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LIMESTONE MINING'S EFFECT ON THE MARUNI RIVER MANOKWARI REGENCY'S WATER QUALITY, WEST PAPUA

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ABSTRACT
One important economic activity in Manokwari Regency West Papua Indonesia is Maruni limestone mining. However, the surrounding ecology particularly the Maruni River's surface water, has been significantly impacted by this mining operation. The goal of this study was to assess the Maruni River's surface water quality in order to determine the degree of environmental harm brought on by mining operations. The Water Quality Index was measured using three parameters (Total Suspended Solids, Turbidity, and Dissolved Oxygen) at three locations along the Maruni River in september 2024 as part of a quantitative research methodology. With an index ranging from 2.26 to 3.78, the investigation of the river's water quality status revealed that it was somewhat contaminated. The Maruni River does not have adequate carrying capacity for the Total Suspended Solids and Turbidity parameters, which are indicators of river water quality. This is due to increased pollution caused by bridge construction and sand mining activities around the river. To address the environmental damage caused by the Maruni limestone mining operation, an integrated coastal management program is needed to achieve sustainability in the affected areas.

Keywords: Maruni river, quality standards, mining, management, coast.

1. INTRODUCTION
Maruni Town is authoritatively found in South Manokwari Locale Manokwari Rule West Papua Territory. South Manokwari Locale is one of 9 locale in Manokwari Rule, with an range of ±2,812.44 km^2 found between 0°57'46.4" - 0°59'39.0" S and 133°59'46.4" - 134°01'39.2" E, with an normal elevation of - 2,897 meters over ocean level (Patandianan, 2020). The Maruni Stream that streams through this town could be a cross-district stream that begins within the Arfak Mountains and streams through Manokwari Regency, with a length of 96 km^2. The Maruni Waterway may be a squander transfer location produced from limestone mining exercises and family squander, so it frequently causes floods that immerse gardens and encompassing settlements (Bungin et al., 2023; Patimah et al., 2024).

Mining activities in the area often ignore government-set procedures, resulting in violations of designated mining areas. As a result, mining waste and unused minerals are usually dumped directly into water bodies, potentially degrading river water quality and affecting various uses such as household consumption and irrigation (Basri et al., 2022; Emelly et al., 2024). Similar concerns have been raised in other mining-impacted areas, where exploitation of mineral resources has led to increased levels of metals and nutrients in surrounding water bodies, jeopardizing their benefits (Meck et al., 2009). To gain a comprehensive understanding of the current impacts of mining

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activities on the water quality of the Maruni River, researchers will analyze the collected data and compare the results with relevant water quality standards.

Maruni Limestone Mining is a significant economic activity in Manokwari Regency West Papua Indonesia. However, this mining operation has significantly impacted the surrounding environment especially the surface water of the Maruni River (Apodaca et al., 2018; Saleh, 2021; Patimah et al., 2024). The Maruni River is a major waterway that flows through the mining area and is a vital resource for the local community, providing water for domestic, agricultural and other purposes. Mining activities have led to a decline in the river's water quality, threatening the ecosystem and the communities that depend on it. One primary concern is the impact of mining on the physicochemical properties of river water (Patimah et al., 2023).

Studies have shown that concentrations of chemicals such as cyanide can exceed safe drinking water limits, endangering local residents' health (Patimah et al., 2022). Furthermore, mining activities have resulted in changes in river hydrology with increased sedimentation and erosion disrupting the natural flow of water. These changes have cascading impacts on aquatic ecosystems, affecting biodiversity and the livelihoods of communities dependent on river resources. The effect of Maruni limestone mining on surface water in the Maruni River is a complex issue that requires a comprehensive approach to address environmental and social consequences (Suhernomo et al., 2023).

Mining activities include extraction, leaching, tailings disposal and topsoil removal. Can have significant impacts on the physical, chemical and biological characteristics of soil and water (Emelly et al., 2024). Communities around the Maruni limestone mining area and those living near the mouth of the Maruni River have complained that mining waste often enters the Maruni River causing turbidity problems during rainy seasons. The Maruni River is the primary water source for various community needs such as bathing, drinking, washing and fishing. Understanding the current water quality and the impact of limestone mining activities on the river is essential to ensure the sustainable use of this valuable resource.

Limestone mining around the Maruni Stream has raised concerns among nearby communities approximately potential natural impacts. The release of mining squander and collection of stagnant water from the mine pits have been watched to influence the water quality of the waterway, which is an critical water source for the encompassing towns (Saleh, 2021; Maddala et al., 2021). The most objective of this ponder is to evaluate the affect of limestone mining on the surface water quality of the Maruni Stream. This ponder will utilize the Water Contamination Index method, as sketched out within the Proclaim of the Serve of Environment No. 115 of 2003, to decide the water quality status of the Maruni Stream. This ponder will analyze water tests taken from different areas along the waterway upstream and downstream of the mining location (Famiyeh et al., 2020). The impact of mining exercises on encompassing water bodies may be a common issue in numerous locales, as ponders within the Philippines and Peru have appeared. Disintegration of water quality, decreased trim efficiency and sedimentation of channels and waterways are a few of the watched results of mining within the zone. (Yuslem et al., 2022; Saleh, 2021).

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The results of this study will provide valuable insights into the environmental consequences of limestone mining activities in the Maruni River Basin. The data collected will be used to develop appropriate mitigation strategies and environmental management plans to ensure local communities' sustainable use of river resources. Similar studies on the impact of mining activities on surface water quality in other areas of Indonesia support this study. Deterioration in water quality can have significant impacts on local ecosystems and communities that depend on rivers for their livelihoods. To address the environmental damage caused by Maruni limestone mining operations, an integrated coastal management program is needed to achieve sustainability in the affected areas.

2. METHOD

This think about was conducted in September 2024, by taking water tests from three areas along the Maruni Stream and analyzing them within the research facility. This consider employments a subjective inquire about technique, utilizing the Water Quality File to evaluate water quality at three examining focuses. Three water quality parameters were measured: Add up to Suspended Solids, Turbidity and Broken down Oxygen (Basri et al., 2022; Patang et al., 2018; Pari-Huaquisto et al., 2020; Apodaca et al., 2018). The areas of water inspecting were at a few focuses along the Maruni Waterway. The facilitates of the testing focuses can be seen in Table 1 and Figure 1 inspecting areas.

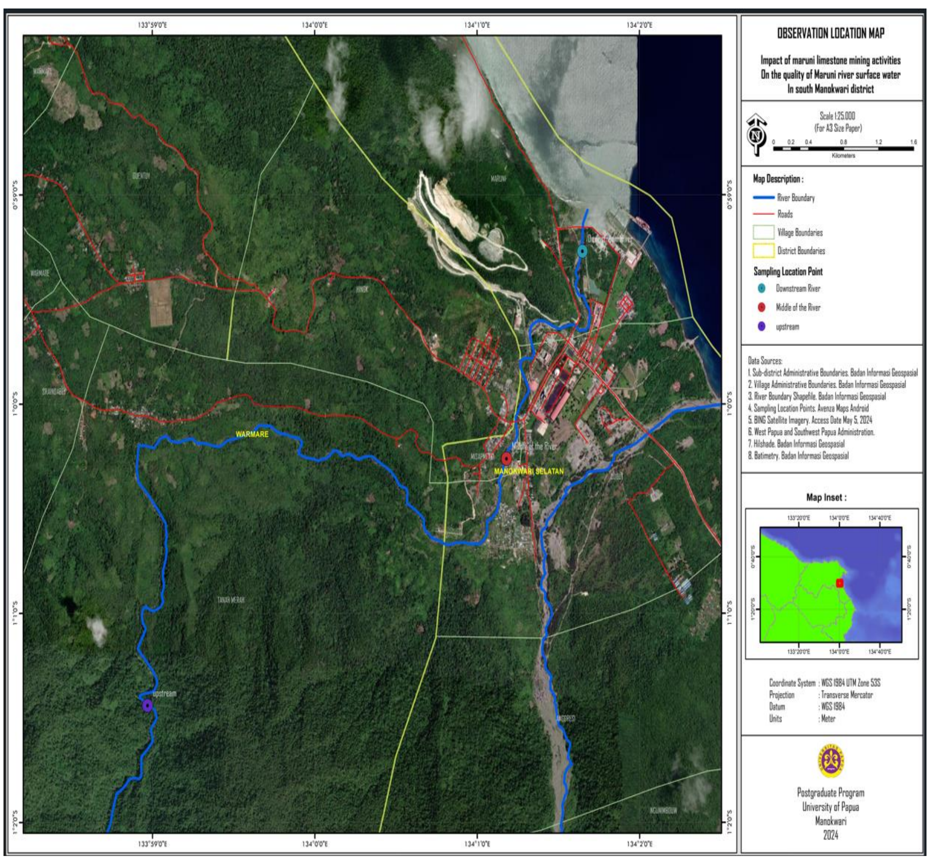

Figure 1. Map of Research Locations and Sampling

Table 1 Coordinate Points for Sampling

Location Description	Coordinate Points
Point 1 Upstream	Lat -1,005212^o
	Long 134.019469^o
Point 2 Middle	Lat – 0, 998465^o
	Long 134. 020659^o
Point 3 Muara	Lat – 0,98498^o
	Long 134. 022742^o

Water quality is an important factor in maintaining ecological balance and ensuring the safety of water resources. Various environmental dynamics influence water quality, such as pH, temperature, turbidity, nutrient levels, hardness, alkalinity and dissolved oxygen content (OS & Udongwo, 2021). Assessment of the physicochemical parameters of water is very important to determine the level of acceptance of water for consumption, irrigation and other purposes (OS & Udongwo, 2021). Surface water quality analysis can be carried out using various methods and tools (Meybeck & Helmer, 1989). This can be seen in the following table

Table 2 Water Quality Test Methods

No	Parameter	Methods/Tools
A	**Physics**	
1	temperature	Thermometer
2	Electrical Conductivity	Conductivity meter
3	Suspended Solids (TSS)	APHA, 20th Ed., 19992540 C
4	Dissolved Solids (TDS)	APHA, 20th Ed., 19992540 C
5	Turbidity	Turbidity Meter
B	**Inorganic Chemistry**	
1	PH	PH meter
2	DO	DO meter
3	COD	HACH Method, 8000
C	**Microbiology**	
1	Total Coliform	MPN

The common strategy utilized to evaluate water quality status is the Contamination File strategy. This strategy includes assessing all water quality parameters to decide whether they meet or surpass the built up quality guidelines (Nath et al., 2020). The fundamental rule of the Contamination Record strategy is to compare the gotten water quality information with significant water quality benchmarks, in agreement with appropriate directions or approaches (Nath et al., 2020; Xu et al., 2020). The Contamination File Esteem is decided by deciding the status of clean water quality. The Contamination File strategy could be a widely used approach to survey water quality. The essential guideline of the Contamination Record strategy is to relate the level of

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contamination from great to exceptionally contaminated by considering whether waterway water meets the necessities for a specific reason, based on the chosen parameter values (Harun et al., 2021). In expansion, the data is utilized to explore issues related to the utilize of sullied records. Diverse water quality limits are connected within the Contamination File strategy, so when utilizing this strategy the normal esteem of all Ci/Lij proportions is required to decide the extent of contamination. Be that as it may, this esteem may not be significant on the off chance that one of the Ci/Lij or Lij values surpasses 1. Hence, this note incorporates the most elevated Ci/Lij esteem. The equation utilized to decide the contamination level is as takes after:

$$IPi = \sqrt{\frac{\left(\frac{Ci}{Lij}\right)^2 + \left(\frac{Ci}{Lij}\right)^2}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

L_{ij} = Clean water quality criteria contained in national standards for water use (j)
C_i = Clean water quality criteria in the field
P_{ij} = Designation pollution index (j)
$(C_i/L_{ij})_M$ = Value, Maximum Ci/Lij
$(C_i/L_{ij})_R$ = Value, Ci/Lij average

Water quality evaluation is an vital viewpoint of natural administration, because it specifically influences the appropriateness of water assets for different purposes. One of the broadly utilized methods for assessing water quality is the Water Contamination List, which straightforwardly relates the level of water contamination to a set threshold value, as appeared within the taking after table:

Table 3 Pollution index values

No	**Index Value**	**Index Value Description**
1	$0 \leq PIj \leq 1$	Good condition
2	$1 < PIj \leq 5$	Light Pollution
3	$5 < PIj \leq 10$	Moderate Pollution
4	$PIj > 10$	Heavy Pollution

Source: Decree of the Minister of Environment and Forestry No. 115 of 2003

The Water Pollution Index provides a comprehensive assessment of the overall water quality status at a given location, considering multiple water quality parameters (Nath et al., 2020; Xu et al., 2020; Divya & Soloman, 2021). These indices serve as valuable tools for decision-makers, helping them prioritize interventions and allocate resources effectively (Sullivan et al., 2003). The development and utilization of water quality indices, such as the Water Pollution Index, has been the focus of extensive research. These indices combine multiple water quality indicators into a single measure, allowing for a more holistic understanding of the level of water pollution. The Water Poverty Index, for example, integrates physical, social, economic and environmental aspects related to water accessibility and use, making it particularly relevant at the community or sub-basin scale. (Sullivan et al., 2003) Continuous monitoring of river systems is essential to evaluate

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the impact of environmental factors on water quality, to ensure sustainable development and proper utilization of water resources (Nath et al., 2020). The water quality status can be easily understood by applying the Water Pollution Index and the suitability of water resources for various beneficial uses can be determined.

3. DISCUSSION

Limestone mining such as quarrying, washing, tailings disposal, and topsoil removal. Can have significant impacts on the physical, chemical and biological characteristics of soil and water quality (Meck et al., 2009). According to information gathered from local communities near the Maruni limestone mining area and those living near the mouth of the Maruni River. Effluents from limestone mining often enter the Maruni River, causing turbidity during rainfall as the mine pits fill with water (Meck et al., 2009). The Maruni River serves as a major water source for the surrounding communities who rely on it for bathing, drinking, washing and fishing (Ramachandran, 2018). Researchers have found that mining activities can lead to increased conductivity, iron, manganese, nitrate and water hardness in rivers downstream of mining operations. (Meck et al., 2009) In addition, wastewater discharge and sedimentation of mining waste can carry various pollutants such as heavy metals and nutrients, into rivers, potentially degrading water quality and affecting its suitability for domestic and recreational use. To address this issue, it is important to assess the current surface water quality of the Maruni River and understand the extent of the impact of limestone mining activities.

3.1. RESULTS

Observing the level of surface water contamination within the Maruni Waterway. The comes about of the consider displayed in this paper can be utilized as a reference for checking the level of surface water contamination within the Maruni Waterway. The government can too use the information collected and analyzed to address long-term negative impacts of water contamination within the Maruni Waterway. Contamination of surface water bodies such as waterways has gotten to be a far reaching natural issue, with critical suggestions for environmental frameworks and human wellbeing (Egbueri & Unigwe, 2020; Patil, 2019). Improper disposal of solid waste along river banks is a major contributor to this problem causing problems such as water pollution, unpleasant odors and various other forms of environmental damage. Surface water pollution can also have far-reaching consequences impacting public health, food security and economic activities (Patil, 2019).

Environmental impact assessments of surface water pollution have been conducted to address this issue. These studies have highlighted the importance of monitoring water quality parameters, understanding the spatial and temporal variability of pollutants, and implementing effective remediation strategies. Furthermore, the collection and analysis of comprehensive datasets can provide Valuable insights to policy makers and environmental managers. enabling them to develop evidence-based policies and interventions to mitigate the negative impacts of water pollution. In the context of the Maruni River, this study aims to contribute to this growing body of knowledge by providing a detailed assessment of the current state of surface water quality and its potential environmental consequences. As follows

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3.1.1. River Water Quality

River water quality is essential in determining its suitability for domestic and agricultural use. Assessment of parameters such as temperature, pH, total hardness, chloride, phosphate, nitrate and heavy metals such as arsenic, cadmium, chromium, copper, molybdenum, nickel and zinc is essential to understand the level of river pollution (Rahayu et al., 2020; Nalado et al., 2018). Previous studies conducted in the Chunies River in South Africa and the Jiulongjiang River in China have highlighted the importance of evaluating chemical and microbial water quality parameters to determine its suitability for domestic and agricultural use (Nalado et al., 2018; Adilah & Nadia, 2020; Patang et al., 2018). This study was conducted at three points along the Maruni River which flows through an area with workshop centers, cement storage and limestone mining centers in the southeastern part of the watershed. The Maruni River water quality analysis results are presented in Table 4.

Table 4 Results of Maruni River Water Quality Analysis

No	Parameter	Quality standards	Unit	Analysis Results		
				Point 1	Point 2	Point 3
A	**Physics**					
1	temperature	± 3	^{0}C	28	29	31
2	Electrical Conductivity	1500	µS/cm	116	114	115
3	Suspended Solids (TSS)	50	mg/L	4	23	43
4	Dissolved Solids (TDS)	1000	mg/L	0,21	0,20	0,22
5	Turbidity	25	NTU	2,10	26,5	30,6
B	**Inorganic Chemistry**					
1	pH	6-9		8,7	8,6	6
2	DO	4	mg/L	6,2	6,8	6,7
3	COD	25	mg/L	6,99	7,87	8,75
C	**Microbiology**					
1	Total Coliform	5000	MPN	322	331	333

The Maruni River Basin is the site of limestone mining operations which has raised concerns about its potential impacts on the area's surface water quality. The study presented in this paper aims to assess changes in surface water quality parameters before and after the commencement of limestone mining activities in the Maruni River Basin. According to the information provided in the prompt, analysis of water quality parameters in the Maruni River before mining operations indicated that the values were within the water quality standards stipulated in Government Regulation No. 22 of 2022 for Class II water use (Okolo et al., 2018). However, after the commencement of limestone mining activities, the study revealed an increase in Total Suspended Solids levels, turbidity and a decrease in Dissolved Oxygen in the Maruni River with some parameters exceeding the stipulated water quality standards. These findings are consistent with observations reported in other studies on the impact of mining activities on surface water quality.

The unintentional discharge of mining waste into coastal lagoons has been shown to result in the formation of acid mine drainage and the introduction of particulates and dissolved heavy metals

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leading to toxicity in receiving water bodies. Similarly, a study conducted in a coal mining area in South Africa found that mining activities were associated with adverse impacts on raw water quality, with parameters such as pH, turbidity, total dissolved solids, and manganese levels being affected. Additionally, a study in Nigeria has documented contamination of surface water resources by heavy metals due to opencast mining activities with concentrations of arsenic, cadmium, copper, lead and zinc exceeding WHO permissible limits (Okolo et al., 2018). The observed decline in surface water quality in the Maruni River Basin is likely a result of mining operations which can result in the release of a variety of pollutants, including suspended solids, heavy metals, and changes in water chemistry.

3.1.2. IP Calculation Results for TSS, Turbidity, and DO Parameters
A. TSS Parameters
Suspended solids or total suspended solids, play an important role in aquatic ecosystems by affecting water clarity. High concentrations of suspended solids can block sunlight penetration into the water, limit the ability of aquatic organisms to photosynthesize and disrupt the ecosystem as a whole (Svobodova, 1993). Research conducted in the Maruni River revealed that the concentration of total suspended solids varied significantly along the river. At the first sampling point, the TSS concentration was measured at 4 mg/l, while at the second and third points, the values were 23 mg/l and 43 mg/l, respectively. This concentration is close to the water quality standard for Class 2 rivers, which is set at 50 mg/l according to Government Regulation No. 22 of 2021 (Plecha et al., 2014). The high TSS values observed in the Maruni River can be attributed to several factors. The discharge of domestic waste into the river is likely one of the causes, as indicated by previous studies (Haby & Loftis, 2001). In addition, the influx of suspended solids from upstream tributaries and the presence of gravel mining activities in the river may also increase TSS levels especially at the third sampling point. (Omo-Irabor & Olobaniyi, 2010)

Similar patterns of high suspended sediment concentrations in the upstream areas during tidal conditions have been observed in other coastal lagoon systems, where proximity to river inputs and the influence of tidal dynamics contribute to the spatial and temporal variability of suspended solids (Plecha et al., 2014). Additionally, studies in the Sundarbans region have shown that long-term variations in water quality such as salinity and pH, can also influence the distribution and transport of suspended solids in river systems (Burman et al., 2019). The findings of this study highlight the importance of understanding suspended solids dynamics and their impact on water clarity in the Maruni River. Targeted efforts to address sources of suspended solids such as controlling domestic waste discharge and managing gravel mining activities, can help improve water quality and the ecological health of the river system (Burman et al., 2019; Yamamoto et al., 2018).

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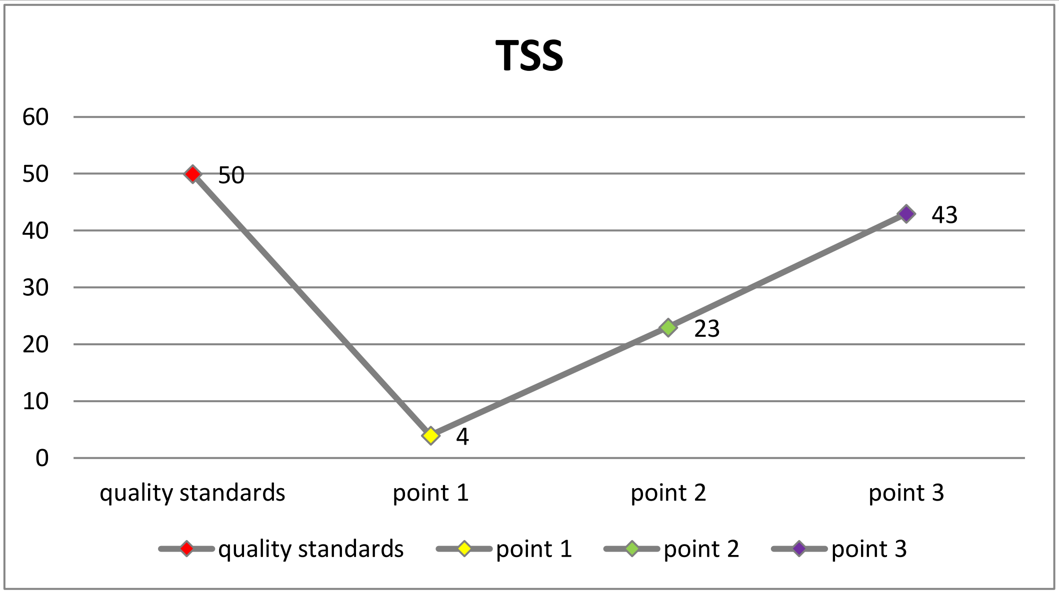

Figure 2 Data from the results of measuring the TSS parameters of the Maruni River

B. Turbidity Parameters

Turbidity in water bodies is significant because it is directly related to water clarity. The presence of turbidity can block or reduce the penetration of sunlight into the water (Yamamoto et al., 2018). The results of turbidity parameter measurements in the Maruni River showed a concentration of 2.1 mg/L at the first sampling point, 26.5 mg/L at the second point and 30.6 mg/L at the third point. The concentrations at the second and third points exceeded the Class 2 river water quality standard of 25 mg/L according to Government Regulation No. 22 of 2021 (Patang et al., 2018).The high turbidity level can be associated with the entry of domestic waste into the river (Omo-Irabor & Olobaniyi, 2010)

Maruni River the turbidity concentration at the third sampling point located near the residential area. Was significantly higher than the first point, which may be due to the influx of domestic waste and the influence of small tributary inflows and gravel mining activities in the river (Omo-Irabor & Olobaniyi, 2010; Nalado et al., 2018). Benthic macroinvertebrate diversity has been used as a bioindicator to evaluate water quality in various rivers (Patang et al., 2018). For example, in the Karang Mumus River the dominance of Chironomus sp. and Melanoides tuberculata indicates polluted conditions (Patang et al., 2018). Similarly, physical habitat assessment and benthic macroinvertebrate diversity in the Musi River indicated poor water quality conditions (Patang et al., 2018; Trisnaini et al., 2018).

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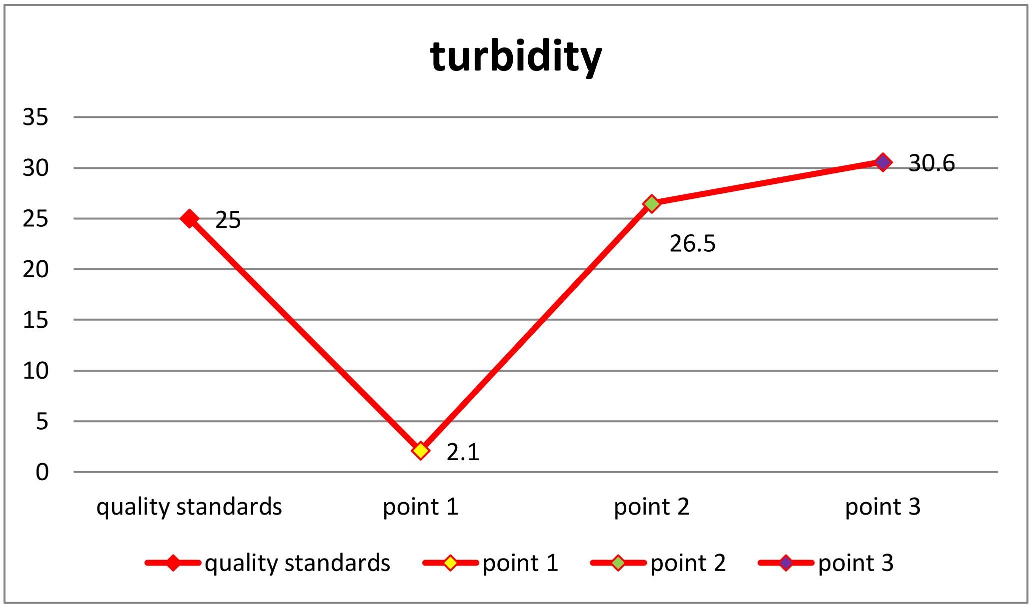

Figure 3. Data from the results of measuring the turbidity parameters of the Maruni River.

C. DO Parameters

Broken down oxygen can demonstrate the degree or level of squander contamination in water bodies (Xu et al., 2021). The higher the broken up oxygen, the lower the level of squander contamination (Viji et al., 2017). Waters can be categorized as great and have moo contamination on the off chance that the DO concentration surpasses 5 mg/l (Garcia et al., 2013). The comes about of DO estimations within the Maruni Stream itself appear that the DO concentration meets the Course 2 stream water quality measures of 4 mg/l (Viji et al., 2017; Bate et al., 2004). The comes about of the DO parameter examination are displayed in Figure 4, nitrogen observing in streams more often than not employments sensor checking and research facility testing. Be that as it may, a arbitrary forest-based forecast system has been proposed as an elective to research facility testing for water quality checking (Xu et al., 2021). Pond supervisors have to be get it that broken up oxygen is an critical water quality figure, because it can offer assistance deliver high-quality angle by keeping up ordinary oxygen levels (Garcia et al., 2013). Moo broken down oxygen levels can rapidly result in tall push in angle, disappointment of the nitrification biofilter, and noteworthy angle misfortunes.

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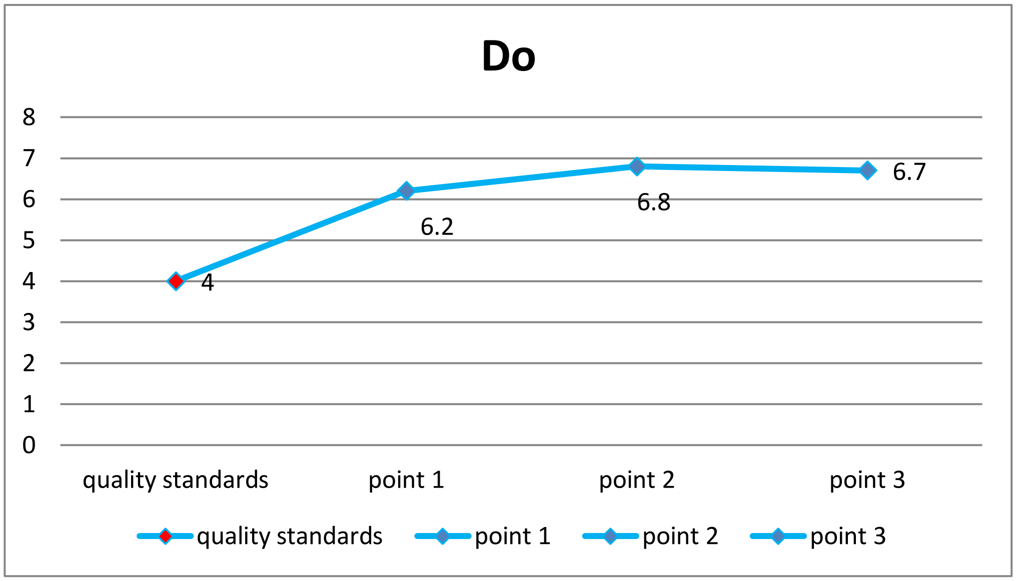

Figure 4 Maruni River measurement data DO parameters

According to the results of the analysis, the turbidity levels at two of the three sampling points along the river exceeded the water quality standards stipulated in government regulation PP No. 22 of 2022 (Hadian et al., 2017). In addition, the total suspended solids levels at the same two points were found to be close to the maximum permissible levels for Class II air as stipulated in the same regulation (Patang et al., 2018). This suggests that the river may have reached its capacity to accommodate the sediment load it receives, potentially leading to increased sedimentation and decreased carrying capacity (Patang et al., 2018; Nalado et al., 2018). The high levels of suspended solids are of particular concern, as they can cause river sedimentation. This rapid sedimentation has the potential to reduce the river's ability to handle future sediment loads, leading to further declines in air quality and ecosystem health (Patang et al., 2018). Based on the results of this analysis, it underlines the need for immediate action to address the problems of air quality and sedimentation in the Maruni River. Steps to reduce the input of suspended solids and turbidity pollutants, as well as to manage river sediment loads should be a priority for local governments and stakeholders. The graph of the third point is as shown in the following figure.

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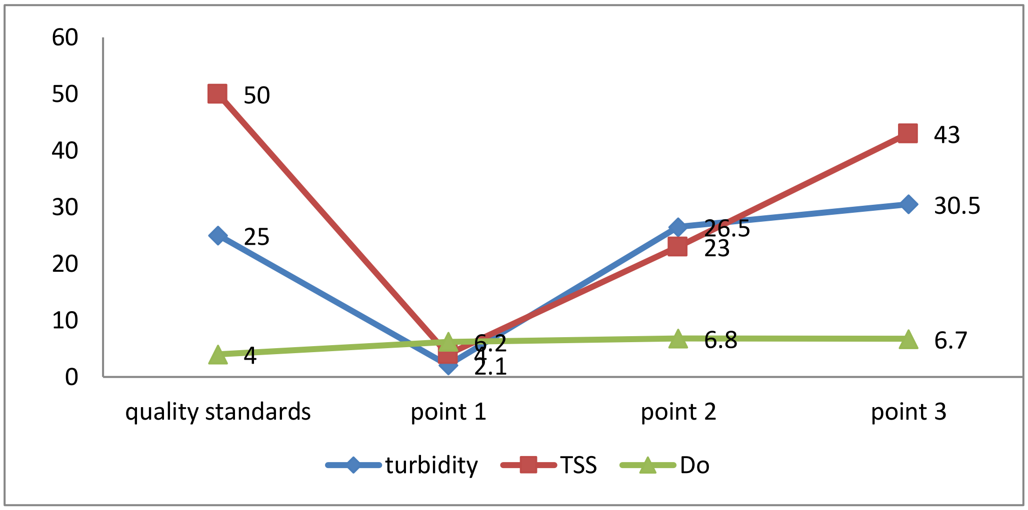

Figure 5 Maruni River parameters points 1,2 and 3

3.2. Environmental Impact of Limestone Mining in the Maruni River Basin

The extractive nature of mining operations creates a variety of environmental impacts before, during and after the mining process (Barabadi & Lu, 2015). These impacts include air, water and soil pollution, loss of biodiversity, land degradation, depletion of natural resources, occupational health hazards, waste disposal and groundwater depletion issues (Maddala et al., 2021). Mining activities can also release hazardous gases such as sulfur oxides, nitrogen compounds and hydrogen sulfide contributing to air pollution and acid rain negatively impacting endangered flora and fauna (Maddala et al., 2021). Furthermore, over-exploitation of minerals can lead to surface and groundwater pollution which affects sustainable development (Maddala et al., 2021).

In a study of a limestone mine in Neka, Iran the main environmental impacts examined included dust distribution ground vibrations due to drilling and blasting, and soil erosion (Barabadi & Lu, 2015). Another study in Indonesia reviewed the impact of gold mining on the water quality of the Sako River reporting significant increases in turbidity, total dissolved solids, and heavy metal concentrations downstream of the mining site. To mitigate these environmental impacts, adopting green mining techniques such as using more energy-efficient equipment, water recycling and proper waste management is essential. To address the ecological damage caused by the Maruni limestone mining operation, an integrated coastal management program is needed to achieve sustainability in the affected area.

4. CONCLUSION

The comes about of the investigation of the water quality status of the Maruni Stream appeared a marginally contaminated condition with an record extending from 2.26 to 3.78 at the three estimation focuses. The Maruni Waterway does not have satisfactory capacity for the Entire Suspended Solids and turbidity parameters, coming about from expanded contamination from bridge development and sand mining exercises around the stream. Diminished water quality, decreased plant efficiency and sedimentation of channels and rivers are a few results watched from mining within the range. To overcome the natural harm caused by the Maruni limestone mining operation, an coordinates coastal administration program is required to realize maintainability within the influenced area. This consider appears that the chemical quality of the Maruni Waterway water is influenced by mechanical and mining exercises within the encompassing region. Assist inquire about is required to completely get it the level and sources of contamination within the Maruni Waterway and to create fitting relief techniques.

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