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

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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 isoterm 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 isoterm 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, isoterm adsorpsi, kitosan, *response surface methodology*, pengolahan sekuensial

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PREFACE

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Bogor, July 2026

Nathasia

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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	=	Adorption 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.