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THE USE OF FLOCCULANTS IN ANAEROBIC DIGESTION OF PALM OIL MILL EFFLUENT

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THE USE OF FLOCCULANTS IN ANAEROBIC DIGESTION OF PALM OIL MILL EFFLUENT

By

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LIST OF ABBREVIATIONS

A	:	Flocculant FO8990 SH (Trade Name)
a.d.	:	Anaerobic Digestion
ALK	:	Alkalinity
ALK_{ML}	:	Mixed Liquor Alkalinity
B	:	Flocculant Zetag 88N (Trade Name)
BOD	:	Biochemical Oxygen Demand
C	:	Flocculant FO4290 (Trade Name)
COD	:	Chemical Oxygen Demand
c	:	Yield Constant
Ca^{++}	:	Calcium Ion
CH_4	:	Methane
Co	:	Cobalt
CO_2	:	Carbon Dioxide
COD_E	:	Chemical Oxygen Demand of Effluent
COD_s	:	Soluble Chemical Oxygen Demand
COD_{sp}	:	Chemical Oxygen Demand of Supernatant
COD_T	:	Total Chemical Oxygen Demand
D	:	Flocculant FO 42408 SH (Trade Name)
d	:	Day
E	:	Flocculant FO 8650 (Trade Name)

F	:	Flocculant Kurifloc (Trade Name)
Fe	:	Iron
FFB	:	Fresh Fruit Bunches
G	:	Flocculant FL18 (Trade Name)
g	:	Daily Gas Production
H	:	Flocculant C20 (Trade Name)
HCl	:	Hydrochloric Acid
HRT=θ	:	Hydraulic Retention Time
H_2O	:	Water
H_2SO_4	:	Sulphuric Acid
I	:	Flocculant FL 17 (Trade Name)
k	:	Maximum Rate of Substrate Utilization Per Unit Mass of Micro-organism.
k_d	:	Microbial Decay Coefficient/Endogenous Respiration Rate
k_s	:	Half Velocity Rate Constant
MARS	:	Membrane Anaerobic Reactor System
ML	:	Mixed Liquor
MLVSS	:	Mixed Liquor Volatile Suspended Solids
N	:	Nitrogen
N	:	Normality
NH_4^+	:	Ionized Ammonia
NH_3-N	:	Ammoniacal Nitrogen
Ni	:	Nickel

θ_C	:	Mean Cell Residence Time
θ_c^m	:	Minimum Solid Retention Time
O&G	:	Oil and Grease
OLR	:	Organic Loading Rate
OLR_{BOD}	:	BOD Organic Loading Rate
OLR_{COD}	:	COD Organic Loading Rate
OLR_{VS}	:	VS Organic Loading Rate
POME	:	Palm Oil Mill Effluent
P	:	Phosphorous
P_B	:	Biogas Pressure
POMS	:	Palm Oil Mill Sludge
pH_E	:	pH of Effluent
pH_I	:	pH of Influent
pH_{ML}	:	pH of Mixed Liquor
pH_2	:	Hydrogen Pressure
ppm	:	Part Per Million
Q_F	:	Influent Rate
Q_E	:	Effluent Rate
Q_{FC}	:	Flocculant Rate
q	:	Specific Rate of Microbial Substrate Utilization
q_m	:	Maximum Microbial Specific Substrate Utilization Rate
S	:	Limiting Substrate Concentration or Concentration of Effluent Substrate

SS	:	Suspended Solids
S_o	:	Concentration of Influent Substrate
$(SVI)_{60}$	:	Sludge Volume Index
TKN	:	Total Kjedhall Nitrogen
TS	:	Total Solids
UASB	:	Upflow Anaerobic Sludge Blanket
VFA	:	Volatile Fatty Acid
VFA_{ML}	:	Mixed Liquor Volatile Fatty Acid
VS	:	Volatile Solids
V	:	Digester Working Volume
V_B	:	Biogas Volume
VSS	:	Volatile Suspended Solid
V_{ss}	:	Volume of Settled Sludge in Effluent
X	:	Mixed Liquor Suspended Solid
Y	:	Growth Yield Coefficient
Y_G	:	True Growth Yield Constant
μ	:	Net Specific Biomass Growth Rate
μ	:	Maximum Mixrobial Specific Growth Rate

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The use of flocculant in the anaerobic digestion of palm oil mill effluent (POME) was studied. The use of flocculant had enabled pelletization in mesophilic anaerobic digestion to occur within three months of start-up for the substrate which is difficult to granulate naturally. The effect of pelletization had resulted in an increase in biomass concentration and produce a good-solid-liquid separation within the digester resulting in enhanced treatment performance and the ability to tolerate higher organic loads.

Various flocculants were initially tested to assess their effectiveness in forming flocs which exhibited good settling properties with no inhibitory effects on the anaerobic digestion of POME. Zetag 88N, a cationic polyacrylamide of high molecular density was found to be the most effective flocculant. Once pelletization occured, flocculant dosage was able to be discontinued without affecting the process performance.

Two semi-continuous digesters, each of 4 liter capacity and equipped with a stirrer, were operated on a fill and draw system at mesophilic (37°C) and thermophilic (55°C) temperatures. The results indicated that stable mesophilic anaerobic digestion can be achieved up to a maximum organic loading rate of 19 kg COD m^{-3} day^{-1} (HRT = 3.6 days) with 96% COD removal efficiency. This rate is three times better than the contact process. The effect of the higher temperature enabled an increase in the organic loading rate to 27 kg COD m^{-3} day^{-1} accompanied by a shorter hydraulic retention time (1.8 days) and higher methane yield (0.27 m^3 kg^{-1} COD destroyed) with 91% COD removal efficiency.

The kinetic coefficients of Y, k_d, k, K_s and θ_c^m in the mesophilic anaerobic digestion of POME were determined to be 0.48 mg VSS mg^{-1} BOD utilised, 0.057 day^{-1}, 1.96 day^{-1}, 2627 mg BOD ℓ^{-1} and 1.3 days respectively using the Lawrence and McCarty model. Preliminary economic assessment showed the process to be viable.

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PENGGUNAAN FLOKULANT DALAM PENCERNAAN ANAEROBIK EFLUEN KELAPA SAWIT

oleh

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Tesis ini membentangkan penemuan kajian penggunaan flokulant dalam proses pencernaan efluen kelapa sawit. Penggunaan flokulant dalam pencernaan anaerobik mesofilik telah menghasilkan phenomena pembentukan pelet ("pelletization") terhadap substrak yang biasanya sukar membentuk granul secara semulajadi dalam tempoh tiga bulan selepas permulaan pencernaan. Kesan dari pembentukan pelet ini telah dapat meningkatkan kepekatan biomass dan seterusnya dapat menghasilkan pemisahan pepejal dengan baik. Kewujudan pelet ini juga dapat meningkatkan ketahanan reaktor terhadap bebanan organik yang tinggi.

Beberapa jenis flokulant telah diuji untuk menentukan kebolehannya membentuk flok yang boleh mendak dengan cepat dan yang tidak mengganggu proses pencernaan anaerobik. Zetag 88N, suatu poliakrilamida kation yang mempunyai kepadatan molekular tinggi didapati flokulasi yang paling berkesan. Setelah

pembentukan pelet berlaku, proses pencernaan boleh terus berjalan tanpa penambahan flokulant.

Dua pencerna separa berterusan bermuatan 4 liter dilengkapi dengan pengacau, telah dijalankan pada suhu mesofilik (37°C) dan termofilik (55°C). Keputusan kajian menunjukkan proses pencernaan anaerobik yang stabil boleh dicapai dengan kadar bebanan organik maksimum 19 kg COD m^{-3} $hari^{-1}$ dan masa tahanan hidraulik, 3.6 hari. Kecekapan reaktor ialah 96%. Kadar ini adalah tiga kali ganda lebih tinggi daripada proses kontak. Peningkatan suhu telah membolehkan penambahan bebanan organik kepada 27 kg COD m^{-3} $hari^{-1}$ diikuti dengan masa tahanan hidraulik yang singkat, iaitu 1.3 hari dan penghasilan gas methana sebanyak 0.27 m^3 kg^{-1} COD termusnah. Kecekapan rawatan adalah sebanyak 91%.

Dengan menggunakan Model Lawrence dan McCarty, Pekali Kinetik iaitu Y, k_d, k, K_s dan θ_c^m dalam proses pencernaan pada tahap mesofilik adalah 0.48 mg VSS mg^{-1} BOD termusnah, 0.057 day^{-1}, 1.96 day^{-1}, 2627 mg BOD ℓ^{-1} dan 1.3 hari masing-masing. Penilaian awal ekonomi menunjukkan proses pencernaan anaerobik menggunakan flokulant dapat menjimatkan kos pembinaan reaktor untuk rawatan efluen kelapa sawit.

CHAPTER 1

INTRODUCTION

Background

Malaysia has a strong and well developed agro-based industry (e.g. palm oil, rubber and sago) which through the years have been contributing to pollution in natural rivers. With the continued growth in size and scale of this industry and the development of industries related to down-stream processing of these agro-industries, the pollution problem has been increasing in both severity and public awareness.

Since the enactment of the Environmental Quality (Crude Palm Oil) Regulation 1977 which specified a final BOD effluent of 50 ppm, several treatment systems have been developed by the palm oil industry in Malaysia (Chan and Chooi, 1982; Lim 1981; Lim et al., 1984). Palm oil mill effluent (POME) having a high organic content is easily amenable to biodegradation. Therefore, the treatment systems for POME consists essentially of anaerobic and aerobic or facultative processes. The three most common treatment systems adopted are the ponding, open-tank digester with extended aeration and close tank digester with biogas recovery and land application systems. Of these, the ponding system is adopted by more than 85% of the palm oil mills in Malaysia (Ma and Ong, 1985).

All these treatment systems have their disadvantages due either to incomplete treatment, large land area or high capital and/or running costs. Overall, it would appear that the development of a high rate and efficient anaerobic process would be the most effective solution (Cail and Lane, 1986).

Objectives of Research Work

The present work aims to study a high rate anaerobic process for treating POME with the purpose of solving the pollution control problems towards compliance with the regulatory standards. The high rate anaerobic process is highly attractive as an effective treatment system due to savings in land required for housing the treatment system as well as low capital and running costs of the system itself. Moreover, the production of biogas can be harnessed as fuel to generate heat and electricity and the production of the treated waste sludge can be used as fertilizer to assist in recovering back the treatment costs. The process may also be able to absorb shock loads, a common problem which the other systems are unable to handle.

Existing anaerobic treatment systems suffer inefficiencies due to the low biomass yield and the poor separation of solids from liquids. The biological system which have been chosen seeks to overcome these two problems by the use of flocculants, which assist to artificially granulate the active digester bacteria and biomass resulting in a high separation of solid from liquid. This would result in improved treatment efficiency with high loading rates and shorter retention times coupled with a significant reduction in start-up time.

Thus, the objectives of this research are to be achieved along the following investigations:

(a) To select a non-inhibitory flocculant for use in anaerobic digestion which will yield biomass aggregation with good settling properties.

(b) To investigate the performance of a semi-continuous digester, that uses flocculant, to treat palm oil mill effluent at mesophilic temperature.

(c) To investigate and compare the improved performance of the modified anaerobic digestion, that uses flocculants, to treat palm oil mill effluent at thermophilic temperature as against mesophilic temperature.

(d) To derive the process kinetics of the systems.

(e) To ascertain the economic viability of the system.

Direction of Research

Chapter II reviews the recent development in the anaerobic digestion for the treatment of wastewater leading to the use of flocculants as well as the POME treatment technologies in Malaysia. Reference material (e.g. granulation, fundamentals of anaerobic digestion, kinetics) were provided for understanding and development of the present research study.

Chapter III outlines the methodology developed for assessing the relative effectiveness of the chemical flocculants for biomass accummulation. Subsequently the experimental and analytical procedures for the operation of the anaerobic digesters at mesophilic and thermophilic temperatures with the use of the selected flocculant are described.