



PREDICTION OF ANAEROBIC SYSTEM STABILITY FOR PALM OIL MILL EFFLUENT TREATMENT WITH LIMITED PARAMETER INPUT USING IWA ANAEROBIC DIGESTION MODEL NO.1

WINDYARTI MUSTIKA CAKRANINGTYAS



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



@Hak cipta milik IPB University

Hak Cipta Dilindungi Undang-undang

1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber :
 - a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah
 - b. Pengutipan tidak merugikan kepentingan yang wajar IPB University.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB University.

DECLARATION OF THE UNDERGRADUATE THESIS INFORMATION SOURCES AND COPYRIGHT TRANSFER

I hereby declare that the undergraduate student thesis titled “Prediction of Anaerobic System Stability for Palm Oil Mill Effluent Treatment With Limited Parameter Input Using IWA Anaerobic Digestion Model No.1” is my work under the guidance of my supervisors and has not been published or submitted to any university in any form. The source of information derived or quoted from unpublished or published documents by any other authors has been mentioned in the text and has also been included in the bibliography at the end of the thesis.

Hereby, I assign the copyright of the undergraduate thesis to the IPB University.

Bogor, February 2025

Windyarti Mustika Cakraningtyas
F4401211015



@Hak cipta milik IPB University

Hak Cipta Dilindungi Undang-undang

1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber :
 - a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah
 - b. Pengutipan tidak merugikan kepentingan yang wajar IPB University.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB University.

ABSTRACT

WINDYARTI MUSTIKA CAKRANINGTYAS. Prediction of Anaerobic System Stability for Palm Oil Mill Effluent Treatment with Limited Parameter Input Using IWA Anaerobic Digestion Model No.1. Supervised by ALLEN KURNIAWAN and YUDI CHADIRIN.

The palm oil industry in Indonesia generates 20% of its waste as OPEFB and 80% as POME from total production, with >85% of treatment systems still relying on conventional pond systems. The research integrated a UASB–OPEFB Adsorption–Modified RBC system to enhance the efficiency of POME treatment. The ADM1 modeling method was applied to the UASB unit to predict acetate (S_{ac}) accumulation using a limited parameter input. Variations in UASB (HRT 2, 4, and 6 d) achieved high removal efficiencies with TSS at 97.92%, O&G at 95.12% $\pm$ 0.03% (HRT 6 d), and SCOD at 11.86% $\pm$ 0.07% (HRT 2 d). The results showed a decrease in TVFA from 12280 to 4693 mg/L (61.77%), propionate/acetate ratio (from 0.57 to 0.05), and an increase in S_{ac} dominance to 28.5%. The ADM1 model validation yielded a Spearman correlation coefficient of 0.6257 and ANNOVA $p = 0.2442$. Methane production at an HRT of 6 d (29188 ppm), with the highest SMP (38150 μ L CH₄/gCOD removed) and an average (19.63 mL CH₄/gCOD) confirming the effectiveness of the model and reactor system in improving POME treatment performance.

Keywords: ADM1, acetate, VFA, UASB, methane

ABSTRAK

WINDYARTI MUSTIKA CAKRANINGTYAS. Prediction of Anaerobic System Stability for Palm Oil Mill Effluent Treatment With Limited Parameter Input Using IWA Anaerobic Digestion Model No.1. Dibimbing oleh ALLEN KURNIAWAN dan YUDI CHADIRIN.

Industri kelapa sawit di Indonesia menghasilkan limbah 20% TKKS dan 80% LCKS dari total produksi dengan lebih dari 85% pengolahan masih mengandalkan sistem kolam konvensional. Penelitian ini mengintegrasikan sistem UASB–Adsorpsi TKKS–RBC Modifikasi untuk meningkatkan efisiensi pengolahan POME. Metode pemodelan ADM1 pada UASB untuk memprediksi akumulasi asetat (S_{ac}) dengan input parameter terbatas. Variasi UASB (HRT 2, 4, 6 hari) mencapai efisiensi penghilangan yang tinggi dengan TSS 97,92%, O&G 95,12% $\pm$ 0,03% (HRT 6 hari), dan SCOD 11,86% $\pm$ 0,07% (HRT 2 hari). Hasil menunjukkan penurunan TVFA dari 12.280 menjadi 4.693 mg/L (61,77%), rasio propionat/asetat (0.57 menjadi 0.05), dan peningkatan S_{ac} menjadi 28,5%. Validasi model ADM1 menghasilkan koefisien Spearman 0,6257 dan ANNOVA $p = 0.2442$. Produksi metana pada HRT 6 hari (29.188 ppm) dengan SMP tertinggi (38.150 μ L CH₄/gCOD removed) dan rata-rata 19,63 mL CH₄/gCOD, membuktikan efektivitas model dan sistem reaktor dalam meningkatkan kinerja pengolahan LCKS.

Kata kunci: ADM1, asetat, VFA, UASB, metana



Hak Cipta Dilindungi Undang-undang

1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber :
 - a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah
 - b. Pengutipan tidak merugikan kepentingan yang wajar IPB University.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB University.

© Copyrighted by IPB University, 2025
Copyright is protected by Law

It is prohibited to quote parts or all of this paper without acknowledging or citing the source. Citation is only for the purposes of education, research, writing scientific papers, compiling reports, writing criticism, or reviewing a problem, and the citation is not detrimental to IPB University interests.

It is prohibited to publish and reproduce parts or all of this paper without IPB University's permission.

PREDICTION OF ANAEROBIC SYSTEM STABILITY FOR PALM OIL MILL EFFLUENT TREATMENT WITH LIMITED PARAMETER INPUT USING IWA ANAEROBIC DIGESTION MODEL NO.1

WINDYARTI MUSTIKA CAKRANINGTYAS

Undergraduate thesis
as one of the requirements to obtain a Bachelor's Degree in
Civil and Environmental Engineering Department

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



@Hak cipta milik IPB University

IPB University



IPB University
— Bogor Indonesia —

Hak Cipta Dilindungi Undang-undang

1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber :
 - a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah
 - b. Pengutipan tidak merugikan kepentingan yang wajar IPB University.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB University.

Examiner on Undergraduate Thesis Exam:
Ariani Dwi Astuti, S.T., M.T., Ph.D. IPU., ASEAN Eng.

Perpustakaan IPB University



@Hak cipta milik IPB University

Hak Cipta Dilindungi Undang-undang

1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber :
 - a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah
 - b. Pengutipan tidak merugikan kepentingan yang wajar IPB University.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB University.

Title : Prediction of Anaerobic System Stability for Palm Oil Mill Effluent
Treatment with Limited Parameter Input Using IWA Anaerobic
Digestion Model No.1
Name : Windyarti Mustika Cakraningtyas
Student ID : F4401211015

Approved by

Supervisor:

Dr. Eng. Ir. Allen Kurniawan, S.T., M.T.
NIP. 19820729 201012 1 005

Co-supervisor:

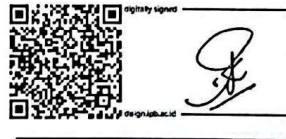
Dr. Ir. Yudi Chadirin, S.TP., M.Agr.
NIP. 19740926 199903 1 004



Acknowledged by

Head of Department:

Dr. Ir. Erizal, M.Agr. IPU.
NIP. 19650106 199002 1 001



Exam Date:
3 July 2025

Graduate Date:

5 JUL 2025

PREFACE

The author expresses profound praise and gratitude to The Almighty God for boundless grace, blessings, and guidance, enabling the author to remain in good health and promptly complete the undergraduate thesis. The thesis, titled "Prediction of Anaerobic System Stability for Palm Oil Mill Effluent Treatment with Limited Parameter Input Using IWA Anaerobic Digestion Model No.1" has been prepared and submitted as part of the requirements to fulfill the degree of Bachelor of Science in the Department of Civil and Environmental Engineering, IPB University.

On the occasion, the author would like to extend heartfelt gratitude to all those who have provided invaluable support, guidance, and encouragement throughout the preparation of the undergraduate thesis. Special thanks are dedicated to:

1. Bambang Suwondo and Sutarti, my beloved father and mother, for their unconditional love, unwavering support, and constant prayers throughout my academic journey;
2. Bantar Tyas Sukmawati Rukmana, my dear sister, for her love, encouragement, and prayers;
3. Dr. Eng. Ir. Allen Kurniawan, S.T., M.T. and Dr. Ir. Yudi Chadirin, S.TP., M. Agr., my esteemed supervisors, for their invaluable guidance, patience, and expertise from the initial stages to the completion of the undergraduate thesis;
4. Gian Azaria and Rizky Mursyidan Baldan, my teammates, for their collaboration, assistance, and insightful advice;
5. Sylvia Wardani, Rahmah Dwi Cahyani, Frans Edvan Setiawan, Gian Azaria, and Ranti Teguh Wicaksono, my fellow Allen-supervised peers, for their support, advice, and camaraderie throughout the journey;
6. Nabiilah Nurjihan, Dina Rahmasari, and Nandareza Devina Raissa Putri, for their invaluable help and contributions to the completion of the undergraduate thesis;
7. Aisyah Anindita, Laila Devi Anggita Putri, Niho Vegaliany Agnesia, Hasannah Alhayyu Refiyon, Aura Putri Zhafira, Valerie Rafa Attalah, and all my friends from Pratistha Rajaluca, for their solidarity, encouragement, and unforgettable memories during my college years;
8. Lastly, the author deeply appreciates your support, assistance, and encouragement to all friends and associates who cannot be mentioned individually.

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

Bogor, February 2025

Windyarti Mustika Cakraningtyas



CONTENTS

LIST OF TABLES	x
LIST OF FIGURES	x
LIST OF APPENDIX	xi
LIST OF NOTATIONS	xi
GLOSSARY	xii
INTRODUCTION	1
1.1 Background	1
1.2 Problem Formulation	4
1.3 Main Objectives	4
1.4 Expected Benefits	4
1.5 Scope of Research	4
II METHODOLOGY	5
2.1 Research Site and Timeline	5
2.2 Instruments and Materials	5
2.3 Research Operation Procedure	6
2.3.1 POME Sampling	8
2.3.2 POME Characteristic Analysis	8
2.3.3 Design and Construction Reactor	9
2.3.4 Seeding and Acclimatization	12
2.3.5 Reactor Operation	13
2.3.6 Sample Testing and Biogas Measurement	15
2.4 Data Analysis and Modeling	17
2.4.1 Specific Methane Production (SMP)	17
2.4.2 Anaerobic Digestion Model No. 1 (ADM1)	17
2.4.3 Validation Model ADM1 in UASB	19
2.4.4 Statistical Analysis	21
2.4.4.1 Coefficient of Determination (R^2)	21
2.4.4.2 Analysis of Variance (ANOVA)	21
2.4.4.3 Spearman's Rank Correlation	23
2.4.5 Variable Operational Scenario in UASB	23
2.4.6 Parameter Kinetic Scenario in UASB	25
2.4.7 Sensitivity Analysis	26
III RESULT AND DISCUSSION	27
3.1 Characterization of POME	27
3.2 Seeding and Acclimatization Biomass	27
3.3 Performance of Integrated Reactor	30
3.4 The UASB Unit Performance Evaluation	35
3.5 ADM1 Model Total Acetate Effluent Estimation	40
3.6 Effect of Operational Variables on UASB Unit Performance	45
3.6.1 Effect of Flow Rate on UASB Unit Performance	45
3.6.2 Effect of Volume on UASB Unit Performance	46
3.6.3 Effect of pH on UASB Unit Performance	46

Hak Cipta Dilindungi Undang-undang
1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber :
a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah
b. Pengutipan tidak merugikan kepentingan yang wajar IPB University.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB University.

3.6.4 Effect of I_{h2} on UASB Unit Performance	46
3.7 Effect of Parameter Kinetic on UASB Unit	47
3.7.1 Effect of K_S on UASB Unit Performance	47
3.7.2 Effect of $k_{m,c4}$ on UASB Unit Performance	48
3.7.3 Effect of Y_{c4} on UASB Unit Performance	48
3.7.4 Effect of $k_{m,pr}$ on UASB Unit Performance	49
3.7.5 Effect of Y_{pro} on UASB Unit Performance	49
3.8 Sensitivity Analysis of Parameter on S_{ac} Estimation	50
IV CONCLUSIONS AND RECOMMENDATIONS	52
4.1 Conclusions	52
4.2 Recommendations	52
REFERENCES	53
APPENDIX	59
AUTOBIOGRAPHY	82