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The Effect of Using Wet Ash as a Substitute for Quicklime in Improving the Quality of Acid Mine Drainage from Coal Mining

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Abstract

Acid Mine Drainage (AMD) is primarily managed using active treatment methods, including chemical neutralizers such as lime ($CaCO_3$, CaO), which are effective but costly. Previous investigations suggested that fly or boiler ash could elevate pH levels. Therefore, this study used a water-containing variant called wet ash, obtained as a byproduct with strong alkalinity (pH 11.92) from bark combustion at a Medium Density Fibreboard company. The aim was to analyze the effect of wet ash addition on AMD characteristics, specifically pH, Total Suspended Solids (TSS), iron (Fe), and manganese (Mn) levels. Samples containing 2.5 g to 15 g of wet ash were mixed with 10 L of AMD, then homogenized for 10 minutes, and analyzed in a laboratory. Based on the results, the optimal treatment was 15g/L, which produced pH 7.21; TSS 326 mg/L; Fe <0.018 mg/L; and Mn 6.42 mg/L. These values complied with the Indonesian wastewater quality standards (Decree No. 113/2003) and showed significant improvement over the initial AMD conditions of pH 3.52; TSS 6.10 mg/L; Fe 0.702 mg/L; and Mn 7.45 mg/L.

Keywords: Acid Mine Drainage, Active treatment, Wet ash, Lime

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Abstrak (Indonesian)

Pengelolaan Air Asam Tambang (AAT) menggunakan metode *active treatment* dengan penambahan bahan kimia penetral kapur ($CaCO_3$, CaO), meskipun efektif biayanya lebih mahal. Penelitian terdahulu mengindikasikan bahwa abu boiler dapat meningkatkan pH. Abu boiler yang digunakan dalam penelitian ini berasal dari sisa pembakaran kulit kayu pada perusahaan *Medium Density Fibreboard*. Abu boiler yang mengandung air tersebut dikenal dengan istilah *Wet Ash* dan bersifat basa kuat (pH sebesar 11,92). Tujuan dilakukannya penelitian ini: menganalisis pengaruh penambahan wet ash dan menganalisis efektifitas pengolahan AAT terhadap karakter pH, Total Suspended Solids (TSS), Fe dan Mn. Metode dalam penelitian ini: sampel *wet ash* sebanyak 2,5 g, 5 g, 7,5 g, 10 g, 12,5 g dan 15 g dicampur dengan 10 L AAT, selanjutnya dihomogenkan selama 10 menit, kemudian dianalisa di laboratorium untuk mengetahui karakteristiknya. Hasil penelitian karakteristik perlakuan *wet ash* 15 g/L dengan pH 7,21; TSS 326 mg/L; Fe <0,018 mg/L; Mn 6,42 mg/L merupakan perlakuan yang paling baik karena memenuhi Baku Mutu Air Limbah berdasarkan Keputusan Menteri Lingkungan Hidup Nomor 113 Tahun 2003 dan lebih baik dibandingkan kosentrasi awal AAT dengan pH 3,52;TSS 6,10 mg/L; Fe 0,702 mg/L; dan Mn 7,45 mg/L.

Kata Kunci: Air Asam Tambang, active treatment, wet ash, kapur

INTRODUCTION

Mining is an effort to extract valuable mineral resources with economic significance [1]. As coal mining activities continue to increase, the potential for negative environmental effects rises simultaneously. Mining operations lead to physical changes in the environment, such as alterations in land morphology and topography. Moreover, microclimatic conditions may be affected because of changes in wind speed, disruptions to biological habitats, including flora and fauna, and soil productivity decline [2].

During the mining process, rock formations become exposed to the atmosphere, leading to the oxidation of metals previously confined beneath the surface. Consequently, Acid Mine Drainage (AMD) is formed when these oxidized metals react with water [3]. AMD is generated through the oxidation of specific sulfide minerals present in rocks, which react with atmospheric oxygen in an aqueous environment [4]. The generated AMD can infiltrate surface water or groundwater sources, potentially disrupting surrounding ecosystems and affecting living organisms [5].

Management is conducted in excavation areas by pumping the accumulated water at the bottom of the mine into a sedimentation pond, then treatment is performed with quicklime (CaO) to increase the pH. In stockpile areas, the management includes surface runoff control, where the runoff water is directed into a sedimentation pond. Subsequently, the treatment follows the same procedure as the type applied in the excavation areas [6].

AMD generated from mining activities is treated using several strategies, including active and passive methods. However, both methods present certain limitations in the application, such as high capital requirements, the formation of hazardous precipitates from reagent addition, and constraints related to technical feasibility and efficiency [7]. AMD management is commonly conducted through active treatment, which comprises the addition of alkaline agents including lime ($CaCO_3$, CaO) to neutralize acidity and precipitate metals such as iron (Fe) and manganese (Mn). The direct application of quicklime to the water body has proven effective in raising pH levels, but continuous dosing and precise application rates are required to maintain the effectiveness [8].

Several studies have been conducted to neutralize AMD through the adsorption process. Adsorption is a highly preferred treatment alternative due to removing pollutants effectively as well as being cost-efficient and relatively simple to implement. Considering the porous solid structure, internal cavities, and high thermal stability, zeolite-like materials can function as metal catalysts or adsorbents [9]. The porous nature of zeolite structures is a key characteristic that enables the use of adsorbent materials for capturing industrial pollutants [10]. Fly or boiler ash is a potential raw material that can be used as a low-cost adsorbent.

Fly ash holds significant potential as an environmentally friendly adsorbent. Enhancing the adsorption capacity can make coal fly ash-based adsorbent competitive with activated carbon and zeolites [11].

Generally, fly ash contains high levels of alkaline metal oxides such as quicklime or calcium oxide (CaO), silicon dioxide (SiO_2), iron (III) oxide (Fe_2O_3), and a very high amount of aluminum oxide (Al_2O_3). These compounds can react with acidic components in AMD to form neutralizing compounds. For example, silica, iron (III) oxide, quicklime, and aluminum oxide react with acid to form silicates, iron sulfate ($FeSO_4$), calcium sulfate ($CaSO_4$), and aluminum sulfate ($Al_2(SO_4)_3$), respectively. Furthermore, the reactions contribute to a rise in pH by reducing the total acidity [12]. The use of wet ash derived from the combustion of bark waste in boilers presents a cost-effective alternative to quicklime for AMD treatment.

The characteristics of wet ash derived from bark combustion include the alkaline nature, with a pH exceeding 12.5. This alkalinity is attributed to the combustion process in the boiler furnace and is generally comparable to the properties of bottom ash produced in coal-fired power plants [13].

MATERIALS AND METHODS

Materials

The equipment used in this study included a pH meter, atomic absorption spectrometer, beakers, volumetric pipette, volumetric flasks, Erlenmeyer flasks, glass funnels, analytical balance, sample plastic containers, storage, manual stirrers, experimental tanks, vacuum filtration system, wash bottles, and tweezers. Meanwhile, the materials used were Acid Mine Drainage sourced from PT. Baturona Adimulya, quicklime, wet ash obtained from PT. Sumatera Prima Fibreboard, demineralized water, iron (Fe) standard solution, and manganese (Mn) standard solution.

Treatment-Induced Changes in the Characteristics of AMD

The study procedure consisted of several stages, namely sampling of wet ash, AMD sampling, determination of AMD volume at 10 L, measurement of wet ash dosages (2.5 g/L, 5 g/L, 7.5 g/L, 10 g/L, 12.5 g/L, 15 g/L, and a control), mixing AMD with the designated dosages, and stirring the mixture until homogeneous for 10 minutes [14]. Subsequently, the homogenized mixture was analyzed in the laboratory to determine the characteristics.

Analysis Data

The data analysis was conducted at the Laboratory of the Environmental Agency of Banyuasin Regency. The parameters analyzed were pH, total suspended solids (TSS), Fe, and Mn, which were compared with the AMD Quality Standards in accordance with the Minister of Environment Regulation No. 113 of 2003 concerning Wastewater Quality Standards for Coal Mining Businesses or Activities.

RESULTS AND DISCUSSION

Measurement of changes in AMD characteristics (pH, TSS, Fe, and Mn) using wet ash

Wet ash was examined in this study through Proximate and Ash Analysis. The parameters assessed in the Proximate Analysis included moisture, hydrogen, carbon, and nitrogen. The Ash Analysis considered parameters such as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, P_2O_5, MnO_2, Mn_3O_4, SO_3, and pH.

Table 1. Laboratory Analysis Results of Wet Ash Samples

Items	Unit	Result	Methods
Ash Analysis (Dry Basis)			
SiO_2	%	7.28	ASTM D3682-21
Al_2O_3	%	3.42	ASTM D3682-21
Fe_2O_3	%	1,44	ASTM D3682-21
CaO	%	20.06	ASTM D3682-21
MgO	%	6.37	ASTM D3682-21
Na_2O	%	0.29	ASTM D3682-21
K_2O	%	1.86	ASTM D3682-21
TiO_2	%	0.05	ASTM D3682-21
P_2O_5	%	0.02	ISO 622-2016
MnO_2	%	0.29	In House Methode
Mn_3O_4	%	0.76	In House Methode
SO_3	%	0.17	ASTM D5016-16
Undetermained	%	58.00	-
pH	-	11.92	AOAC-994.18

Table 1 shows that wet ash characteristics include the presence of silicon dioxide (SiO_2), which is a major component. The silica content was 7.28%, while the highest analysis result was the CaO content, which reached 20.06%. These values suggested that the characteristics of wet ash were similar to quicklime. The CaO content, which reacted with sulfuric acid in AMD, had the potential to replace quicklime in raising the pH of the water from acidic to neutral. Additionally, the measurement of changes in AMD characteristics (pH, TSS, Fe, and Mn) using wet ash was conducted with three repetitions, producing the standard deviations presented in Table 2.

Measurement results of changes in AMD characteristics (pH, TSS, Fe, and Mn) for experiment numbers 01 to 06 were obtained by mixing AMD with wet ash in a 20-L container using 10 L of water based on the experimental design, followed by homogenization for ±10 minutes. The results of experiment number 07 measure changes in AMD characteristics before wet ash addition, referred to as the control, were obtained using a 20-L container with 10 L of water, followed by homogenization for ±10 minutes. These showed a pH of 3.53, TSS of 8.90 mg/L, Fe content of 0.439 mg/L, and Mn content of 7.16 mg/L.

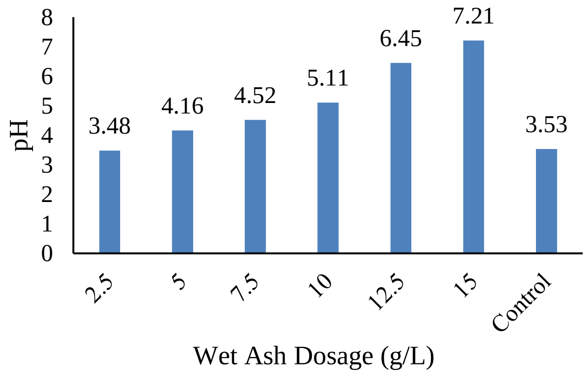

Figure 1. Effect of Wet Ash on pH

Wet ash treatments of 2.5 g/L, 5 g/L, 7.5 g/L, and 10 g/L produced pH values of 3.48, 4.16, 4.52 and 5.11, respectively (**Figure 1**). These pH values were unable to meet the Quality Standards as stipulated in the Minister of Environment Regulation No. 113 of 2003 concerning Wastewater Quality Standards for Coal Mining Businesses or Activities. Therefore, the values did not show potential as a substitute for quicklime in neutralizing the pH of Acid Mine Drainage.

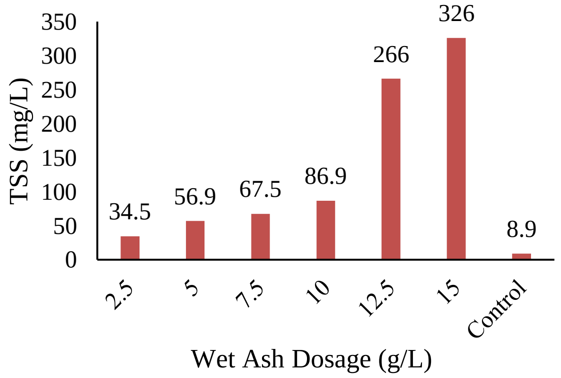

Figure 2. Effect of Wet Ash on TSS

The resulting pH values for treatments of 12.5 g/L and 15 g/L, were 6.45 and 7.21, respectively. These pH values met the Quality Standards as stipulated in the Minister of Environment Regulation No. 113 of 2003 concerning Wastewater Quality Standards for Coal Mining Business or Activities, and showed potential for wet ash to be used as a substitute for quicklime.

Table 2. Measurement of changes in AMD characteristics

Experiment Number	Wet Ash Dosage Applied to AMD (g/L)	Changes in AMD Characteristics
01	2.5	pH = 3.48 TSS = 34.5 mg/L Fe = 0.254 mg/L Mn = 7.05 mg/L
02	5	pH = 4.16 TSS = 56.9 mg/L Fe = <0.018 mg/L Mn = 7.04 mg/L
03	7.5	pH = 4.52 TSS = 67.5 mg/L Fe = <0.018 mg/L Mn = 6.95 mg/L
04	10	pH = 5.11 TSS = 86.9 mg/L Fe = <0.018 mg/L Mn = 6.87 mg/L
05	12.5	pH = 6.45 TSS = 266 mg/L Fe = <0.018 mg/L Mn = 6.42 mg/L
06	15	pH = 7.21 TSS = 326 mg/L Fe = <0.018 mg/L Mn = 6.32 mg/L
07	Control	pH = 3.53 TSS = 8.90 mg/L Fe = 0.439 mg/L Mn = 7.16 mg/L

TSS values for treatments 2.5 g/L, 5 g/L, 7.5 g/L, 10 g/L, 12.5 g/L, and 15 g/L were 34.5 mg/L, 56.49 mg/L, 67.5 mg/L, 86.9 mg/L, 266 mg/L, and 326 mg/L, respectively. All of these values still met the Quality Standards and showed an increase, which was attributed to the presence of particles in the wet ash, compared to the control (**Figure 2** and **Table 2**). Wet ash can reduce TSS in AMD for several reasons, namely by (1) acting as a coagulant that agglomerates TSS particles, leading to easier settling and separation from the water, (2) serving as a filtration medium capable of absorbing and trapping TSS particles when the water passes through, and (3) helping to neutralize AMD pH, thereby enhancing the effectiveness of TSS settling and filtration.

Fe levels observed for treatments of 2.5 g/L, 5 g/L, 7.5 g/L, 10 g/L, 12.5 g/L, and 15 g/L were below 0.018 and all the values met the Quality Standards. These levels decreased because wet ash could reduce the content in water, compared to the control. Wet ash which acted as an adsorbent material could absorb Fe metals from the water, thereby lowering the concentration. In general, as shown on **Figure 3** the use of wet ash was found to effectively reduce Fe levels [15].

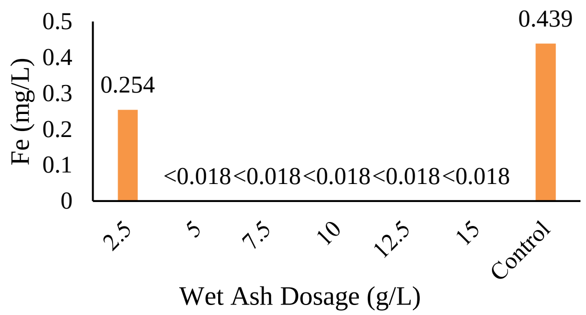

Figure 3. Effect of Wet Ash on Fe

The Mn concentrations for treatments 2.5 g/L, 5 g/L, 7.5 g/L, 10 g/L, 12.5 g/L, and 15 g/L were 7.05 mg/L, 7.04 mg/L, 6.95 mg/L, 6.87 mg/L, 6.42 mg/L, and 6.32 mg/L, respectively (**Figure 4**). Although all of the values exceeded the permissible limits set by the quality standards, there was a decrease in Mn concentrations compared to the untreated control. This insignificant reduction could be attributed to the presence of compounds in wet ash that reacted with Mn and converted Mn into forms less soluble in water, thereby lowering the concentrations. In general, the use of wet ash was found to be effective in reducing Mn levels [16]. **Table 3** serves as a reference for determining wastewater quality standards for Coal Mining Activities based on the Minister of Environment Regulation No. 113 of 2003 concerning Wastewater Quality Standards for Coal Mining Businesses or Activities.

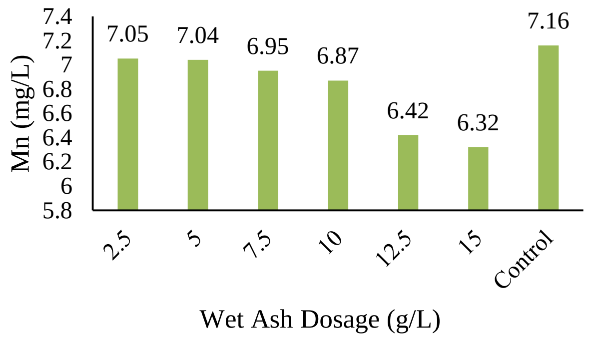

Figure 4. Effect of Wet Ash on Mn

Table 3. Water quality standards for wastewater from coal mining activities

Parameters	Quality Standards
pH (Unit)	6 - 9
Total Suspended Solids (TSS)	400 mg/L
Iron (Fe) total	7 mg/L
Manganese (Mn)	4 mg/L

CONCLUSION

In conclusion, this study showed that the treatment of wet ash at a dosage of 15 g/L produced the most optimal results, with a pH of 7.21, TSS of 326 mg/L, Fe of <0.018, and Mn of 6.32 mg/L. Although the reduction in Mn was below optimal levels, the quality standards were exceeded probably due to the solution not being fully homogeneous during stirring. The mixing was performed manually, and the contact time was less than five minutes. During this process, the wet ash and AMD were mixed, then left to settle briefly before samples were collected for analysis, which affected the generated results. Therefore, wet ash had the potential to be used as a substitute for quicklime in improving the quality of AMD from coal mining.

REFERENCES

[1] G.B.G. Samosir, "Utilization of fly ash, bottom ash, and alum to neutralize acid mine drainage," *Bina Tambang Journal*, vol. 6, no. 4, 99. 1-10, 2021.

[2] N. I. Said, " Teknologi pengolahan air asam tambang batubara "alternatif pemilihan teknologi", BPPT. JAI, vol. 7 no. 2, pp. 149-155, 2014.

[3] M.I. Gemilar, "Utilization of palm oil boiler ash waste on changes in pH and metal content (Fe, Mn) in acid mine drainage," *Thesis*, 2022.

[4] R.G. Sayoga, "Acid mine drainage management: A key aspect of environmentally sustainable mining," *Scientific Oration, ITB Council of Professors*, 2017.

[5] A. Alghifary dan Y.I. Sihombing, " Permeable Reactive Barrier sebagai inovasi remediasi air asam tambang yang berkelanjutan dan ramah lingkungan di Indonesia," *Himasapta Journal*, vol. 6 no. 3, pp. 159-170, 2021.

[6] L. Hidayat, " Pengelolaan lingkungan di kawasan pertambangan batubara (studi kasus pengelolaan air asam tambang di PT. Bhumi Rantau Energi, Kabupaten Tapin, Kalimantan Selatan)," *Jurnal Adhum*, vol. 7, no. 1, pp. 44–52, 2017.

[7] F. Barorah, H. Eko, and I. Rony, " Fitoremediasi air tercemar tembaga (Cu) menggunakan Salvinia molesta dan Pistia stratiotes serta pengaruhnya terhadap budidaya tanaman Brassica rapa," *Jurnal Tanah dan Sumberdaya Lahan*, vol. 5, no. 1, pp. 690–700, 2018.

[8] S. Irhamni, E. Pandia, W. Purba, and W. Hasan, " Analisis limbah tumbuhan fitoremediasi (Typha Latifolia, Enceng Gondok, Kiambang) dalam

menyerap logam berat," *Jurnal Serambi Engineering*, vol. 3, no. 2, pp. 344–351, 2018.

[9] P.A. Gobel, E. Nursanto, D.W. Ratminah, " Efektifitas pemanfaatan fly ash batubara sebagai adsorben dalam menetralisir air asam tambang pada settling pond penambangan Banko PT. Bukit Asam (Persero), Tbk" *Jurnal Mineral, Energi dan Lingkungan*, vol. 2 no. 1, pp. 1-7, 2018.

[10] B. Sutrisno, A. Hidayat, and Z. Mufrodi, " Modifikasi limbah abu layang menjadi adsorben untuk mengurangi limbah zat warna pada industri tekstil," *Chemica*, Vol. 1 No. 2, pp. 1-5, 2014.

[11] Z. Mufrodi, N. Widiastuti, C.R. Kardika, " Adsorpsi zat warna tekstil dengan menggunakan abu terbang (fly ash) untuk variasi massa adsorben dan suhu operasi," *Journal UII*. ISBN: 978-979-3980-15-7, 2008.

[12] A.D. Marwan, Rosihan, and A.D. Farida, "Design of acid mine drainage treatment using the in-situ fly ash aeration method." *Jurnal Sains dan Teknik Terapan*. 2020.

[13] PT. Sumatera Fibreboard, *"Environmental Impact Evaluation Document (DELH)."* 2018.

[14] S.I. Ambarsari, S. Sunandar, and D.M. Setiawan, "Study of acid mine drainage treatment using quicklime ($Ca(OH)_2$) in the settling pond of South Kalimantan Region." *Mine Science and Technology Journal*, Vol. 2 No. 2, 2023.

[15] T. Rofi, D.D. Shalaho, N. Windhu, W. Agus Winarno, and M. Henny, " Optimalisasi penggunaan fly ash untuk reduksi kadar besi (Fe) dan mangan (Mn) serta peningkatan ph dalam air asam tambang," *Manufaktur: Publikasi Sub Rumpun Ilmu Keteknikan Industri*,. Vol. 2 No. 3, 2024.

[16] H. Ayu, E.H. Harminuke, and I. Hartini, " Pengaruh fly ash dan kapur tohor pada netralisasi air asam tambang terhadap kualitas air asam tambang (Ph, Fe & Mn) di IUP Tambang Air Laya PT Bukit Asam (Persero),tbk." *Neliti*. 2014.