

EFFECT OF CHITOSAN CONCENTRATION AND DOSAGE IN SEQUENTIAL BIOSURFACTANT AND CHITOSAN TREATMENT OF PRODUCED WATER

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**CIVIL AND ENVIRONMENTAL ENGINEERING STUDY PROGRAM
FACULTY OF ENGINEERING AND TECHNOLOGY
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BOGOR
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ABSTRACT

NATHASIA. Effect Of Chitosan Concentration and Dosage in Sequential Biosurfactant and Chitosan Treatment of Produced Water. Supervised by ALLEN KURNIAWAN and YUDI CHADIRIN.

Produced water from oil and gas production contains high oil and grease (O&G), Chemical Oxygen Demand (COD), and ammonia, requiring treatment before discharge. This study determined optimum chitosan concentration and dosage for sequential biosurfactant-chitosan treatment, modeled the dosage-concentration interaction using Response Surface Methodology (RSM), and examined the adsorption mechanism via nonlinear isotherms. Highest individual removals were 90% O&G (2.5% dosage, 1% concentration), 52.4% ammonia (4.5%, 1%), and 25.4% COD (1.5%, 0.5%). Canonical analysis confirmed a true maximum for O&G (68.50% predicted at 2.930%, 0.657%), while the COD model was a saddle surface whose stationary point fell outside the tested range (0.5%, 0.1%; 38.6% predicted), and the ammonia model was not significant due to low R^2 value. RSM optimization gave a compromise condition (1.26%, 0.99%) but only 0.40 desirability, reflecting O&G-COD antagonism. Isotherm analysis showed O&G and COD removal were driven mainly by coagulation-flocculation rather than true adsorption. These results support OPEFB biosurfactant and shrimp-shell chitosan as a sustainable pre-treatment for produced water.

Keywords: adsorption isotherm, chitosan, produced water, response surface methodology, sequential treatment

ABSTRAK

Air terproduksi dari industri minyak dan gas mengandung minyak dan lemak (O&G), *Chemical Oxygen Demand* (COD), dan amonia dalam konsentrasi tinggi sehingga memerlukan pengolahan sebelum dibuang. Penelitian ini menentukan konsentrasi dan dosis kitosan optimum untuk pengolahan sekuensial biosurfaktan-kitosan, memodelkan interaksi dosis-konsentrasi menggunakan *Response Surface Methodology* (RSM), dan mengkaji mekanisme adsorpsi melalui isotherm nonlinear. Penyisihan individu tertinggi adalah 90% O&G (dosis 2,5%, konsentrasi 1%), 52,4% amonia (4,5%, 1%), dan 25,4% COD (1,5%, 0,5%). Analisis kanonik mengonfirmasi titik maksimum O&G (prediksi 68,50% pada dosis 2,930%, konsentrasi 0,657%), sedangkan titik maksimum model COD berada di luar rentang uji (0,5%, 0,1%; prediksi 38,6%). Model amonia tidak signifikan karena nilai R^2 yang rendah. Optimasi RSM menghasilkan kondisi kompromi (dosis 1,26%, konsentrasi 0,99%) namun hanya desirability 0,40 akibat antagonisme O&G-COD. Analisis isotherm menunjukkan penyisihan O&G/COD didominasi koagulasi-flokulasi, bukan adsorpsi sejati. Hasil ini mendukung biosurfaktan TKKS dan kitosan kulit udang sebagai pendekatan pra-pengolahan berkelanjutan untuk air terproduksi.

Kata kunci: air terproduksi, isotherm adsorpsi, kitosan, *response surface methodology*, pengolahan sekuensial



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EFFECT OF CHITOSAN CONCENTRATION AND DOSAGE IN SEQUENTIAL BIOSURFACTANT AND CHITOSAN TREATMENT OF PRODUCED WATER

NATHASIA

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

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FACULTY OF ENGINEERING AND TECHNOLOGY
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PREFACE

The author extends praise and gratitude to God Almighty, who has given health and blessings to the author, thus she can complete her undergraduate thesis entitled "Effect of Chitosan Concentration and Dosage in Sequential Biosurfactant and Chitosan Treatment of Produced Water" correctly and on time. This thesis appears and is submitted to fulfill one of the requirements for obtaining a bachelor's degree at the Department of Civil and Environmental Engineering, IPB 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. Yudha Alpinus, Lily Thios, Nathania and Christian, a family who has provided love, support, and prayers.
2. Dr. Eng. Ir. Allen Kurniawan, S.T., M.T. and Dr. Ir. Yudi Chadirin, S.TP., M.Agr., as supervisors who have provided advice and guidance from the beginning until the completion of this thesis.
3. Satrio Waluyojoati Almay Widagdo, Ryu Prananda Sultan Batubara, Zidand Anand Hidayat, Mikael Febrian Aritonang, Adi Aryanto, and Azmya Prasetyaningtyas, Allen's research colleagues who have provided support, advice, and guidance during the lecture period.
4. Rahmah Dwi Cahyani, Dylan Khrisnaya Jamlia Qurrati Aini, and Diandra Mahendra Saputri, as my beloved and prestigious teammates, thank you for all your togetherness, help, and support.
5. Nana Chairunnisa, as a nutritionist and support as a friend were invaluable in ensuring my physical well-being throughout this research.
6. Najwa, Nascit, Domi, Aubi, Desi, Trevi, Maria, Andini, Khansa, Sri, Rila, and all the friends and colleagues who cannot be mentioned one by one for their help and support.
7. A special thanks to Cortis, Martin Edwards, James Chao, Kim Juhoon, Eom Seonghyeon, Ahn Keonho. And Babymonster, Kawai Ruka, Pharita Boonpakdeethaveeyod, Enami Asa, Jung Ahyeon, Shin Haram (Rami), Lee Dain (Rora), and Riracha Phondechaphiphat (Chiquita). the K-pop groups who have indirectly accompanied and provided support throughout the writing.

The author has compiled this 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 2026

Nathasia



CONTENTS

LIST OF TABLES	iii
LIST OF FIGURES	iii
LIST OF APPENDIX	iii
LIST OF NOTATIONS	v
GLOSSARY	vi
I INTRODUCTION	1
1.1 Background	1
1.2 Problem Formulation	3
1.3 Research Objectives	3
1.4 Research Significance	4
1.5 Scope of The Research	4
II STUDY LITERATURE	5
III METHODS	7
3.1 Research Site and Timeline	7
3.2 Tools and Materials	7
3.3 Operating Procedures Research	8
3.4 Data Analysis	14
IV RESULT AND DISCUSSION	22
4.1 Produced Water Characteristic Analysis	22
4.2 Chitosan Characteristic Analysis	23
4.3 Physical Alterations During Sequential Treatment	23
4.4 Contaminant Removal Efficiency	24
4.5 Response Surface Methodology (RSM) for Dosage and Concentration Optimization	28
4.6 Adsorption Isotherm and Kinetic Modelling	38
4.7 Simulation of Scaled-Up Adsorption Scenarios	43
V CONCLUSIONS AND RECOMMENDATIONS	47
5.1 Conclusions	47
5.2 Recommendations	47
REFERENCE	48
APPENDIX	53
AUTOBIOGRAPHY	65

LIST OF TABLES

Table 2.1 Research gap and novelty of this study	18
Table 4.1 Produced water characteristic value	23
Table 4.2 Chitosan characterization	24
Table 4.3 Stage-wise concentration change during treatment	26
Table 4.4 Final contaminant concentration and at the best condition	26
Table 4.5 Pearson correlation calculation	27
Table 4.6 Summary of ANOVA and predictive validation statistics	33
Table 4.7 Canonical analysis for each parameter	38
Table 4.8 Combined optimum condition for all parameters	39
Table 4.9 Summary of R ² and RMSE for the isotherm models	42
Table 4.10 Maximum adsorption capacity and corresponding run conditions	43
Tabel 4.11 Estimated flow rate and reactor volume at various pond scales	45
Table 4.12 Required vs. achieved removal percentage	46

LIST OF FIGURES

Fig. 3.1 Research flow chart	8
Fig. 3.2 Chemical deproteinization process	10
Fig. 3.3 Chemical demineralization process	10
Fig. 3.4 Chemical deacetylation process	11
Fig. 4.1 Visual transition of raw produced water: (a) after biosurfactant addition and aeration; (b) after scum removal; (c) after chitosan addition	25
Fig. 4.2 Heatmap removal O&G (%)	28
Fig. 4.3 Heatmap of change COD (%)	28
Fig. 4.4 Heatmap of change ammonia (%)	29
Fig. 4.5 Effect of biosurfactant concentration on each parameters	30
Fig. 4.6 Effect of biosurfactant with chitosan dosage at 0.1% (A), 0.5% (B), 1% (C), 1.5% (D), and 2% (E) on each parameter	31
Fig. 4.7 Response surface plot of O&G change	34
Fig. 4.8 Response surface plot of COD change	35
Fig. 4.9 Response surface plot of ammonia change	36
Fig. 4.10 Composite desirability contour map for optimization all parameters	38
Fig. 4.11 Comparison of adsorption isotherm models for O&G	40
Fig. 4.12 Comparison of adsorption isotherm models for COD	40
Fig. 4.13 Comparison of adsorption isotherm models for ammonia	41

LIST OF APPENDIX

Appendix 1 Result of experiments	55
Appendix 2 Regression coefficients for all parameters	56
Appendix 3 The MATLAB code for the 3D Response Surface Plot of Oil and Grease (O&G) modelling	57

Appendix 4 The MATLAB code for the 3D response surface plot of COD modelling	58
Appendix 5 The MATLAB code for the 3D response surface plot of Ammonia modelling	59
Appendix 6 The MATLAB code for the combined response surface plot of All Parameters	60
Appendix 7 The MATLAB code for multi-objective Optimization using the Desirability Function Approach	62
Appendix 8 Non-linear isotherm fitting results per model and parameter regression coefficients for all parameters	64

LIST OF NOTATIONS

A	=	Temkin isotherm equilibrium binding constant (L/mg).
B	=	Temkin constant related to the heat of adsorption (mg/g).
C_o	=	Initial concentration of the pollutant in the aqueous phase (mg/L).
C_e	=	Equilibrium concentration of the pollutant in the aqueous phase (mg/L).
F	=	F-statistic (F-value) derived from the Analysis of Variance (ANOVA).
K_F	=	Freundlich isotherm capacity constant (mg/g)(L/mg) ^{1/n}
K_L	=	Langmuir isotherm affinity constant (L/mg)
m	=	Mass of the adsorbent (chitosan) (gram).
n	=	Freundlich empirical exponent related to adsorption intensity
Q	=	Volumetric industrial produced water flow rate capacity (m ³ /day or L/day).
q_e	=	Equilibrium adsorption capacity (mass of adsorbate per unit mass of adsorbent) (mg/g)
q_t	=	Adsorption capacity at a specific time (mass of adsorbate adsorbed per unit mass of adsorbent at time x) (mg/g).
q_{max}	=	Maximum theoretical monolayer adsorption capacity (mg/g).
r	=	Pearson correlation coefficient indicating the strength of a linear relationship.
V	=	Volumetric liquid phase of the wastewater solution in the batch (L).

GLOSSARY

Adsorption	: The physical or chemical process by which ions, atoms, or molecules from a fluid phase (gas or liquid) adhere to the surface of a solid material (adsorbent).
Analysis of Variance (ANOVA)	: A statistical method used to evaluate and compare the means of multiple experimental groups to determine if the observed variations are statistically significant.
Biosurfactant	: A surface-active compound synthesized by microorganisms that reduces surface and interfacial tension between different fluid phases, often used to stabilize or break emulsions.
Concentration	: The measure of the amount of a specific substance (solute) present within a defined volume or mass of a mixture.
Dosage	: The prescribed regimen of a substance, including the amount, frequency, and duration of application, often used in experimental studies to describe the range of amounts being tested as a variable.
Deacetylation	: The chemical reaction involving the removal of acetyl groups from chitin—typically using concentrated alkaline solutions under high temperatures—to convert it into chitosan.
Demineralization	: The chemical processing step used to remove inorganic minerals (primarily calcium carbonate) from raw biomass, such as shrimp shells, using an acidic solution.
Deproteinization	: The chemical separation process targeted at extracting and removing protein fractions from raw materials using dilute alkaline solutions.
Freundlich Isotherm	: An empirical adsorption model that describes multilayer adsorption onto a heterogeneous surface with a non-uniform distribution of adsorption heat.
Hill Isotherm	: A semi-empirical adsorption isotherm model used to describe the cooperative binding behavior of adsorbate molecules onto an adsorbent surface, where the binding of one molecule influences the attachment of subsequent ones.
Jar test	: A standard laboratory experimental procedure used to simulate and optimize coagulation, flocculation, and sedimentation processes in water and wastewater treatment.
Langmuir Isotherm	: A theoretical adsorption model based on the assumption that adsorption occurs as a single layer (monolayer) on



- a finite number of identical, homogeneous active sites with no lateral interaction between molecules.
- Lignin** : A complex, hydrophobic organic polymer found in the cell walls of lignocellulosic biomass that provides structural rigidity and resistance to microbial degradation.
- OPEFB** : (Oil Palm Empty Fruit Bunch) A solid lignocellulosic waste biomass generated in large volumes from the palm oil milling process, commonly utilized as a sustainable raw material for lignin extraction.
- Pearson Correlation** : A statistical index that measures the linear strength and direction of the relationship between two continuous variables, ranging from -1 to +1.
- Power-Law Isotherm** : An empirical model that uses a power function to describe non-linear relationships, commonly applied in adsorption kinetics or rheology to model rates that vary non-proportionally with time or concentration.
- Produced water** : A highly complex wastewater byproduct brought to the surface along with oil and gas during extraction operations, typically containing hydrocarbons, salts, and dissolved organic compounds.
- Response Surface Methodology (RSM)** : A statistical technique that models and analyzes the effects of multiple variables to identify the optimal conditions for a desired response.
- Sodium Lignosulfonate (SLS)** : A water-soluble, anionic surfactant macromolecule derived from the chemical modification and sulfonation of lignin.
- Sulfonation** : A chemical synthesis reaction that introduces a sulfonic acid functional group into an organic molecule to enhance its hydrophilicity and surfactant properties.
- Temkin Isotherm** : An adsorption isotherm model that explicitly accounts for sorbate-adsorbent interactions, assuming that the heat of adsorption decreases linearly with surface coverage.



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