

OPTIMIZATION OF ACTIVATED OIL PALM EMPTY FRUIT BUNCHES FOR INTEGRATED ADSORPTION-BIOLOGICAL TREATMENT OF PALM OIL MILL EFFLUENT

GIAN AZARIA



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

@Hak cipta milik IPB University

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.

DECLARATION OF THE UNDERGRADUATE THESIS INFORMATION SOURCES AND COPYRIGHT TRANSFER

I hereby declare that the undergraduate student thesis titled “Optimization of Activated Oil Palm Empty Fruit Bunches for Integrated Adsorption-Biological Treatment of Palm Oil Mill Effluent” 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 The source of information derived or quoted from unpublished or published documents by other authors has been mentioned in the text and included in the bibliography at the end of this thesis.

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

Bogor, July 2025

Gian Azaria
F4401211016

ABSTRACT

GIAN AZARIA. Optimization of Activated Oil Palm Empty Fruit Bunches for Integrated Adsorption-Biological Treatment of Palm Oil Mill Effluent. Supervised by ALLEN KURNIAWAN and ARIANI DWI ASTUTI.

POME contains high OG levels that hinder biological treatment, requiring preliminary removal through adsorption. This study evaluated the performance of KOH-activated OPEFB in the adsorption unit. Activation with 0.5 M KOH achieved the highest OG removal efficiency at 31.10% and did not increase COD, unlike 1.0 M and 2.0 M concentrations, which increased COD by up to 8.87%. Functional group analysis via FTIR showed a shift in –OH stretching from 3627 to 3745 cm^{-1} and a decrease in C=O and C=C intensity, indicating lignin degradation and enhanced surface polarity. This led to dominant polar interactions and limited OG diffusion into pores. The Bangham model yielded an α value near zero, confirming surface-limited adsorption. Excessive activation caused fiber degradation, increasing TSS to 3880 mg/L. These findings indicate that 0.5 M KOH activation effectively improves OG adsorption efficiency without significant side effects, making it the optimal concentration for OPEFB-based adsorption in POME treatment systems.

Keywords: adsorption kinetics, POME, KOH activation, OPEFB, integrated reactor

ABSTRACT

GIAN AZARIA. Optimizasion of Activated Oil Palm Empty Fruit Bunches in Integrating Adsorption and Biological Unit of Palm Oil Mill Effluent. Dibimbing oleh ALLEN KURNIAWAN dan ARIANI DWI ASTUTI.

LCKS memiliki kandungan OG tinggi yang mengganggu proses biologis dan memerlukan penanganan awal melalui adsorpsi. Penelitian ini mengevaluasi kinerja adsorben TKKS teraktivasi KOH dalam unit adsorpsi. Aktivasi dengan 0,5 M KOH menunjukkan kinerja terbaik dengan efisiensi penyisihan OG sebesar 31,10%, serta tidak menambah kadar COD, berbeda dengan aktivasi 1,0 M dan 2,0 M yang justru meningkatkan COD hingga 8,87%. Analisis gugus fungsi menggunakan FTIR menunjukkan pergeseran pita –OH dari 3627 menjadi 3745 cm^{-1} , serta penurunan intensitas C=O dan C=C, mengindikasikan degradasi lignin dan peningkatan polaritas permukaan. Hal ini berdampak pada dominansi interaksi polar dan terbatasnya difusi OG ke dalam pori. Model Bangham menghasilkan nilai α mendekati nol, yang mengonfirmasi bahwa adsorpsi terjadi pada permukaan luar. Konsentrasi KOH yang terlalu tinggi menyebabkan kerusakan struktur TKKS, meningkatkan TSS hingga 3880 mg/L. Hasil ini menunjukkan bahwa aktivasi 0,5 M KOH mampu meningkatkan efisiensi adsorpsi OG tanpa efek samping signifikan, menjadikannya konsentrasi optimal dalam sistem adsorpsi LCKS berbasis TKKS.

Kata kunci: kinetika adsorpsi, POME, aktivasi KOH, OPEFB, reaktor terintegrasi



- 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.

OPTIMIZATION OF ACTIVATED OIL PALM EMPTY FRUIT BUNCHES FOR INTEGRATED ADSORPTION-BIOLOGICAL TREATMENT OF PALM OIL MILL EFFLUENT

GIAN AZARIA

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

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:
Dr. Ir. Yudi Chadirin, S.TP., M.Agr.



@Hak cipta milik IPB University

IPB University

IPB University
Bogor Indonesia

Perpustakaan 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.

Proposal Title : Optimization of Activated Oil Palm Empty Fruit Bunches
for Integrated Adsorption-Biological Treatment of Palm
Oil Mill Effluent

Name : Gian Azaria
NIM : F4401211025

Approved by

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



Co-Supervisor:
Ariani Dwi Astuti, S.T., M.T., Ph.D. IPU., ASEAN Eng.
NIDN. 0306117001

Acknowledge by

Acting Head of Department:
Prof. Dr. Ir. Chusnul Arif, S.TP., M.Si., IPM.
NIP. 19801206 200501 1 004



Exam Date: July 3rd 2025

Graduate Date: 12 3 JUL 2025

IPB U

ity

PREFACE

The author expresses deep gratitude and praise to God Almighty, Allah SWT, for His blessings and good health, enabling the completion of this undergraduate thesis, titled " *Optimization of Activated Oil Palm Empty Fruit Bunches for Integrated Adsorption-Biological Treatment of Palm Oil Mill Effluent*" in a timely and proper manner. This thesis is presented as a requirement for obtaining a bachelor's degree in the Department of Civil and Environmental Engineering at Bogor Agricultural University.

The author wishes to express gratitude to all colleagues who have provided support throughout the preparation of this thesis, especially to:

1. Dr. Eng. Ir. Allen Kurniawan, S.T., M.T. and Ariani Dwi Astuti, S.T., M.T., Ph.D., IPU., ASEAN Eng. as supervisors who have provided advice and guidance from the beginning until the completion of this thesis.
2. Dr. Ir. Yudi Chadirin, S.TP., M. Agr. as a thesis examiner who has provided advice on my thesis.
3. Edwandi and Angelique, father and mother have provided love, support, and prayers.
4. Arif Nuryadin as laboratory staff who greatly assisted in discussions and the execution of tests throughout the research process;
5. Rizky Mursyidan Baldan and Windyarti Mustika Cakraningtyas as the teammates for all the company, assistance, and advice;
6. Rahmah Dwi Cahyani, Dylan Khrisnaya, Frans Edvan Setiawan, Sylvia Wardani, and Ranti Teguh Wicaksono, Allen's friends who have provided support, advice, and guidance during the lecture period.
7. Aisyah Anindita, Mohamad Daffa Rivansyah, and Muhamad Adlijil Ikram as friends who have provided support and input on this thesis work.
8. Muhammad Reza Nurmansyah, Anthony Dwya Putra, Dzaki Ihsan Tamba, Muhammad Aditiya Resqiyanto, George Martinus, Muhamad Faiq Alghifari, as friends from the same place of residence who have provided input on this thesis work.
9. 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;
10. Lastly, the author deeply appreciates your support, assistance, and encouragement to all friends and associates who couldnot be mentioned individually.

The author has put forth the best effort in compiling this thesis; however, they acknowledge that it may still contain shortcomings in both content and grammar. Therefore, the author welcomes any constructive feedback and corrections for improvement. It is hoped that this thesis will contribute to enriching the readers' knowledge.

Bogor, July 2025

Gian Azaria

CONTENTS

LIST OF TABLES	x
LIST OF FIGURES	x
LIST OF APPENDIXES	x
I INTRODUCTION	1
1.1 Background	1
1.2 Problem Formulation	3
1.3 Main Objectives	3
1.4 Expected Benefits	4
1.5 Scope of The Research	4
II METHODS	5
2.1 Research Site and Timeline	5
2.2 Instrument and Materials	5
2.3 Operating Procedures Research	6
2.3.1 Design and Manufacturing Reactor	6
2.3.2 POME and OPEFB Characteristic Test	7
2.3.3 OPEFB adsorbent pre-treatment	8
2.3.4 Reactor Performance and Data Analysis	8
III RESULTS AND DISCUSSIONS	12
3.1 POME Characteristic Analysis	12
3.2 OPEFB Characteristic Analysis	13
3.2.1 Surface Morphology	13
3.2.2 Surface Chemistry	14
3.2.3 Pre-treatment OPEFB Activation	15
3.3 Performance Evaluation of UASB-Adsorption-RBC configuration	17
3.4 Adsorption Unit Performance	19
3.4.1 Effect of KOH Concentration on POME sCOD	19
3.4.2 Effect of KOH Concentration on POME TSS	21
3.4.3 Effect of KOH Concentration on POME OG	22
3.4.4 Effect of KOH Concentration on POME pH	24
3.5 Adsorption Kinetic Modelling and Statistical Analysis	25
3.6 Influence of Operational Variables on Adsorption Unit Performance	30
IV CONCLUSIONS AND RECOMMENDATIONS	37
4.1 Conclusions	37
4.2 Recommendation	38
REFERENCE	39
APPENDIX	44
AUTOBIOGRAPHY	xi



LIST OF TABLES

Table 2.1 POME quality testing procedure	7
Table 2.2 Variation of OPEFB treatment	8
Table 3.1 POME Characteristic Value	12
Table 3.2 FTIR functional group for OPEFB before and after activation	15
Table 3.3 EDX analysis result	15
Table 3.4 Performance of reactor configuration	18
Table 3.5 sCOD concentration against KOH concentration variation	19
Table 3.6 TSS concentration against KOH concentration variation	21
Table 3.7 OG concentration against KOH concentration variation	22
Table 3.8 Statistical analysis of kinetic model	26
Table 3.9 Adsorption kinetic comparison of each variation on model	28
Table 3.10 ANOVA statistical analysis	30
Table 3.11 Combination variables using multi-objective simulation	36

LIST OF FIGURES

Fig. 2.1 Adsorptionhpg unit configuration for POME treatment	5
Fig. 2.3 View of the OPEFB adsorption reactor (in mm)	7
Fig. 3.1 SEM images of surface OPEFB raw (a) surface (b) cross-section and 2.0M KOH treated (c) 100x (d) 250x	13
Fig. 3.2 FTIR spectra for OPEFB before and after activation	14
Fig. 3.3 Effect of KOH concentration on POME's OG reduction	16
Fig. 3.4 Effect of KOH concentration on POME's sCOD reduction	16
Fig. 3.5 Effect of KOH concentration variation on sCOD	20
Fig. 3.6 visual comparison of OPEFB after activation	21
Fig. 3.7 Effect of KOH concentration variation on TSS	22
Fig. 3.8 Effect of KOH concentration variation on OG	23
Fig. 3.9 OG concentration in whole configuration	24
Fig. 3.10 Effect of KOH concentration variation on pH	25
Fig. 3.11 Modeling adsorption capacity of (a) OG and (b) sCOD	27
Fig. 3.12 Validation of model for (a) OG (b) sCOD adsorption	29
Fig. 3.13 Simulation effect of (a) volume (b) mass (c) C_0 (d) time (e) α (f) k (g)	32
Fig. 3.14 Significance of variable operational to C_t estimation	33
Fig. 3.15 Optimization using Bangham model (a) volume (b) mass (c) C_0 (d) time on effluent concentration	35

LIST OF APPENDIXES

Appendix 1 Table of instrument and chemical for each parameter.....	45
Appendix 2 Table of sCOD concentration measurement data	46
Appendix 3 Table of TSS concentration measurement data	47
Appendix 4 Table of OG concentrations measurement data	48
Appendix 5 Table of pH concentration measurment data	49