OPTIMIZING ELECTRO-COAGULATION PLATE ARRANGEMENT AND OPERATIONAL PARAMETERS COUPLED WITH MOVING BED BIOFILM REACTOR FOR PALM OIL MILL EFFLUENT

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SUMMARY

PRAYOGI, DAFFA AQILLA. Optimizing Electro-Coagulation Plate Arrangement and Operational Parameters Coupled with *Moving Bed Biofilm Reactor* for Palm Oil Mill Effluent. Supervised by ALLEN KURNIAWAN and YUDI CHADIRIN.

Palm oil mill effluent (POME) is a high-strength wastewater characterized by acidic conditions and high concentrations of organic matter, suspended solids, oil and grease, and nitrogen. This study evaluated an integrated treatment system consisting of modified kapok fiber (KF) pretreatment, electrocoagulation (EC), sedimentation, and a moving bed biofilm reactor (MBBR). The objectives were to assess the performance of iron (Fe), aluminum (Al), and copper (Cu) electrodes under unsteady-state conditions and to model pollutant-removal kinetics using the Weibull equation. Raw POME had a pH of 3.4 and contained 12,081 mg/L BOD5, 20,796 mg/L soluble chemical oxygen demand (sCOD), 25,610 mg/L total suspended solids (TSS), 3,243 mg/L oil and grease, and 95 mg/L total nitrogen. The EC unit was operated at 24 V and 10 A, with each electrode material tested for ten days. The KF unit removed approximately 46–53% of oil and grease. Across the integrated system, removal efficiencies ranged from 71.72–81.38% for oil and grease, 41.74–73.38% for TSS, and 52–66% for sCOD. The EC process also increased pH to 6.14–6.86, meeting the regulatory pH range. Copper provided the most stable and generally highest removal of sCOD and TSS, whereas iron offered better operational viability because of its longer expected replacement interval. The Weibull models achieved R^2 values of 0.802–0.818. Sensitivity analysis identified the shape parameter (β) and scale parameter (τ) as the dominant model inputs. At the two-hour EC operating point, oil and grease removal was near its effective range, while sCOD removal remained limited because its characteristic treatment time was substantially longer. Consequently, final sCOD concentrations remained above the Indonesian discharge standard. The integrated KF–EC–MBBR system is promising for POME treatment, but further improvement of MBBR operation and the addition of tertiary treatment, such as advanced oxidation or membrane filtration, are required to achieve compliant and reusable effluent.

Keywords: electrocoagulation, kapok fiber, moving bed biofilm reactor, palm oil mill effluent, Weibull model

RINGKASAN

PRAYOGI, DAFFA AQILLA. Optimasi Susunan Pelat Elektrokoagulasi dan Parameter Operasional yang Dipadukan dengan *Moving Bed Biofilm Reactor* untuk Pengolahan Limbah Cair Pabrik Kelapa Sawit. Dibimbing oleh ALLEN KURNIAWAN dan YUDI CHADIRIN.

Limbah cair pabrik kelapa sawit (POME) merupakan air limbah berkekuatan tinggi yang bersifat asam serta mengandung bahan organik, padatan tersuspensi, minyak dan lemak, serta nitrogen dalam konsentrasi tinggi. Penelitian ini mengevaluasi sistem pengolahan terintegrasi yang terdiri atas praperlakuan serat kapuk termodifikasi (KF), elektrokoagulasi (EC), sedimentasi, dan moving bed biofilm reactor (MBBR). Penelitian bertujuan menilai kinerja elektroda besi (Fe), aluminium (Al), dan tembaga (Cu) pada kondisi tak tunak serta memodelkan kinetika penyisihan pencemar menggunakan persamaan Weibull. POME awal memiliki pH 3,4 serta mengandung kebutuhan oksigen biokimia (BOD5) 12.081 mg/L, kebutuhan oksigen kimia terlarut (sCOD) 20.796 mg/L, padatan tersuspensi total (TSS) 25.610 mg/L, minyak dan lemak 3.243 mg/L, dan nitrogen total 95 mg/L. Unit EC dioperasikan pada tegangan 24 V dan arus 10 A, dengan setiap jenis elektroda diuji selama sepuluh hari. Unit KF mampu menyisihkan sekitar 46–53% minyak dan lemak. Pada keseluruhan sistem terintegrasi, efisiensi penyisihan mencapai 71,72–81,38% untuk minyak dan lemak, 41,74–73,38% untuk TSS, dan 52–66% untuk sCOD. Proses EC juga meningkatkan pH menjadi 6,14–6,86 sehingga memenuhi rentang baku mutu pH. Elektroda Cu menunjukkan kinerja paling stabil dan secara umum menghasilkan penyisihan sCOD dan TSS tertinggi, sedangkan elektroda Fe lebih layak secara operasional karena memiliki perkiraan interval penggantian yang lebih panjang. Model Weibull menghasilkan nilai R^2 sebesar 0,802–0,818. Analisis sensitivitas menunjukkan bahwa parameter bentuk (β) dan parameter skala (τ) merupakan masukan model yang paling dominan. Pada waktu operasi EC dua jam, penyisihan minyak dan lemak telah berada pada rentang efektif, sedangkan penyisihan sCOD masih terbatas karena membutuhkan waktu karakteristik pengolahan yang lebih panjang. Akibatnya, konsentrasi akhir sCOD masih melampaui baku mutu pembuangan di Indonesia. Sistem KF–EC–MBBR memiliki potensi untuk pengolahan POME, tetapi peningkatan operasi MBBR dan penambahan pengolahan tersier, seperti proses oksidasi lanjut atau filtrasi membran, diperlukan untuk menghasilkan efluen yang memenuhi baku mutu dan berpotensi digunakan kembali.

Kata kunci: elektrokoagulasi, limbah cair pabrik kelapa sawit, model Weibull, moving bed biofilm reactor, serat kapuk

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PREFACE

The author prays the praise and gratitude to the Almighty, Allah SWT., who has given the author health and blessing to properly complete the undergraduate thesis entitled "Optimizing Electro-Coagulation Plate Arrangement and Operational Parameters Coupled with Moving Bed Biofilm Reactor for Palm Oil Mill Effluent" right on time. The thesis was created and submitted to fulfill the requirement for a bachelor's degree in the Department of Civil and Environmental Engineering, IPB University.

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The author has contrived the thesis as best as possible, but the author is also aware of many imperfections in both content and grammar. Consequently, the author welcomes any suggestions and constructive corrections to improve. The author wishes this thesis would help enrich readers' knowledge.

Bogor, August 2026

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