*) dan WWZP1003 (*Penicillium corylophilum*) telah digunakan untuk menilai prestasi proses LSB pada skala-berkelompok dan skala-loji di bawah keadaan tidak dikawal yang optima tanpa penambahan substrat-sampingan dari segi biodegradasi, biopemisahan, pengumpulan biopepejal, pemendapan dan penyahcairan bagi enapcemar DWTP.

Tiga parameter berangka yang dinamakan kepekatan enapcemar TSS (w/w %), saiz-saiz inokulum (v/w %) dan sela masa penyuapan inokulum (hrs) dengan tiga peringkat rekabentuk statistik di bawah kaedah rekabentuk permukaan (RSM) telah

dioptimakan dengan penambahan dan tanpa penambahan substrat-sampingan bagi menilai prestasi proses dari segi kebolehadaptasi dan biodegradasi bagi enapcemar DWTP di bawah keadaan-keadaan tidak-dikawal (semulajadi). Parameter-parameter proses yang optima bagi TSS (w/w %), saiz inokulum (v/w %) dan sela masa penyuapan inokulum (hrs) telah diperolehi masing-masing pada 1% w/w, 5 %v/w dan 11 hrs, tanpa penambahan substrat-sampingan untuk mendapatkan nilai jangkaan maksima bagi adaptasi dan penyingkiran COD pada masing-masing 98% dan 96.7% di dalam enapcemar rawatan fungi oleh LSB di bawah keadaan tidak-dikawal (semulajadi) di dalam kelalang goncang.

Satu lagi rekabentuk statistik tiga peringkat di bawah RSM telah digunakan untuk mengoptimakan parameter-parameter proses iaitu kadar pengudaraan (vvm) dan kadar pengadukan (rpm) pada skala loji 100 L dengan menggunakan nilai optima yang telah diperolehi daripada kelalang goncang. Rekabentuk ini telah dipilih bagi menilai prestasi biopenukaran dengan menggunakan kultur campuran P/A di bawah keadaan semulajadi pada skala-loji dari segi kebolehbiodegradasi dan kebolehbionyahcairan bagi enapcemar DWTP. Kadar pengudaraan (vvm) dan kadar pengadukan (rpm) yang optima adalah masing-masing diperolehi pada 0 vvm dan 10.5 rpm, bagi memperolehi maksima hasil jangkaan COD dan SRF masing-masing pada 98.9% dan 98% di dalam enapcemar rawatan fungi oleh LSB di bawah keadaan semulajadi pada skala-loji.

Dari segi biodegradasi, biopemisahan dan pengumpulan biopepejal oleh enapcemar DWTP, keputusan pengesahan yang diperolehi daripada model-model statistik di dalam kelalang goncang dan skala-loji menunjukkan bahawa kecekapan LSB di dalam skala-loji adalah lebih tinggi berbanding di dalam kelalang goncang. Sehubungan dengan itu, nilai-nilai optima yang telah diperolehi daripada dua model statistik telah digunakan pada skala-loji 200 L bagi mengkaji ciri-ciri kebolehmendapan dan kebolehnyahcairan di dalam rawatan fungi enapcemar DWTP pada keadaan semulajadi. Keputusan kebolehmendapan menunjukkan bahawa 65% daripada enapcemar telah mendap setelah satu minit jangkamasa pemendapan dengan 99% penurunan maksima TSS. Penurunan indeks isipadu enapcemar (SVI) sebanyak 86% bagi enapcemar terawat dan tidak terawat masing-masing pada 10 dan 180 minit. Rintangan spesifik kepada pemendapan (SRF) didapati menurun sebanyak 98% di dalam enapcemar terawat selepas tiga hari rawatan fungi jika dibandingkan dengan enapcemar tanpa rawatan. Ini mencadangkan kebolehmendapan dan kebolehnyahcairan enapcemar DWTP di dalam proses LSB yang telah dibangunkan ini adalah sangat dipengaruhi oleh pemerangkapan filamen fungi di bawah keadaan tidak-dikawal (semulajadi) pada skala-loji.

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I certify that an examination committee met on the 13th of June,2008 to conduct the final examination of Hind F.A.Barghash on her Doctor of Philosophy thesis entitled "**Optimization Of Sludge Settleability And Dewaterability Using Pilot Scale Liquid State Bioconversion Process Under Non-Controlled Conditions**" 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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The thesis was submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of The Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institution.

HIND F.A. BARGHASH

Date:

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AR	Analytical reagents
AAS	Atomic adsorption spectrophotometer
AA	Auto analyzer
A	Area of the filter paper, m^2
APHA	Air pollution health association
A	*Asperbillus niger*
COD	Chemical oxygen demand
CS	Co-substrate concentration (% w/w)
Cu	Copper
Cr	Chromium
Cd	Cadmium
Ca	Calcium
DBS	Dry biosolids
DWTP	Domestic wastewater treatment plant
DNS	Dinitro-salicylic acid
FT	Inoculum feeding intervals (hrs)
IS	Inoculum size (% v/w)
IWK	Indah Water Konsortium
K	Potassium
LR	Lab reagents
MLSS	Mixed liquor suspended solids
Mg	Magnesium
Mn	Manganese
Ni	Nickel

OD	Optical density
Pb	Lead
P	Phosphorous
P	Pressure of filtration, N/m^2
PDB	Production of dry biosolids
PSE	Pilot scale experimeents
P	*Phenicillium corylophilum*
P/A	*Penicillium corylophilum* and *Aspergillus niger*
RS	Reducing sugar
RSM	Response surface methodology
r	Specific resistance to filtration
R_m	Resistance on the medium, 1/m
SP	Soluble protein
SCP	Soluble crude protein
SEM	Scanning electron microscope
SFE	Shake flasks experiments
SRF	Scecific resistance to filteration
SSB	Solid state bioconversion
S	Sugar (cane)
SSV	Settled sludge volume (mL/L)
SVI	Sludge volume index
TSS	Total suspended solids
TDS	Total dissolved solids
t	Filtration time, sec
V	Volume of filtrate, m^3

v/w	volume/weight
vvm	volume per volume of substrate per minute
WF	Wheat flour
Zn	Zinc
μ	Viscosity of filtrate, N-s/m^2
c*	Weight of dry solids per volume of filtrate, kg/m^3