OXYGEN TRANSFER AND AMMONIA NITRIFICATION MODELING FOR AERATION OPTIMIZATION IN INTEGRATED BIOFILM–MEMBRANE RECIRCULATING AQUACULTURE SYSTEMS

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ABSTRACT

RYU PRANANDA SULTAN BATUBARA. Oxygen Transfer and Ammonia Nitrification Modeling for Aeration Optimization in Integrated Biofilm–Membrane Recirculating Aquaculture Systems. Supervised by ALLEN KURNIAWAN and SATYANTO KRIDO SAPTOMO.

Recirculating Aquaculture System (RAS) is an aquaculture technology capable of maintaining water quality through recirculation and biological treatment processes. One of the main challenges in this system is ammonia control, which can affect fish health and water quality stability. This study evaluated three experimental airflow conditions (100, 150, and 190 L/min) and simulated additional airflow scenarios from 80 to 220 L/min using a Monod-based nitrification model. The research methodology involved the development of a Monod kinetics-based mathematical model considering the effects of NH_3, dissolved oxygen (DO), alkalinity, temperature, and pH on the activity of ammonia oxidizing bacteria (AOB). The results showed that increasing airflow enhanced DO concentration, resulting in more effective nitrification and lower NH_3 effluent concentration. Model validation showed the strongest agreement at an airflow of 190 L/min, with R2 of 0.923 and RMSE of 0.049 mg/L, indicating that the calibrated model captured the observed NH_3 effluent trend under this operating condition. Although higher airflow improved oxygen availability, the highest percentage NH_3 removal was observed at 150 L/min, while 190 L/min produced the lowest effluent NH_3 and the best model fit under a lower influent load.

Keywords: Airflow Optimization, Ammonia, Dissolved Oxygen, Monod Kinetics, Recirculating Aquaculture System

ABSTRAK

RYU PRANANDA SULTAN BATUBARA. *Pemodelan Transfer Oksigen dan Nitrifikasi Amonia untuk Optimalisasi Aerasi dalam Sistem Akuakultur Resirkulasi Biofilm-Membran Terintegrasi*. Dibimbing oleh ALLEN KURNIAWAN dan SATYANTO KRIDO SAPTOMO.

Sistem Akuakultur Resirkulasi (RAS) adalah teknologi akuakultur yang mampu menjaga kualitas air melalui resirkulasi dan proses pengolahan biologis. Salah satu tantangan utama dalam sistem ini adalah pengendalian amonia, yang dapat memengaruhi kesehatan ikan dan stabilitas kualitas air. Studi ini mengevaluasi tiga kondisi aliran udara eksperimental (100, 150, dan 190 L/min) dan mensimulasikan skenario aliran udara tambahan dari 80 hingga 220 L/min menggunakan model nitrifikasi berbasis Monod. Metodologi penelitian melibatkan pengembangan model matematika berbasis kinetika Monod yang mempertimbangkan pengaruh NH_3, oksigen terlarut (DO), alkalinitas, suhu, dan pH terhadap aktivitas bakteri pengoksidasi amonia (AOB). Hasil menunjukkan bahwa peningkatan aliran udara meningkatkan konsentrasi DO, menghasilkan nitrifikasi yang lebih efektif dan konsentrasi NH_3 efluen yang lebih rendah. Validasi model menunjukkan kesesuaian terkuat pada aliran udara 190 L/min, dengan R2 sebesar 0,923 dan RMSE sebesar 0,049 mg/L, yang mengindikasikan bahwa model yang dikalibrasi mampu menangkap tren NH_3 dalam air limbah yang diamati pada kondisi operasi ini. Meskipun aliran udara yang lebih tinggi meningkatkan ketersediaan oksigen, persentase penghilangan NH_3 tertinggi diamati pada 150 L/min, sedangkan 190 L/min menghasilkan NH_3 dalam air limbah terendah dan kesesuaian model terbaik pada beban air limbah yang lebih rendah..

Kata kunci: Amonia, kinetika monod, Oksigen Terlarut, Optimasi Aliran Udara, Sistem Akuakultur Resirkulasi

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PREFACE

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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, May 2026

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