UNIVERSITI PUTRA MALAYSIA

BIODEWATERABILITY AND LIQUID STATE BIOCONVERSION OF ACTIVATED SLUDGE UNDER NON-STERILIZED CONDITIONS

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

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DEDICATION

TO

MY PARENTS, PARENTS- IN –LAW, BROTHERS, SISTERS AND WIFE

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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By

MD. ABDUL MANNAN SARKAR

January 2006

Chairman: Associate Professor Fakhru'l-Razi Ahmadun, PhD

Faculty: Engineering

The study was conducted to evaluate the microbial treatment of domestic wastewater treatment plant (DWTP) or activated sludge by Liquid State Bioconversion (LSB) process under non-sterilized conditions. The selected two filamentous fungi, *Penicillium corylophilum* and *Aspergillus nige*r isolated from Activated sludge were used to evaluate the treatment performance in LSB process under non-sterilized conditions through adaptation. It was observed that *Penicillium corylophilum* (WWZP1003) was the better strain compared to the *Aspergillus niger* (SCahmA103) for the bioconversion of activated sludge through adaptation. The visual observation in plate culture showed that about 95%-98% of cultured microbes (*Penicillium corylophilum* and *Aspergillus niger*) dominated in treated sludge after two days of treatment. In this study, it was also found that the *Penicillium corylophilum* was capable of removing 94.40 % of chemical oxygen demand (COD) and 98.95% of turbidity of filtrate with minimum dose of inoculum

of 10% v/v in activated sludge with total suspended solids (TSS) of 1% w/w. The pH level was lower at 3.4-3.5 (acidic condition) in the fungal treatment with maximum reduction of COD, turbidity and specific resistance to filtration (SRF) were observed. The results for SRF showed that the fungi led a great role to enhance the dewaterability and filterability. In particular, the strain *Penicillium corylophilum* had more capability (than *Aspergillus niger*) of reducing 93.20 % of SRF compared to the uninoculated sample. Effective results were observed by using fungal inoculum after 2 days of treatment. A statistical optimization of process factors was carried out to evaluate the linear and interaction effects on effective bioconversion of activated sludge using *Penicillium*. Three parameters namely temperature, agitation and pH with three levels were used to evaluate the process factors in term of biodegradability and biodewaterability/biofilterability of activated sludge of 1% (w/w) TSS with 10% of inoculum dose of *Penicillium corylophilum*. A 3-level full factorial design (3^3) and response surface methodology (RSM) were used for the optimization of process factors through the biodegradability (removal of COD) and biodewaterability (SRF) of treatment sludge by a statistical software Minitab. The experimental data were designed by developing a second order polynomial regression model considering linear, quadratic and interaction effect. The optimum temperature, agitation and pH were observed to be 33.5°C, 105 rpm and 5.5 respectively by the regression analysis on using experimental data under RSM. The maximum removal 98.5 % of COD, 99.0 % of turbidity and 95.0 % of SRF reduction were observed at that optimum process conditions in the activated sludge treatment by LSB under non-sterilized conditions. The maximum dry biosolids of 17.4 g/kg production was observed with optimum process conditions by the fungal treatment (*Penicillium corylophilum*).

The results in this study clearly indicate the effective bioconversion of activated sludge under non-sterilized conditions which may provide better waste management and disposal concerned.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

BIOPENGAIRAN SISA PENCEMAR DAN BIOPENUKARAN KEADAAN ENAPCEMAR TERAKTIF DIBAWAH KEADAAN TIDAK STERIL

Oleh

MD. ABDUL MANNAN SARKAR

Januari 2005

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

Fakulti: **Kejuruteraan**

Kajian ini dijalankan untuk menilai keberkesanan rawatan mikrobiologi bagi air sisa domestik dari loji rawatan air sisa domestik (DWTP) atau enapcemar teraktif dengan menggunakan proses biopenukaran keadaan cecair (LSB) di dalam keadaan tak steril. Dua jenis fungi berfilamen yang dipilih, iaitu *Penicillium corylophilum* dan *Aspergillus niger* yang diasingkan daripada sisa enapcemar DWTP atau enapcemar teraktif telah digunakan untuk menilai prestasi rawatan bagi proses LSB di bawah keadaan tak steril melalui adaptasi. Melalui pemerhatian, didapati yang *Penicillium corylophilum* (WWZP1003) merupakan spesis yang lebih baik untuk digunakan dalam biopenukaran enapcemar teraktif menilai adaptasi berbanding *Aspergillus niger* (SCahmA103). Pemerhatian visual di dalam plat kultur menunjukkan bahawa kira-kira 95%-98% daripada mikrob yang terkultur (*Penicillium corylophilum* dan *Aspergillus niger*) mendominasi enapcemar yang dirawat setelah dua hari rawatan dijalankan. Di dalam kajian ini, didapati juga bahawa *Penicillium corylophilum* berupaya untuk menyingkirkan sebanyak

94.40% permintaan oksigen kimia (COD) dan 98.95% kekotoran hasil turasan dengan dos inokulum minimum sebanyak 10% v/v dalam enapcemar teraktif, dengan jumlah pepejal terampai (TSS) sebanyak 1% w/w. Aras pH dalam rawatan fungi adalah rendah sebanyak 3.4-3.5 (keadaan berasid) dengan penurunan maksimum dalam kandungan COD, kekotoran dan kerintangan tentu penapisan (SRF). Keputusan untuk SRF menunjukkan bahawa fungi memainkan peranan yang besar dalam meningkatkan kebolehnyahairan dan kebolehtapisan. Spesis *Penicillium* terutamanya mempunyai kebolehan yang lebih signifikan (daripada *Aspergillus niger*) dalam menurunkan 93.20% SRF berbanding sampel yang tidak terinokulasi. Keputusan memberangsangkan diperhatikan dengan penggunaan inokulum fungi selepas dua hari rawatan dijalankan. Pengoptimuman statistik bagi faktor-faktor proses dijalankan untuk menilai kesan linear dan interaksi ke atas keberkesanan biopenukaran enapcemar teraktif menggunakan *Penicillium*. Tiga parameter iaitu suhu, agitasi dan pH digunakan dalam 3 tahap, untuk menilai factor-faktor proses dari segi kebolehan biodegradasi dan biopenyahairan/biopenapisan enapcemar teractif sebanyak 1% (w/w) TSS dengan 10% dos inokulum *Penicillium corylophilum*. Minitab yang merupakan suatu pakej perisian statistik digunakan untuk mengoptimumkan factor-faktor proses melalui kebolehan biodegradasi (penyingkiran COD) dan biopenyahairan (SRF) rawatan enapcemar. Rekabentuk faktorial penuh 3-aras (3^3) dan metodologi rekabentuk tindakbalas permukaan (RSM) digunakan untuk pengoptimuman factor-faktor proses ini. Data eksperimen direkabentuk dengan menghasilkan model regresi polinomial darjah kedua dengan mengambilkira kesan lelurus, kuadratik dan interaksi. Melalui pemerhatian menggunakan model regresi pada data ujikaji dibawan RSM, suhu, agitasi dan pH optimum adalah 33.5°C, 105 rpm dan 5.5

mesing-mesing. Penyingkiran maksimum 98.5% COD, 99.0% kekotoran dan penurunan 95.0% SRF telah diperhatikan berlaku pada suhu, agitasi dan pH optimum tersebut di dalam rawatan enapcemar teraktif menggunakan proses LSB di dalam keadaan tak steril. Perolehan maksimum biopepejal sel kering sebanyak 17.4 g/kg diperhatikan berlaku di bawah sekitaran proses yang optimum dalam rawatan mikrobiologi dengan menggunakan *Penicillium corylophilum*. Di dalam kajian ini, keputusan yang diperoleh dalam proses LSB jelas menunjukkan bahawa biopenukaran enapcemar teraktif di bawah keadaan tak steril boleh membantu pengurusan dan pembuangan sisa ini.

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LIST OF ABBREVIATIONS

AR	Analytical reagents
AAS	Atomic absorption spectrophotometer
AA	Auto analyzer
A	Area of the filter paper, m^2
APHA	American Public Health Association
BOD	Biological oxygen demand
COD	Chemical oxygen demand
Cr	Chromium
Cd	Cadmium
Ca	Calcium
DSC	Dry sludge cake
DWTP	Domestic wastewater treatment plant
IWK	Indah Water Konsortium
K	Potassium
LSB	Liquid State Bioconversion
Mg	Magnesium
Mn	Manganese
Ni	Nickel
Pb	Lead
P	Phosphorous
P	Pressure of filtration, N/m^2
r	Specific resistance to filtration
R_m	Resistance on the medium, 1/m

RSM	Response Surface Methodology
SSB	Solid state bioconversion
TSS	Total suspended solids
TS	Total 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
w/w	Weight/Weight
Zn	Zinc
μ	Viscosity of filtrate, $N\text{-}s/m^2$
c*	Weight of dry solids per volume of filtrate, kg/m^3

CHAPTER I

INTRODUCTION

1.1 Problem Statement

The sludge treatment and disposal in proper way are probably the most costly and difficult task not only in Malaysia but also all over the world. With increased civilization and urban development, the large amount of sludge generation and disposal and its affects on the environment are required. The U.S. Environmental Protection Agency (U.S EPA, 1999) reported, quantity of domestic sludge (biosolids) produced annually in the United States has increased dramatically, from roughly 4.6 millions dry tons in 1972 to 6.9 millions dry tons in 1998 (Bastian, 1997). Sludge (biosolids) generation is expected to increase to 8.2 millions dry tons by year 2010. The present management cost for sludge is U.S. $35 to $38 per dry ton (U.S EPA, 1999). In another survey, the member states of European Commission (EC) produce about 5.5 millions dry tons of biosolids per year (Bowden, 1987).

The management of ever increasing volume of sewage sludge has been one of prime environmental issues in Malaysia (Alam, 2002). Kadir and Velayutham (1999) have reported that Indah Water Konsortium (IWK) produces approximately 3.8 millions cubic meters of sewage sludge annually in Malaysia. It is required more than RM 1.00 billion (U.S. $ 0.25 billion) for the management yearly. Sludge production in Malaysia is expected to increase in the future and to be double by the