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Analysis of Water Quality in Traditional Oil Mining Using The Pollution Index Method in Gampong Alue Peuno

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Abstract

Gampong Alue Peuno, Bireuen, us a region in Aceh known for its rich petroleum resources. This abundance has led to many oil wells being freely managed by the local community. This study aims to analyze water quality in Gampong Alue Peuno according to established water quality standards, utilizing the Pollution Index method in reference to the Indonesian Minister of Environment Decree No. 115 of 2003. The Pollution Index assesses water quality across ten points, considering parameters such as pH, temperature, oil and fat, TDS, BOD, COD, and DO. Water quality calculations for Gampong Alue Peuno yielded Pollution Index (IP) values at points 1 through 10 of 2.423, 3.505, 2.022, 2.534, 2.241, 2.328, 1.847, 3.180, 4.370, 1nd 1.510, respectively. Based on Decree No. 115 of 2003, all teat points fall into the light pollution category ($1.0 < IP \leq 5.0$ for Class II water quality standards. Water in Class II with light pollution is not recommended for daily activities such as washing dishes, washing clothes, bathing, irrigating plants, and livestock care, or other needs requiring similar water quality. Polluted water usage can directly or indirectly affect public health and harm aquatic ecosystems.

Keywords: *gampong alue peuno, oil mining, petroleum resources, pollution index, water quality*

Abstrak

Gampong Alue Peuno, Bireuen, adalah sebuah di Aceh yang dikenal dengan sumber daya minyak bumi yang melimpah. Kekayaan ini telah menyebabkan banyak sumur minyak bumi dikelola secara bebas oleh masyarakat setempat. Studi ini bertujuan untuk menganalisis kualitas air di Gampong Alue Peuno berdasarkan standar kualitas air yang telah ditetapkan, dengan menggunakan metode Indeks Pencemaran yang mengacu pada Keputusan Menteri Lingkungan Hidup Nomor 115 Tahun 2003. Indeks Pencemaran ini menilai kualitas air di sepuluh titik, dengan mempertimbangkan parameter seperti pH, suhu, minyak dan lemak, TDS, BOD, COD, dan DO. Perhitungan kualitas air untuk Gampong Alue Peuno menghasilkan nilai Indeks Pencemaran (IP) di titik 1 hingga 10 berturut-turut sebesar 2,423; 3,505; 2,022; 2,534; 2,241; 2,328; 1,847; 3,180; 4,370; dan 1,510. Berdasarkan Keputusan Menteri LH No. 115 Tahun 2003, semua titik uji termasuk ke dalam kategori cemar ringan ($1,0 < IP \leq 5,0$) untuk kualitas air Kelas II. Air di Kelas II dengan kategori cemar ringan tidak direkomendasikan untuk aktivitas sehari-hari seperti mencuci piring, mencuci pakaian, mandi, menyiram tanaman, dan perawatan ternak, atau kebutuhan lain yang membutuhkan kualitas air serupa. Penggunaan air yang tercemar dapat mempengaruhi kesehatan masyarakat baik secara langsung maupun tidak langsung serta merusak ekosistem air.

Kata Kunci: *gampong alue peuno, indeks pencemaran, kualitas air, sumber minyak, tambang minyak*

1. Introduction

Indonesia is a country rich in natural resources across various sectors, including agriculture, plantations, fisheries, livestock, forestry, mining, and energy [1]. Oil and natural gas are significant non-tax revenue contributors through exploration activities. Aceh, Indonesia's westernmost province, has special autonomy and is known for its abundant natural resources, including oil, ranking 25th in potential with 4.6 billion barrels and 21st globally in crude oil production at one million barrels per day [2].

Article 33, Paragraph 3 of the Constitution states that "water, land, and natural resources therein are controlled by the state and used to maximize the prosperity of the people". Increased population density disrupts water balance, placing environmental pressures to meet demand. Aceh's wealth has led to illegal oil drilling by certain local actors, which contradicts the Ministry of Mines and Energy Regulation No. 1285.K/M/20/M.PE/1996 concerning oil mining on old wells. This unauthorized activity is motivated by potential profits but has negative repercussions, including environmental degradation and workplace accidents, because of improper practices. In Gampong Alue Peuno, explosions occurred at traditional oil

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wells in 2016 and 2021 because of oil pumps located near storage areas. Although the Bireuen District Government researched this issue in 2022, there has been no policy response to address the problem of illegal oil mining.

Oil and gas mining generates various wastes, notably liquid waste that poses a significant threat to the environment, especially water. The chemical composition of this waste is hazardous and toxic, endangering local aquatic life [3]. Water, a vital element for life, is essential to maintaining cleanliness and usability for human activities [4].

This study examines water quality in Gampong Alue Peuno, using seven parameters–pH, temperature, oil and fat, total dissolved solid (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO)–to assess pollution levels through the Pollution Index (IP) method, as outlined in the Ministry of Environment Decree No. 115 of 2003 on Water Quality Status Determination [5]. Water quality refers to the chemical, physical, and bacteriological characteristics necessary for its use as a water source [6]. IP offers a simple method for evaluating river quality against specified standards.

Based on the explanation above, the water usage by the local community in Gampong Alue Peuno needs to be investigated. Likewise, the water quality in Gampong Alue Peuno should be assessed using the Pollution Index according to the Decree of the Minister of Environment No. 115 of 2003. Therefore, this study is conducted with the aim of analyzing the water quality in Gampong Alue Peuno using the Pollution Index as outlined in the Decree of the Minister of Environment No. 115 of 2003.

2. Material and Methods

Research Location

The research was conducted through field data collection, sample collection, and sample testing at the Environmental Laboratory of the Environmental Agency of Pidie Regency. Data and samples were collected from Alue Peuno, Bireuen, where ten water samples were taken. Sampling was carried out on-site, with data gathered through field testing as well as laboratory testing of the samples.

Sampling and Data Collection

Primary data includes data collected directly in the field during the research, including pH, temperature, oil and fat, TDS, BOD, COD, and DO measurements. Secondary data required for this study includes geographical data on Bireuen Regency, Class II water quality standards according to Government Regulation No. 22 of 2021, and water quality categories based on the Ministerial Decree No. 115 of 2003.

Sampling points were randomly selected in Gampong Alue Peuno, Bireuen. A total of ten samples were collected because of time constraint. All sampling points were divided into two measurement types, for both general and specific parameters. Sampling points are illustrated in Fig. 1. Water quality testing was conducted using 10 water samples from various points. Point 1, 2, and 10 were taken from residents' wells, while points 3–9 were taken from the river flowing through Gampong Alue Peuno. This testing involved both field and laboratory parameters. The field parameters included pH and temperature, while laboratory parameters included oil and fat, TDS, BOD, COD, and DO. Before taking water samples, the jerry cans were rinsed three times with the water to be sampled.

General parameter measurement were taken using a pH meter and a water thermometer. Water pH was measured with the pH meter, and temperature was measured with the thermometer at each point. Specific parameter data was obtained using laboratory testing tools following specific SNI standards.

The measurement of specific parameters was carried out in the laboratory following SNI 6989.27:2019 [7] for gravimetric testing of TDS, SNI 06-6989.14-2004 [8] for Winkler testing of DO, SNI 6989.72-2009 [9] for titrimetris testing of BOD, SNI 6989.2:2009 for spectrophotometric testing of COD, and SNI 6989.10-2011 for gravimetric testing of oil and fat.

After obtaining the results of the water quality tests in Gampong Alue Peuno, all test parameters–pH, temperature, oil and fat, TDS, BOD, COD, and DO–were calculated using the pollution index method based on the Minister of Environment Decree No. 115 of 2003, utilizing Equation 1 and analyzed using **Table 1**.

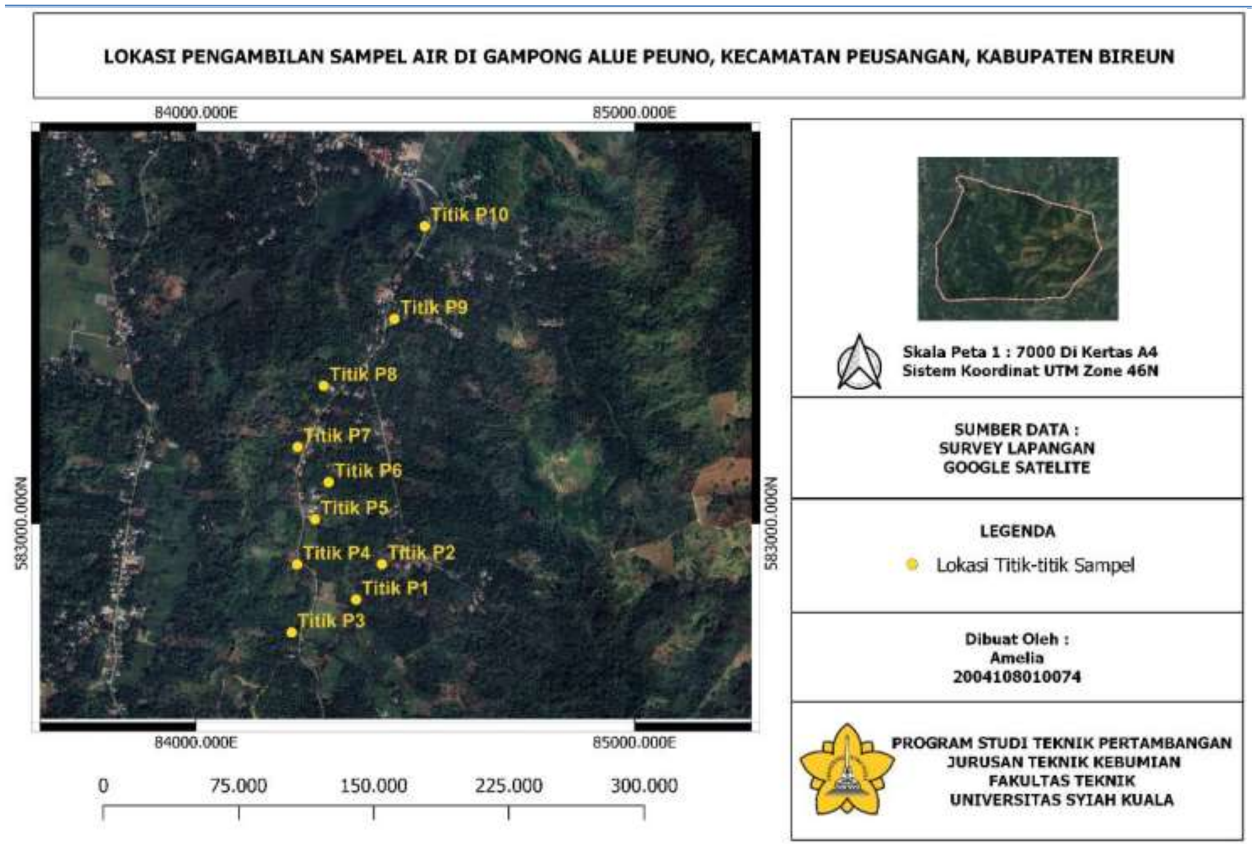

Fig 1: Sampling points

$$IP = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)_R^2 + \left(\frac{C_i}{L_{ij}}\right)_M^2}{2}} \quad (1)$$

Where PI is pollution index, C_1 is concentration of the tested parameter results, L_{ij} is concentration of the parameter according to Class II water quality standards, $(C_{ij}/L_j)_R$ is average value of C_i/L_{ij}, and $(C_{ij}/L_j)_M$ is maximum value of C_i/L_{ij}. The relationship between all parameters and the pollution index value indicates that the higher the parameter values (exceeding the water quality standards), the more polluted the area becomes. The followings are the categories of Pollution Index (PI) values presented in **Table 1**.

Table 1. Water quality categories

Water Quality Index	Description
$0 \leq PI \leq 1$	Meets quality standards (Good condition)
$1 \leq PI \leq 5$	Lightly polluted
$5 \leq PI \leq 10$	Moderately polluted
$PI > 10$	Heavily polluted

Source: Minister of Environment Decree No. 115 (2003)

3. Results and Discussion

Alue Peuno is located in the Peusangan subdistrict of Bireuen Regency, Aceh Province. Peusangan has an area of 122.48 km^2, accounting for 6.44% of Bireuen Regency's total area. Geographically Alue Peuno borders Gampong Paloh to the north, Gampong Me Rayeuk to the south, Gampong Seunebok Rawa to the west, and Gampong Lung Barou to the east.

pH

Residents of Alue Peuno independently manage crude oil resources at several points where oil is extracted. The discovery of oil occurred during the drilling of local wells, which released oil, leading residents to explore other points using traditional methods. An oil-producing well can be seen in Fig. 2.

Fig 2: Oil-containing well

In the vicinity of the oil mining area in Gampong Alue Peuno, there is a river located near residential areas. This river water is used for daily activities such as washing dishes, washing clothes, bathing, irrigating plants, livestock care, and also for oil mining purposes. However, the river water in Gampong Alue Peuno is not used for drinking or cooking because of contamination from oil mining waste. The mining waste is directly discharged around the river by miners, causing oil contamination in the river.

The pH value indicates the acidity level of the river water, which can influence microbial activity and chemical reactions within the water. Based on Fig. 3, the water pH shows varying values at each point. The lowest pH was found at point 6, with a value of 4.5, and the highest pH was at point 10, with a value of 7.1. A low pH in a body water indicates high toxic levels of heavy metals, while a higher pH correlated with a decrease in heavy metal toxicity [10].

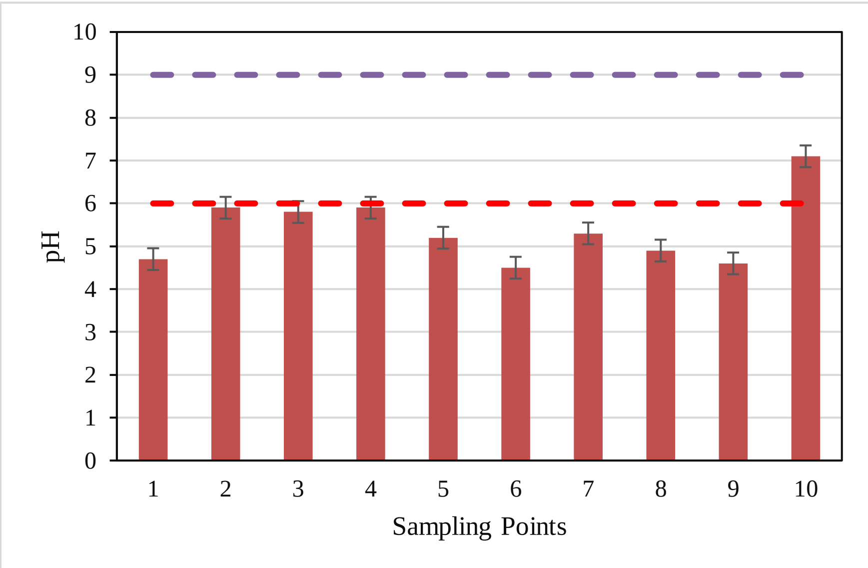

Fig. 3: pH water testing results

The pH concentration at point P1, with a value of 4.7, is below the established threshold. This is because of household activities around the well, which is located next to resident's homes. Soap waste from bathing, washing clothes, and washing dishes flows near the well, containing harmful chemicals that lower the water's pH, making it acidic. At point 2, a pH of 5.9 was recorded, also below the threshold. This is because of local activities around the well, which is close to oil mining and located behind homes. The well

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water at point 2 is acidic, as residents use it for oil mining and daily activities like washing clothes and dishes, which flow near the well and seep into the soil, gradually contaminating the well water.

The pH measurements at points 3, 4, and 5 were 5.8, 5.9, and 5,2, all below threshold. These points are river water located near the roadside and residential gardens. The surrounding environmental is green, with wild plants and trees along the riverbanks, which can increase the water's carbon dioxide content. The respiration process of plants releases carbon dioxide, lowering the water's pH to a more acidic level. At point 6, the pH dropped to 4.5, which is below the threshold. This river location is beside resident's homes, with wild plants growing nearby. The river water is used by residents for washing clothes on the riverbank. Acidic mine drainage, which releases sulfuric acid and other acidic compounds, can also lower pH if mining activities are nearby [11].

At sampling point 7, a pH of 5.3 was recorded, also below the established threshold. The river at point 7 is located close to homes and oil mining areas used by residents for mining and daily needs. Oil mining waste and household garbage are discharged directly into the river, causing a decrese in water pH. The pH at point 8 was 4.9, which is below the threshold. The river at point 8 is behind residnts's homes, and the water is acidic because of dishwashing soap waste and used cooking oil being discarded near the river, contaminating the river water. At point 9, the pH dropped to 4.6, below the threshold, in a river close to oil mining. This is because the water has already been contaminated by oil waste, making it acidic. Acididc water cannot support aquatic life, and organisms in the water may die. The last point, 10, had a pH of 7.1, within the established threshold. This point is located at a well far from residential areas and is rarely used, allowing the well water to have a neutral pH.

Temperature

The temperature of a body of water affects chemical reactions [12], the increase and decrease of dissolved oxygen, as well as the distribution and abundance of aquatic organisms. If the water temperature rises or falls outside the established threshold, it can accelerate, slow down, or inhibit metabolic activity within the water.

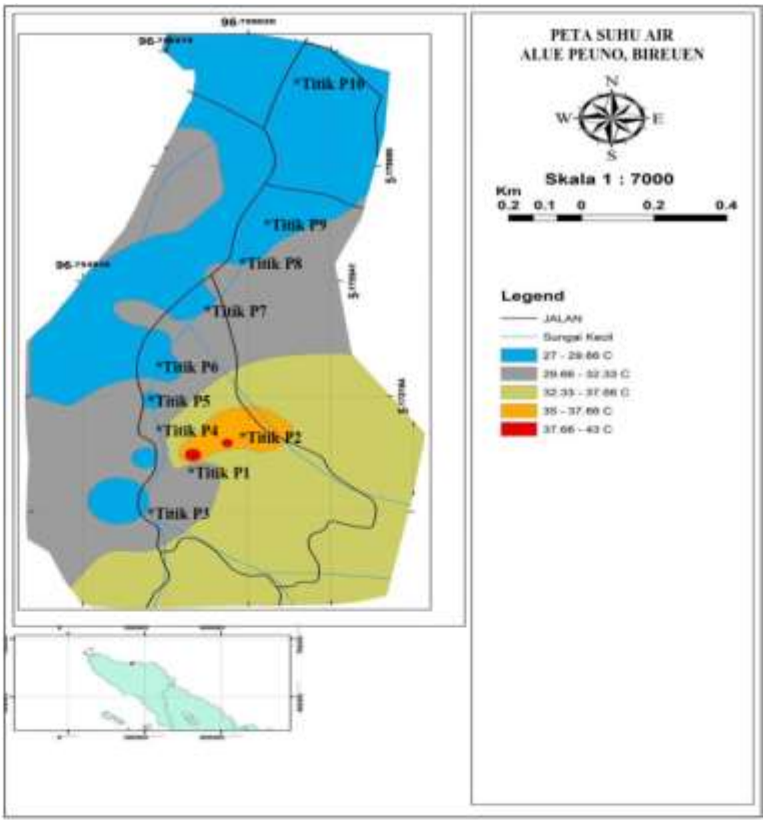

Fig. 4: Temperature values at testing points

Based on **Fig. 4**, the temperature parameter varies at each point. The lowest temperature is at point 8 with a value of 27°C, while the highest temperature, 35°C, is at point 2. Water temperature can be influenced by many factors, such as sunlight intensiy, shade from trees, and heat exchange between the water and

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surrounding air. Higher temperatures at certain testing points can be affected by weather conditions at the time of measurement, especially during hot weather.

The temperature concentrations at points 1, 3, 7, and 8, with values of 27^{o}C–28^{o}C, fall within the established threshold range (**Fig. 5**). This is because of the surrounding environment of the wells and river water, which are located in areas with many trees. The edges of the wells and river are still surrounded by trees and wild plants, which block sunlight from reaching the water, resulting in lower water temperatures. At points 2, 4, 5, 6, 9, and 10, temperatures of 29^{o}C–35^{o}C were recorded, which exceed the threshold range. This is likely because of the testing being conducted later in the day. Additionally, most of these points are located along the river, where medium-sized wild plants surround the water, allowing more sunlight to penetrate and increase water temperature.

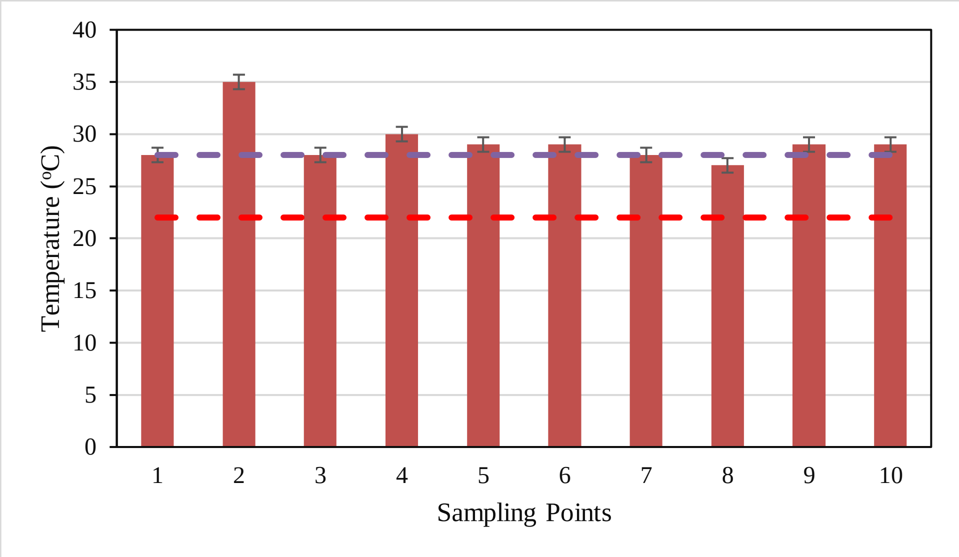

Fig. 5: Water temperature testing result

Oil and Fat

The oil and fat values indicate the dispersed oil and fat content in the water. This oil can come from various sources, including industrial and household waste. Based on **Fig. 6**, the oil and fat parameter shows varying values at each point. The lowest oil and fat concentration is at point 6, with 0.2 mg/L, while the highest concentration is at point 9, with 9.4 mg/L. The high oil content is because of the proximity of the oil mining site to the testing point.

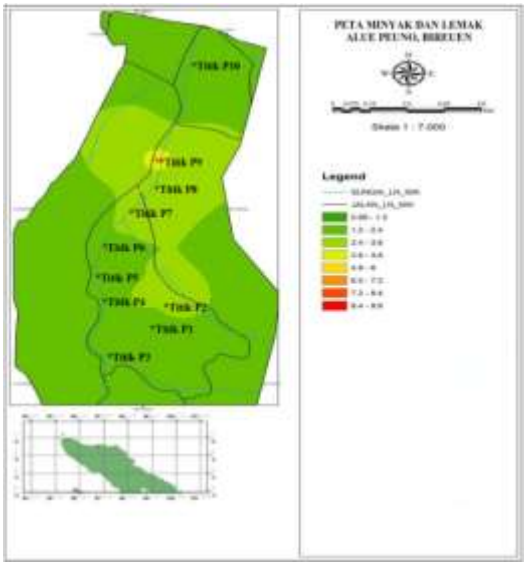

Fig. 6: Oil and fat values at testing points

High concentrations of dissolved oil in the water can cause serious environmental issues by polluting the water, disrupting aquatic ecosystems, endangering organisms, and posing health risks to humans. Oil in the water will form a layer on the surface because of its lower density compared to water. This high oil content blocks sunlight from entering the water, which disrupts the aquatic ecosystem, and, if consumed, can also lead to health issues.

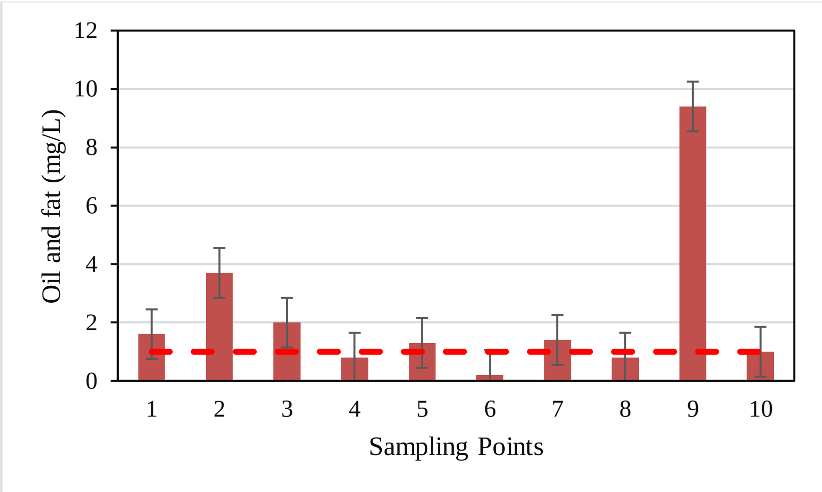

Fig. 7: Oil and fat testing results

The oil and fat concentration values at points 1, 2, and 10, with 1.6 mg/L, 3.7 mg/L, and 1 mg/L respectively, exceed the threshold (**Fig. 7**). This is because of these points being located at wells, where the natural oil resources in Gampong Alue Peuno cause the well water to contain oil. Points 3, 5, and 7 have values of 2 mg/L, 1.3 mg/L, and 1.4 mg/L, also exceeding the threshold, because of the river being contaminated with used cooking oil and oil mining waste flowing into the area. Point 9 shows a significant increase with a value of 9.4 mg/L, as it is very close to local oil mining activities, with mining waste flowing into the river, causing a high oil and fat concentration. Lastly, points 4, 6, and 8, with values of 0.8 mg/L, 0.2 mg/L, and 0.8 mg/L, fall within the threshold as these sample points are relatively far from the oil mining site.

Total Dissolved Solid

The TDS value indicates the concentration of dissolved solids, including both organic and inorganic substances, in the water. Based on **Fig. 8**, the TDS parameter shows varying values at each point. The lowesr TDS value is at point 10, with 1558 mg/L, and the highest is at point 8, with 4530 mg/L. The low TDS concentration can be attributed to the point's distance from human activities, resulting in minimal waste entering the water. High TDS concentrations are influenced by human activities, particularly oil waste entering the water, and the impact of soil runoff, making the water unsuitable for consumption.

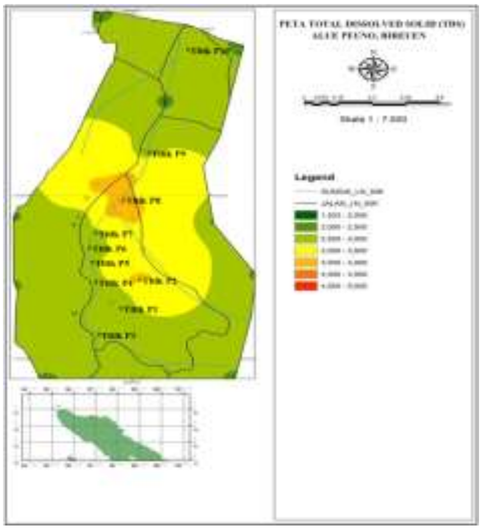

Fig. 8: TDS values at testing points

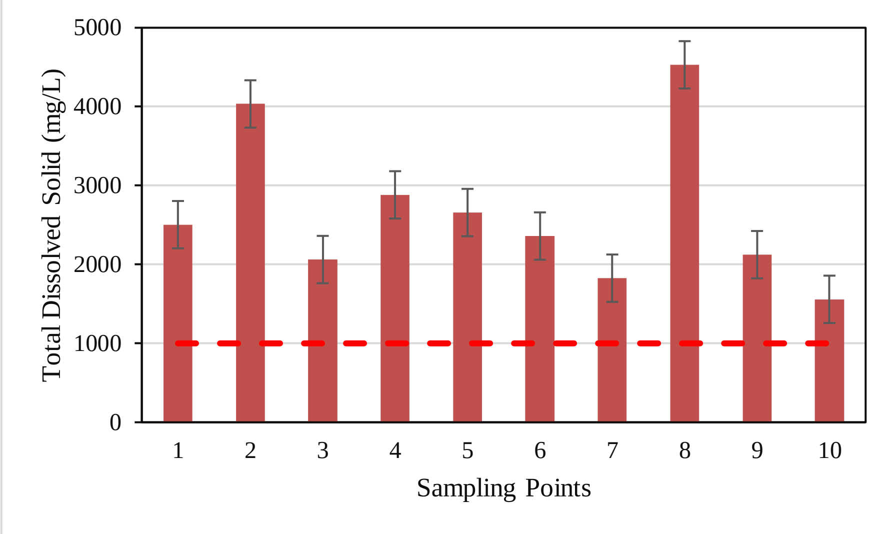

Fig. 9: TDS testing results

The TDS concentration value at point 1 is 2504 mg/L, which exceeds the threshold, and at point 2, there is a significant increase to 4034 mg/L (**Fig. 9**). This is because the well at this point has been contaminated by waste, primarily from used soap water containing hazardous chemicals and waste from oil drilling, which triggers the increase in TDS levels. At points 3–7, there is a decrease in TDS with values of 1816 mg/L–2882 mg/L, respectively, because of the locations being near the river. The area around the river has many trees and wild plants, so dry leaves fall directly into the river, causing the leaves to decay and settle at the riverbed. The river water at point 8 experiences a very signifivant increase because of the presence of dry leaves falling into the river, plastic waste from resident's homes, and waste from mining that flows into the river.

Next, point 9, the river water is close to oil drilling with a TDS value of 2124 mg/L. The river water is used for oil drilling activities such as washing hands, cleaning oil drilling equipment, and the produced oil waste directly flows into the river, causing the river water to contain many inorganic materials that trigger the TDS value to exceed the threshold. At the last point, 10, there is a decrease with a value of 1558 mg/L because point 10 is located in a well that is far from resident's homes. This leads to minimal activity from residents around the well, but wild plants on the well walls cause the TDS value to exceed the threshold.

Biochemical Oxygen Demand

The BOD value indicates a quantitative measure of the amount of oxygen required by microorganisms to decompose organic material in water [13]. The higher the BOD value, the lower the water quality and the higher the level of pollution in a body of water.

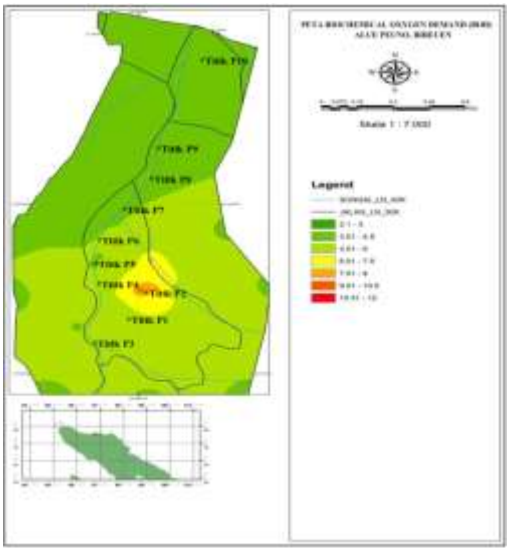

Fig. 10: BOD values at testing points

Based on **Fig. 10**, it can be seen that the BOD parameters has varying values at each point. The lowest BOD value is found at point 10, which is 2.3 mg/L. While the highest BOD value is at point 2, which is 11.5 mg/L. The high BOD value can be influenced by community activities in Gampong Alue Peuno. The disposal of oil mining waste into the water contributes to the increase in BOD values. High BOD in water can reduce the dissolved oxygen content, which can cause problems for aquatic organisms, such as fish, that need oxygen to survive.

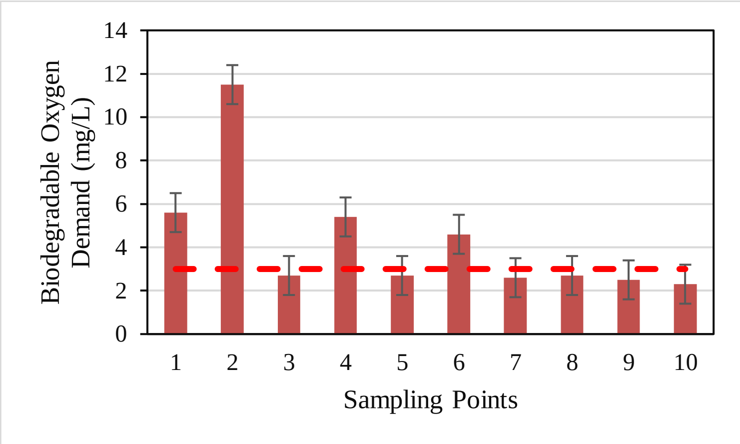

Fig. 11: BOD test results

The BOD concentration value at point 1 is 5.6 mg/L, which exceeds the threshold (**Fig. 11**). This is because the activities of the community around the well. At point 2, there is a significant increase to 11.5 mg/L, likely because the weather was very hot during the testing, affecting the activity rate of microorganisms in the water and resulting in a higher oxygen demand from these microorganisms. At points 4 and 6, the values are 5.4 mg/L and 4.6 mg/L, respectively, exceeding the threshold because of agricultural activities that use pesticides.

Next, at the sampling points 3, 5, 7, 8, and 9, which are river sites, the BOD values are 2.5–2.7 mg/L, respectively, all within the threshold. This is caused by the open land environmental around the river, which is abundant with trees and wild plants. This condition promotes an increase in oxygen content around the river and enters the water, thus reducing the oxygen levels needed by microorganisms in the water. Finally, at point 10, the value is 2.3 mg/L, which is within the threshold because the well is far from resident activities and there are many plants around the river.

Chemical Oxyen Demand

The COD value indicates the amount of organic material in water that has been chemically decomposed [14] A high COD concentration in a water body indicates a high level of organic waste in that body of water [15]. One of the causes of inorganic waste is industrial activities. Therefore, the higher the COD value, the greater the amount of waste produced by industries and other activities, as well as the higher the level of pollution in the water.

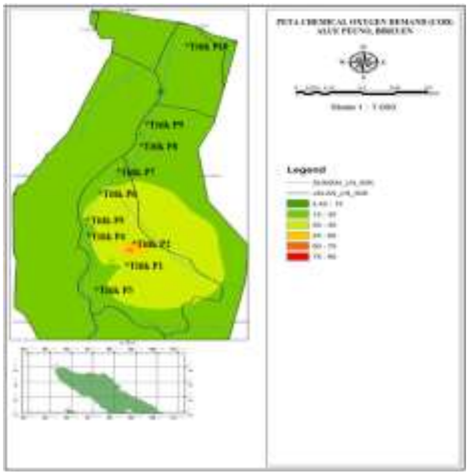

Fig. 12: COD values at testing points

Based on **Fig. 12**, it can be seen that the COD parameter has varying values at each point. The lowest COD value is found at point 4, which is 2.5 mg/L, while the highest COD value is at point 2, which is 81.2 mg/L. Factors that can influence the differences in the high or low COD values obtained are the activities of the community around the testing points. The majority of the community engages in unregulated oil mining, which triggers the high COD values.

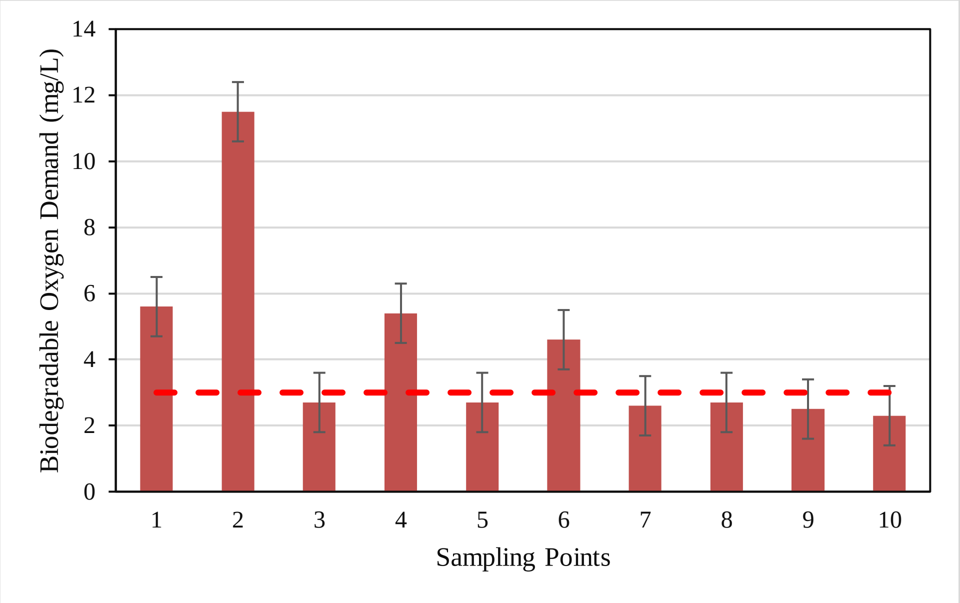

Fig. 13: COD test results

The concentration values at points 1, 3, 4, 5, 7, 8, 9, and 10 are 2.5–22.5 mg/L (Fig. 13). The differences in the high and low COD values obtained are because of the activities of the residents around the testing points. These activities include livestock farming, agriculture, and oil mining, which have the potential to influence the increase in COD values. At points 2 and 6, with values of 81.2 mg/L and 41.9 mg/L, respectively, they exceed the threshold because of agricultural activities that use synthetic fertilizers and oil mining that produces waste, thus contaminating the water at those testing points. High COD values in a water body indicate that the water contains a high livel of inorganic waste, which causes a decline in water quality and has negative impacts on human health and aquatic life.

Dissolved Oxygen

The DO value indicates the amount of dissolved oxygen in water. A high DO value indicates a high level of oxygen contained in the water. Based on **Fig. 14**, it can be seen that the DO parameter has varying values at each point. The lowest DO value is found at point 2, which is 5.6 mg/L, while the highest DO value is at point 9, which is 7.3 mg/L. An increase in DO values indicates an improvement in water quality in that body of water. Conversely, a decrease in DO values reflects a decline in water quality. High DO values can be caused by the continues flow of water, which facilitates the aeration process, allowing additional oxygen from the air to enter the water.

The concentration values at points 1, 2, and 10 are 5.6–6.0 mg/L, showing only slight differences because of the testing being conducted during the dry season, which limits the amount of oxygen entering the water and leads to a decrease in DO values in the well water, also influenced by the depth of the well. At points 3–8, the DO values are 5.7–6.3 mg/L, all of which fall within the threshold. This is because of the influence of the uneven riverbed conditions, which tend to slope downward, allowing for the recovery of DO values through the aeration process, thus increasing the oxygen content at these testing points. Point 9 shows a significant increase to 7.3 mg/L, which is within the threshold, because of the sloping riverbed at this point, causing the flowing water to be quite rapid and facilitating the aeration process, allowing oxygen from the air to enter the river.

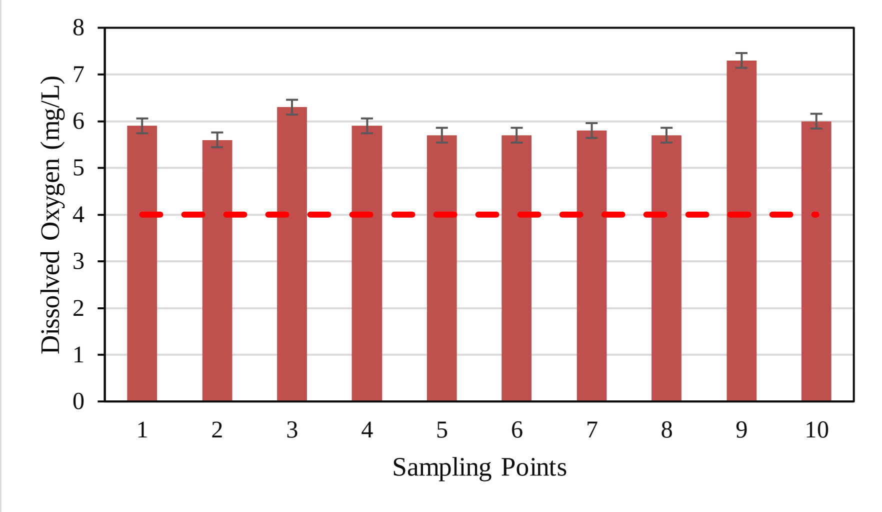

Fig. 14: DO test results

Analysis of the Water Pollution Index of Alue Peuno

The results of the pollution index analysis from field and laboratory tests in Gampong Alue Peuno, consider parameters such as water pH, temperature, oil and fat, TDS, BOS, COD, and DO. Based on the water quality calculations in Gampong Alue Peuno, the Polution Index (PI) values vary, with PI values of 1.847 and 1.510 at points 7 and 10. At points 1, 3, 4, 5, and 6, the PI values increased to 2.022–2.534. Points 2 and 8 show significant increase in PI values at 3,505 and 3.180, while the highest PI is at point 9, with a value of 4.37.

According to **Table 1**, all test points fall within the light pollution category ($1 < PI \leq 5$) for Class II water quality standard. Water in Class II with light pollution is not recommend for daily activities, such as dishwashing, laundry, bathing, irrigation, livestock, and other uses requireig similar water quality. The pollution in this area is primarily because of unregulated oil extraction and improper waste disposal around the river, leading to water pollution in Gampong Alue Peuno. Using polluted water can directly or indirectly impact public health and harm the aquatic ecosystem. Therefore, special attentiap from local government and stakeholders is needed for water quality management and pollution control in Gampong Alue Peuno.

4. Conclusion

Based on the research conducted in the oil mining area of Gampong Alue Peuno, a river is located close to residential areas. This river is used for daily activities such as dishwashing, laundry, bathing, irrigation, livestock, and oil extraction purposes. Mining waste is directly discharged near the river, contaminating it with oil. Water quality based on PI for parameters like pH, temperature, oil and fat, TDS, BOD, COD, and DO at 10 testing points falls within the light pollution category ($1 < PI \leq 5$) for Class II water quality standards, according to Minister of Environment Decree No. 115 of 2003. Future research should increase the number of sampling points to provide more accurate results and conduct further analysis of water quality in Gampong Alue Peuno based on Class III and IV water quality standards.

5. Acknowledgment

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6. Abbreviations

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
PI	Pollution Index
TDS	Total Dissolved Solid

7. References

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