PREDICTION OF METHANE POTENTIAL PRODUCTION FROM HIGH VOLATILE FATTY ACIDS IN A MODIFIED ANAEROBIC SYSTEM OF PALM OIL MILL EFFLUENT

ALIMAH HASYYATI SAHDA

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
FACULTY OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
IPB UNIVERSITY
BOGOR
2025

STATEMENT REGARDING THE THESIS AND SOURCES OF INFORMATION AND COPYRIGHTS

I declare that the thesis entitled "Prediction of Methane Potential Production from High Volatile Fatty Acids in Modified Anaerobic System of Palm Oil Mill Effluent" is my work under the direction of my supervisor and has not been submitted to any university. Sources of information derived or quoted from published and unpublished works of other authors have been mentioned in the text and included in the bibliography at the end of this thesis.

I assign the copyright of my writing to IPB University.

Bogor, December 2025

Alimah Hasyyati Sahda
F4501241016

RINGKASAN

ALIMAH HASYYATI SAHDA. Prediction of Methane Potential Production from High Volatile Fatty Acids in Modified Anaerobic System of Palm Oil Mill Effluent. Dibimbing oleh ALLEN KURNIAWAN dan SITI NIKMATIN.

Pengolahan limbah cair kelapa sawit (LCKS) masih menjadi tantangan besar sebab karakteristiknya yang sangat kompleks, mengandung polutan organik yang tinggi, padatan tersuspensi, minyak dan lemak, serta komponen lignoselulosa yang sulit terdegradasi. Pengolahan dengan sistem anaerobik konvensional cenderung mengalami ketidakstabilan akibat akumulasi asam lemak volatil (VFA), ketidakseimbangan fase fermentasi-metanogenesis, serta tingginya fraksi COD resisten yang tidak dapat didegradasi secara efektif. Oleh sebab itu, penelitian ini dilakukan untuk mengevaluasi sistem terintegrasi antara unit filtrasi serat tandan kosong kelapa sawit (TKKS) sebagai pra-perlakuan dan anaerobic modifikasi *rotating biological contactor* (AnMRBC) sebagai unit pengolahan biologis untuk meningkatkan efisiensi pengolahan LCKS.

Penelitian dilakukan dengan menggunakan stalk dan spikelet fiber dari TKKS sebagai media filtrasi fisik-adsorptif untuk menurunkan beban organik dan partikulat sebelum memasuki reaktor biologis. Unit AnMRBC dioperasikan dengan variasi *hyraulic retention time* (HRT) 4, 3, dan 2 hari dalam sistem aliran kontinyu. Hasil penelitian menunjukkan bahwa unit filtrasi OPEFB mampu menurunkan TSS, OG, TN, dan BOD dengan rata-rata 55.62%, 44.39%, 35.45%, dan 20.17%, sehingga menurunkan beban organik menuju unit biologis. Variasi HRT pada AnMRBC (4, 3, dan 2 hari) menghasilkan efisiensi penghilangan TCOD 71.40-83.50%, SCOD 42.60-84.46%, BOD 28.57-77.78%, OG 29.09-96.57%, dan TN 49.58-79.70%, dengan performa terbaik pada HRT 4 hari.

Berdasarkan formula empiris POME ($C_7H_{11}O_2N$), nilai *stoichiometric methane yield* diperoleh sebesar 0.385 L CH_4/g COD dengan komposisi gas teoritis 69.77% CH_4, sedangkan *stoichiometric methane production* harian berada pada kisaran 9.83-39.45 L CH_4/L·hari. Analisis kinetic model menghasilkan parameter μ_m (3.255 hari^{-1}), K_s (0.246 g/L), B_o (0.335 L CH_4/gCOD), dan *refractory coefficient* (0.485), menandakan tingginya fraksi COD yang tidak terurai. Hasil evaluasi kinetika menunjukkan bahwa hidrolidid di dalam reaktor AnRBC tidak terhambat, namun pertumbuhan methanogen yang belum optimal menyebabkan metana belum terproduksi. Secara keseluruhan, sistem efektif sebagai pengolahan awal dan primer, namun efluen belum memenuhi baku mutu sehingga diperlukan unit polishing tambahan.

Kata kunci: AnMRBC, HRT, LCKS, model kinetik, stoikiometri metana, TKKS

SUMMARY

ALIMAH HASYYATI SAHDA. Prediction of Methane Potential Production from High Volatile Fatty Acids in Modified Anaerobic System of Palm Oil Mill Effluent. Supervised by ALLEN KURNIAWAN and SITI NIKMATIN.

The treatment of palm oil mill effluent (POME) remains a major challenge due to its highly complex characteristics, comprising elevated concentrations of organic pollutants, suspended solids, oils and greases, and recalcitrant lignocellulosic compounds. Conventional anaerobic systems frequently experience operational instability resulting from the accumulation of volatile fatty acids (VFAs), imbalances between the fermentation and methanogenesis phases, and a substantial fraction of refractory COD that cannot be effectively degraded. Therefore, this study was conducted to evaluate an integrated treatment system combining an oil palm empty fruit bunch (OPEFB) fiber filtration unit as a pretreatment step and a modified anaerobic rotating biological contactor (AnMRBC) as the biological treatment unit to enhance POME processing efficiency.

The research utilized stalk and spikelet fibers from OPEFB as physical–adsorptive filtration media to reduce particulate and organic loads before the biological reactor. The AnMRBC unit was operated under continuous flow with hydraulic retention times (HRTs) of 4, 3, and 2 days. The results showed that the OPEFB filtration unit successfully reduced TSS, OG, TN, and BOD by an average of 55.62%, 44.39%, 35.45%, and 20.17%, respectively, thereby decreasing the organic loading entering the biological unit. Variations in HRT in the AnMRBC (4, 3, and 2 days) produced TCOD removal efficiencies of 71.40–83.50%, SCOD 42.60–84.46%, BOD 28.57–77.78%, OG 29.09–96.57%, and TN 49.58–79.70%, with the best performance observed at an HRT of 4 days.

Based on the empirical formula of POME ($C_7H_{11}O_2N$), the stoichiometric methane yield was calculated to be 0.385 L CH_4/gCOD with a theoretical methane composition of 69.77%, while the estimated daily stoichiometric methane production ranged from 9.83 to 39.45 L CH_4/L·day. Kinetic modeling produced parameter values of μm (3.255 day^{-1}), Ks (0.246 g/L), B_0 (0.335 L CH_4/gCOD), and a refractory coefficient (0.485), indicating a high proportion of non-degradable COD. The kinetic evaluation revealed that hydrolysis in the AnMRBC reactor was not inhibited, yet suboptimal methanogen growth limited methane generation. Overall, the integrated system demonstrated effectiveness as a pretreatment and primary treatment approach, but the effluent still failed to meet regulatory discharge standards, indicating the need for additional polishing units.

Keywords: AnMRBC, HRT, kinetic model, OPEFB, POME, stoichiometry methane

Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan atau menyebutkan sumbernya. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik, atau tinjauan suatu masalah, dan pengutipan tersebut tidak merugikan kepentingan IPB.

Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apa pun tanpa izin IPB.

PREDICTION OF METHANE POTENTIAL PRODUCTION FROM HIGH VOLATILE FATTY ACIDS IN A MODIFIED ANAEROBIC SYSTEM OF PALM OIL MILL EFFLUENT

ALIMAH HASYYATI SAHDA

A Thesis
Submitted in partial fulfillment of the requirements for the
Magister's Degree in
Civil and Environmental Engineering

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
FACULTY OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
IPB UNIVERSITY
BOGOR
2025

>

Examiner Team on Thesis Exam:
Prof. Dr. -Ing. Ir. Suprihatin, IPU.

Title : Prediction of Methane Potential Production from High Volatile Fatty Acids in Modified Anaerobic System of Palm Oil Mill Effluent

Name : Alimah Hasyyati Sahda

ID : F4501241016

Approved by

Supervisor:
Dr. Eng. Allen Kurniawan, S.T., M.T.

Co-supervisor:
Dr. Siti Nikmatin, S.Si., M.Si.

Known by

Head of Study Program:
Prof. Dr. Satyanto Krido Saptomo, S. TP., M. Si.
NIP. 19703411 200501 1 002

Dean of Agricultural Engineering and Technology:
Prof. Dr. Ir. Slamet Budijanto, M. Agr.
NIP. 19610502 198603 1 002

Exam Date:
15 December 2025

Graduate Date: 29 DEC 2025

PREFACE

Praise and gratitude to the Almighty, Allah SWT., for the blessings the author to properly complete the undergraduate thesis entitled "Prediction of Methane Potential Production from High Volatile Fatty Acids in Modified Anaerobic System of Palm Oil Mill Effluent" right on time. The research was conducted from December 2024 until July 2025 and submitted to fulfill the requirement for a master's degree in the Department of Civil and Environmental Engineering, IPB University. The author would also like to praise the gratitude to:

1. The author's beloved parents and family, for their support and encouragement to complete the studies in college.
2. Dr. Eng. Allen Kurniawan, S.T., M.T., and Dr. Siti Nikmatin, S.Si, M.Si. as supervisors who have given suggestions and guidance from the beginning until the completion of the thesis.
3. Arif Nuryadin as laboratory staff who greatly assisted in discussions and the execution of tests throughout the research process.
4. Rais Rahmadi, S.T., M.T. and Frans Devan Setiawan, S.T. as the RBC teammate for all the company, assistance, and advice.
5. Khusnita Azizah, Arya Muhammad Koernia, Rizky Mursyidan Baldan, and Daffa Aqila Prayogi as fellow comrades for all the encouragement, and cooperation.
6. The Ministry of Research, Technology, and Higher Education and the National Achievement Center of the Republic of Indonesia, which funded, and supported this innovation and research.
7. Lastly, PT. Perkebunan Nusantara VIII Cigudeg, Bogor, for granting permission to collect POME and OPEFB samples.

Hopefully, this scientific work will be useful for those who need it and for the advancement of science.

Bogor, December 2025

Alimah Hasyyati Sahda

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES