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The Efficacy of Chemical Grade Alumina Waste Processing in Mitigating Water Pollution

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Abstrak

Penelitian ini bertujuan untuk mengkaji efektivitas pengolahan limbah Chemical Grade Alumina dalam mitigasi pencemaran air di PT Indonesia Chemical Alumina (PT ICA) Indonesia. Memanfaatkan metode pengujian laboratorium dan wawancara komprehensif dengan pemangku kepentingan, penelitian ini mengukur parameter kualitas air limbah seperti Total Padatan Tersuspensi (TSS), pH, konsentrasi Besi (Fe), Tembaga (Cu), Nikel (Ni), dan Permintaan Oksigen Kimia (COD) . Temuan tersebut menunjukkan efektivitas instalasi pengolahan air limbah (IPAL), ditandai dengan penurunan drastis (di atas 80%) hasil pengujian parameter setelah pengolahan. Namun ada catatan untuk parameter TSS yang tidak lolos pengujian pada poin pertama. Perhatian juga tertuju pada parameter Besi (Fe) yang menunjukkan peningkatan signifikan pada jarak 1.500 meter dari outlet IPAL. Wawancara mengungkapkan adanya kesenjangan antara hasil pemeriksaan laboratorium dengan kenyataan yang dialami masyarakat, serta tantangan pengawasan dan kekurangan sumber daya manusia. Rekomendasinya mencakup optimalisasi proses pengolahan awal, pemantauan sumber kontaminasi, pemeriksaan kualitas rutin, peningkatan kapasitas dan sumber daya manusia, pendidikan masyarakat, kepatuhan hukum, peningkatan infrastruktur IPAL, pengembangan teknologi baru, dan pengembangan kolaborasi multi-pihak.

Kata Kunci: Pengawasan Lingkungan, Efektivitas IPAL, Mitigasi Pencemaran, Kualitas Air Limbah, Pengolahan Limbah

Abstract

This research aims to assess the effectiveness of Chemical Grade Alumina waste treatment in water pollution mitigation in PT Indonesia Chemical Alumina (PT ICA) Indonesia. Utilizing laboratory testing methods and comprehensive interviews with stakeholders, the study measured wastewater quality parameters such as Total Suspended Solids (TSS), pH, Iron (Fe) concentration, Copper (Cu), Nickel (Ni), and Chemical Oxygen Demand (COD). The findings indicate the effectiveness of the wastewater treatment plant (WWTP), marked by a drastic reduction (above 80%) in the test results of parameters after treatment. However, a note is made for the TSS parameter, which did not pass the test at the first point. Attention is also drawn to the Iron (Fe) parameter, which showed a significant increase at 1,500 meters from the WWTP outlet. Interviews revealed a discrepancy between laboratory test outcomes and the reality experienced by the community, as well as challenges in supervision and human resource shortages. Recommendations include optimizing initial treatment processes, monitoring contamination sources, routine quality checks, enhancing capacity and human resources, community education, legal compliance, improving WWTP infrastructure, developing new technologies, and fostering multi-party collaboration.

Keywords: *Environmental Supervision, WWTP Effectiveness, Pollution Mitigation, Wastewater Quality, Waste Treatment*

INTRODUCTION

Indonesia, with its rich mineral resources, significantly contributes to the mineral processing industry, particularly in transforming bauxite ore into Chemical Grade Alumina (CGA). This industry's growth is exemplified by PT Indonesia Chemical Alumina (PT ICA), situated in Tayan Hilir, Sanggau, West Kalimantan. PT ICA not only spearheads CGA production in Indonesia but also ranks as a leading producer in the Asia Pacific region (Komalasari Dewi, 2023). This prominence is evidenced by the fluctuating bauxite production reported by the Central Statistics Agency (BPS), with an increase from 16.59 million tons in 2019 to 25.86 million tons in 2020, followed by a slight decrease to 25.78 million tons in 2021(Kusuma et al., 2021).

Chemical Grade Alumina comprises products like aluminum hydroxide and alumina, utilized in various sectors beyond the primary aluminum industry (Kusuma et al., 2021). For instance, the CGA project in Tayan processes bauxite residue from Antam, aiming to produce 300,000 tons of CGA annually (Wahyinto et al., 2022). These products are integral to manufacturing refractories, abrasives, Integrated Circuits (ICs), and LCD screen materials, catering to markets in Japan and beyond, alongside domestic consumption in Indonesia.

PT ICA adheres to strict safety and environmental management protocols, including a comprehensive Waste Water Treatment Plant (WWTP) system. This system consists of four specialized WWTPs, each designed to treat wastewater with unique characteristics like pH, temperature, and suspended solids content (Sigit et al., 2021). This study will particularly focus on the WWTP within the factory, critical for the CGA production process, assessing its capability to manage the alkaline nature of the wastewater produced (Adhyaksa & Lutfi, 2019).

The research aims to provide an in-depth analysis of the water quality parameters at PT ICA's WWTP and evaluate the treated wastewater's compliance with standards necessary for sustainable applications such as irrigation. This assessment is crucial in the context of increasingly stringent government regulations concerning environmental management in industries (Qatrunada et al., 2023; Rarasari et al., 2018). The study will investigate the effectiveness of PT ICA's existing WWTP in mitigating environmental impacts of CGA production, managing highly alkaline wastewater, and adhering to regulatory standards (Lolo & Pambudi, 2020; Sutanhaji et al., 2021). The intent of this research is to perform a detailed analysis of the wastewater treatment effectiveness at PT Indonesia Chemical Alumina's WWTP, aiming to identify and assess the processes and outcomes of the treatment, and to offer actionable recommendations for enhancing the wastewater management efficiency of the company.

METHODS

This section should explain how the research was conducted. It should be detailed to describe the procedure.

Research Site

This study was conducted at PT Indonesia Chemical Alumina (PT ICA), located in the remote village of Desa Pedalaman, Tayan Hilir Subdistrict, Sanggau District, West Kalimantan. PT ICA is a leading company in Indonesia, specializing in the production of Chemical Grade Alumina (CGA) (Wahyinto et al., 2022).

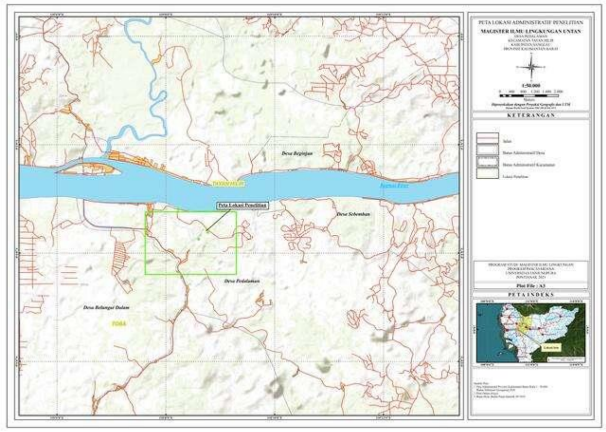

Figure 1 Research Site

This location was selected for the study due to PT ICA's representation of a large-scale industrial installation with complex CGA production processes and an integrated liquid waste treatment system (Wahyinto et al., 2022). Furthermore, its situation in West Kalimantan, a region known for its rich mineral resources, provides a relevant context for understanding the challenges and dynamics of environmental management in the mining and mineral processing industry (Wahyinto et al., 2022). The focus of this research is the industrial wastewater treatment plant (WWTP) of PT Indonesia Chemical Alumina (PT ICA). The geographical position of PT ICA is illustrated below.

The research implementation period spanned from July 2023 to December 2023. This timeframe was selected to allow researchers to gain a comprehensive understanding of the Chemical Grade Alumina (CGA) production processes at PT Indonesia Chemical Alumina (PT ICA) and the operational dynamics of the factory's Wastewater Treatment Plant (WWTP) under varying conditions and operational fluctuations. During this period, the research was conducted in several phases, starting with initial observation, followed by sample collection, interviews with stakeholders, and culminating in data analysis.

Materials and Equipment

The primary material used in this research was the waste samples from the Wastewater Treatment Plant (WWTP) of PT Indonesia Chemical Alumina (PT ICA). The research conducted at PT Indonesia Chemical Alumina (PT ICA) utilized a range of equipment essential for data collection, analysis, and documentation. Writing tools were employed as needed for note-taking and documentation purposes, allowing for the accurate recording of observations and findings in real-time (World Meteorological Organization., 2008). Additionally, a singular work notebook served as a central repository for recording detailed observations and notes, ensuring that all data and insights were systematically documented. Internet access played a crucial role in supporting various research activities, including data analysis, literature review, and communication with stakeholders. A mobile phone and a laptop, one of each, were indispensable tools that facilitated research activities, especially in data collection, communication, and data processing. A key instrument in the study was a pH Meter, used to accurately measure the pH levels of wastewater samples, providing essential data for analyzing the wastewater treatment process. A single bucket was utilized as a temporary storage container for various samples during the collection process. For more specific measurements, a Special COD Bottle containing sulfuric acid preservative was used to store Chemical Oxygen Demand (COD) samples, while a Special Metal Bottle with nitric acid preservative was designated for metal samples, ensuring the preservation of sample integrity for accurate analysis. Finally, a Jerrycan or Bottle was used as a container for storing pH and Total Suspended Solids (TSS)

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samples, playing a crucial role in facilitating the transportation and subsequent analysis of these samples. The judicious selection and utilization of these tools and equipment were fundamental in ensuring the accuracy and reliability of the research findings (World Meteorological Organization., 2008).

Data Collection Techniques

This study employed a quantitative approach. The data collected primary data sources (Creswell, 2009). In the primary data collection phase of the study at PT Indonesia Chemical Alumina (PT ICA), the focus was on analyzing various characteristics of wastewater samples. Several key parameters were measured using standardized methods in compliance with Indonesian National Standards (SNI) (Peraturan Menteri Negara Lingkungan Hidup Nomor 34 Tahun 2009 Tentang Baku Mutu Air Limbah Bagi Usaha Dan/Atau Kegiatan Pertambangan Bijih Bauksit, 2009). The pH level of the wastewater was determined using a digital pH meter, following the guidelines of SNI 06-6989.11.2004. The Total Suspended Solids (TSS) were measured using a gravimetric method as per SNI 06-6989.3-2004. The Chemical Oxygen Demand (COD) was quantified through a titration method in accordance with SNI 06-6989.2-2004. For specific metal concentrations, the levels of Iron (Fe) were measured using a spectrophotometric method as outlined in SNI 06-6989.49-2005. The concentration of Copper (Cu) was determined following SNI 06-2514-1991, and the Nickel (Ni) concentration was also measured using a spectrophotometric method, adhering to SNI 06-6989.48-2005. The wastewater sampling was conducted at four distinct points within the WWTP of PT ICA: one at the inlet and three at the outlet points, as illustrated in Figure 3.2. To ensure the accuracy of the data, sampling at each of these points was repeated three times. The timing of sample collection was coordinated in accordance with the factory's conditions and Standard Operating Procedures (SOP), taking into account the 12-hour intervals for the opening and closing of gates. This rigorous approach to sample collection was essential to provide a comprehensive and accurate assessment of the wastewater treatment process.

Data Analyze

In the primary data collection phase of the study at PT Indonesia Chemical Alumina (PT ICA), the focus was on analyzing various characteristics of wastewater samples. Several key parameters were measured using standardized methods in compliance with Indonesian National Standards (SNI) (Peraturan Menteri Negara Lingkungan Hidup Nomor 34 Tahun 2009 Tentang Baku Mutu Air Limbah Bagi Usaha Dan/Atau Kegiatan Pertambangan Bijih Bauksit, 2009). The pH level of the wastewater was determined using a digital pH meter, following the guidelines of SNI 06-6989.11.2004. The Total Suspended Solids (TSS) were measured using a gravimetric method as per SNI 06-6989.3-2004. The Chemical Oxygen Demand (COD) was quantified through a titration method in accordance with SNI 06-6989.2-2004. For specific metal concentrations, the levels of Iron (Fe) were measured using a spectrophotometric method as outlined in SNI 06-6989.49-2005. The concentration of Copper (Cu) was determined following SNI 06-2514-1991, and the Nickel (Ni) concentration was also measured using a spectrophotometric method, adhering to SNI 06-6989.48-2005. The wastewater sampling was conducted at four distinct points within the WWTP of PT ICA: one at the inlet and three at the outlet points, as illustrated in Figure 2. To ensure the accuracy of the data, sampling at each of these points was repeated three times. The timing of sample collection was coordinated in accordance with the factory's conditions and Standard Operating Procedures (SOP), taking into account the 12-hour intervals for the opening and closing of gates. This rigorous approach to sample collection was essential to provide a comprehensive and accurate assessment of the wastewater treatment process.

Figure 2 Four Distinct Points

The timing for wastewater sample collection in the study at PT Indonesia Chemical Alumina (PT ICA) was meticulously planned, aligning with the operational schedule of the WWTP gates and the speed of the water flow reaching the Kapuas River, located 1.5 kilometers (1500 meters) from the WWTP gates. The water velocity (v) was calculated using the formula v = d/t, where 'v' represents the velocity of the water in meters per second (m/s), 'd' is the distance in meters, and 't' is the time in seconds. Given the distance (d) of 1.5 km (or 1500 meters) and the gate operation cycle of 12 hours (or 43200 seconds), it was determined that the wastewater takes a maximum of 12 hours to travel from the WWTP exit gates to the Kapuas River. The calculated water velocity was 0.0347 m/s.

In the study at PT Indonesia Chemical Alumina (PT ICA), the wastewater sampling points were strategically chosen to accurately assess the flow and characteristics of the wastewater. The first point, known as the Inlet, was considered the starting point and was situated at 0 meters from the WWTP. The second sampling point was placed 3 meters away from the WWTP exit gate. It was estimated that water would take approximately 87 seconds, or about 0.02 hours, to reach this point, providing an early-stage analysis of the wastewater. The third point was located further away, at a distance of 650 meters from the WWTP exit gate. This location was pivotal in understanding the wastewater's progression, as it would take the water around 5.2 hours, or about 18732 seconds, to reach this point. Such a distance allowed for a more comprehensive analysis of the wastewater over time and space. Finally, the fourth sampling point was positioned right at the WWTP exit gate, marking a total distance of 1500 meters from the Kapuas River. This final point was crucial, as it took the longest time for the wastewater to reach, approximately 12 hours or 43228 seconds. This provided insights into the final composition and characteristics of the wastewater just before it entered the river, completing the assessment of the wastewater journey from the WWTP to the natural water body.

Based on these calculations, the wastewater takes about 0.02 hours to reach the second sampling point, which is 3 meters from the exit gate. For the third sampling point, located 650 meters away, the wastewater takes about 5.2 hours. Finally, for the fourth sampling point at the exit gate, the wastewater reaches this point approximately 12 hours after discharge begins. Therefore, the sampling at Point 1 or the Inlet is conducted immediately after the discharge begins, followed by sampling at Point 2, then Point 3, and finally at Point 4 after the discharge process starts.

RESULTS AND DISCUSSION

In this study focused on evaluating the efficacy of the chemical grade alumina waste treatment system, a quantitative was employed. The laboratory tests were meticulously designed to measure crucial wastewater parameters, including pH, Total Suspended Solids (TSS), heavy metal content, and Chemical Oxygen Demand (COD). These tests were not just scientific assessments of the wastewater's condition, but they also served as direct indicators of the treatment process's effectiveness (Lolo & Pambudi, 2020). This approach of empirical data gathering from laboratory tests was crucial in addressing a vital research question: What is the effectiveness of the treatment of Chemical Grade Alumina Waste in mitigating water pollution? The resolution of this query holds significant implications for environmental sustainability and the health and well-being of communities reliant on clean, safe water resources.

The initial results, based on wastewater samples collected from various points and tested at the BSPJI Pontianak Testing Laboratory, revealed diverse findings. At point 1 (the inlet), parameters such as pH levels, TSS, iron, copper, nickel, and COD were measured. These results were then compared against the standards set by the government under the Regulation of the Minister of Environment No 34 of 2009, Annex 3. The wastewater tests indicated that some parameters did not meet the established standards. For instance, TSS concentrations were significantly high across all samples, far exceeding the permissible maximum of 50 mg/L. This suggested an excessive presence of suspended particles in the wastewater. Similarly, the pH levels recorded were highly alkaline, not aligning with the standard range of 6 to 9, implying potential corrosiveness and environmental challenges. Conversely, the concentrations of iron, copper, and nickel were within acceptable limits, indicating compliance in these aspects. However, the COD values were alarmingly high, signifying a substantial presence of organic matter in the wastewater and surpassing the maximum standard of 100 mg/L. This high COD level indicated a high potential for pollution and necessitated intensive treatment processes to bring it down to safe levels. These findings, particularly from the inlet point, underscored the need for significant attention in managing the wastewater, especially in reducing TSS, balancing pH, and decreasing COD to meet the established environmental standards, thereby safeguarding public health and the environment (Peraturan Menteri Negara Lingkungan Hidup Nomor 34 Tahun 2009 Tentang Baku Mutu Air Limbah Bagi Usaha Dan/Atau Kegiatan Pertambangan Bijih Bauksit, 2009).

Following the initial tests at the inlet, researchers conducted further tests at the second point, located 3 meters from the WWTP exit gate. The laboratory results for this sampling point provided detailed data on the quality of the wastewater. The Total Suspended Solids (TSS) measurements showed values of 70, 68, and 40 mg/L across three repetitions. These data indicated the amount of suspended particles in the water and demonstrated some variability in particle concentration between tests (Na et al., 2021). The pH measurements of the wastewater showed a nearly uniform consistency with values of 8.55, 8.56, and 8.57. These readings fell within a range indicating weakly basic water, with minimal variation between repetitions, suggesting stability in the wastewater's acidity characteristics. The iron (Fe) concentration in the wastewater was recorded at relatively low values: 0.0899, 0.0860, and 0.3789 mg/L. There was a significant increase in the third repetition, possibly indicating a change in the processes or conditions affecting the iron content in that sample. For copper (Cu) and nickel (Ni), both parameters showed concentrations below the detection limits in all repetitions, indicating very low levels of these metals, potentially insignificant in the context of pollution. The Chemical Oxygen Demand (COD), which measures the amount of oxygen required to oxidize organic material in water, was recorded at 61,959, 62,090, and 66,494 mg/L. These figures demonstrated relatively small variations between repetitions, possibly indicating consistency in the oxidized organic content in the wastewater samples. Laboratory results for Sampling Point 2 thus provided a snapshot of the wastewater composition and quality, viewed through several important parameters. Consistency in some parameters indicated stability in wastewater characteristics, while variations in others suggested fluctuations in the processes or conditions affecting the wastewater samples. When comparing these results to the established standards, the findings were mixed. For TSS, the concentrations significantly exceeded the maximum allowed limit of 50 mg/L, indicating that the wastewater at this point contained a greater amount of suspended particles than permitted. In contrast, the pH levels were within the acceptable standard range of 6 to 9. The iron concentration was well below the permissible limit of 5 mg/L, indicating no excessive iron content. Similarly, copper and nickel concentrations were well below the maximum allowed limits of 2 mg/L and 0.5 mg/L, respectively, suggesting compliance for these metals. The COD values were also within the acceptable range, reflecting the compliance of the organic content level in the wastewater. In summary, the laboratory tests at Sampling Point 2 revealed that while some parameters like TSS did not meet the required standards, others like pH, iron, copper, nickel, and COD were within acceptable limits. This indicated the need for specific attention to certain aspects of the wastewater treatment process to ensure overall compliance with environmental standards (Na et al., 2021).

Subsequent to the testing conducted at the first two points, the researchers proceeded to collect samples from the third point, situated 650 meters from the WWTP exit gate. The results from the laboratory tests for this location provided insightful details on the wastewater's quality (Kusuma et al., 2021). For the Total Suspended Solids (TSS) parameter, the test results exhibited a consistent concentration range between 30 and 33 mg/L. These values indicated a stable presence of dissolved particles in the water, measured according to SNI 6989.3:2019. The pH measurements of the wastewater consistently showed weakly basic values, ranging from 8.52 to 8.55, indicating a stable basic characteristic of the wastewater, as per the guidelines of SNI 6989.11:2019. The concentration of iron (Fe) in the wastewater showed slight variation, with the lowest concentration at 0.1094 mg/L and the highest at 0.1797 mg/L. These numbers, though varied, were still within the tolerable limits of the applicable standards, as per SNI 6989.84:2019. Intriguingly, for both copper (Cu) and nickel (Ni), the concentrations were below the detection limits of the testing methods, indicated by <0.019 mg/L for copper and <0.025 mg/L for nickel. This meant that if these metals were present in the wastewater, their concentrations were extremely low and undetectable by the instruments used, as stipulated by SNI 6989.84:2019. Finally, the Chemical Oxygen Demand (COD), an important indicator of the amount of oxygen required to oxidize organic and inorganic material in water, recorded values ranging from 46,403 to 59,379 mg/L. These figures provided an insight into the organic load in the wastewater, measured in accordance with SNI 6989.2:2019, which outlines the guidelines for accurate COD testing (Peraturan Menteri Negara Lingkungan Hidup Nomor 34 Tahun 2009 Tentang Baku Mutu Air Limbah Bagi Usaha Dan/Atau Kegiatan Pertambangan Bijih Bauksit, 2009). Upon comparing these results with the established standards, it was found that all tested parameters passed the criteria. The TSS results, ranging from 30 to 33 mg/L, were below the standard threshold of 50 mg/L, indicating that the wastewater met the specified clarity criteria. The recorded pH levels, within the range of 8.52 to 8.55, also fell within the acceptable standard range of 6 to 9, indicating suitable acidity levels for the wastewater. The detected iron concentration, ranging from 0.1094 to 0.1797 mg/L, was well below the maximum permissible limit of 5 mg/L, suggesting no significant iron-related concerns. The concentrations of both copper and nickel were below the detection limits, indicating levels far lower than the maximum allowed standards of 2 mg/L for copper and 0.5 mg/L for nickel. The COD measurements also painted a similar picture, with values significantly below the maximum standard of 100 mg/L, suggesting that the wastewater did not contain a high organic content that would require extensive oxygen for degradation. In conclusion, the wastewater quality evaluation at the third sampling point indicated that all tested parameters successfully met the established standards, reflecting effective management of the wastewater's composition and quality at this stage of the treatment process.

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At the fourth sampling point, located 1,500 meters from the WWTP exit gate, the researchers conducted a series of tests to evaluate the quality of the wastewater. The results from these tests provided significant insights into the final stage of the wastewater treatment process. The Total Suspended Solids (TSS) measurements at this point showed values of 35 mg/L in the first two repetitions and a slightly lower concentration of 28 mg/L in the third repetition. These results indicated a relatively stable and acceptable level of suspended particles in the wastewater, well within the normal range for this parameter (Na et al., 2021). The pH values of the wastewater were measured to be between 7.09 and 7.25, suggesting that the wastewater had nearly neutral acidity levels. This neutrality is crucial, as extreme pH levels can be harmful to the environment and aquatic life (Na et al., 2021). The near-neutral pH indicated that the wastewater at this stage was unlikely to cause pH-related environmental issues. Regarding the iron (Fe) content, the concentrations varied slightly but remained within a low range, between 1.9063 mg/L and 2.0001 mg/L. While these values confirmed the presence of iron in the wastewater, they were well below the maximum threshold considered harmful, indicating that iron levels in the wastewater were not a cause for concern (Alvarez et al., 2022). For copper (Cu) and nickel (Ni), the concentrations in the wastewater were below the detection limits of the testing methods, denoted by <0.019 mg/L for copper and <0.025 mg/L for nickel. This indicated that the concentrations of these metals, if present, were extremely low and not of significant concern from an environmental pollution standpoint. The Chemical Oxygen Demand (COD) values varied across the three repetitions, with the highest being 99,429 mg/L and the lower values around 70,889 mg/L and 70,907 mg/L. Although there was some variation, these COD values were indicative of a significant presence of organic matter in the wastewater. However, the values were all within safe limits, suggesting that the wastewater's organic content was manageable and did not exceed the maximum permissible levels (Alvarez et al., 2022). In summary, the testing results from the fourth sampling point showed that the wastewater consistently met the established environmental standards across all parameters (Peraturan Menteri Negara Lingkungan Hidup Nomor 34 Tahun 2009 Tentang Baku Mutu Air Limbah Bagi Usaha Dan/Atau Kegiatan Pertambangan Bijih Bauksit, 2009). The TSS values indicated clear water, the pH levels were within a safe range, and the iron, copper, and nickel concentrations were low and not excessive. The COD values, though varying, remained within acceptable limits, reflecting the effectiveness of the wastewater treatment process in handling organic matter. These results collectively indicated that the treated wastewater at this final sampling stage was well within the environmental compliance parameters.

As a preliminary step in understanding the quality of the wastewater being tested, the researchers have presented data from tests conducted at each sampling point, compared with established standards (Peraturan Menteri Negara Lingkungan Hidup Nomor 34 Tahun 2009 Tentang Baku Mutu Air Limbah Bagi Usaha Dan/Atau Kegiatan Pertambangan Bijih Bauksit, 2009). This foundational data sets the stage for a more in-depth analysis phase, where each parameter will be examined in detail. This detailed examination is crucial for identifying specific parameters that require further attention and determining potential measures to address environmental concerns. In upcoming discussions, the researchers plan to elucidate more clearly the parameters that show significant results—both those that meet the standards and those exceeding permissible limits. This approach will provide a more comprehensive understanding of the wastewater condition and its implications for water pollution mitigation efforts. This nuanced analysis is essential for pinpointing areas where the wastewater treatment process can be improved. By focusing on parameters that do not meet the required standards, researchers can identify the aspects of the treatment process that may need refinement or additional measures. For instance, if certain heavy metals or organic compounds are present in concentrations higher than the allowed limits, targeted treatment methods can be developed or enhanced to reduce these specific pollutants. Moreover, understanding parameters that

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consistently meet the standards is equally important (Na et al., 2021). It helps in affirming the effectiveness of certain aspects of the treatment process and provides a benchmark for maintaining such standards in the future. It also allows for a broader assessment of the overall efficacy of the wastewater treatment system in place. Ultimately, the aim is to ensure that the wastewater discharged into the environment poses minimal risk to ecological and human health.

By conducting a thorough analysis of each parameter and understanding the overall condition of the wastewater, the researchers intend to contribute valuable insights towards improving water pollution mitigation strategies. This effort aligns with the broader environmental goals of safeguarding water quality and promoting sustainable practices in wastewater management (Yusmur, Ardiansyah, and Mansur 2019).

Tabel 1 Sampling point one

No	Parameter	Repetation (mg/L)			Avarage	Status
		1	2	3		
1	TSS	474	470	300	387	Polluted
2	pH	12.44	12.48	12.44	12, 46	Polluted
3	Besi (Fe)	0.1836	0.1758	0.1806	0.1.800	Acceptable
4	Tembaga (Cu)	<0.019	<0.019	<0.019	<0.019	Acceptable
5	Nikel (Ni)	<0.025	<0.025	<0.025	<0.025	Acceptable
6	COD	821,788	838,426	826,474	828.896	Polluted

The table 1 presents results for six different water quality parameters at a specific testing point. Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD) showed high levels of 387 mg/L and 828,896 mg/L, respectively, indicating a polluted status. Similarly, the pH value averaged at 12.46, also reflecting a polluted condition. In contrast, levels of Iron (Fe), Copper (Cu), and Nickel (Ni) were within acceptable limits, with averages of 0.1800 mg/L, less than 0.019 mg/L, and less than 0.025 mg/L, respectively, thus meeting environmental standards. This table highlights the varied compliance of different pollutants with environmental norms at the testing location.

Tabel 2 Sampling point two

No	Parameter	Repetation (mg/L)			Average	Status
		1	2	3		
1	TSS	70	68	40	59.33	Polluted
2	pH	8,55	8,56	8,57	8.56	Acceptable
3	Besi (Fe)	0,0899	0,0860	0,3789	0.18493	Acceptable
4	Tembaga (Cu)	< 0,019	< 0,019	< 0,019	<0.019	Acceptable
5	Nikel (Ni)	< 0,025	< 0,025	< 0,025	<0.025	Acceptable
6	COD	61,959	62,090	66,494	63.514	Acceptable

At sampling point two, the results for various water quality parameters were as follows: Total Suspended Solids (TSS) averaged at 59.33 mg/L, categorizing it as polluted. The pH level, however, was within the acceptable range, averaging at 8.56. Iron (Fe) also fell within acceptable limits with an average of 0.18493 mg/L. Both Copper (Cu) and Nickel (Ni) showed levels below 0.019 mg/L and 0.025 mg/L respectively, categorizing them as acceptable. Chemical Oxygen Demand (COD) was within acceptable standards with an average of 63.514 mg/L. This indicates a mix of successful and inadequate contaminant management at this point.

Tabel 3 Sampling point three

No	Parameter	Repetation (mg/L)			Average	Status
		1	2	3		
1	TSS	32	30	33	31.67	Acceptable
2	pH	8,55	8,53	8,52	8.53	Acceptable
3	Besi (Fe)	0,1250	0,1094	0,1797	0.138	Acceptable
4	Tembaga (Cu)	< 0,019	< 0,019	< 0,019	< 0,019	Acceptable
5	Nikel (Ni)	< 0,025	< 0,025	< 0,025	< 0,025	Acceptable
6	COD	46,403	46,817	59,379	50.866	Acceptable

At sampling point three, the results indicate that all tested water quality parameters were within acceptable levels. Total Suspended Solids (TSS) averaged at 31.67 mg/L, pH was stable around 8.53, and Iron (Fe) levels averaged at 0.138 mg/L. Both Copper (Cu) and Nickel (Ni) showed concentrations below the detection limits of 0.019 mg/L and 0.025 mg/L, respectively. Chemical Oxygen Demand (COD) was also within acceptable limits, averaging at 50.866 mg/L. These results suggest effective management of pollutants at this sampling location.

Tabel 4 Sampling point four

No	Parameter	Repetation (mg/L)			Average	Status
		1	2	3		
1	TSS	35	35	28	32.67	Acceptable
2	pH	7,21	7,25	7,09	7.18	Acceptable
3	Besi (Fe)	2,0001	1,9610	1,9063	1.622	Acceptable
4	Tembaga (Cu)	< 0,019	< 0,019	< 0,019	< 0,019	Acceptable
5	Nikel (Ni)	< 0,025	< 0,025	< 0,025	< 0,025	Acceptable
6	COD	99,429	70,889	70,907	80.408	Acceptable

At sampling point four, the results for various water quality parameters were all within acceptable levels. Total Suspended Solids (TSS) had an average of 32.67 mg/L. The pH level was balanced, averaging at 7.18. Iron (Fe) levels were higher but still acceptable at an average of 1.622 mg/L. Both Copper (Cu) and Nickel (Ni) were below the detection limits, indicating no significant presence. The Chemical Oxygen Demand (COD) was also within an acceptable range, with an average of 80.408 mg/L. These results suggest effective water quality management at this point.

Tabel 1 Waste change in percentage per point

Water quality parameter	Sampling Points							
	1	Percentage change	2	Percentage change	3	Percentage change	4	Percentage change
TSS	387	0.00	55	-85.79	31.5	-91.86	31.5	-91.86
COD	830	0.00	65	-92.17	55	-93.37	85	-89.76
Besi	0.1797	0.00	0.2324	-19.59	0.1445	-19.59	1.9532	+ 986.92
Tembaga	0.019	0.00	0.019	0.00	0.019	0.00	0.019	0.00
Nikel	0.025	0.00	0.025	0.00	0.025	0.00	0.025	0.00
pH	12.46	0.00	8.535	-31.50	8.56	-31.30	7.15	-42.62

(+) Percentage increase

(-) Percentage decrease

Table 5 shows the percentage change in various water quality parameters across four sampling points. There was a significant decrease in Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD) levels from the first to subsequent points, with reductions over 85% and 89% respectively. Iron (Fe) levels increased dramatically by approximately 987% from the first to the fourth point. Conversely, Copper (Cu) and Nickel (Ni) levels remained constant across all points. The pH level saw a considerable decrease, moving from highly alkaline at point one to more neutral levels by point four.

In addressing the research question concerning the effectiveness of Chemical Grade Alumina Waste treatment in mitigating water pollution, various parameters were tested, yielding varied results. These results help determine the level of pollution and compliance with environmental standards. For Total Suspended Solids (TSS), test results indicated that at the second testing point (the first point after the WWTP exit), the TSS concentration did not meet the established standards. This suggests that wastewater management regarding TSS at this point requires improvement to comply with the set standards, indicating the need for better management practices. Regarding pH measurements, significant variations were observed between the testing points. At the first point (the inlet), the recorded pH values were highly alkaline, ranging from 12.44 to 12.48, surpassing the standard pH limit of 6 to 9. This indicates a discrepancy that needs addressing. However, the other testing points showed pH values within the acceptable standard range, indicating conditions more in line with environmental requirements and demonstrating the WWTP's success in mitigating this parameter. For iron (Fe) concentration, results from all testing points were below the maximum allowed limit of 5 mg/L. However, at one point, the iron concentration approached the upper limit of the standard, with values between 0.0860 mg/L and 0.3789 mg/L. This calls for stricter monitoring to prevent potential increases and suggests the possibility of leaks not originating from the WWTP. Further research in this area is highly recommended. In terms of copper (Cu) and nickel (Ni), these metals were either undetected or below the detection limits at all testing points, indicating that wastewater met the established standards for both parameters, with Cu ≤ 2 mg/L and Ni ≤ 0.5 mg/L. This suggests that regarding the presence of these heavy metals, the wastewater does not pose concerns. Contrastingly, the Chemical Oxygen Demand (COD) showed a striking contrast between the first testing point and the others. At the first point, the COD value was exceedingly high, ranging from 821,788 to 838,426 mg/L, far exceeding the permitted standard of 100 mg/L and indicating a high level of pollution requiring immediate remediation. However, at the other testing points, the COD values were significantly lower and within the permitted limits, indicating compliance with standards and more effective waste management. These test results suggest that several aspects of wastewater treatment successfully meet the established standards. However, some parameters, particularly pH and COD at the first testing point, indicate areas needing attention and improvement to ensure full compliance with environmental standards.

Regarding the findings reported in this study, the researchers utilized the theory of the self-purification of water bodies and the concept of Hydraulic Retention Time (HRT) to explain the observed phenomena (Alvarez et al., 2022). The study's results indicated that the Total Suspended Solids (TSS) levels were below the maximum permitted limits, demonstrating the initial effectiveness of the Wastewater Treatment Plant (WWTP) in managing suspended particles. However, significant variations in pH and high Chemical Oxygen Demand (COD) values at the first point suggested discrepancies in the initial treatment process. The theory of the self-purification of water bodies can explain the improvement in water quality at subsequent testing points. Natural processes such as sedimentation and biological degradation by microorganisms contribute to the reduction in pH and COD. These processes require time and distance from the discharge point to achieve significant effects, which might not be available within the WWTP itself but occur in the natural environment post-discharge. Therefore, the improvement in the WWTP's wastewater condition after 1,500 meters can be understood as a natural remediation process (Alvarez et al., 2022).

Furthermore, the concept of Hydraulic Retention Time (HRT) provides insight into the importance of allowing sufficient time for wastewater to interact with the treatment processes within the WWTP (Alvarez et al., 2022). The very high COD values at the first point might indicate that the wastewater did not have enough retention time in the WWTP system for the oxidation and degradation of organic materials to be effective. This could be due to inadequate WWTP design or fluctuations in the incoming wastewater volume, which do not match the designed capacity. On the other hand, the reduction in COD values at subsequent testing points suggests that natural processes outside the WWTP, such as dilution and microbial activity, might have contributed further to reducing pollutant concentrations. This highlights the significance of considering both the engineered treatment processes within the WWTP and the natural self-purification mechanisms in the environment when evaluating the overall effectiveness of wastewater treatment systems (Lapointe et al., 2020; Na et al., 2021).

CONCLUSIONS

The study's analysis of six wastewater parameters revealed varied results, highlighting both the effectiveness and areas for improvement in the treatment process. There was a significant reduction in Total Suspended Solids (TSS) across the testing points, indicating effective removal of suspended particles, though the initial levels post-WWTP exit were above standard. The pH levels were excessively high at the inlet but adjusted closer to the standard range at subsequent points. Iron (Fe) concentrations remained below the maximum limit across all points, with a notable increase at the final testing point, suggesting potential external contamination. Copper (Cu) and Nickel (Ni) were undetected or below detection limits, indicating compliance with standards. Chemical Oxygen Demand (COD) showed a dramatic reduction after the first point, where it was significantly high, demonstrating the treatment's effectiveness in reducing organic pollution. Overall, the study suggests successful aspects of the wastewater treatment, particularly in heavy metal and organic content management, while identifying the need for improvements in initial TSS and pH treatment.

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