OPTIMASI KOMPOSISI MIXED MATRIX MEMBRANE POLIMER-MOF UNTUK APLIKASI PEMISAHAN GAS CO_2/N_2

SKRIPSI

diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar Sarjana Sains pada Program Studi Kimia

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OPTIMASI KOMPOSISI MIXED MATRIX MEMBRANE POLIMER-MOF UNTUK APLIKASI PEMISAHAN GAS CO_2/N_2

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LEMBAR PERNYATAAN

Dengan ini saya menyatakan bahwa skripsi dengan judul "Optimasi Komposisi Mixed Matrix Membrane Polimer-MOF untuk Aplikasi Pemisahan Gas CO_2/N_2" ini beserta seluruh isinya adalah benar-benar karya saya sendiri. Saya tidak melakukan penjiplakan atau pengutipan dengan cara-cara yang tidak sesuai dengan etika ilmu yang berlaku dalam masyarakat keilmuan. Atas pernyataan ini, saya siap menanggung risiko/sanksi apabila dikemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain terhadap keaslian karya saya ini.

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KATA PENGANTAR

Puji dan syukur penulis panjatkan kepada Allah SWT atas segala berkat dan karunia-Nya kepada penulis sehingga penulis dapat menyelesaikan skripsi ini. Skripsi ini berjudul "Optimasi Komposisi Mixed Matrix Membrane Polimer-MOF untuk Aplikasi Pemisahan Gas CO_2/N_2". Adapun skripsi ini disusun untuk memenuhi salah satu syarat memperoleh gelar Sarjana Sains pada Program Studi Kimia, Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia.

Dalam penyusunan skripsi ini penulis menyadari bahwa masih banyak kekurangan dan keterbatasan dalam skripsi ini. Oleh karena itu, penulis mengharapkan adanya kritik dan saran yang membangun dari semua pihak. Penulis berharap skripsi ini dapat bermanfaat bagi penulis dan pembaca.

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ABSTRAK

Perubahan iklim yang disebabkan oleh emisi CO_2 dari pembakaran bahan bakar fosil mendorong pengembangan teknologi pemisahan gas CO_2. *Mixed Matrix Membrane* (MMM) berbasis *Metal-Organic Frameworks* (MOF) dan polimer merupakan salah satu material yang banyak digunakan untuk pemisahan gas CO_2/N_2. Namun, proses sintesis dan optimasi komposisi MMM dengan polimer dan MOF yang berbeda membutuhkan waktu dan biaya yang signifikan jika dilakukan melalui eksperimen. Pada penelitian ini, *Machine Learning* (ML) dengan algoritma *Artificial Neural Network* (ANN) dikembangkan untuk memperoleh komposisi dan karakteristik MMM yang optimum. Data eksperimental dari literatur dianalisis menggunakan korelasi Pearson dan normalisasi data. Model ANN kemudian diperoleh melalui *data training* untuk memprediksi performa membran. Model ANN yang dihasilkan menunjukkan nilai R^2 dan RMSE yang baik. Model yang dihasilkan digunakan untuk mempelajari hubungan komposisi dan karakteristik membran untuk menghasilkan performa pemisahan yang optimum. Berdasarkan hasil prediksi ANN, IL-CS dan PGMA-co-POEM merupakan polimer terbaik sebagai penyusun MMM untuk pemisahan gas gas CO_2/N_2, dengan UiO-66 sebagai fillernya. Hasil optimasi menunjukkan bahwa MMM dengan *loading filler* MOF tinggi, ketebalan rendah, dan ukuran filler besar memberikan permeabilitas optimal, sedangkan *loading filler* MOF dan ketebalan yang tinggi, serta ukuran filler kecil lebih menguntungkan untuk selektivitas. Studi ini menunjukkan bahwa optimasi berbasis ANN dapat menjadi pendekatan yang efektif dalam mendesain MMM untuk pemisahan gas CO_2/N_2 serta memberikan panduan yang lebih efisien dan hemat biaya dibandingkan metode eksperimental konvensional.

Kata kunci: *Mixed Matrix Membrane* (MMM), *Machine Learning* (ML), *Artificial Neural Network* (ANN), *Metal-Organic Framework* (MOF), polymer, pemisahan CO_2/N_2

ABSTRACT

Climate change driven by CO_2 emissions from fossil fuel combustion has accelerated the development of CO_2 gas separation technologies. Mixed Matrix Membranes (MMMs) based on Metal-Organic Frameworks (MOFs) and polymers are among the most widely used materials for CO_2/N_2 gas separation. However, the process of synthesizing and optimizing MMM compositions with various polymers and MOFs can be time-consuming and costly if done solely through experimental methods. In this study, Machine Learning (ML) with an Artificial Neural Network (ANN) algorithm was developed to determine the optimal composition and characteristics of MMMs. An experimental data points from the literature were analyzed using Pearson correlation and data normalization. The ANN model was then trained to predict membrane performance. The resulting ANN model shows good R^2 and RMSE values. This model was subsequently used to study the relationship between membrane composition and characteristics to achieve optimal separation performance. Based on the ANN predictions, IL-CS and PGMA-co-POEM were identified as the best polymers for MMM components in CO_2/N_2 gas separation, with UiO-66 as the filler. The optimization results indicate that MMMs with high MOF loading filler, low thickness, and large filler size yield optimal permeability, while high MOF loading filler and thickness, combined with small filler size, are more advantageous for selectivity. This study demonstrates that ANN-based optimization can be an effective approach for designing MMMs for CO_2/N_2 gas separation, offering more efficient and cost-effective guidance compared to traditional experimental methods.

***Keywords**: Mixed Matrix Membrane (MMM), Machine Learning (ML), Artificial Neural Network (ANN), Metal-Organic Frameworks (MOF), polymer, CO_2/N_2 separation*

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