Jurnal Serambi Engineering JSE
Volume XI, No.4, Oktober 2026 Hal 21747 - 21752
p-ISSN : 2528-3561
e-ISSN : 2541-1934

Analysis of Coal Mine Wastewater Quality Based on pH, Total Suspended Solid, Fe, and Mn Parameters Against Environmental Quality Standards

Helmi Rinaldi, Sinardi*

Chemical Engineering Department, Universitas Fajar, Makassar, Indonesia
***Corresponding author**: sinardi@unifa.ac.id

Received: 26 Agustus 2026 Approved:

Abstract
Coal mining activities can generate wastewater containing suspended solids and dissolved metals that may affect receiving-water quality. This study analyzed coal mine wastewater based on pH, Total Suspended Solid (TSS), iron (Fe), and manganese (Mn) and evaluated the results against applicable environmental quality standards. Samples were collected from three locations, namely Location A, Location B, and Location C, during morning and afternoon sampling periods. Each sample was analyzed in triplicate. Data were evaluated descriptively and using two-way ANOVA to determine the effects of sampling location and sampling time. Location A showed the best overall quality, with mean pH 6.60, TSS 200.00 mg/L, Fe 2.24 mg/L, and Mn 0.90 mg/L, all within the applicable limits. Location B had mean pH 5.97, TSS 354.67 mg/L, Fe 5.68 mg/L, and Mn 1.99 mg/L; only pH did not meet the standard. Location C had the lowest quality, with mean pH 5.58, TSS 457.67 mg/L, Fe 7.70 mg/L, and Mn 3.96 mg/L; pH, TSS, and Fe exceeded the applicable limits, while mean Mn remained below the maximum limit. Afternoon samples generally showed lower quality than morning samples. Two-way ANOVA indicated significant effects of location and sampling time on all parameters, while the location × time interaction was not significant for pH ($p = 0.344$).
Keywords: *coal mine wastewater; total suspended solid; iron; manganese; environmental quality standard*

Abstrak
Kegiatan pertambangan batubara dapat menghasilkan air limbah yang mengandung padatan tersuspensi dan logam terlarut yang berpotensi memengaruhi kualitas badan air penerima. Penelitian ini menganalisis kualitas air limbah tambang batubara berdasarkan parameter pH, Total Suspended Solid (TSS), besi (Fe), dan mangan (Mn), serta mengevaluasi hasilnya terhadap baku mutu lingkungan yang berlaku. Sampel diambil pada tiga lokasi, yaitu Lokasi A, Lokasi B, dan Lokasi C, pada waktu pagi dan sore hari. Setiap sampel dianalisis sebanyak tiga kali pengulangan (triplo). Data dianalisis secara deskriptif kuantitatif dan menggunakan ANOVA dua arah untuk mengetahui pengaruh lokasi dan waktu pengambilan sampel. Lokasi A memiliki kualitas terbaik dengan rata-rata pH 6,60, TSS 200,00 mg/L, Fe 2,24 mg/L, dan Mn 0,90 mg/L yang seluruhnya memenuhi baku mutu. Lokasi B memiliki rata-rata pH 5,97, TSS 354,67 mg/L, Fe 5,68 mg/L, dan Mn 1,99 mg/L, dengan parameter pH tidak memenuhi baku mutu. Lokasi C memiliki kualitas terendah dengan rata-rata pH 5,58, TSS 457,67 mg/L, Fe 7,70 mg/L, dan Mn 3,96 mg/L; parameter pH, TSS, dan Fe tidak memenuhi baku mutu, sedangkan Mn rata-rata masih berada di bawah batas maksimum. Sampel sore hari secara umum menunjukkan kualitas yang lebih rendah dibandingkan pagi hari. ANOVA dua arah menunjukkan lokasi dan waktu berpengaruh signifikan terhadap seluruh parameter, sedangkan interaksi lokasi × waktu tidak signifikan pada pH ($p = 0,344$).
Kata kunci: *air limbah tambang batubara; total suspended solid; besi; mangan; baku mutu lingkungan*

1. Introduction

Coal mining is an industrial activity that can generate wastewater from mining areas, rainfall runoff, settling ponds, and water that directly contacts mining materials. Such wastewater may contain suspended solids and dissolved metals and can reduce receiving-water quality if discharged without adequate management. One of the important problems in coal mining is the formation of acid mine drainage (AMD). Oxidation of sulfide minerals, particularly pyrite, can produce acidic conditions and increase the solubility of metals such as Fe and Mn. Therefore, pH, TSS, Fe, and Mn are relevant parameters for evaluating coal mine wastewater quality.

Previous studies have reported variations in coal mine wastewater quality under different mining and wastewater-management conditions. Altaf and Husain (2023) evaluated settling pond water quality at a coal mining site in Bunyu, North Kalimantan, demonstrating the importance of monitoring wastewater generated from mining activities. Kiswanto and Wintah (2025) characterized acidic water from a former coal mine in West Aceh, focusing on the characteristics of acidic mine water. In addition, Ferdian (2020) evaluated the management of acid mine drainage based on pH, TSS, Fe, and Mn parameters. These studies indicate that wastewater characteristics and pollutant concentrations may differ according to location and site conditions.

Differences in mining activities, contact between water and mining materials, and wastewater-management systems may influence the quality of discharged water. Gobel et al. (2025) also investigated the treatment of coal acid mine drainage using NaOH and polyaluminium chloride, highlighting the need for appropriate management to reduce the environmental impact of acidic wastewater. Furthermore, Geometri et al. (2025) reported the use of activated carbon from sugarcane bagasse to reduce Fe, Mn, and TSS in acid mine drainage. Therefore, systematic monitoring of wastewater quality at different locations and sampling periods is necessary to obtain representative information on the condition of coal mine wastewater. This study was conducted to analyze coal mine wastewater quality at three locations during morning and afternoon sampling periods and to compare the measured parameters with the environmental quality standards applicable to coal mining wastewater.

2. Materials and Methods

2.1 Research location and period

The research was conducted for approximately two months, from May to June 2026, at the sample laboratory in the mining area of PT Sumber Daya Energi, Kotabaru, South Kalimantan, Indonesia.

2.2 Materials and equipment

The main material was coal mine wastewater collected from Location A (Pond 1), Location B (Pond 2), and Location C (Pond 3). Supporting materials included distilled water, filter paper, Fe and Mn standard solutions, diluents, and chemicals required by the laboratory procedures. Equipment included sample bottles, measuring cylinders, beakers, a calibrated pH meter, filtration equipment, oven, desiccator, analytical balance, and an Atomic Absorption Spectrophotometer (AAS) for Fe and Mn analysis.

2.3 Sampling and variables

Samples were collected at three locations (A, B, and C) at two sampling times (morning and afternoon). The fixed sample volume for each analysis was 250 mL. The independent variables were sampling location and sampling time, while the measured response variables were pH, TSS, Fe, and Mn. For each sampling condition, the collected sample was analyzed three times (triplicate analysis), rather than being collected three times.

2.4 Analytical methods

pH was measured using a calibrated pH meter. TSS was determined by filtration and gravimetry, in which the retained solids were dried in an oven, cooled in a desiccator, and weighed to constant mass. Fe and Mn were analyzed using AAS or the available spectrophotometric procedure. The reported analytical references were SNI 6989.11:2019 for pH, SNI 6989.3:2019 for TSS, and APHA 3120 B for Fe and Mn.

2.5 Data analysis and environmental standard

The data were presented as means and evaluated descriptively according to sampling location and time. Two-way ANOVA was used to test the effects of location, sampling time, and their interaction. The results were compared with the coal mine wastewater quality standards stated in the report, based on Decree of the Minister of Environment Number 113 of 2003: pH 6–9, TSS 400 mg/L, Fe 7 mg/L, and Mn 4 mg/L.

3. Results and Discussion

3.1 pH of coal mine wastewater

The pH values were 6.73 and 6.47 at Location A in the morning and afternoon, 6.07 and 5.87 at Location B, and 5.73 and 5.43 at Location C, respectively. The values decreased from Location A toward Location C and were lower in the afternoon. Based on the 6–9 standard, A morning, A afternoon, and B morning met the standard, whereas B afternoon, C morning, and C afternoon were below the minimum

limit. The lower pH at Location C can be associated with stronger contact between water and sulfide-bearing mining materials and the formation of acid mine drainage.

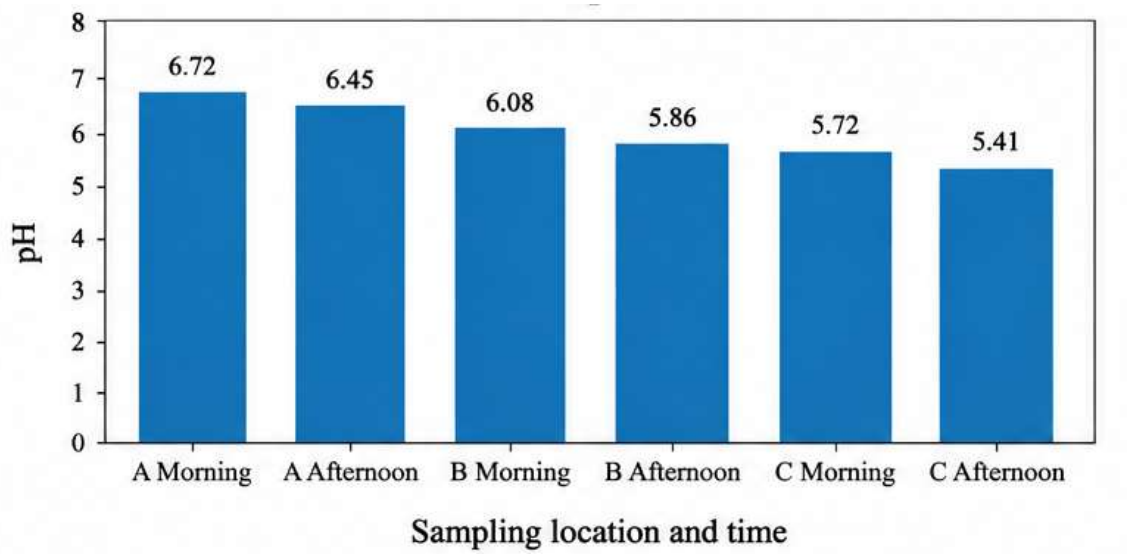


Figure 1. pH of coal mine wastewater at each sampling location and time.

3.2 Fe concentration

Fe concentrations increased from Location A to Location C and from morning to afternoon. The measured values were 2.09 and 2.38 mg/L at A, 4.87 and 6.48 mg/L at B, and 7.28 and 8.12 mg/L at C. The applicable maximum Fe concentration is 7 mg/L. Thus, only C morning and C afternoon exceeded the limit. The higher Fe concentration at Location C is consistent with its lower pH, because acidic conditions can increase the solubility of iron from mining materials. Differences in geological material and contact between water and mining materials may also contribute to the observed variation.

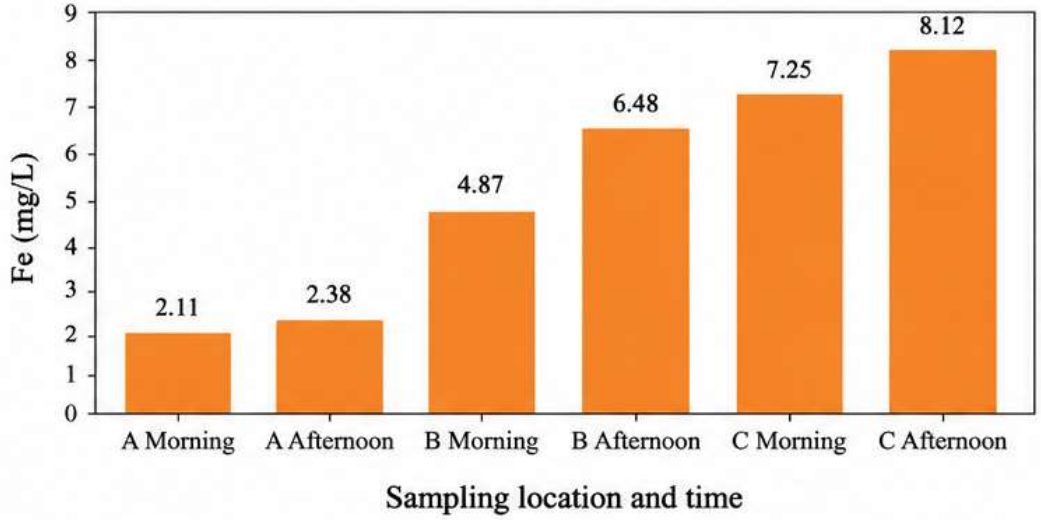


Figure 2. Fe concentration in coal mine wastewater at each sampling location and time.

3.3 TSS concentration

TSS values increased from Location A to Location C and from morning to afternoon. The measured values were 187.67 and 212.33 mg/L at A, 321.00 and 388.33 mg/L at B, and 417.67 and 497.67 mg/L at C. The applicable maximum TSS concentration is 400 mg/L. Therefore, C morning and C afternoon exceeded the standard. The increase in TSS can be associated with suspended soil, fine coal particles, erosion products, and runoff entering the wastewater. Continued mining activity during the day may also contribute to the higher afternoon values.

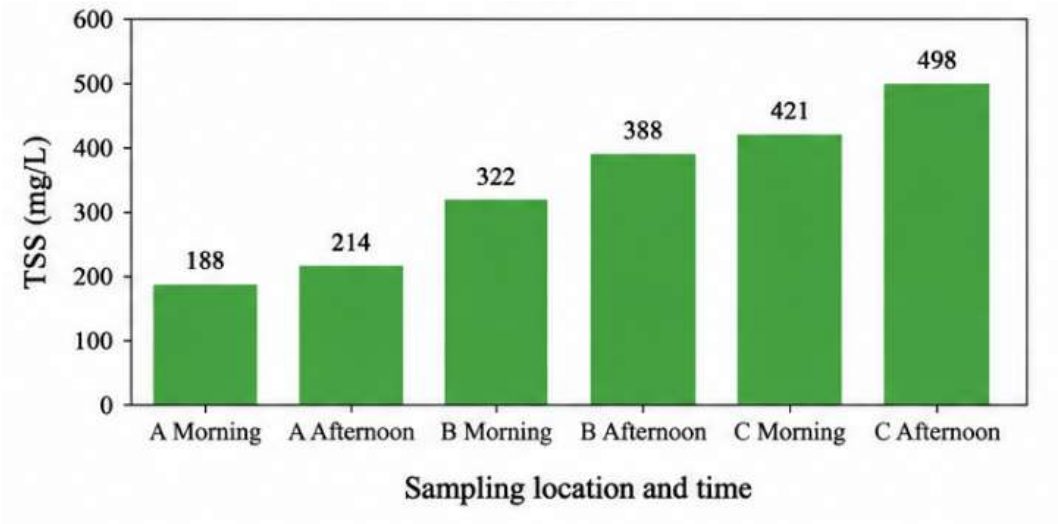


Figure 3. TSS concentration in coal mine wastewater at each sampling location and time.

3.4 Mn concentration

Mn concentrations increased from Location A to Location C and from morning to afternoon. The measured values were 0.84 and 0.95 mg/L at A, 1.65 and 2.33 mg/L at B, and 3.63 and 4.28 mg/L at C. The applicable maximum Mn concentration is 4 mg/L. All samples met the standard except C afternoon, which reached 4.28 mg/L. The higher Mn concentration at Location C can be related to its lower pH, which favors manganese solubility, together with geological characteristics and mining activity.

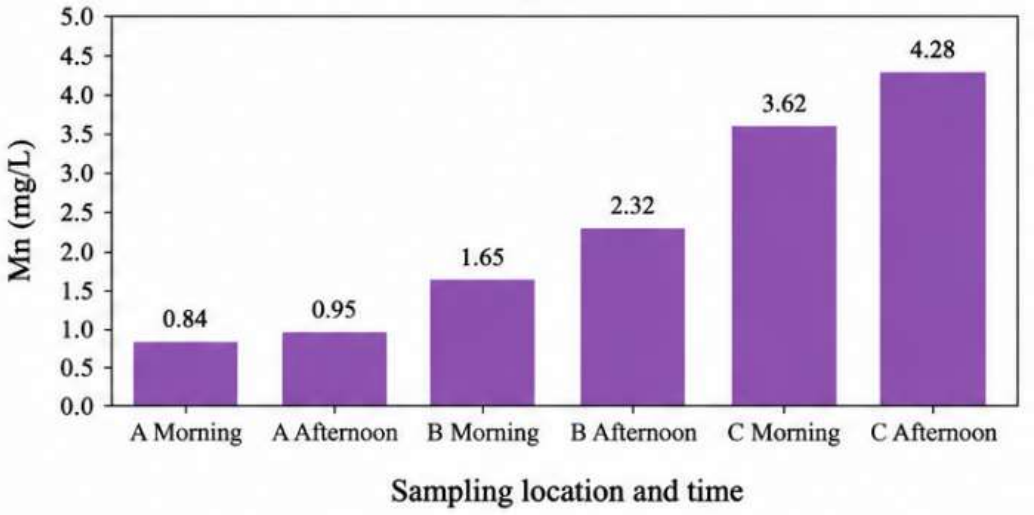


Figure 4. Mn concentration in coal mine wastewater at each sampling location and time.

Table 1. Mean coal mine wastewater quality by sampling location

Location	Mean pH	Mean TSS (mg/L)	Mean Fe (mg/L)	Mean Mn (mg/L)	Evaluation
A	6.60	200.00	2.24	0.90	All parameters meet
B	5.97	354.67	5.68	1.99	pH does not meet
C	5.58	457.67	7.70	3.96	pH, TSS, Fe do not meet

Table 2. Two-way ANOVA results

Parameter	Factor	df	F-value	p-value	Conclusion
pH	Location	2	474.50	<0.001	Significant
pH	Time	1	88.17	<0.001	Significant
pH	Location × Time	2	1.17	0.344	Not significant
TSS	Location	2	6285.42	<0.001	Significant
TSS	Time	1	1792.35	<0.001	Significant
TSS	Location × Time	2	128.74	<0.001	Significant
Fe	Location	2	12846.57	<0.001	Significant
Fe	Time	1	3215.83	<0.001	Significant
Fe	Location × Time	2	457.26	<0.001	Significant
Mn	Location	2	8964.13	<0.001	Significant
Mn	Time	1	1968.74	<0.001	Significant
Mn	Location × Time	2	239.85	<0.001	Significant

3.5 Overall quality and comparison with previous studies

The overall pattern shows that Location A had the best wastewater quality, whereas Location C had the poorest quality, as indicated by the relatively lower pH and higher concentrations of Fe, Mn, and TSS. The afternoon samples generally showed lower pH and higher concentrations of Fe, Mn, and TSS than the morning samples. This pattern may be associated with differences in mining activities, runoff, sediment transport, and prolonged contact between water and mining materials. Similar variations in mine wastewater quality have been reported in previous studies. Altaf and Husain (2023) evaluated settling pond water quality in a coal mining area in Bunyu, North Kalimantan, and demonstrated the importance of monitoring wastewater quality at mining sites. Kiswanto and Wintah (2025) also reported variations in acidic water characteristics from a former coal mine in West Aceh. These findings support the observation that differences in sampling location and site conditions can influence coal mine wastewater quality.

4. Conclusion

Coal mine wastewater quality differed among Locations A, B, and C and between morning and afternoon sampling. Location A had the best overall quality, with mean pH 6.60, TSS 200.00 mg/L, Fe 2.24 mg/L, and Mn 0.90 mg/L, all meeting the reported environmental standards. Location B had mean pH 5.97, TSS 354.67 mg/L, Fe 5.68 mg/L, and Mn 1.99 mg/L, with pH below the standard. Location C had mean pH 5.58, TSS 457.67 mg/L, Fe 7.70 mg/L, and Mn 3.96 mg/L; pH, TSS, and Fe did not meet the standard, while mean Mn remained below the maximum limit. Sampling time significantly affected all parameters, with afternoon samples generally showing lower pH and higher TSS, Fe, and Mn. The location × time interaction was significant for TSS, Fe, and Mn, but not for pH. These findings imply that coal mine wastewater management should prioritize Location C and consider temporal variations in pollutant concentrations. Regular monitoring at different locations and sampling times is necessary to identify changes in wastewater quality and to determine appropriate treatment strategies, particularly for controlling pH, TSS, Fe, and Mn before wastewater is discharged into the receiving environment.

5. Recommendations

Periodic monitoring and wastewater treatment should be maintained, particularly at locations showing parameters above the environmental quality standards. Future research should include additional water-quality parameters and more detailed evaluation of the factors controlling spatial and temporal variation in coal mine wastewater.

6. References

[1] Alieftiyani Paramita Gobel, A., Nur Athiyya, N., Nadia Thereza, N., Muhamad Hidayatul Ilham, M., & Chairunnisa Van Gobel, C. (2025). Optimasi penggunaan NaOH dan Poly Aluminium Chloride pada pengolahan air asam tambang batubara, Tanjung Enim, Sumatera Selatan. INSOLOGI: Jurnal Sains dan Teknologi, 4(3), 528–536. https://doi.org/10.55123/insologi.v4i3.5346

[2] Altaf, M. A. D., & Husain, J. R. (2023). Kajian kualitas air settling pond pada tambang batubara Kepulauan Bunyu Kabupaten Bulungan Kalimantan Utara. Jurnal Aneka Tambang, 1(3), 83–89. https://doi.org/10.33096/bcxt4m59

[3] Andrawina, A., Ernawati, R., Cahyadi, T. A., SB, W., & Amri, N. A. (2020). Penerapan metode constructed wetland dalam upaya pengelolaan limbah air asam tambang pada penambangan batubara berdasarkan literature review. Prosiding Nasional Rekayasa Teknologi Industri dan Informasi XV Tahun 2020 (ReTII), 201–207. https://journal.itny.ac.id/index.php/ReTII/article/view/2027

[4] Brilliant Mercy Geometri, B. M. G., Shalaho Dina Devy, S. D., Lucia Litha Respati, L. L. R., Harjuni Hasan, H. H., & Rety Winonazada, R. W. (2025). Pengaruh karbon aktif ampas tebu (adsorben) terhadap air asam tambang untuk mengurangi kadar Fe, Mn, dan TSS pada Sump PT Alreksa Bara Mitra. Venus: Jurnal Publikasi Rumpun Ilmu Teknik, 3(4), 227–238. https://doi.org/10.61132/venus.v3i4.1089

[5] Desiana, N., Ngatijo, & Lagowa, M. I. (2022). Pengelolaan air limbah tambang dengan metode bioadsorbsi menggunakan karbon aktif tempurung kelapa. Jurnal Teknologi Mineral dan Batubara, 18(2), 97–103. https://doi.org/10.30556/jtmb.Vol18.No2.2022.1175

[6] Envirotek, A. A. P., Meicahayanti, I., Envirotek, S. N., Envirotek, I., & Zulya, F. (2023). Pengaruh waktu kontak serta jenis elektroda Al-Al dan Al-Fe pada elektrokoagulasi dalam penyisihan Fe dan Mn air asam tambang. Jurnal Envirotek, 15(2), 124–128. https://doi.org/10.33005/envirotek.v15i2.272

[7] Ferdian, I. (2020). Analisis keberhasilan penanganan air asam tambang berdasarkan parameter pH, TSS, Fe dan Mn pada KPL AL 01 PT Bukit Asam, Tbk. *Prosiding Seminar Nasional Lahan Suboptimal ke-8 Tahun 2020*, 1080–1090. Universitas Sriwijaya.

[8] Kiswanto, K., & Wintah, W. (2025). Characterization of acidic water from the former coal mine of PT Mifa Bersaudara in West Aceh. Journal of Environmental and Science Education, 5(1), 1–9. https://doi.org/10.15294/jese.v5i1.7347

[9] Kusnanto, F. A., Devy, S. D., Winarno, A., Hasan, H., & Respati, L. L. (2023). Penggunaan kalsium hidroksida (Ca(OH)2) dan aluminium sulfat ((Al2SO4)3) dalam pengolahan air limbah settling pond pada PT Internasional Prima Coal. Journal Scientific of Mandalika, 4(11), 263–270. https://doi.org/10.36312/10.36312/vol4iss11pp263-270

[10] Maulida, S. A., & Purwanti, I. F. (2023). Kajian pengolahan air asam tambang industri pertambangan batu bara dengan constructed wetland. Jurnal Teknik ITS, 12(1). https://doi.org/10.12962/j23373539.v12i1.111230

[11] Mukhlisah, I. E. (2020). Penaatan perusahaan tambang batubara di Kalimantan Timur terhadap peraturan air limbah pertambangan. Jurnal Ecolab, 8(2), 61–68. https://doi.org/10.20886/jklh.2014.8.2.61-68

[12] Musyaffa, A. M., Asrifah, R. D., Suharwanto, S., Irawan, A. B., & Kristanto, W. A. D. (2024). Pengaruh penggunaan kapur dalam penetralan air asam tambang dan laju pengendapan kolam Apokayan PT Darma Henwa Tbk, Bengalon Coal Project. Prosiding Seminar Nasional Teknik Lingkungan Kebumian SATU BUMI, 5(1). https://doi.org/10.31315/psb.v5i1.11639

[13] Ningtias, A., Respati, L. L., Devy, S. D., & Hasan, H. (2026). Efektivitas campuran karbon aktif daun nanas–batubara dalam peningkatan pH dan penurunan Fe, Mn, serta TSS air asam tambang PT Alreksa Bara Mitra. *Venus: Jurnal Publikasi Rumpun Ilmu Teknik, 4*(1), 107–114.

[14] Norfaeda, R., & Kartini. (2024). Pengolahan air limbah tambang menggunakan limbah kulit langsat: Penurunan kadar logam total Fe dan Mn. Jurnal Geomine, 12, 152–162.

[15] Nugroho, S., Meicahayanti, I., & Adi Putri, A. (2024). Pengaruh waktu kontak dan jenis pasangan elektroda dalam proses elektrokoagulasi terhadap pH dan TSS air asam tambang. Jurnal Reka Lingkungan, 12(1), 37–49. http://dx.doi.org/10.26760/rekalingkungan.v12i1.37-49