Pak. j. life soc. Sci. (2024), 22(2): 21052-21064 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2024-22.2.000201

RESEARCH ARTICLE

Assessment of the Impact of Sand Mining on Land Change and Water Quality in the River Bila, South Sulawesi, Indonesia

Muh Assabul Kahfi Selman[1*], Usman Arsyad[2], St. Fauziah[3]

[1] Department of Environmental Management, Graduate School, Hasanuddin University, Makassar 90245, Indonesia

[2] Faculty of Forestry, Hasanuddin University Makassar 90245, Indonesia

[3] Department of Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University, Makassar 90245, Indonesia

ARTICLE INFO

Received: Sep 22, 2024

Accepted: Dec 16, 2024

Keywords

Sand Mining

River Morphology

Water Quality

Pollution Index

***Corresponding Author:**

kahfiashabul432@gmail.com

ABSTRACT

Sand mining in the Bila River has resulted in changes to the river area and decreased water quality. This research emphasizes the novelty aspect by simultaneously emphasizing two aspects, namely river morphology and water quality. In addition, this research combines geomorphological and hydrological approaches in detail to combine river morphology mapping and water quality analysis in areas that have never been explored. This study aims to determine the impact of sand mining activities on changes in the shape of the river area and water quality of the Bila River in Sidenreng Rappang Regency. The results showed changes in the shape of the area that occurred in the Bila River for ten years by analyzing every five years in 2014, 2019, and 2024 of 25.8 Ha, while the results of water quality observations showed turbidity concentrations ranging from 47.98-93.33 NTU, Total Suspended Solids (TSS) ranging from 38-70 mg/L, temperature ranging from 28.4-30.4 0C, pH ranging from 7.36-7 42, Dissolved Oxygen (DO) ranges from 3.51-5.22 mg/L, Biological Oxygen Demand (BOD) ranges from 2.64-3.64 mg/L and Chemical Oxygen Demand (COD) ranges from 14-32 mg/L shows by using the pollution index analysis method with a value range of 0.24-0.46 using third class quality standards based on government regulation number 22 of 2021 appendix six concerning national water quality standards can be categorized in good condition. This research can be a reference for local governments conducting environmental monitoring and reclamation in areas experiencing river changes.

INTRODUCTION

The Bila River in Sidenreng Rappang District, South Sulawesi, is an essential natural resource that sustains the lives of local communities, especially for agricultural irrigation and freshwater fisheries [Hallatu et al., 2021]. However, intensified sand mining activities in the area have triggered significant changes to the river ecosystem, particularly in river morphology and water quality [Abdelrazek & Abdallah El Naka, 2022]. This phenomenon is an increasingly pressing environmental issue, given that sand mining is often not accompanied by adequate management policies [Daley, 2024], potentially permanently damaging aquatic ecosystems [Koehnken et al., 2020].

The Bila River in Sidenreng Rappang District, South Sulawesi, is an important natural resource that sustains the lives of local communities, especially for agricultural irrigation and freshwater fisheries. However, intensified sand mining activities in the area have triggered changes to the river ecosystem, particularly in relation to river morphology and water quality This phenomenon is an increasingly urgent environmental problem, given that sand mining is often not accompanied by adequate management policies, thus potentially damaging aquatic ecosystems permanently.

Globally, the impact of sand mining on river morphology and water quality has been the focus of numerous studies[Deng et al., 2022]. Several studies reveal that these activities cause bank erosion, increased sedimentation, and degraded water quality through increased total suspended solids (TSS) and water turbidity [Bari & Haque, 2022]. Furthermore, changes in flow patterns due to sand mining accelerate the degradation of aquatic ecosystems, including a decrease in dissolved oxygen (DO) concentrations, adversely affecting aquatic biota's life [Daley, 2024]. This condition can disrupt biodiversity and reduce the quality of the environment, which depends on rivers as a source of clean water [J. Shaji, 2021].

Although a number of studies have explored the impacts of sand mining in various regions, there are very limited studies that integrate comprehensive analysis of river morphology and water quality using satellite imagery in Indonesia [Abdulaziz Alhassan et al., 2022]. Previous studies have often focused on measuring water quality or changes in river morphology separately without considering the interconnectedness of the two in the context of long-term mining activities [Suwatanti et al., 2022], such as Nwobondo et al's (2021) study on the impact of sand mining on land use/land cover on river environments in developing countries: Case study of Ava River in Enugu State, Nigeria, Gandaria et al (2023) on Biophysical Environmental Impact Analysis of Sand Mining in Mawasangka District, Central Buton Regency. This GAP (research gap) shows that few studies in Indonesia utilize remote sensing technology to monitor changes in river morphology regularly and relate them to the decline in water quality due to sand mining activities. [Farhan et al., 2024].

This study aims to provide a comprehensive evaluation of the impact of sand mining in Sungai Bila on river morphology and water quality and provide a scientific basis for formulating more effective and sustainable environmental management policies. The findings of this study are also expected to increase the awareness of stakeholders and the general public about the importance of environmentally friendly mining practices and the preservation of river ecosystems.

MATERIALS AND METHODS

Research design

This study used a descriptive quantitative approach to evaluate the impact of sand mining on river morphology and water quality in Bila River, Sidenreng Rappang Regency, South Sulawesi [Bayazidy et al., 2024]. This study uses a longitudinal method, where changes in river morphology are monitored over ten years (2014, 2019, and 2024) by utilizing Google Earth Pro satellite imagery [Hunter et al., 2024]. In addition, water quality measurements were conducted through sampling at four observation stations selected based on strategic locations related to sand mining activities [Abdulaziz Alhassan et al., 2022].

Location and time of research

This research was conducted in Bila River, Bila Riase Village, Sidenreng Rappang Regency, South Sulawesi. This location was chosen due to the high intensity of sand mining activities, significantly affecting the river ecosystem. Data was collected from February to June 2024 to monitor changes in river morphology and water quality [Li et al., 2022].

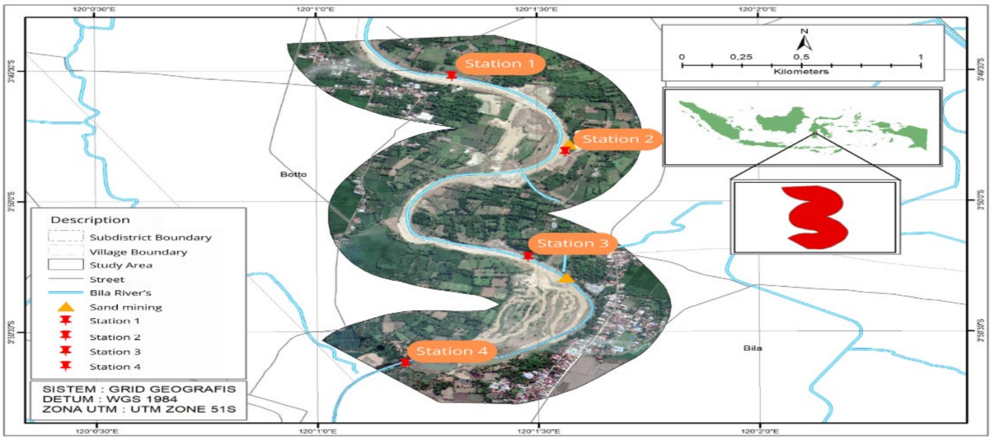

Figure 1: Study area map

Figure 1 shows the location map of the study area, which covers the area along the Bila River with four sampling station points scattered along the area before, during, and after sand mining activities [Davies et al., 2020].

Water quality sampling stations were located along the Bila River, as described in Table 1, to provide a comprehensive representation of the impact of mining activities on water quality at different locations [Kamboj & Kamboj, 2020].

Table 1: Sampling locations

Station	**Coordinates**		**Description**
	X	**Y**	
1	120,021905	-3,825405	Before the mining area
2	120,026158	-3,830233	Mining Area
3	120,024744	-3,836945	Mining Area
4	120,020089	-3,843736	After the mining area

Table 1 describes the X and Y coordinates of stations 1, 2, 3, and 4 with X coordinates of 120.021905, 120.026158, 120.024744, and 120.020089, respectively. Meanwhile, the Y coordinates at each station from station 1 to station 4 are -3.825405, -3.830233, -3.836945, and -3.843736 [Chen et al., 2021] This value is based on the station's location before the mining area, the mining area, and the area after mining [Stets et al., 2020]. Hallatu et al. (2021) describe that X and Y coordinates are used in mapping the area's morphology and physical structure accurately on the map so that data regarding changes in the shape of the area can be analyzed quickly and efficiently.

River morphology data collection

Collecting data on changes in river morphology by *stratified random sampling* is a practical approach in environmental research, especially by using satellite images and GIS such as ArcGIS [Jati & Pratomo, 2021]. This approach groups the population into homogeneous strata to improve the estimation accuracy. High-resolution satellite images from Google Earth Pro were processed using on-screen digitization in ArcGIS 10.8 to ensure geometric accuracy [Rofikha et al., 2024]. Bari et al. (2022) explained that using Google Earth Pro provides convenience in analysis, morphological and mapping studies, and temporal resolution within a certain time interval. Manual digitization was conducted to identify land use types (vegetation, open land, settlements, water bodies) by visual interpretation, which was then analyzed between periods using post-classification comparison to detect land use change [R. Li et al., 2020]. Overlay analysis with the “Union” or “Intersect” tools in ArcGIS enables data integration to understand environmental interactions better. Describes the overlay analysis approach in providing an in-depth understanding of land change and its impact on the environment and resource management through geographic information systems (GIS) by combining multiple layers of spatial data based on their geographic location.

Water quality data collection

Water quality data collection is carried out at four observation stations determined based on strategic locations, covering areas before, during, and after sand mining activities [Jati & Pratomo, 2021]. Water quality parameters measured include turbidity, Total Suspended Solids (TSS), temperature, pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) [Hunter et al., 2024]. Bayazidy et al. (2024) suggested that measuring water quality parameters is critical in understanding the health conditions of the aquatic environment and monitoring human activities such as mining, industry, and other related sectors so that the parameters can be determined through laboratory tests.

Each sample is taken by the Indonesian National Standard (SNI) and analyzed using standardized methods [Indriyani et al., 2020]. Temperature and pH measurements were conducted *in situ* at the sampling location using a portable device, while other parameters were analyzed in the laboratory. Samples for TSS and turbidity were stored in the dark at ≤ 6°C and analyzed within 24 hours after collection [Arsyad et al., 2020]. DO was measured through the iodometric titration method, while BOD and COD were analyzed using the potentiometric method and UV-VIS spectrophotometry

[Indriyani et al., 2020]. Kamboj et al. (2020) analyzed water samples to test water quality based on the parameters of temperature, DO, BOD, COD, turbidity, and their heavy metal analysis in periodic laboratory tests.

To maintain the accuracy of the results, samples were treated according to standard procedures. Temperature and pH measurements were taken *in situ* [Stets et al., 2020]. The samples for turbidity and TSS parameters were analyzed on the same day. Water samples for DO were acidified before titration, while BOD and COD samples were stored at ≤ 6°C before being analyzed in the laboratory [Ward et al., 2020].

Data analysis

The accuracy test process on land cover data is called overall accuracy with the following equation.

Table 2: Confusion matrix

Comparison		**Reference Data (Field Check)**			**Total**
		A	**B**	**C**	
Image Classification Result Data	A	X_n			ΣX_n
	B				
	C				
Total		ΣX_n			N

Description:

A, B, C : Reference data

A\`, B\`, C\`: Image classification result data

Xn : Data tested

ΣXn : Number of each reference data/image classification

N : Total data tested

After obtaining the data and compiling it in the confusion matrix percentage table, then the accuracy test will be carried out using the overall accuracy calculation [Tanjung et al., 2022], with equation (1).

$$OA = X/N \times 100\% \qquad (1)$$

Description :

X: Sum of the diagonal values of the matrix

N: Sum of matrix samples

Water quality analysis is carried out using the *Pollution Index* (*PI*) method which refers to the Decree of the Minister of Environment Number 115 of 2003 [Jayanto et al., 2021]. The pollution index was calculated for each observation station based on the measured water quality parameters, using the following formula:

$$PIj = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}}$$

Description:

(Ci/Lij) M is the maximum value of Ci/Lij

(Ci/Lij) R is the average value of Ci/Lij

The pollution index value is categorized into four classes according to the quality standards listed in Government Regulation Number 22 of 2021 concerning water quality standards [Eddiwan, 2020].

Table 3: Relationship between pollution index and water quality status

Pollution Index	Water Quality Status
0 ≤ IPj ≤ 1,0	Meets quality standards (Good Condition)
1,0 < IPj ≤ 5,0	Lightly polluted
5,0 < IPj ≤ 10	Moderately Polluted
IPj > 10	Heavily Polluted

Table 3 describes the relationship between pollution index and water quality status with different scales, ranging from 0 ≤ Ipj ≤ 1.0 (meeting quality standards) to IPj > 10 scale indeks, which has a heavily polluted water quality category. According to WHO (Word Health Organization), the pollution index in water quality standards varies based on the parameter, such as heavy metals have a maximum limit of 10 µg/L and the physical parameter of turbidity should not exceed 5 NTU [Pongoh et al., 2021].

This study also used person correlation analysis to identify the influence of river area changes due to mining [Oktavia et al., 2024] In addition, t-test statistical analysis was used to find the effect of water quality degradation around sand mining [Rendana et al., 2022].

RESULTS AND DISCUSSION

Changes in river area and land cover around the river

Based on the results of image classification in 2014, 2019 and 2024 in the river around sand mining, changes can be seen in Table 4.

Table 4: Land change

Land Type	2014		2019		2024	
	Land Area (Ha)	Percentage (%)	Land Area (Ha)	Percentage (%)	Land Area (Ha)	Percentage (%)
Shrubs	37,83	13,67	31,21	11,28	29,87	10,80
Dry Agricultural Land	152,38	55,08	114,32	41,32	110,11	39,80
Open Land	3,74	1,35	7,37	2,66	7,79	2,82
Market	0,35	0,13	0,53	0,19	0,53	0,19
Settlement	27,8	10,05	31,01	11,21	31,09	11,24
Swamp	0,18	0,07	0,18	0,07	0,18	0,07
Wet Agricultural Land	24,94	9,02	32,72	11,83	34,95	12,63
River	29,42	10,63	59,3	21,44	62,12	22,46
Total	**276,64**	**100**	**276,64**	**100**	**276,64**	**100**

Table 4 describes land use changes from 2014 to 2024 in a total area of 276.64 Ha. There is a significant decrease in shrubland, from 37.83 Ha (13.67%) in 2014 to 29.87 Ha (10.80%) in 2024, indicating a shift in land use. Dry agricultural land also experienced a sharp decline from 152.38 Ha (55.08%) in 2014 to 110.11 Ha (39.80%) in 2024, reflecting the same trend as shrubs, i.e., a reduction in the use of this land. In contrast, open land increased from 3.74 Ha (1.35%) in 2014 to 7.79 Ha (2.82%) in 2024, indicating areas left vacant or unused [Patrick Ozovehe Samuel & Mutiyat F. Alabi, 2022]. Research by Jayanto et al. (2021) found changes in land and river areas due to mining in Jayapura, Indonesia, using the multitemporal satellite image method to see changes in watersheds from 2020 to 2024 with changes in river areas from 34.78 Ha to 20.98 Ha.

Market land use increased slightly from 0.35 Ha (0.13%) to 0.53 Ha (0.19%) between 2014 and 2019 and remained constant until 2024. Residential land also experienced a moderate increase, from 27.8

Ha (10.05%) in 2014 to 31.09 Ha (11.24%) in 2024, which aligns with population growth. Swamp land did not change and remained at 0.18 Ha (0.07%) [Aprilia et al., 2023]. In contrast, wet agricultural land has increased from 24.94 Ha (9.02%) in 2014 to 34.95 Ha (12.63%) in 2024, indicating increased efforts to support more productive wet agriculture [Idomeh et al., 2019] Riverine land experienced the most significant increase, from 29.42 Ha (10.63%) in 2014 to 62.12 Ha (22.46%) in 2024, which may be due to the expansion of water areas or changes in the shape of river flows [Zhi et al., 2021] Overall, land use change is more likely to reduce the area of shrubs and dry agricultural land while increasing land use for wet agriculture, settlements, and water bodies (Aprilia et al., 2023). The total land area did not change, remaining at 276.64 Ha, indicating that the changes occurred were shifts between existing land types [Hu et al., 2022]. Rendana et al. (2022) explained that this land change was caused by the erosion of heavy mining equipment and increased erosion due to increased water pressure along with mining activities and natural nature. Changes in river land due to mining activities from year to year can be seen in Figure 2.

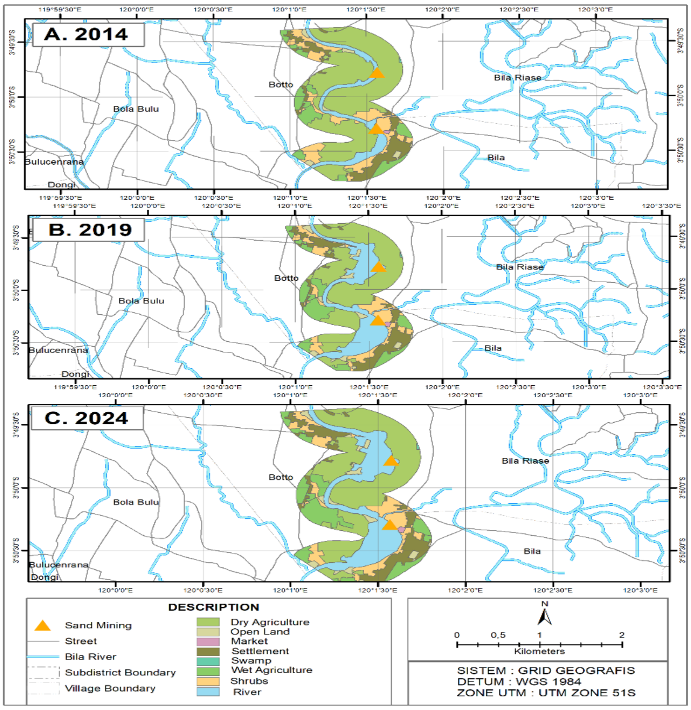

Figure 2: Land change

The results of land cover interpretation are then tested for accuracy of the classification results obtained by comparing land cover in the field through field surveys (ground truth). There are 76 coordinate points in the specified land cover class; the confusion matrix table can be seen in Table 5.

Table 5: Accuracy test matrix

Land Type	***Ground Truth)***									
	SH	**DA**	**OL**	**MK**	**SM**	**SW**	**WA**	**RV**	**Total**	***User's Accuracy (%)***
SH	17	2	0	0	0	0	0	0	19	89
DA	0	8	0	0	0	0	0	0	8	100
OL	0	1	14	0	0	0	0	0	15	93
MK	0	0	0	1	0	0	0	0	1	100
SM	0	0	0	0	15	0	0	0	15	100
SW	0	0	0	0	0	1	0	0	1	100
WA	0	0	0	0	0	0	11	0	11	100
RV	0	0	0	0	0	0	0	6	6	100
Total	17	11	14	1	15	1	11	6	76	0
Producer Accuracy (%)	100	73	100	100	100	100	100	100	0	73

Description:

🟦 : *ground truth* point values that match the image interpretation

SH : Shrubs

DA : Dry Agriculture

OL : Open Land

MK : Market

SM : Settlement

SW : Swamp

WA : Wet Agriculture

SG : River

Based on Table 5, the results of the *cunfusion* matrix are 73 points out of 76 sample points that match the interpretation results and field conditions [Karolina et al., 2022]. The accuracy parameters are shrubs (SH), dry agriculture (DA), open land (OL), market (MK), settlement (SM), swamp (SW), wet agriculture (WA), and river (RV) [Marlina & Melyta, 2019]. According to Zhi et al. (2021) describe certain parameters in analyzing the accuracy test matrix at several points by focusing on areas affected by mining such as agricultural sites, rivers, gardens, and settlements. To determine the level of accuracy in the land cover around the sand mining area in the river if in 2024 the *kappa accuracy* equation is carried out.

$$KA = \frac{N \sum_{i=1}^{r} xii - \sum_{i=1}^{r} xii + x + i}{N^2 \sum_{i=1}^{r} xii + x + i} X100\%$$

$$= \frac{4543}{4771} X100\%$$

$$= 95{,}22$$

The confusion matrix results obtained confidence in the results of the image interpretation kappa index value (*kappa accuracy)* 95.22% [Ward et al., 2020]. The acceptable level of accuracy of image interpretation is 85% [S. Li et al., 2022]. Strengthening the theory is done by Karolina et al. (2022), which explains that the level of confidence in the results of the Kappa index value is above the value of 95% - 100%, with a minimum index of accuracy reaching 85%.

Water quality analysis: The results of measurements and observations of water parameters at the research site from station 1 to station 4 are shown in Table 6.

Table 6: Analysis results of quality parameters

PARAMETERS	**SOURCE**	**METHODS**	**OBSERVATION RESULT (STATION)**				**REFERENCE**
			1	**2**	**3**	**4**	
Turbidity	NTU	Nefelometer	47,98	49,46	71,66	93,33	SNI 06-6989.25-2005
TSS (Total Suspended Solids)	mg/L	Gravimetry	38	40,4	56	70	SNI 6989.03-2019
Temperature	°C	Termometer	30	30,4	29	28,4	SNI 06-6989.23-2005
pH (Degree of Acidity)	-	Potensiometry	7,36	7,41	7,42	7,36	SNI 6989.11-2019
DO (Dissolved Oxygen)	mg/L	Yodometry	5,22	5,01	4,06	3,51	SNI 06-6989.14-2004

BOD (Biological Oxygen Demand)	mg/L	Titrimetry/ Potensiometry	2,64	2,86	3,64	3,64	SNI 6989.72-2009
COD (Chemical Oxygen Demand)	mg/L	Spectrophotometer UV-Vis	14	16	29,5	32	SNI 6989.02-2019

Table 6 describes the turbidity values at several river stations, ranging from 47.98 NTU to 93.33 NTU, indicating a significant variation in suspended particle levels along the river. Station 1, located before the sand mining area, showed the lowest turbidity level (47.98 NTU). In contrast, Stations 2 and 3, located in the sand mining area, experienced a gradual increase in turbidity, with values of 49.46 NTU and 71.66 NTU [Samlafo & Adakwah, 2021]. Station 4, located after the mining area, showed the highest turbidity level (93.33 NTU). This indicates that sand mining activities significantly contributed to increased sediment and suspended particles in the river [Rendana et al., 2022]. Research by Aprilia et al. (2023) found that river conditions in the DKI Jakarta area due to sand mining on the coast reached a turbidity level of 50.87 NTU based on the SNI (Indonesian National Standard) scale. TSS concentrations showed a similar pattern, with Station 1 recording the lowest TSS (38 mg/L) while Station 4 recorded the highest TSS (70 mg/L). This increase reflects the significant physical disturbance in the river due to mining activities, which accelerated erosion and particle transport [Indriyani et al., 2020]. Shi and Li (2024) explained that the TSS concentration of a water body is due to excessive industrial activities, so erosion and physical disturbance can increase the TSS value of the water body.

Table 6 also explains that the water temperature along the stations ranged from 28.4°C to 30.4°C and remained within the limits set for class 3 according to PP 22 Year 2021 [Hunter et al., 2024]. Station 1, before the mining area, showed stable thermal conditions. However, at Stations 2 and 3, temperatures remained consistent with little change, suggesting that sand mining may not significantly impact water temperatures [Rendana et al., 2022]. Aprilia et al. (2023) also produced a temperature value of DKI Jakarta river waters reaching 30.8oC under normal conditions. The pH values at all stations were relatively neutral, ranging from 7.36 to 7.52, indicating that mining activities did not significantly alter the chemical properties of the water. Sinaga et al. (2024) found water pH conditions in South Sumatra rivers with pH values reaching 8.6, which increased due to exposure to heavy metals used in mining. Dissolved oxygen (DO) values decreased gradually from Station 1 (5.22 mg/L) to Station 4 (3.51 mg/L), indicating a decline in water quality after passing through the sand mining area, possibly due to increased organic and sediment loads [Sahid & Zainab, 2024]. BOD and COD levels also increased from Station 1 to Station 4, indicating that sand mining increases the concentration of organic and chemical pollutants that reduce water quality downstream [Marlina & Melyta, 2019]. Although the water quality still complied with the class 3 quality standard, sand mining activities negatively impacted several water quality parameters [Majoro et al., 2020]. Scott et al. (2021) describe that COD, BOD, and DO values of water areas are affected by human activities such as industry and mining, although not significantly, but can affect various types of marine biota in the aquatic environment.

Pollution index (PI)

This study determined the River Water Pollution Index at four sampling locations by analyzing six parameters, including Temperature, Turbidity, TSS, DO, pH, BOD, and COD [Harmayani et al., 2023]. The quality standard used is the water quality standard based on the water class listed in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management [Sun et al., 2021]. The pollution index values obtained from the calculation results at four sampling locations are shown in Table 7.

Table 7: Calculation of pollution index (PI)

Station	Pollution Indeks (PI)

	Value	**Water Quality Status**
1	0,43	Good Condition
2	0,45	Good Condition
3	0,66	Good Condition
4	0,82	Good Condition

Based on the data in Table 7, the results of the Water Pollution Index (IP) calculation show that river stations 1 to 4 have good condition criteria. This can be seen from the highest pollution index at station 4, with a pollution index of 0.82, and the lowest pollution index at station 1, with a pollution index of 0.43 [Scott & Haggard, 2021]. The pollution index value of each station is at an index of $0 \leq IPj \leq 1.0$ based on the quality standards listed in Government Regulation Number 22 of 2021 concerning water quality standards, so each river station is classified as meeting quality standards (good condition) [Sahid & Zainab, 2024]. In addition, the value of the pollution index from stations 1 to 4 has increased [Sinaga et al., 2024]. This is due to the influence of mining in the river area, although it is not above the quality standard pollution threshold. Permana et al. (2023) also found the pollution index of river water in several regions in Indonesia with the pollution index in the good condition category (value = 0.67 - 0.80) based on reference to Government Regulation Number 22 of 2021 concerning water quality standards [Permana et al., 2023].

Statistical data test

Correlation coefficient analysis (R^2)

Table 9: Correlation coefficient of mine production to river area

Correlation coefficient (R^2)	
Variabel	**Nilai R^2**
Perubahan Luas Wilayah Sungai – Penambangan Pasir	0,97

Based on Table 9, the correlation coefficient value obtained is 0.97, so the relationship between mining production and river area shows a strong and positive relationship between the two variables [Ekoko Eric et al., 2023]. It can be seen that the value of r is close to 1, which means that it shows a perfect positive relationship, meaning that a proportional increase always follows every increase in one variable in the other variable [Torres et al., 2021]. When the river area increases, mining production also tends to increase. Conversely, mine production tends to decrease if the river area decreases[Pacheco et al., 2023]. Abirami et al. (2023) suggested that the correlation coefficient value has a strong correlation between 2 variables if it has a value above 0.5 (<0.5) to 0.99. The correlation coefficient helps see the relationship between variables in a particular group.

T-Test Analysis

The t-test results of mining impact data on river area before (variable 1) mining and after (variable 2) mining can be seen in Table 10 [Liu et al., 2021].

Table 10: T-Test analysis of the impact of mining on river area

	Variable 1	***Variable 2***
Mean	20,74286	28,14571429
Variance	319,7675	708,1174952
Observations	7	7
Pooled Variance	513,9425	
Hypothesized Mean Difference	0	
df	12	
t Stat	-0,61091	
P(T<=t) one-tail	0,276328	
t Critical one-tail	1,782288	
P(T<=t) two-tail	0,552656	

t Critical two-tail	2,178813	

Based on the t-test results data in Table 10, the degree of freedom (df) value is 12, and the t-stat is -0.61. The degree of freedom of 12 indicates the data used in the analysis [Mendes et al., 2023]. The t-statistic value shows the comparison between the means of the tested groups(Banze wa Mutombo et al., 2022). The negative value of t-stat = -0.61 indicates that the average impact before mining is lower than the average after mining on the river area [Ahmed et al., 2020]. However, a t-value close to zero (-0.61091) indicates that this difference is insignificant. Pacheco et al. (2023) found a t-stat = -0.78 from a t-test statistical analysis of pre- and post-mining impacts on the Brumadinho River, Brazil, so the significant difference is not very large.

CONCLUSIONS

Based on this research, the incorporation of river geography models and river water quality at the Bila Riase village sand mining site experienced significant changes over ten years from 2014 to 2024, with a river area of 25.8 and river water quality experiencing a decrease in river water quality as indicated by not exceeding the quality standards at all stations based on Class III river water quality standards according to Government Regulation Number 22 of 2021. The river water quality at that time, based on the analysis of river water quality using the pollution index method, did not show a significant decrease in water quality. In contrast, the sand mining site was in good condition. This encourages research towards successive analysis of the morphology of the river area and water quality so that the leading cause is found. The government can suppress both legal and illegal mining activities to create clean water conditions so that all aquatic biota can maintain their life cycle for the welfare of human life.

Acknowledgments: The authors would like to thank the supervisors, examiners, and all staff of the Oceanographic Chemistry Laboratory, Faculty of Marine Science and Fisheries, Hasanuddin University.

REFERENCES

Abdelrazek, S. A. E., & Abdallah El Naka, K. (2022). The Importance of Afforestation in Rehabilitation Degraded Lands in the State of Kuwait. *Alexandria Science Exchange Journal*, *43*(4), 503–509. https://doi.org/10.21608/asejaiqjsae.2022.264165

Abdulaziz Alhassan, Kudirat O. Yusuf, Aliyu A. Abdulazeez, & Salihu Usman. (2022). Iron Ore Tailings as Partial Replacement for Fine Aggregate in Concrete Production – Review. *International Journal of Engineering and Management Research*, *12*(4), 64–71. https://doi.org/10.31033/ijemr.12.4.10

Abirami, K., Radhakrishna, P. C., & Venkatesan, M. A. (2023). Water Quality Analysis and Prediction using Machine Learning. *2023 IEEE 12th International Conference on Communication Systems and Network Technologies (CSNT)*, 241–245. https://doi.org/10.1109/CSNT57126.2023.10134661

Ahmed, S. N., Anh, L. H., & Schneider, P. (2020). A dpsir assessment on ecosystem services challenges in the mekong delta, Vietnam: Coping with the impacts of sand mining. In *Sustainability (Switzerland)* (Vol. 12, Issue 22, pp. 1–29). MDPI. https://doi.org/10.3390/su12229323

Aprilia, M., Effendi, H., & Hariyadi, S. (2023). Spatial and temporal distribution of dissolved oxygen in the Ciliwung River, DKI Jakarta Province. *IOP Conference Series: Earth and Environmental Science*, *1260*(1), 012017. https://doi.org/10.1088/1755-1315/1260/1/012017

Arsyad, A., Rukmana, D., Salman, D., & Alimuddin, I. (2020). Impact of sand mining on the changes of morphological and physical dynamics in Sa'dang River, Pinrang District, Indonesia. *Journal of Degraded and Mining Lands Management*, *8*(1), 2451–2460. https://doi.org/10.15243/jdmlm.2020.081.2451

Banze wa Mutombo, A., Atibu, E. K., Mbuya wa Mutombo, J., Kalonda, E. M., Bakatula, E. N., Kanda, V. N., Koy, R. K., Mulaji, C. K., Carvalho, F. P., & Poté, J. (2022). Contamination by heavy metals from mining activities: An ecological impact assessment of Mura and Kimpulande Rivers, Democratic Republic of the Congo. *Watershed Ecology and the Environment*, *4*, 148–157. https://doi.org/10.1016/j.wsee.2022.10.004

Bari, E., & Haque, S. E. (2022). Legal and Illicit Sand Mining Practice in Bangladesh: Exploring Supply Chain and its Value. *Journal of Illicit Economies and Development*, *4*(1), 44–57. https://doi.org/10.31389/jied.149

Bayazidy, M., Maleki, M., Khosravi, A., Shadjou, A. M., Wang, J., Rustum, R., & Morovati, R. (2024). Assessing Riverbank Change Caused by Sand Mining and Waste Disposal Using Web-Based Volunteered Geographic Information. *Water*, *16*(5), 734. https://doi.org/10.3390/w16050734

Chen, D., Feng, Q., Li, W., Song, Y., & Zhao, C. (2021). Effects of acid drainage from abandoned coal mines on the microbial community of Shandi River sediment, Shanxi Province. *International Journal of Coal Science & Technology*, *8*(4), 756–766. https://doi.org/10.1007/s40789-021-00433-5

Daley, J. (2024). Reforestation done right is a multi-tasking climate solution. *Frontiers in Forests and Global Change*, *7*. https://doi.org/10.3389/ffgc.2024.1381078

Davies, P., Lawrence, S., Turnbull, J., Rutherfurd, I., Grove, J., Silvester, E., & Macklin, M. (2020). Mining modification of river systems: A case study from the Australian gold rush. *Geoarchaeology*, *35*(3), 384–399. https://doi.org/10.1002/gea.21775

Deng, M., Li, Q., Li, W., Lai, G., & Pan, Y. (2022). Impacts of Sand Mining Activities on the Wetland Ecosystem of Poyang Lake (China). *Land*, *11*(8), 1364. https://doi.org/10.3390/land11081364

Eddiwan, K. (2020). Impact of chicken livestock waste on the quality of sail river in Pekanbaru City, Riau. *MOJ Ecology & Environmental Sciences*, *5*(1). https://doi.org/10.15406/mojes.2020.05.00171

Ekoko Eric, B., Etutu, M. E. M. M., Adama, A., Salomon Betrant, B., Esue, M. F., Mengu, E. E., & Njeck Rexon, A. (2023). Trace metal geochemistry sediments from the Dibamba River, SW Cameroon: Implication for heavy metal assessment and origin. *Heliyon*, *9*(8), e18866. https://doi.org/10.1016/j.heliyon.2023.e18866

Farhan, R., Muntalif, B. S., Chazanah, N., Suharyanto, & Ismi, M. A. (2024). The analysis of macrozoobenthos abundances as bioindicators based on biotic index and pollution index on Citarum River, West Java. *E3S Web of Conferences*, *485*, 03014. https://doi.org/10.1051/e3sconf/202448503014

Hallatu, T. G. R., Wisadirana, D., Mu'adi, S., & Chawa, A. F. (2021). Illegal sand mining and sar local wisdom: a case study in Merauke. *International Journal of Social Sciences and Humanities*, *5*(1), 45–56. https://doi.org/10.29332/ijssh.v5n1.827

Harmayani, K. D., Jaya, N. M. P., Widhiawati, I. A. R., Parahita, I. G. A. A., Wiryananda, N. G. A. K., Supriyani, N. N. D., Mahendra, D. R., Baskhara, I. G. A. G. W., & Hutagalung, D. S. F. (2023). Assessment of Surface Water Quality Status Using the Pollution Index Method in Tukad Badung River. *Jurnal Presipitasi : Media Komunikasi Dan Pengembangan Teknik Lingkungan*, *20*(1), 175–185. https://doi.org/10.14710/presipitasi.v20i1.175-185

Hu, C., Zhang, S., & Zhang, X. (2022). Research on Water and Sediment Regulation of the Yellow River under New Situation. *Chinese Journal of Engineering Science*, *24*(1), 122. https://doi.org/10.15302/J-SSCAE-2022.01.013

Hunter, M., Perera, D. H. N., Barnes, E. P. G., Lepage, H. V., Escobedo-Pacheco, E., Idros, N., Arvidsson-Shukur, D., Newton, P. J., de los Santos Valladares, L., Byrne, P. A., & Barnes, C. H. W. (2024). Landscape-Scale Mining and Water Management in a Hyper-Arid Catchment: The Cuajone Mine, Moquegua, Southern Peru. *Water*, *16*(5), 769. https://doi.org/10.3390/w16050769

Idomeh, J. E., Isokpehi, N. A., Shittu, O. B., & Fasina, K. A. (2019). Seasonal variations affect the physical and chemical parameters of inland waters: a case study of Warri River in Nigeria. *International Journal of Halal Research*, *1*(1), 1–7. https://doi.org/10.18517/ijhr.1.1.1-7.2019

Indriyani, K., Hasibuan, H., & Gozan, M. (2020). Impacts of Land Use and Land Use Change In River Basin to Water Quality of Cirarab River, Indonesia. *Proceedings of the Proceedings of the 1st International Conference on Environmental Science and Sustainable Development, ICESSD 2019, 22-23 October 2019, Jakarta, Indonesia*. https://doi.org/10.4108/eai.22-10-2019.2292423

J. Shaji, J. S. (2021). Sand Auditing for Sustainable River Sand Miningin Kerala, India– An Overview. *Current World Environment*, *16*(3), 764–773. https://doi.org/10.12944/CWE.16.3.10

Jati, A., & Pratomo, D. G. (2021). Analysis of River Shape and River Bank from West Pillar in Sebatik Island to AA2 Pillar Using Multi-Temporal Satellite Imagery and its Influence to Determine Boundary of Indonesia-Malaysia. *IPTEK Journal of Proceedings Series*, *0*(6), 88. https://doi.org/10.12962/j23546026.y2020i6.8939

Jayanto, G. D., Widyastuti, M., & Hadi, M. P. (2021). Laundry wastewater characteristics and their relationship with river water quality as an indicator of water pollution. Case study: Code Watershed, Yogyakarta. *E3S Web of Conferences*, *325*, 02011. https://doi.org/10.1051/e3sconf/202132502011

Kamboj, V., & Kamboj, N. (2020). Spatial and temporal variation of zooplankton assemblage in the mining-impacted stretch of Ganga River, Uttarakhand, India. *Environmental Science and Pollution Research*, *27*(21), 27135–27146. https://doi.org/10.1007/s11356-020-09089-1

Karolina, A., Ardelia, V., & Ridho, Moh. R. (2022). Water Quality Analysis at Komering River Kayuagung City Ogan Komering Ilir Regency. *IOP Conference Series: Earth and Environmental Science*, *995*(1), 012011. https://doi.org/10.1088/1755-1315/995/1/012011

Koehnken, L., Rintoul, M. S., Goichot, M., Tickner, D., Loftus, A., & Acreman, M. C. (2020). Impacts of riverine sand mining on freshwater ecosystems: A review of the scientific evidence and guidance for future research. *River Research and Applications*, *36*(3), 362–370. https://doi.org/10.1002/rra.3586

Li, R., Huang, H., Yu, G., Yu, H., Bridhikitti, A., & Su, T. (2020). Trends of Runoff Variation and Effects of Main Causal Factors in Mun River, Thailand During 1980–2018. *Water*, *12*(3), 831. https://doi.org/10.3390/w12030831

Li, S., Yu, L., Jiang, W., Yu, H., & Wang, X. (2022). The Recent Progress China Has Made in Green Mine Construction, Part I: Mining Groundwater Pollution and Sustainable Mining. *International Journal of Environmental Research and Public Health*, *19*(9), 5673. https://doi.org/10.3390/ijerph19095673

Liu, M., Jia, S., & Wang, X. (2021). Environmental impact analysis for the construction of subway stations: Comparison between open-excavation and underground-excavation scheme. *Environmental Impact Assessment Review*, *91*. https://doi.org/10.1016/j.eiar.2021.106644

Majoro, F., Wali, U. G., Munyaneza, O., Naramabuye, F.-X., Bugenimana, E. D., & Mukamwambali, C. (2020). Sediment Transport and Its Impacts on Lake Kivu, Gihira Water Treatment Plant and Various Hydropower Plants along Sebeya River in Rwanda. *Journal of Water Resource and Protection*, *12*(11), 934–950. https://doi.org/10.4236/jwarp.2020.1211055

Marlina, N., & Melyta, D. (2019). Analysis Effect of Cloud Cover, Wind Speed, and Water Temperature to BOD and DO Concentration Using QUAL2Kw Model (Case Study In Winongo River, Yogyakarta). *MATEC Web of Conferences*, *280*, 05006. https://doi.org/10.1051/matecconf/201928005006

Mendes, R. G., do Valle Junior, R. F., de Melo Silva, M. M. A. P., de Morais Fernandes, G. H., Fernandes, L. F. S., Pissarra, T. C. T., de Melo, M. C., Valera, C. A., & Pacheco, F. A. L. (2023). Scenarios of environmental deterioration in the Paraopeba River, in the three years after the breach of B1 tailings dam in Brumadinho (Minas Gerais, Brazil). *Science of the Total Environment*, *891*. https://doi.org/10.1016/j.scitotenv.2023.164426

Oktavia, L., Karnaningroem, N., Wirjodirdjo, B., & Titah, H. S. (2024). Analyzing raw water quality of drinking water of Pelayaran River: Tribute to Brantas River. *Indonesian Journal of Multidisciplinary Science*, *3*(5). https://doi.org/10.55324/ijoms.v3i5.808

Pacheco, F. A. L., do Valle Junior, R. F., de Melo Silva, M. M. A. P., Tarlé Pissarra, T. C., de Souza Rolim, G., de Melo, M. C., Valera, C. A., Moura, J. P., & Sanches Fernandes, L. F. (2023). Geochemistry and contamination of sediments and water in rivers affected by the rupture of tailings dams (Brumadinho, Brazil). *Applied Geochemistry*, *152*. https://doi.org/10.1016/j.apgeochem.2023.105644

Patrick Ozovehe Samuel, & Mutiyat F. Alabi. (2022). Spatial and Temporal Variations in Physico-Chemical Parameters and Abundance of Mollusc Species in Shiroro Lake, Minna, Niger State. *Aquaculture and Fisheries Studies*, *3*(5). https://doi.org/10.31038/AFS.2021353

Permana, I., Sudirja, R., & Jupesta, J. (2023). Potential of Vermifiltration Technique to Reduce Chemical Oxygen Demand, Biological Oxygen Demand, and Total Suspended Solid of Farm Dairy Effluent in Developing Countries: Case of Indonesian Farm Dairy Industry. *Green and Low-Carbon Economy*. https://doi.org/10.47852/bonviewGLCE3202933

Pongoh, A. W., Putra, F., & Soemarno, S. (2021). The Study of River Water Quality in Water Pollution Control: Case Study ofTalawaan River, North Minahasa District, North Sulawesi Province. *Indonesian Journal of Environmental Management and Sustainability*, *5*(2). https://doi.org/10.26554/ijems.2021.5.2.72-80

Qian, W., Zhang, S., Tong, C., Sardans, J., Peñuelas, J., & Li, X. (2022). Long‐Term Patterns of Dissolved Oxygen Dynamics in the Pearl River Estuary. *Journal of Geophysical Research: Biogeosciences*, *127*(7). https://doi.org/10.1029/2022JG006967

Rendana, M., Yandriani, Y., Pitayati, P. A., Izzudin, M., & Lestari, M. (2022). Assessment of Water Quality Status and Pollution Index in Musi River, South Sumatera, Indonesia. *Indonesian Journal of Environmental Management and Sustainability*, *6*(4), 114–118. https://doi.org/10.26554/ijems.2022.6.4.114-118

Rofikha, A. A., Hanandha, A., Faturokhman, U., & Sugiarta, J. (2024). Sedimentation Management Good Practice (SMGP) to Manage Sedimentation at Kawanua Flood Disaster, Seram Island. *IOP Conference Series: Earth and Environmental Science*, *1343*(1), 012034. https://doi.org/10.1088/1755-1315/1343/1/012034

Sahid, A. N., & Zainab, S. (2024). Comparison of Total Suspended Solids (TSS) in the estuary of the Bengawan Solo Gresik River using satellite image data. *Jurnal Syntax Transformation*, *5*(1), 108–117. https://doi.org/10.46799/jst.v5i1.893

Samlafo, V. B., & Adakwah, D. (2021). Evaluative Study of River Birim in Denkyembuor, Ghana, Using Water Quality Indices. *Chemical Science International Journal*, 39–51. https://doi.org/10.9734/CSJI/2021/v30i930253

Scott, E. E., & Haggard, B. E. (2021). Natural Characteristics and Human Activity Influence Turbidity and Ion Concentrations in Streams. *Journal of Contemporary Water Research & Education*, *172*(1), 34–49. https://doi.org/10.1111/j.1936-704X.2021.3353.x

Semeniuk, N. (2023). ECOLOGICAL WATER QUALITY. *Ukrainian Journal of Natural Sciences*, *2*, 45–56. https://doi.org/10.35433/naturaljournal.2.2023.45-56

Sinaga, A. P., Ibrahim, E., & Hadiah, F. (2024). Assessment of Changes in Water Quality of Enim River, Muara Enim, South Sumatera, Indonesia to Determine Environmental Designations. *Indonesian Journal of Environmental Management and Sustainability*, *8*(2), 63–70. https://doi.org/10.26554/ijems.2024.8.2.63-70

Stets, E. G., Sprague, L. A., Oelsner, G. P., Johnson, H. M., Murphy, J. C., Ryberg, K., Vecchia, A. V., Zuellig, R. E., Falcone, J. A., & Riskin, M. L. (2020). Landscape Drivers of Dynamic Change in Water Quality of U.S. Rivers. *Environmental Science & Technology*, *54*(7), 4336–4343. https://doi.org/10.1021/acs.est.9b05344

Sun, X., Liu, J., Wang, J., Tian, L., Zhou, Q., & Li, J. (2021). Integrated monitoring of lakes' turbidity in Wuhan, China during the COVID-19 epidemic using multi-sensor satellite observations. *International Journal of Digital Earth*, *14*(4), 443–463. https://doi.org/10.1080/17538947.2020.1868584

Suwatanti, E. P. S., Maridi, M., & Suntoro, S. (2022). Water Quality Analysis using Pollution Index Method in Klampok Sub-watershed, Semarang Regency, Indonesia. *Caraka Tani: Journal of Sustainable Agriculture*, *37*(2), 243. https://doi.org/10.20961/carakatani.v37i2.58393

Tanjung, R., Yonas, M., Suwito, S., Maury, H., Sarungu, Y., & Hamuna, B. (2022). Analysis of Surface Water Quality of Four Rivers in Jayapura Regency, Indonesia: CCME-WQI Approach. *Journal of Ecological Engineering*, *23*(1), 73–82. https://doi.org/10.12911/22998993/143998

Torres, A., Simoni, M. U., Keiding, J. K., Müller, D. B., zu Ermgassen, S. O. S. E., Liu, J., Jaeger, J. A. G., Winter, M., & Lambin, E. F. (2021). Sustainability of the global sand system in the Anthropocene. In *One Earth* (Vol. 4, Issue 5, pp. 639–650). Cell Press. https://doi.org/10.1016/j.oneear.2021.04.011

Ward, A. S., Wondzell, S. M., Schmadel, N. M., & Herzog, S. P. (2020). Climate Change Causes River Network Contraction and Disconnection in the H.J. Andrews Experimental Forest, Oregon, USA. *Frontiers in Water*, *2*. https://doi.org/10.3389/frwa.2020.00007

Zhi, W., Feng, D., Tsai, W.-P., Sterle, G., Harpold, A., Shen, C., & Li, L. (2021). From Hydrometeorology to River Water Quality: Can a Deep Learning Model Predict Dissolved Oxygen at the Continental Scale? *Environmental Science & Technology*, *55*(4), 2357–2368. https://doi.org/10.1021/acs.est.0c06783