MICROBIAL COMMUNITY AND SUSPENDED SOLID REMOVAL IN ANAEROBIC HYBRID REACTOR OF PALM OIL MILL EFFLUENT

MISS KANLAYANEE MEESAP
ID: 51920102

A THESIS SUBMITTED AS A PART OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
IN ENVIRONMENTAL TECHNOLOGY

THE JOINT GRADUATE SCHOOL OF ENERGY AND ENVIRONMENT
AT KING MONGKUT'S UNIVERSITY OF TECHNOLOGY THONBURI

2ND SEMESTER 2010

MICROBIAL COMMUNITY AND SUSPENDED SOLID REMOVAL IN ANAEROBIC HYBRID REACTOR OF PALM OIL MILL EFFLUENT

MISS KANLAYANEE MEESAP
ID: 51920102

A THESIS SUBMITTED AS A PART OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL TECHNOLOGY

THE JOINT GRADUATE SCHOOL OF ENERGY AND ENVIRONMENT AT KING MONGKUT'S UNIVERSITY OF TECHNOLOGY THONBURI

2ND SEMESTER 2010

Microbial Community and Suspended Solid Removal in Anaerobic Hybrid Reactor of Palm Oil Mill Effluent

Miss Kanlayanee Meesap

ID: 51920102

A Thesis Submitted as a Part of the Requirements
for the Degree of Doctor of Philosophy
in Environmental Technology

The Joint Graduate School of Energy and Environment
at King Mongkut's University of Technology Thonburi

2nd Semester 2010

Thesis Advisory Committee

(Assoc. Prof. Dr. Pawinee Chaiprasert)	Supervisor
(Dr. Somkiet Techkarnjanaruk)	Co- Supervisor
(Assoc. Prof. Dr. Sirintornthep Towprayoon)	Member
(Assoc. Prof. Dr. Soydoa Vinitnantharat)	Member
(Prof. Dr. Birgitte K. Ahring)	External examiner

Thesis Title: Microbial Community and Suspended Solid Removal in Anaerobic Hybrid Reactor of Palm Oil Mill Effluent

Student's name, organization and telephone/fax numbers/email

Miss Kanlayanee Meesap

The Joint Graduate School of Energy and Environment (JGSEE)

King Mongkut's University of Technology Thonburi (KMUTT)

126 Pracha Uthit Rd., Bangmod, Tungkru, Bangkok 10140 Thailand

Telephone: 0-8912-91325

Email: kanlayanee.mee@kmutt.ac.th

Supervisor's name, organization and telephone/fax numbers/email

Assoc. Prof. Dr. Pawinee Chaiprasert

Division of Biotechnology, School of Bioresources and Technology,

King Mongkut's Univerisity of Technology Thonburi (Bang Khun Thian)

83 Moo 8 Thakham, Bangkuntien, Bangkok, 10150 Thailand

Email: pawinee.cha@kmutt.ac.th

Co-Supervisor's name, organization and telephone/fax numbers/email

Dr. Somkiet Techkarnjanaruk

Excellent Center of Waste Utilization and Management,

National Center for Genetic Engineering and Biotechnology,

King Mongkut's University of Technology Thonburi (Bang Khun Thian)

83 Moo 8 Thakham, Bangkuntien, Bangkok, 10150 Thailand

Email: somkiet@pdti.kmutt.ac.th.

Topic: Microbial Community and Suspended Solid Removal in Anaerobic Hybrid Reactor of Palm Oil Mill Effluent

Name of student: Miss Kanlayanee Meesap **Student ID:** 51920102

Name of Supervisor: Assoc. Prof. Dr. Pawinee Chaiprasert

ABSTRACT

Anaerobic hybrid reactor (AHR) has been applied in palm oil mill effluent treatment (POME) system. It is composed of two parts: the upper part or packed zone contains media supports to serve as a fixed film (FF) bioreactor and lower part or sludge zone is the upflow anaerobic sludge blanket (UASB) section where flocculants and granular sludge are developed. Residual suspended solid (SS) and oil and grease (O&G) in POME are the main causes that affect the process performance and stability of AHR as well as changes in microbial activity and population. Thus, the aims of this research were to study the effects of SS and O&G concentrations on process performance and stability including microbial characteristics in terms of microbial community, population and microbial activity in sludge and packed zones of AHR.

The study consisted of four operational phases; low-strength (5-7 g SS l^{-1} and 0.9-1.4 g O&G l^{-1}), high-strength (10-11 g SS l^{-1} and 1.9-2.3 g O&G l^{-1}), shock load (12.5 g SS l^{-1} and 2.7 g O&G l^{-1}), and recovery with operational back to 10 g SS l^{-1} and 1.8 g O&G l^{-1}, with constant HRT at 5 days. At low-strength POME operation, the normal condition of process stability in both the sludge and packed zones was detected. The range of pH 7.1 to 7.3 and TVA/Alk was 0.20 to 0.43. Reactor performances were achieved at 50-90, 65-76 and 50-80% of TCOD, SS and O&G removal, respectively. However, low methane yield at 0.13-0.20 l CH_4 g^{-1} $COD_{removed}$ was obtained because most of the organic compounds were used for microbial growth and less remained for methane production. High-strength POME not only promoted the process performance in organic removal but also increased methane production rate. At 10 g SS l^{-1}operation, maximum methane yield at 0.30 l CH_4 g^{-1} $COD_{removed}$.was obtained. Moreover, the number of non-methanogens and methanogens were found at 10^7-10^8 and 10^4-10^6 copies rDNA g^{-1}VSS, respectively. Microbial activities and communities increased corresponding to the organic load. High non-methanogenic activity (1.32-1.65 g COD g^{-1}VSS d^{-1}) was achieved in the sludge zone while high methanogenic activity (0.26-0.34 gCOD-CH_4 g^{-1}VSS d-1) was achieved in the packed zone of AHR. Fermentative bacterium communities detected were *γ-Proteobacteria*, *Pseudomonas* sp. *Bacteroidetes bacterium*, and *Clostridium. Methanosaeta* sp. was dominant

methanogen in acetoclastic methanogenesis pathway of methane formation. Nevertheless, high-strength POME with 11 g SS l^{-1} and 2.3 g O&G l^{-1} led to process performance deterioration.

According to these results found that the sludge zone showed higher acidic condition than that packed zone due to high organic acid accumulation. High organic acid concentration affect to process performance in SS and O&G removal decreased to 50 and 40%, respectively. Biogas production rate decreased to 4,000 ml d^{-1} and the methane yield was lower than 0.15 l CH_4 $g^{-1}COD_{removed}$ due to the acidic condition which inhibited methanogenic activity. These results indicated that the high process performance and microbial activity were obtained under AHR operation at OLR less than 4.0 g COD l^{-1} d^{-1} with 10 g SS l^{-1} and 1.9 g O&G l^{-1}. Organic shock load was observed at reactor operation with OLR 6.0 g COD l^{-1} d^{-1}, 12.5 g SS l^{-1} and 2.7 g O&G l^{-1} within 27 d of operation time. Decreasing of process performance and stability were observed. Sludge zone was violently affected from shock load higher than that packed zone due to suspended sludge characteristics, which is directly attacked by organic acid while packed zone was protected by biofilm forming. Under shock load condition, high acid tolerant non-methanogens could work but most of methanogens were completely inhibited. However, temporary organic shock load condition was recovered in a short time by effluent recirculation. Moreover, high process performance of reactor operational back to 10 g SS l^{-1} and 1.8 g O&G l^{-1} were achieved within 6 HRTs. High overall process performance and normal process stability were resumed by detecting higher than 50% organic removal and pH approaching to normal condition. High SS concentration which were accumulated and presented in POME influent influenced increasing of specific hydrolytic bacteria such as *Bacillus* and *γ-Proteobacterium*, which were the key players of cellulose decomposer in anaerobic digestion system. The number of non-methanogenic and methanogenic populations increased to 10^7-10^9 and 10^3-10^5 copies rDNA g^{-1}VSS, respectively.

Key words: anaerobic hybrid reactor, oil and grease, POME, suspended solid, sludge and packed zone. microbial characteristics

ACKNOWLEDGEMENTS

The author would like to express my deepest gratitude to my advisors, Assoc. Prof. Dr. Pawinee Chaiprasert and co-advisor Dr. Somkiet Techkarnjanaruk, for their valued guidance, advice and support. The author also thanks the other members of the thesis committee: Assoc. Prof. Dr. Sirintornthep Towprayoon, Assoc. Prof. Dr. Soydoa Vinitnantharat and Prof. Dr. Birgitte K. Ahring for their helpful suggestions.

The author also would like to express the sincerely gratitude to Joint Graduate School of Energy and Environment (JGSEE) for the Ph.D. Scholarship, Excellent Center of Waste Utilization and Management (ECoWaste) and Gene Technology Laboratory for facility and experimental supports and the Director of Thai Industry Integrating Center (TiTEC) for his permission to allow me to study full time for three years.

My sincere thanks also go to my beloved family who were very supportive for me. They played an important role not only in my project, but in my life. Last but not least, my greatest gratitude goes to my dear class mates and colleagues for all their advice, encouragement and care.

CONTENTS

CONTENTS (Cont')

CONTENTS (Cont')

LIST OF TABLES

LIST OF TABLES (Cont')

LIST OF FIGURES

LIST OF FIGURES (Cont')

Specific methanogenic activity (SMA) and specific activity

The SMA is measured using solution in the methanogenic reactor. SMA can be expressed on the basis of microbial mass (liters of biogas produced per unit mass of microbial population). The specific activity of the process is described as the fraction of the organic load biodegraded in a unit mass of sludge. These parameter are shown in the below.

$$SMA = \frac{Q_{CH4}}{V \cdot VSS}$$

Where Q is the influent flow rate (l/day), V is the volume of the reactor (liters), VSS is the sludge concentration in the reactor and Q_{CH4} is the methane production rate (liters CH_4/day)