



OPTIMIZATION OF KAPOK FIBER ADSORPTION IN INTEGRATED ELECTROCOAGULATION AND MOVING BED BIOFILM REACTOR FOR TREATING PALM OIL MILL EFFLUENT

SYLVIA WARDANI



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



@Hak cipta milik IPB University

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 COPYRIGHTS TRANSFER

I hereby declare that the undergraduate student thesis entitled “Optimization of Kapok Fiber Adsorption in Integrated Electrocoagulation and Moving Bed Biofilm Reactor for Treating Palm Oil Mill Effluent” is my own work under the guidance of my supervisors and has not been published or submitted to any university in any form. Source of information derived or quoted from unpublished or published document by any other authors have been mentioned in the text and has also been included in the bibliography at the end of this thesis.

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

Bogor, Juni 2025

Sylvia Wardani
F4401211029

@Hak cipta milik IPB University

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

SYLVIA WARDANI. Optimization of Kapok Fiber Adsorption in Integrated Electrocoagulation and Moving Bed Biofilm Reactor for Treating Palm Oil Mill Effluent. Supervised by ALLEN KURNIAWAN dan CHUSNUL ARIF.

The integrated Electrocoagulation (EC) and Moving Bed Biofilm Reactor (MBBR) system still faces limitations in effectively removing oil and grease (O&G) from palm oil mill effluent (POME). This study aimed to enhance O&G removal efficiency by incorporating chemically modified kapok fiber (KF) as an adsorbent medium. The fibers were treated using tetraethyl orthosilicate (TEOS) and trimethylchlorosilane (TMCS), followed by pyrolysis at 300°C and 400°C. The research involved four stages: media preparation, reactor assembly, biomass seeding and acclimatization, and performance evaluation. The best result was achieved using KF (1:1)/300, with an O&G removal efficiency of 90.45%. The Redlich–Peterson isotherm model provided a more accurate prediction of adsorption parameters compared to the Langmuir model. Additionally, the modified EC–MBBR unit successfully reduced TSS by 78%, sCOD by 66%, and increased the pH from acidic to neutral–alkaline conditions. It is recommended to replace kapok media periodically and explore further chemical modifications to prevent the final-stage rise in sCOD levels.

Keywords: kapok, pre-treatment, oil and grease, adsorption, palm oil mill effluent

ABSTRAK

SYLVIA WARDANI. Optimizati On Kapok Fiber Adsorption In Integrated Electrokoagulasi dan Moving Bed Biofilm Reaktor untuk Memerapakan Limbah Cair Kelapa Sawit. Diberikan oleh ALLEN KURNIAWAN dan CHUSNUL ARIF.

Kinerja integrasi Elektrokoagulasi (EC) dan *Moving Bed Biofilm Reactor* (MBBR) masih kurang optimal dalam mengurangi kandungan minyak dan lemak (oil and grease/O&G) pada limbah cair kelapa sawit (POME). Penelitian ini bertujuan meningkatkan efisiensi penyisihan O&G dengan menambahkan media adsorpsi berupa serat kapuk yang telah dimodifikasi secara kimia menggunakan TEOS dan TMCS, kemudian dipirolysis pada suhu 300°C dan 400°C. Penelitian dilakukan melalui empat tahap, yaitu persiapan media, perakitan reaktor, proses seeding dan aklimatisasi, serta pengujian kinerja reaktor. Hasil terbaik diperoleh pada variasi kapuk (1:1)/300 dengan efisiensi penyisihan O&G mencapai 90,45%. Model isoterm Redlich–Peterson terbukti lebih akurat dalam memprediksi parameter adsorpsi dibandingkan model Langmuir. Selain itu, unit EC–MBBR juga berhasil menurunkan kadar TSS sebesar 78%, sCOD sebesar 66%, serta meningkatkan pH dari kondisi asam menjadi netral–basa. Media kapuk disarankan diganti secara berkala dan dilakukan eksplorasi modifikasi kimia lanjutan untuk mengatasi peningkatan sCOD pada akhir proses.

Kata Kunci: kapuk, pra-perlakuan, minyak dan lemak, adsorpsi, limbah cair kelapa sawit

© Copyrighted by IPB University, tahun 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 report, 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.

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.



OPTIMIZATION OF KAPOK FIBER ADSORPTION IN INTEGRATED ELECTROCOAGULATION AND MOVING BED BIOFILM REACTOR FOR TREATING PALM OIL MILL EFFLUENT

SYLVIA WARDANI

Undergraduate thesis
as the requirement to obtain Bachelor's Degree in
Civil and Environmental Engineering Department

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



@Hak cipta milik IPB University

IPB University

Examiner on Undergraduate Thesis Exam:
Dr. Ir. Yudi Chadirin, S.TP., M.Agr.

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.

@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 of Research Proposal : Optimization of Kapok Fiber Adsorption in Integrated Electrocoagulation and Moving Bed Biofilm Reactor for Treating Palm Oil Mill Effluent

Name : Sylvia Wardani

Student ID : F4401211029

Approved by

Supervisor:

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



Co-supervisor:

Prof. Dr. Ir. Chusnul Arif, S.TP., M.Si., IPM.
NIP. 19801206 200501 1 004



Known by

Head of Departement:

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



Exam Date: 3 July 2025

Graduate Date: 14 JUL 2025



PREFACE

The author extends praise and gratitude to God Almighty, Allah SWT, who has given health and blessings to the author, thus she can complete his undergraduate thesis entitled "Optimization of Kapok Fiber Adsorption in Integrated Electrocoagulation and Moving Bed Biofilm Reactor for Treating Palm Oil Mill Effluent " correctly and on time. This thesis appears and submitted to fulfill one of the requirements for obtaining a bachelor's degree at the Department of Civil and Environmental Engineering, Bogor Agricultural University.

On this occasion, the author would like to thank all colleagues who have provided support in the preparation of the thesis, especially to:

1. Joko Wardoyo and Dasilah, father and mother who have provided love, support, and prayers.
2. Tiban Abadi, beloved brother for his love, support, and prayers.
3. Dr. Eng. Ir. Allen Kurniawan, S.T., M.T. and Prof. Dr. Ir. Chusnul Arif, S.TP., M.Si., IPM. as supervisors who have provided advice and guidance from the beginning until the completion of this thesis.
4. Rahmah Dwi Cahyani, Windyarti Mustika Cakraningtyas, Dylan Khrisnaya, Frans Edvan Setiawan, Gian Azaria, and Ranti Teguh Wicaksono, Allen's friends who have provided support, advice, and guidance during the lecture period.
5. Khusnita Azizah and Daffa Aqilla Prayogi, as EC-MBBR teammates for all their togetherness, help, and support.
6. Satya Galih Utami, Sabrina, Natasha Arfiani, and Firmansyah Faturrohman my beloved friends who always accompany me in every cry in making this thesis.
7. Finally, all the friends and colleagues who cannot be mentioned one by one for their help and support.

The author has compiled this undergraduate thesis as well as possible, but the author also realizes that there are many imperfections both in content and grammar. Therefore, the author welcomes any constructive suggestions and corrections to improve it. The author hopes that this thesis can help enrich the knowledge of the readers.

Bogor, July 2025

Sylvia Wardani

CONTENTS

LIST OF TABLES	xiii
LIST OF FIGURES	xiii
LIST OF APPENDIX	xiv
LIST OF NOTATIONS	xv
GLOSSARY	xvi
I INTRODUCTION	1
1.1 Background	1
1.2 Problem Formulation	3
1.3 Research Objectives	4
1.4 Scope of The Research	4
II METHODS	5
2.1 Research Site and Timeline	5
2.2 Tools and Materials	5
2.3 Operation Procedures Research	7
2.3.1 POME Sample Collection and Characteristic Analysis	8
2.3.2 Kapok Fiber Adsorption Experiment	9
2.3.3 Comparison of Temperature and Addition TMCS of Kapok Fiber	10
2.3.4 Biomass Seeding and Acclimatization Process	11
2.3.5 Adsorption Isotherm Analysis	11
2.4 Statistics Analysis	13
2.4.1 Normality Test	13
2.4.2 Hypothesis Test	13
2.4.3 Non-Parametric Test	13
2.4.1 Approach to Determining Optimum Adsorbent Mass Based on Initial Concentration	14
2.4.2 Optimization of Operational Variables and Kinetic Parameters on Adsorption Unit Performance	14
2.4.3 Sensitivity Analysis of Parameter on C_t Estimation	14
2.4.4 Reactor Operation	15
2.4.5 Reactor Performance Evaluation	15
2.4.6 Reaction Rate Kinetics of the Adsorption Unit	16
2.4.7 Validity of the Kinetic Model	17
III RESULTS AND DISCUSSION	18
3.1 Characterization of POME	18
3.2 Characterization of Kapok Fiber	19
3.2.1 Surface Morfology	19
3.2.2 Surface Chemistry	21
3.3 Kapok Fiber Optimal for Pre-treatment Unit	24
3.4 Adsorption Isotherm Analysis	26
3.5 Determination of Optimal Initial O&G Concentration Based on Kapok Variations	30
3.6 Approach to Determining Optimum Adsorben Mass Based on Initial Concentration	32
3.7 Optimization of Operational Variables and Kinetic Parameters on KF Unit Performance	34
3.8 Sensitivity Analysis of Parameter on C_t Estimation	35

3.9 Statistics Analysis	36
3.10 Microorganism Seeding and Acclimatization	38
3.11 Reactor Performance Evaluation	39
3.11.1 Effect of KF Pretreatment on MLSS and sCOD Concentrations	39
3.11.2 Effect of KF Pretreatment on MLSS and O&G Concentrations	43
3.11.3 Effect of Pre-treatment on BOD and TN Concentrations	44
3.11.4 The Effect of KF Pre-treatment on MLSS, Temperature, and pH	46
3.12 Reaction Rate Kinetics of the Adsorption Unit	48
3.13 Limitations and Recommendations	50
3.13.1 sCOD and TN Parameters Effluent Standards	50
3.13.2 Adsorption–Desorption Cycle Test	51
3.13.3 Energy Analysis of EC and TMCS Cost	52
CONCLUSIONS AND RECOMMENDATIONS	53
4.1 Conclusions	53
4.2 Recommendations	53
REFERENCES	54
APPENDIX	59
AUTOBIOGRAPHY	82

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.