INTISARI

Industri pertambangan batubara memainkan peran penting dalam pasokan energi global dan perekonomian nasional, namun menghasilkan air limpasan yang mengandung logam terlarut, *total suspended solids* (TSS), serta *Acid Mine Drainage* (AMD), yang berpotensi mencemari lingkungan. Pengolahan konvensional menggunakan *settling pond* hanya memindahkan polutan dari fase cair ke padat, sehingga menghasilkan efluen fluktuatif dan akumulasi lumpur bervolume besar dengan kadar air tinggi serta filterabilitas rendah, yang meningkatkan kebutuhan lahan pengeringan dan biaya operasional.

Penelitian ini bertujuan untuk mengkarakterisasi air dan lumpur limpasan batubara, serta mengevaluasi efektivitas pra-perlakuan koagulasi-flokulasi dan ozonasi dalam meningkatkan filterabilitas dan efisiensi proses *dewatering*. Karakterisasi meliputi kualitas air (pH, TSS, Fe, Mn) dan sifat lumpur (ukuran partikel, zeta potensial, kadar air, serta filterabilitas). Pra-perlakuan dilakukan melalui proses koagulasi-flokulasi dengan menggunakan PAC, $FeCl_3$, dan $Al_2(SO_4)_3$, serta proses ozonasi yang dikendalikan berdasarkan variasi dosis dan nilai *oxidation reduction potential* (ORP). Evaluasi kinerja dilakukan melalui uji filtrasi, penurunan kekeruhan, peningkatan filterabilitas, indeks performa (IP), dan analisis biaya operasional.

Hasil menunjukkan karakterisasi lumpur memiliki TSS tinggi (86.540-533.100 mg/L) yang melebihi Standar Baku Mutu Air Limbah Tambang Batubara dan Lignit sebesar 400 mg/L, ukuran partikel dominan 1,66-7,33 µm, dan zeta potensial sangat negatif (-24,37 hingga -37,43 mV), mengindikasikan kestabilan koloid tinggi. Ozonasi berbasis ORP menurunkan kekeruhan 90-97% dan meningkatkan filterabilitas, namun menyebabkan penurunan pH, peningkatan TDS, serta biaya operasional tinggi (Rp 213-688 per liter) dengan IP 2,66- 8,11yang tercemar ringan ke sedang. Koagulasi-flokulasi dengan $FeCl_3$ memberi performa stabil memenuhi baku mutu yang baik dengan IP 0,51-0,69 dan biaya lebih ekonomis (Rp 50-150 per liter). Maka, $FeCl_3$ merupakan metode pra-perlakuan paling efektif dan efisien secara teknik dan ekonomi, sedangkan ozonasi dosis rendah dapat digunakan sebagai metode tambahan untuk mendukung pengelolaan lumpur tambang batubara secara berkelanjutan. Hasil penelitian ini diharapkan dapat menjadi dasar rekomendasi strategi pengolahan lumpur yang optimal dan ramah lingkungan.

Kata kunci: *Dewatering*, Filterabilitas, Koagulasi-flokulasi, Lumpur Limpasan Tambang Batubara, Ozonasi

ABSTRACT

The coal mining industry significantly contributes to global energy supply and national economic development, yet it generates runoff containing dissolved metals, total suspended solids (TSS), and Acid Mine Drainage (AMD), which pose serious environmental risks. Conventional treatment using settling ponds primarily transfers pollutants from the liquid phase to the solid phase, resulting in fluctuating effluent quality and large volumes of sludge with high moisture content and poor filterability, increasing land requirements and operational costs.

This study aims to characterize coal mine drainage water and sludge, and to evaluate the effectiveness of coagulation-flocculation and ozonation pretreatment in improving sludge filterability and dewatering efficiency. Water quality parameters (pH, TSS, Fe, Mn) and sludge properties (particle size, zeta potential, moisture content, and filterability) were analyzed. Pretreatment methods included coagulation-flocculation using PAC, $FeCl_3$, and $Al_2(SO_4)_3$, and ozonation controlled by dosage and real-time oxidation-reduction potential (ORP). Performance evaluation was conducted through filtration tests, turbidity reduction, filterability improvement, performance index (IP), and operational cost analysis.

The results show that the sludge characterization exhibited high TSS levels (86,540-533,100 mg/L), exceeding the Coal and Lignite Mining Wastewater Quality Standard of 400 mg/L. The particle size was predominantly in the range of 1.66-7.33 µm, and the zeta potential was highly negative (-24.37 to -37.43 mV), indicating strong colloidal stability. ORP-based ozonation reduced turbidity by 90-97% and improved filterability; however, it caused a decrease in pH, an increase in TDS, and relatively high operational costs (Rp 213-688 per liter), with an IP value of 2.66-8.11, indicating light to moderate pollution conditions. In contrast, coagulation-flocculation using $FeCl_3$ showed stable performance that met the acceptable quality standards, with a good condition and an IP value of 0.51-0.69, as well as more economical operational costs (Rp 50-150 per liter). Therefore, $FeCl_3$ is identified as the most effective and efficient pretreatment method in terms of both technical and economic performance, while low-dose ozonation can be considered as a supplementary method to support sustainable coal mine sludge management. These findings are expected to serve as a basis for recommending an optimal and environmentally friendly sludge treatment strategy.

Keywords: *Dewateing, Filterability, Coagulation-flocculation, Coal mine runoff sludge, Ozonation*