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Composition of Environmental Parameters in Aquatic Sediments in West Sumatra

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Abstract: This study aims to identify the factors influencing environmental parameters in water and sediment and evaluate their impacts on ecosystems and biota, thereby providing a scientific basis for effective and sustainable water resource management. Measurements were conducted at 10 natural ecosystem locations comprising rivers, beaches, estuaries, and lakes in West Sumatra. The parameters measured in the water were temperature, pH, DO, and salinity, while in the sediment, pH, TOC, ammonium, nitrate, nitrite, phosphate, and sulfate were measured. The results of the environmental parameter analysis in the water were Temperature (26.3 ± 0.65°C), pH (7.62 ± 0.43), DO (4.5 ± 0.81 mg/L), and Salinity (13.78 ± 13.95 ppt). In the sediment, the results were pH (6.74 ± 0.86), TOC (1.49 ± 0.29%), Ammonium (12.95 ± 5.34 mg/L), Nitrite (76.33 ± 34.26 mg/L), Nitrate (31.60 ± 5.25 mg/L), Phosphate (29.5 ± 20.37 mg/L), and Sulfate (29.46 ± 8.23 mg/L). Overall, the factors affecting water and sediment parameters are biological activity, land input, and anthropogenic contaminants. The ability of sediment to accumulate and absorb particles and chemicals is one of the factors causing the high concentration of environmental parameters in sediment.

Keywords: Environmental Parameters; Natural Ecosystem; Sediment

Introduction

West Sumatra has a diverse range of aquatic ecosystems, including rivers, beaches, estuaries, and lakes. Each of these ecosystems possesses unique characteristics influenced by the composition of environmental parameters in both water and sediment. An in-depth understanding of these environmental parameters is crucial for the management and preservation of existing natural resources (Supardiono et al., 2023b).

The aquatic ecosystems in West Sumatra consist of rivers flowing from the mountains to the sea, beaches where land meets the ocean, estuaries that are transition zones between freshwater and seawater, and lakes formed due to tectonic or volcanic activity (Fitriani et al., 2021; Melo et al., 2024). This diversity of ecosystems creates complex and varied habitats for various types of flora and fauna.

Environmental parameters such as temperature, pH, salinity, dissolved oxygen (DO), and nutrient concentrations (nitrate, phosphate, and sulfate) play a vital role in determining the water quality and ecological conditions of these ecosystems (Pratiwi et al., 2023; Supardiono et al., 2023b). Sediment, which is the deposition of particles at the bottom of water bodies, also contains important information about environmental quality, including the content of heavy metals, organic matter, and suspended particles (Rohyani, 2021).

Human activities such as urbanization, agriculture, fishing, and industry have a significant impact on the quality of water and sediment in river, beach, estuary, and lake ecosystems (Fitriani et al., 2021; Supardiono et al., 2023b). Improper disposal of domestic, industrial, and agricultural waste can cause pollution that affects the physico-chemical parameters of water and sediment (Supardiono et al., 2023a). Eutrophication, heavy metal pollution, and increased organic matter are some of the environmental problems often caused by human activities (Pratiwi et al., 2023).

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Global climate change and natural phenomena such as changes in rainfall patterns, rising temperatures, and extreme events like floods and droughts also affect the composition of environmental parameters in the waters of West Sumatra. Climate change can result in fluctuations in water temperature, water quality, and nutrient distribution, which in turn affect ecosystem health (Supardiono et al., 2023a; Supardiono et al., 2023b).

Comprehensive monitoring and research on the composition of environmental parameters in water and sediment in river, beach, estuary, and lake ecosystems are highly necessary. This data is important for understanding ecosystem dynamics, identifying pollution sources, and assessing the impact of environmental changes on biota and ecosystems (Mangallo & Oktaviani, 2023; Supardiono et al., 2023a; Supardiono et al., 2023b). This research will also provide the necessary information for sustainable water resource management and mitigation of the negative impacts of human activities and climate change.

This study aims to examine the composition of environmental parameters in water and sediment in river, beach, estuary, and lake ecosystems in West Sumatra. The study also aims to identify the factors influencing changes in these environmental parameters and evaluate their impact on ecosystems and biota. The results of this research are expected to provide a scientific basis for effective and sustainable water resource management in West Sumatra.

Therefore, this research is an important step in the efforts to conserve and manage aquatic ecosystems in West Sumatra. These efforts are not only aimed at preserving biodiversity but also at enhancing the welfare of communities that depend on these natural resources.

Method

Research on the composition of environmental parameters in water and sediment in river, beach, estuary, and lake ecosystems in West Sumatra (Figure 1) involves several systematic methodological stages. These methods include research design, data collection, laboratory analysis, and data analysis and interpretation of results.

The parameters measured in water (temperature, pH, DO, and salinity) were conducted directly in the water bodies, while the measurement of sediment parameters (pH, TOC, ammonium, nitrate, nitrite, phosphate, and sulfate) was carried out in the Environmental Engineering Laboratory of Andalas University.

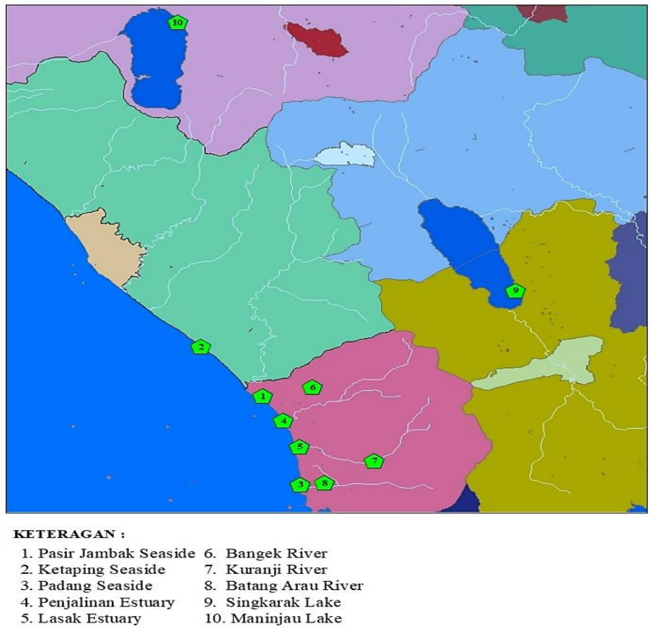

Figure 1. Sampling Location

Sampling points were strategically selected in the waters of West Sumatra (Table 1). The considerations for determining sampling locations included areas with high population density and regions expected to receive a significant amount of anthropogenic pollutants. Statistical analysis of environmental parameter data was performed using One Way ANOVA or Kruskal-Wallis.

Table 1. Sample Collection Location

Sample Location	Location Description
Pasir Jambak Seaside	Tourist Area
Ketaping Seaside	Market Area
Padang Seaside	Tourist Area (Lots of Waste)
Penjalinan Estuary	Tourist and Fishing Area (Lots of Dead Fish and Waste), Open Water
Lasak Estuary	Fishing Area, Residential Area
Bangek River	Residential Area, Agricultural Area, Open Water
Kuranji River	Sand Mining Area, Residential Area, Domestic Activities, Agricultural Area, Narrow Water
Batang Arau River	Residential Area, Domestic and Industrial Activities (Rubber Factory)
Singkarak Lake	Residential Area and Domestic Activities
Maninjau Lake	Eutrophication

Result and Discussion

Environmental Parameters of the Aquatic Area

The results of the environmental parameter measurements of the aquatic area presented include temperature, pH, DO, and salinity at each location. The measurement data for each location were subjected to statistical testing, starting with the Shapiro-Wilk normality test, followed by significance analysis using One Way ANOVA or Kruskal-Wallis. The results of the environmental parameter measurements of the aquatic area can be seen in Table 2.

Temperature

Water temperature in coastal ecosystems ranges between 25.7 - 27.1°C with an average of 26.3 ± 0.72°C. In estuarine ecosystems, it ranges from 26.3 - 27.2°C with an average of 26.75 ± 0.64°C. In river ecosystems, it ranges from 25.1 - 27.2°C with an average of 26.23 ± 1.06°C, and in lake ecosystems, it ranges between 25.9 - 26.3°C with an average of 26.1 ± 0.28°C. The highest temperatures are found at Penjalinan Eastuary and Bangek River at 27.2°C, while Kuranji River has the lowest temperature at 25.1°C. Normality tests for temperature indicate a non-normal distribution, therefore significance testing was conducted using the non-parametric Kruskal-Wallis test. The significance test showed a sig value > 0.05, indicating that the temperatures in the 10 ecosystems do not differ significantly.

The relationship between temperature and water is crucial and complex because temperature affects various aspects of water (Mangallo & Oktaviani, 2023). Higher temperatures can increase the rate of water evaporation from sources such as rivers, lakes, and reservoirs. This can lead to increased concentrations of remaining pollutants in the water, as the water volume decreases and pollutant concentrations rise (Mangallo & Oktaviani, 2023). Causes of high and low water temperatures include weather conditions, wind influences, sunlight intensity, and others (Dhea et al., 2023; Melo et al., 2024). During the measurements at each location, the weather conditions were similar, tending towards clear skies. Water temperature is influenced by sunlight intensity, geographical elevation, and the canopy coverage of surrounding vegetation (Yolanda, 2023). The optimal temperature range for aquatic organisms' life is between 18-30°C. The optimum temperature for the growth of phytoplankton and fish life in tropical areas ranges from 25.0 - 31.0°C (Melo et al., 2024). Therefore, it can be concluded that the water temperatures at the research locations still support the life of organisms living within them.

pH

The water pH in coastal ecosystems ranges between 7.7 - 8.1 with an average of 7.9 ± 0.2, in estuarine ecosystems it ranges from 7 - 7.9 with an average of 7.4 ± 0.63, in river ecosystems it ranges from 7.2 - 8 with an average of 7.6 ± 0.4, and in lake ecosystems it ranges between 6.8 - 7.9 with an average of 7.3 ± 0.78. The highest pH value is found at Padang Seaside at 8.1, while Singkarak Lake has the lowest pH value at 6.8. Normality tests for pH indicate that pH values are not normally distributed, therefore significance testing was conducted using the non-parametric Kruskal-Wallis test. The significance test showed a sig value > 0.05, indicating that pH values in the 10 ecosystems do not differ significantly.

Table 2. Environmental Parameters

				Sediment					Water		
Location	pH	TOC (%)	Ammonium (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulfate (mg/L)	DO (mg/L)	Temperature (°C)	Salinity (ppt)	pH
Pasir Jambak Seaside	6.80	1.18	7.79	41.43	26.80	13.94	20.95	3.30	25.70	26.00	7.70
Ketaping Seaside	6.80	1.24	11.19	44.86	31.93	26.82	26.50	4.00	27.10	29.00	7.90
Padang Seaside	7.10	1.31	8.08	36.41	25.89	17.30	39.32	3.90	26.10	32.10	8.10
Penjalinan Estuary	7.10	1.59	17.55	67.23	27.87	25.15	39.52	3.60	27.20	21.10	7.90
Lasak Estuary	8.00	1.58	16.35	96.64	32.31	23.00	41.33	5.40	26.30	29.20	7.00
Bangek River	4.50	1.19	9.85	109.99	37.21	21.64	17.35	5.70	27.20	0.30	7.20
Kuranji River	6.40	2.02	24.93	94.00	35.67	65.69	30.04	4.00	25.10	0.00	8.00
Batang Arau River	7.30	1.89	15.45	110.25	31.98	44.53	22.57	5.20	26.40	0.00	7.70
Singkarak Lake	6.80	1.52	10.55	130.21	41.54	20.40	24.80	4.90	26.30	0.00	6.80
Maninjau Lake	6.60	1.35	7.74	32.30	24.83	36.51	32.26	5.20	25.90	0.10	7.90
Rata-rata	6.74	1.49	12.95	76.33	31.60	29.50	29.46	4.52	26.33	13.78	7.62
Std Dev	0.86	0.29	5.34	34.26	5.25	20.37	8.23	0.81	0.65	13.95	0.43
P Value	>0.05	<0.05	<0.05	<0.05	<0.05	>0.05	<0.05	>0.05	>0.05	>0.05	>0.05

Regulation No. 22 of 2021 on the Implementation of Environmental Protection and Management states that the normal pH of water suitable for aquatic life is around 6-9 (Pemerintah Republik Indonesia, 2021). This concludes that the pH values of water at all locations are within the normal range. Seawater has a slightly alkaline or neutral pH due to the balance between acidic and basic ions within it (Dhea et al., 2023; Mangallo & Oktaviani, 2023; Pratiwi et al., 2023).

Seawater contains various salts and minerals, including sodium chloride (NaCl), magnesium sulfate ($MgSO_4$), and calcium carbonate ($CaCO_3$) (Dhea et al., 2023; Yolanda, 2023). When these salts dissolve in seawater, they dissociate into ions that play a role in determining the pH of seawater. The ions most involved in stabilizing seawater pH are hydrogen ions (H^+) and hydroxide ions (OH^-) (Dhea et al., 2023). The ideal pH for the life of aquatic organisms generally ranges from 6.5 to 8.5 (Supardiono et al., 2023b). The pH of water in this study still indicates an ideal pH for the growth of aquatic organisms.

DO

The DO (Dissolved Oxygen) levels in coastal ecosystems range between 3.3 - 4 mg/L with an average of 3.73 ± 0.37 mg/L. In estuary ecosystems, DO ranges between 3.6 - 5.4 mg/L with an average of 4.5 ± 1.27 mg/L. In river ecosystems, DO ranges between 4 - 5.7 mg/L with an average of 4.96 ± 0.87 mg/L. In lake ecosystems, DO ranges between 4.9 - 5.2 ± 9.21 mg/L. The highest DO value is found in Bangek River at 5.7 mg/L, while Pasir Jambak Beach has the lowest DO value at 3.3 mg/L. Normality tests of DO values show that DO values are not normally distributed, so significance testing is conducted using non-parametric Kruskal-Wallis test. The significance test shows a sig value >0.05, indicating that DO values across the 10 ecosystems do not differ significantly.

According to (Supardiono et al., 2023a), DO levels of 2.0 to 6.4 mg/L are considered to be moderately polluted water quality. The DO levels in this study fall within the moderately polluted condition. The minimum DO concentration to support aquatic life is 2 mg/(Dhea et al., 2023; Supardiono et al., 2023; Supardiono et al., 2023b). Ideally, the DO concentration should not be less than 1.7 mg/L for 8 hours. The lowest DO concentration is found at Pasir Jambak Beach, which is 3.3 mg/L. One factor affecting the DO levels in water is temperature; higher temperatures increase DO levels, and lower temperatures decrease DO levels (Dhea et al., 2023). The temperature at Pasir Jambak Beach is one of the lowest compared to other locations at 25.7°C, whereas the location with the highest DO level, Bangek River, has the highest temperature at 27.2°C.

Additionally, maximum DO levels occur in the afternoon and decrease in the morning (Palomo et al., 2016). Sampling at Pasir Jambak Beach was conducted in the morning, which is one reason for the low DO levels at that location. Measurement time or weather conditions in the field also affect DO levels in the water (Melo et al., 2024). Aquatic organisms need oxygen to breathe. Adequate DO levels ensure that these organisms get the oxygen required for their respiratory processes (Supardiono et al., 2023a; Supardiono et al., 2023b). DO levels also influence biochemical processes in the water. For instance, aerobic bacteria need oxygen to decompose organic matter (Hermiyanti & Wulandari, 2018). Low DO levels can hinder this decomposition process, leading to the accumulation of undecomposed organic matter, which in turn can damage aquatic ecosystems (Dhea et al., 2023).

Salinitas

The water salinity in coastal ecosystems ranges between 26 - 32.1 ppt with an average of 29.03 ± 3.05 ppt. In estuarine ecosystems, salinity ranges between 21.1 - 29.2 ppt with an average of 25.15 ± 5.73 ppt. River and lake ecosystems are locations without salinity. The highest salinity is found at Padang Beach, which is 32.1 ppt, while Kuranji River, Batang Arau River, and Lake Singkarak have no salinity or 0 ppt. The normality test for salinity shows that salinity is not normally distributed, so significance testing is conducted using the non-parametric Kruskal-Wallis test. The significance test shows a sig value > 0.05, indicating that salinity levels across the 10 ecosystems do not differ significantly.

The salinity levels at coastal and estuarine locations show differences compared to river and lake locations. Coastal and estuarine locations have high salinity levels (21.1 to 32.1 ppt) compared to river and lake locations, where salinity levels are generally absent (0 to 0.3 ppt). This is because river and lake water usually comes from rainwater or groundwater springs that do not contain salt (Yolanda, 2023). However, the significance test results indicate that salinity levels at the study locations are the same. Several reasons why different data can show the same significance value include that when data groups have the same sample size, the significance values are likely similar, especially if the data distributions are also similar, resulting in similar significance values (Mallikarjuna & Dash, 2023). This can be related to the salinity levels in each group, i.e., coastal, estuarine, river, and lake, showing the same or similar distribution.

Salinity refers to the concentration of salt in water, which affects the composition and diversity of aquatic ecosystems (Hermiyanti & Wulandari, 2018; Yolanda, 2023). Living organisms in water must be able to withstand varying ranges of salinity, and drastic changes in salinity can affect biological communities, including species distribution and ecosystem productivity (Melo et al., 2024). Water microorganisms have different tolerance levels to salinity. Some species can survive in a wide range of salinity, while others are more specific to certain salinity levels. Changes in salinity in the aquatic environment can affect the composition and abundance of existing microorganisms (Yolanda, 2023).

Padang Beach has the highest salinity level at 32.1 ppt. One factor affecting the varying salinity levels is weather, as observations at Padang Beach were made during relatively hot weather, resulting in high salinity. High evaporation in the sea reduces the volume of seawater, while the salt in it does not evaporate, thus increasing seawater salinity (Pratiwi et al., 2023). Salinity is related to temperature in influencing aquatic life (Mangallo & Oktaviani, 2023). Increasing temperatures will be followed by an increase in salinity due to increased evaporation. The salinity levels in the sea are influenced by various factors, such as water circulation patterns, evaporation, rainfall, and river flow (Hermiyanti & Wulandari, 2018). The Penjalinan estuary has the lowest salinity level compared to other estuarine locations, which is 21.1 ppt. The low salinity level in this water indicates an influence from the land, such as mixing with freshwater brought by river flow. The presence of salinity levels in estuarine waters is influenced by several factors, including the interaction of freshwater entering estuarine waters through rivers, evaporation, and rainfall (Yolanda, 2023). Estuarine waters have varying salinity gradients, depending on the freshwater supply from rivers and seawater through tides (Hermiyanti & Wulandari, 2018).

The surface salinity in river estuaries ranges between 15 - 35 ppt. Therefore, the salinity levels at the study locations are still within the general salinity range of estuarine waters.

Sediment Area Environmental Parameters

The results of environmental parameter measurements in the sediment area presented include measurements of pH, TOC, ammonium, nitrate, nitrite, phosphate, and sulfate at each location. The measurement data for each location were subjected to statistical tests starting with the Shapiro-Wilk normality test, followed by significance testing using One-Way ANOVA or Kruskal-Wallis tests.

pH

The sediment pH in coastal ecosystems ranges between 6.6 - 7.2 with an average of 6.9 ± 0.19. In estuarine ecosystems, it ranges between 6.8 - 8 with an average of 7.5 ± 0.54. In river ecosystems, it ranges between 4.3 - 7.4 ± 1.25, and in lake ecosystems, it ranges between 6.4 - 6.9 ± 1.18. Overall, the highest pH value is found at Muara Lasak, which is 8, while Bangek River is the location with the lowest pH value, which is 4.5. The normality test for pH values shows that they are normally distributed, so significance testing is conducted using One Way ANOVA. The significance test shows a sig value < 0.05, indicating that sediment pH in the 10 ecosystems differs significantly.

The significance test results show that the average sediment pH in the study locations is significantly the same, which is due to the water conditions at the measurement points generally being residential areas, where human activities such as waste disposal can cause similar changes in sediment pH at the impacted locations (Rohyani, 2021). However, the pH is slightly higher at Muara Lasak. Muara Lasak is a densely populated residential area that can produce waste containing alkaline chemicals (such as detergents, soaps, and cleaning agents). Such waste can accumulate in the aquatic sediment and increase the pH of the sediment. Alkaline compounds in household waste, such as sodium hydroxide (NaOH) and potassium hydroxide (KOH), can increase the water pH when discharged into water bodies and eventually accumulate, raising the sediment pH (Liu et al., 2023; Mangallo & Oktaviani, 2023).

Bangek River has a sediment pH of 4.5, which falls into the acidic category, although the water pH measurement shows a normal pH of 7.2. Even though the water pH is typically neutral, around 7, sediment pH can vary widely depending on the environmental conditions where the sediment forms and evolves (Gandhi et al., 2022). One main cause of acidic sediment pH is biological activity, such as the decomposition of organic matter and the metabolism of living organisms within the sediment (Garcia et al., 2022). This process can produce carbonic acid (HCO_3^-) and sulfuric acid (HSO_4^-), both of which can lower sediment pH. Additionally, biological activity can produce dissolved oxygen, which can react with minerals in the sediment to produce acids (Shi et al., 2020). Agricultural activities around Bangek River can also contribute to the low pH value at this location. During watering or rainfall, fertilizers applied to farmland can be carried by water flow and rainwater. Soil erosion can also cause soil particles containing fertilizers to be carried into the river. Fertilizers used in agriculture, including chemical and organic fertilizers, can be transported to the river and affect the sediment's chemical properties. Chemical fertilizers often contain chemicals that can lower sediment pH, such as sulfate ions or nitric acid. Meanwhile, organic fertilizers can increase the organic matter content in the sediment, affecting its chemistry and pH (Supardiono et al., 2023a).

This study shows that sediment pH values differ from water pH values. Water and sediment indeed have different sources, compositions, and chemical characteristics, affecting the quality and health of the aquatic environment. Water usually consists of water molecules (H_2O) and various dissolved compounds such as hydrogen ions (H^+) and hydroxide ions (OH^-), which determine the acidity or alkalinity (pH) of the water. On the other hand, sediment consists of solid particles that can contain various minerals and organic materials, influencing the sediment's chemical characteristics (Rohyani, 2021).

pH is a crucial chemical parameter in determining the quality and condition of the aquatic environment. The relationship between pH and water is close and has significant impacts on the living organisms within it and the chemical processes that occur (Dhea et al., 2023). Aquatic organisms, including fish, plankton, bacteria, and other living creatures, have specific pH ranges within which they can survive and reproduce. pH fluctuations outside this range can disrupt the biological balance and health of these organisms (Melo et al., 2024).

TOC

Sediment TOC in coastal ecosystems ranges between 1.15% - 1.36% with an average of 1.24 ± 0.07%, in estuarine ecosystems ranges between 1.54% - 1.64% with an average of 1.58 ± 0.03%, in river ecosystems ranges between 0.99% - 1.96% ± 1.7%, and in lake ecosystems ranges between 1.31% - 1.63% with an average of 1.43 ± 0.11%. The highest TOC value is found in the Kuranji River at 2.02%, while the lowest TOC value is found at Pasir Jambak Beach at 1.18%. The normality test for TOC shows that TOC values are normally distributed, so significance testing is conducted using One Way ANOVA. The significance test shows a sig value < 0.05, indicating that TOC in the 10 ecosystems differs significantly.

The significance test results show that the average sediment TOC in the study locations differs significantly. Factors that can influence the difference in TOC values between locations include the availability of organic material, human activities, industrial pollutants, and domestic waste (Hermiyanti & Wulandari, 2018).

Sampling points in rivers are close to residential areas and domestic activities, which can increase TOC values. Organic material accumulated in sediment increases over time with the increase in human activities. One of the main causes of high TOC concentrations in water bodies is domestic and industrial waste containing organic material that enters the water through rainwater runoff or irrigation (Rohyani, 2021). The study location is an open water area, where organic carbon content in open ecosystems is generally lower compared to closed ecosystems (Hermiyanti & Wulandari, 2018). This is because the very high accumulation of organic material is influenced by the amount of incoming organic material, the rate of sediment deposition, and the rate of organic material degradation (Mallikarjuna & Dash, 2023). Marine sediment has an organic carbon content of 4.69% (Mahto & Das, 2022). Total nitrogen in marine sediment ranges between 2.4% - 10.2%, so the organic carbon content of sediment in each water body varies but fluctuates (Zhu et al., 2023a). The organic carbon values obtained in the sediment at the study locations indicate significant sedimentation from organic material, suggesting that the organic carbon content at the study locations is still within safe limits.

The relationship between TOC and water is crucial in evaluating the quality and characteristics of the aquatic environment. Most organic material in water comes from the remains of living organisms, such as leaves, litter, and microscopic organisms. When this organic material decomposes, it releases TOC into the water. TOC in water can serve as a nutrient source for aquatic organisms and waterborne microbes (Dai et al., 2021).

Amonium

The ammonium content in sediment for coastal ecosystems ranges between 6.82 - 12.02 mg/L with an average of 9.02 ± 1.9 mg/L, for estuarine ecosystems ranges between 14.84 - 18.4 mg/L with an average of 16.95 ± 1.17 mg/L, for river ecosystems ranges between 8.83 - 25.42 mg/L with an average of 16.74 ± 6.62 mg/L, and for lake ecosystems ranges between 6.71 - 11.74 mg/L with an average of 9.14 ± 1.9 mg/L. The highest ammonium content is found in the Kuranji River at 24.93 mg/L, while the lowest ammonium content is found in Lake Maninjau at 7.74 mg/L. The normality test for ammonium content shows that the ammonium content is normally distributed, so significance testing is conducted using One Way ANOVA. The significance test shows a sig value < 0.05, indicating that the ammonium content in the 10 ecosystems differs significantly.

Factors influencing the ammonium content in the Kuranji River are due to human activities around the river. Agricultural and residential activities around the Kuranji River can lead to increased ammonium content in the water due to the release of chemicals and organic materials into the aquatic environment (Hendrayana et al., 2022; Hermiyanti & Wulandari, 2018). Agricultural activities can also contribute to increased ammonium content in the water through nutrient runoff from agricultural land, such as nitrogen fertilizers, into the water. Waters near agricultural land tend to have high ammonium content (Hendrayana et al., 2022). Waste from settlements around the Kuranji River can also result in high ammonium content in the river. Household waste containing ammonium can come from urine, feces, and microbial decomposition of organic materials found in natural water or household wastewater (Hermiyanti & Wulandari, 2018). Additionally, it can come from organic substances in natural water (rivers, lakes, springs, or wells) or industrial/domestic waste decomposed by decomposer microorganisms.

High ammonium content is also found in the Yellow and Bohai Seas in China, ranging from 26.1-79.17 mg/kg (Liu et al., 2020). Aquatic sediments are rich in biogeochemical activity, where nitrogen compounds can undergo chemical and biological transformations. For example, organic nitrogen in organism remains can be decomposed by microorganisms into inorganic nitrogen compounds, such as ammonium, nitrite, and nitrate (Zheng et al., 2019). Organisms in the sediment, such as bacteria, algae, and invertebrates, can also influence nitrogen compound concentrations through their metabolism and nutrient cycling activities. These organisms can process, transform, and consume nitrogen compounds, affecting nitrogen concentrations in the sediment (Wang et al., 2016).

The availability of ammonium in water can influence the growth and population of nitrogen-decomposing bacteria. High ammonium concentrations can increase the activity of nitrifying bacteria, which in turn increases the number of nitrogen-decomposing bacteria in the environment (Ding et al., 2023).

Nitrite

The average nitrite content in sediment for coastal ecosystems ranges between 36.06 - 46.34 mg/L with an average of 40.9 ± 3.76 mg/L, for estuarine ecosystems ranges between 66.99 - 97.12 mg/L with an average of 81.93 ± 1.61 mg/L, for river ecosystems ranges between 93.22 - 111.07 mg/L with an average of 104.75 ± 8.08 mg/L, and for lake ecosystems ranges between 31.76 - 130.76 mg/L with an average of 81.25 ± 5.36 mg/L. The highest nitrite content is found in the Batang Arau River at 110.25 mg/L, while the lowest nitrite content is found in Lake Maninjau at 32.3 mg/L. The normality test for nitrite content shows that nitrite content is not normally distributed, so significance testing is conducted using the non-parametric Kruskal-Wallis test. The significance test shows a sig value < 0.05, indicating that nitrite content in the 10 ecosystems differs significantly.

The high nitrite content in the Batang Arau River is suspected to be due to the influence of nearby residential areas, domestic activities, and industrial activities (rubber factories). Domestic waste from residential areas can contain ammonia, which can eventually be converted into nitrite by microorganisms (Hendrayana et al., 2022; Hermiyanti & Wulandari, 2018). Low or stagnant water flow at the sampling point can increase the decomposition of organic matter in the water, especially under anaerobic (oxygen-free) conditions, which can produce nitrite as a byproduct (Struk-Sokolowska et al., 2022).

The variation in nitrite content in each ecosystem is influenced by the high activity of decomposing bacteria due to household waste disposal, agriculture, and industry (Hendrayana et al., 2022). Household waste containing nitrite can come from urine and food scraps. Additionally, wastewater from washing, bathing, and dishwashing activities can also contain nitrite (Hermiyanti & Wulandari, 2018). In some cases, household waste containing nitrate can also be converted into nitrite by microorganisms in the aquatic or soil environment, which can then affect the overall quality of water and the aquatic environment (Sun et al., 2020). High nitrite concentrations are also caused by adsorption processes, where dissolved substances from the water accumulate in the sediment, increasing the concentration of sediment chemistry, including nitrite (Baeza et al., 2004). Nitrogen compounds can settle and accumulate in aquatic sediments over time. This process can involve the binding of nitrogen compounds to sediment particles or other chemical processes that affect the accumulation of nitrogen compounds in the sediment. Sediments richer in minerals and organic particles tend to be more effective at retaining dissolved substances, including nitrogen compounds (Xu et al., 2020a).

Nitrite concentrations are often used as an indicator of water quality. Nitrite is an intermediate form of ammonia being converted into nitrate in the nitrification process. High nitrite concentrations in water usually indicate problems in the nitrogen cycle, such as nitrogen overloading, excessive organic decomposition, or failure of waste treatment systems (Zheng et al., 2019).

Nitrat

The average nitrate content in sediment for coastal ecosystems ranges between 24.9 - 34 mg/L with an average of 28.21 ± 3.15 mg/L, for estuarine ecosystems between 27.1 - 33.29 mg/L with an average of 30.09 ± 2.7 mg/L, for river ecosystems between 30.89 - 37.38 mg/L with an average of 34.95 ± 2.43 mg/L, and for lake ecosystems between 23.25 - 42.72 mg/L with an average of 33.19 ± 9.27 mg/L. The highest nitrate content is found in Lake Singkarak at 41.54 mg/L, while the lowest is in Lake Maninjau at 24.83 mg/L. The normality test for nitrate content shows that nitrate content is normally distributed, so significance testing is conducted using One Way ANOVA. The significance test shows a sig value < 0.05, indicating that nitrate content in the 10 ecosystems differs significantly.

The high nitrate content in Lake Singkarak is due to the sampling location being near residential areas and domestic activities. Waste from these activities is largely discharged directly into the lake. Nitrate levels in water are greatly influenced by nitrate input from water bodies (Hendrayana et al., 2022; Hermiyanti & Wulandari, 2018). The main sources of nitrate are household and livestock waste, including animal and human excreta (Wijaya & Putra, 2021). Differences in nitrate content among ecosystems are influenced by factors such as agricultural activity, plant and animal waste, pollution, and natural processes like rock weathering (Zhu et al., 2023a). The primary source of increased nitrate levels in water comes from agricultural runoff (Hermiyanti & Wulandari, 2018).

The lower nitrate concentration at the surface layer compared to the near-bottom layer is due to the surface layer's nitrate being more utilized or consumed by phytoplankton (Garcia et al., 2022). Additionally, the slightly higher nitrate concentration near the bottom is influenced by sediment. In the sediment, nitrate is produced from the biodegradation of organic matter into ammonia, which is then oxidized into nitrate (Galloway et al., 2008). Nitrate concentrations are categorized as < 3 mg/L = low, 3 – 10 mg/L = moderate, and > 10 mg/L = high (Pemerintah Republik Indonesia, 2021), so the nitrate content in this study is considered high. High nitrate content is also found in the Lancang River and Langxun Lake in China, at 30.75-30.13 mg/kg (Ding et al., 2023; Xu et al., 2020a). Aquatic sediments can also accumulate nitrogen from external sources such as wastewater runoff, agricultural inputs, and organic waste from aquatic biological resources. These external inputs can increase the concentration of nitrogen compounds like nitrate in the sediment (Ding et al., 2023).

Nitrate is a primary source of nitrogen for aquatic plants and algae. The availability of nitrate in water can affect the growth and productivity of aquatic plants (Prayitno et al., 2023). Increased nitrate content can trigger excessive algae growth, leading to eutrophication and various environmental issues (Monica et al., 2023). Increased nitrate content can be an indicator of pollution and may prompt stricter environmental protection measures (Xu et al., 2020a).

Fosfat

The average phosphate content in sediment for coastal ecosystems ranges between 13.69 - 40.93 mg/L with an average of 19.35 ± 8.55 mg/L, for estuarine ecosystems between 18.36 - 35.21 mg/L with an average of 24.07 ± 6.28 mg/L, for river ecosystems between 5.39 - 107.64 mg/L with an average of 43.95 ± 3.17 mg/L, and for lake ecosystems between 13.76 - 45.17 mg/L with an average of 28.45 ± 1.09 mg/L. The highest phosphate content is found in the Kuranji River at 65.69 mg/L, while the lowest is at Pasir Jambak Beach at 13.94 mg/L. The normality test for phosphate content shows that phosphate content is not normally distributed, so significance testing is conducted using the non-parametric Kruskal-Wallis test. The significance test shows a sig value > 0.05, indicating that phosphate content in the 10 ecosystems does not differ significantly.

The main natural sources of phosphate come from the water itself through processes such as decomposition, weathering, decomposition of plants, remains of dead organisms, and waste discharge from land (domestic, industrial, agricultural, livestock, and feed residue) which are broken down by bacteria into nutrients (Supardiono et al., 2023a). The Kuranji River has slightly higher phosphate levels. The high phosphate content at the study location is influenced by the large amount of detergent waste entering the water through drainage channels from residential activities because the sampling point is near residential areas and domestic activities. Detergents can increase phosphate levels because phosphate ions are one of the components of detergents (Hendrayana et al., 2022; Supardiono et al., 2023a). Organic waste such as detergents and the degradation of organic materials can also produce phosphate (Pratiwi et al., 2023). Sediments are a good reservoir for phosphorus (Hendrayana et al., 2022).

Plants and animals that die are decomposed by decomposer bacteria, which then settle at the bottom of the water. The high phosphate content at the bottom of the water is because the bottom of the water is generally rich in nutrients, both from sediment decomposition and organic compounds from dead flora and fauna (Hendrayana et al., 2022). Phosphorus compounds bound in sediment can undergo decomposition with the help of bacteria or through abiotic processes, producing dissolved phosphorus compounds (Supardiono et al., 2023a). The main source of phosphate comes from land, especially through rock weathering transported to the sea mainly by rivers (Hermiyanti & Wulandari, 2018). Phosphate is also formed as a result of the breakdown of organic matter under aerobic conditions (Zhu et al., 2023b). The phosphate content in the sediment of Muara Punduh is 88.43 mg/L, higher than in this study. Phosphate concentrations in sediment are generally higher than in the water body due to long-term accumulation (Al-Dhabi et al., 2021).

Phosphate is a form of phosphorus found in water and has an important relationship with water quality and aquatic ecosystems (Wijaya & Putra, 2021). Phosphate is needed for the metabolism, growth, and development of aquatic plants and algae. Therefore, the availability of phosphate in water can affect primary productivity and the composition of biological communities in aquatic ecosystems (Tsitouras et al., 2021).

Sulfat

The average sulfate content in sediment for coastal ecosystems ranges between 19.37 - 42.74 mg/L with an average of 28.92 ± 8.4 mg/L, for estuarine ecosystems between 38.87 - 43.86 mg/L with an average of 40.42 ±

1.74 mg/L, for river ecosystems between 15.49 - 31.82 mg/L with an average of 23.32 ± 5.7 mg/L, and for lake ecosystems between 22.9 - 35.69 mg/L with an average of 28.52 ± 4.69 mg/L. The highest sulfate content is found in Muara Lasak at 41.33 mg/L, while the lowest is in Bangek River at 17.35 mg/L. The normality test for sulfate content shows that sulfate content is not normally distributed, so significance testing is conducted using the non-parametric Kruskal-Wallis test. The significance test shows a sig value < 0.05, indicating that sulfate content in the 10 ecosystems differs significantly.

The highest sulfate content is found in Eastuary Lasak, suspected to originate from residential waste around the estuary. Waste from human activities can contain sulfate, increasing sulfate levels in the water (Prayitno et al., 2023). The high sulfate content in each ecosystem is influenced by several factors such as human activities, water quality, and environmental factors. Waste discharged into the water will bind with dissolved particles or precipitate as particles through various chemical compounds or biological processes occurring in the water, eventually reaching the sediment indirectly (Wang et al., 2016). Seawater intrusion into the water can cause an increase in sulfate content because seawater contains sulfate ions (Wang et al., 2020). Sulfate can react with organic components in the water sediment through processes involving oxidation. Sulfate is a compound that can react with various organic components, including polymers, carbon, and other organic materials, to produce more complex and stable compounds (Prayitno et al., 2023). This process often occurs in aquatic environments, where sulfate can react with organic components contained in sediment or water. The reaction of sulfate with organic components can also affect the sulfate content in sediment, as sulfate reacting with organic components can increase the sulfate concentration in sediment (Wang et al., 2016).
Sulfate concentration in water can be used as an indicator of water quality. High sulfate levels can indicate the presence of pollution, especially from human activities (Prayitno et al., 2023). An increase in sulfate concentration in water can lead to changes in water quality and affect aquatic life (Wang et al., 2023). Sulfate can also originate from natural processes such as the weathering of sulfate rocks and sulfide minerals. Rainwater passing through sulfate mineral deposits can also contain significant sulfate concentrations. In some areas, groundwater sources are also rich in sulfate (Xu et al., 2020b).

Conclusion

The results of environmental parameter analysis from 10 sediment samples in natural ecosystems in West Sumatra, including coastal, estuarine, river, and lake environments, are as follows: sediment pH (4.5 – 8), water pH (6.8 – 8.1), TOC (1.18-2.02%), Ammonium (7.74 – 24.93 mg/L), Nitrite (32.3 – 110.25 mg/L), Nitrate (24.83 – 41.54 mg/L), Phosphate (13.94 – 65.69 mg/L), Sulfate (17.35 – 41.33 mg/L), DO (3.3 – 5.7 mg/L), temperature (25.1 – 27.2°C), and Salinity (0 – 32.1 ppt). Overall, the factors affecting water and sediment parameters are biological activity, land input, and anthropogenic contaminants. The ability of sediment to accumulate and absorb particles and chemicals is one of the factors causing the high concentration of environmental parameters in sediment.

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Authors Contribution
Conceptualization, S. H., Z. Z., P. S. K.,; methodology, S. H., Z. Z., P. S. K.,; validation, Z. Z. and.; S. H formal analysis, S. H.; investigation, S. H ; resources, S. H; data curation, S. H: writing—original draft preparation, S. H; writing— review and editing, S. H.: visualization, S. H. All authors have read and agreed to the published version of the manuscript.

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All author declares that there is no conflict of interest.

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