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Analysis of Soil Substrate Based on Chemical and Textural Aspects of Soil on the Tamarupa Coast, Pangkep Regency, Indonesia

Andi Puspa Sari Idris
Department of Aquaculture, Pangkep State Agricultural Polytechnic, Pangkep, 90761, Indonesia

ABSTRACT

This study aims to determine the quality of the substrate soil on the Tamarupa Coast in Pangkep Regency. This study is a survey, involving sampling of substrate soil based on its characteristics and research objectives, followed by laboratory analysis. The collected data included ammonia, nitrate, pH, nitrogen, phosphate, and soil texture. The data were then analyzed using descriptive analysis. The results of the study showed that the ammonia content of the substrate soil at the research location was still relatively high because it was greater than 1 ppm, the nitrate content of the substrate soil at the research location was relatively low. The pH value of the substrate soil was in the normal range, namely 7.31 to 7.66. The nitrogen content of the substrate soil at the research location was still relatively low. The highest phosphate content was at ST 3, which is a location close to residential areas and fish farms, namely 0.006 ppm. The phosphate value for all research locations was still relatively low. Furthermore, the texture of the substrate soil at the research location had a dusty texture.

KEYWORDS: Soil substrate, chemical aspects, soil texture, beach, Tamarupa

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Corresponding Author:
Andi Puspa Sari Idris

INTRODUCTION

Coastal regions are places where terrestrial and marine ecosystems meet, each with distinct traits and vulnerability to environmental shifts. Because of the construction of shrimp farms, coastal regions are under stress and undergoing quick environmental changes. Ecosystems, coastline typology, features, carrying capacity, and the potential of shrimp pond regions are all altered by the quick rate of land use change (Utojo et al., 2009).

Uncontrolled use and management of coastal areas with spatial planning that lacks distinct boundaries and designations leads to biophysical degradation of the coastal environment, disputes over use and authority over the use of coastal areas, which can harm coastal ecosystems and land resources, and decreases management efficacy. Therefore, in developing aquaculture business, it must be careful, controlled, effective, economical, and environmentally friendly (Utojo and Erna, 2013), and the exploitation of coastal seabed resources results in changes in sediment texture and the natural characteristics of both suspended and deposited sediments (Rifardi, 2006). Therefore, information and data related to the condition of the coastal area are needed.

Although Indonesia has a relatively large area of aquaculture, when compared to the area under cultivation, the resulting production is not proportional to the area being cultivated. This is due to the limited knowledge regarding the characteristics of pond soil suitable for aquaculture (Hidayanto et al., 2004). In developing aquaculture areas, land suitability evaluations are necessary to inform land use decisions. Because land is not created equal and has different physical, social, economic, and geographic qualities, Rossiter (1996) asserts that evaluating land appropriateness is essential. These differences may have an impact on appropriate land uses, such as aquaculture (Mustafa et al., 2008).

Pangkep Regency is a coastal area that has enormous resources and benefits for the lives of the community, along with the development of civilization and socio-economic activities, the community utilizes coastal areas for various interests (Bidayani, 2014), and one of the coastal areas in Pangkep Regency is Tamarupa beach which is located in Mandalle District. The Tamarupa coastline has many community activities such as fish ponds, seaweed cultivation, and has a small river estuary that connects this area to sea waters. Research on the Tamarupa coast's soil chemistry has been done due to the beach's vulnerability to community and fishing activities. Around Tamarupa Beach there are several community activities such as fishing, fish farming, seaweed cultivation, rice fields, and various other activities that can directly or indirectly affect the condition of the beach.

Soil characteristics play a crucial role in determining whether land is suitable for aquaculture. Good soil not only retains water but also provides a variety of nutrients for the natural food of fish and shrimp. The soil's ability to provide the various nutrients necessary for the growth of natural food is influenced by the fertility of the pond and its chemical composition (Afrianto and Liviawaty, 1991). Analyzing the land's carrying capacity for fisheries cultivation is crucial to ensure that aquaculture efforts do not encounter obstacles (Mustofaa and Decky, 2021). Poernomo (1979) stated that important aspects that must be met in evaluating land suitability for pond cultivation are ecology and topography, soil, and biology. Engineering aspects, soil quality, water quality, climate, and infrastructure facilities are aspects commonly considered by Karthik et al. (2005) in evaluating land for pond cultivation. The requirements for land evaluation for pond cultivation sometimes have variables with different values and depend on geographic location (Prasita, 2007).

Each commodity cultivated in ponds requires varying soil quality for optimal growth. Therefore, this study aimed to determine the relationship between soil quality variables and pond productivity for various brackishwater fishery commodities in an effort to refine the criteria for land suitability for pond cultivation (Mustafa et al., 2008). Soil quality is another environmental aspect taken into account when determining whether a piece of land is suitable for pond farming, in addition to water quality. According to Mustafa et al. (2008), soil quality can either have a positive impact on a given land use due to its advantageous qualities or a negative impact by acting as a barrier or restriction to land use due to its deleterious qualities.

MATERIALS AND METHODS

This type of research is descriptive research using a survey method that aims to determine the quality of the coastal substrate of Tamarupa Beach, Mandalle District, Pangkep Regency. This research was conducted at the Tamarupa Coastal Beach, Pangkep Regency, and the Water Quality Laboratory of the Pangkep State Agricultural Polytechnic. Sampling was carried out at four stations, namely Station (ST) 1, which is in the Tamarupa River Estuary area, Station (ST) 2, which is in the mangrove vegetation area, and Station (ST) 3, which is in the area adjacent to residential areas and fish ponds. This research was conducted from March to April 2026. Soil sampling was conducted at each location or observation station. The data used in this study were primary data collected directly on-site and secondary data collected from various research findings.

Plastic, titration apparatus, spectrophotometers, measuring cylinders, analytical pipettes, buckets, cold boxes, and stationery were among the instruments and supplies utilized in this investigation. Distilled water, Lugol's solution, soil or substrate at each research site, and supplies for measuring ammonia, pH, phosphate, nitrate, nitrogen, and soil texture levels were all utilized in this investigation. Additionally, soil samples were collected for laboratory investigation of soil quality factors. The soil samples were allowed to air dry in a dedicated chamber free of contaminants and shielded from the sun. Following drying, the soil samples were pulverized using a porcelain mortar and then passed through a 2.0 mm sieve (Mustafa and Admi, 2014). To obtain 0.5 mm sized particles, a sample of 2.0 mm sized particles was ground and sieved with a 0.5 mm sieve. Soil quality analyzed in the laboratory included pH, total nitrogen (N total) using the Kjedahl method, and phosphate (PO_4) using the Bray 1 method, following the instructions of Eviati and Sulaeman (2009); ammonium levels in the extract can be determined by distillation (Sabang and Rahmiyah, 2012). Nitrate levels refer to SNI 06-6989.31-2005 (Subiakto et al., 2019). Soil texture measurements were conducted by calculating the percentage of each fraction, and the texture classification was determined based on the USDA texture triangle (Handayani & Karnilawati, 2018). Material analysis was conducted in the Chemistry and Water Laboratory of the Pangkep State Agricultural Polytechnic. In this study, the data were presented in the form of images and graphs, followed by a descriptive discussion regarding the quality of the research location substrate consisting of ammonia, nitrate, pH, nitrogen, phosphate, and texture.

RESULTS AND DISCUSSION

Ammonia (NH_3)

Ammonia can exist in the non-ionized form, namely NH_3, or the ionic form NH_4^+, where NH_3 is more toxic than NH_4 (Poernomo, 1988). The main source of NH_3 is organic matter in the form of leftover food, fish waste, or in the form of plankton from suspended organic matter (Mustafa and Admi, 2014). Figure 1 shows the highest substrate soil ammonia content at ST 2 at 0.562 ppm, which is a station located around mangrove vegetation, and the lowest at ST 1, which is a location around the Tamarupa River Estuary. The low ammonia content in ST is thought to be due to the high rate of seawater and freshwater exchange at that location. According to Djajadiredja et al. (1980), waters containing NH_3 no more than 0.1 mg/L are considered normal, while those containing more than 1 ppm are considered polluted. If the NH_3 content exceeds 0.20 ppm, the water is toxic to some fish species (Sawyer and McCarty, 1978). If the subsequent decomposition process (nitrification) does not proceed smoothly, NH_3 can accumulate to levels that are harmful to fish. Ammonia can penetrate cell membranes more quickly than NH_4 (Colt and Armstrong, 1981). Fish cannot tolerate excessively high levels of NH_3, as it can interfere with the process of oxygen binding in the blood and ultimately lead to suffocation (Mustafa and Admi, 2014).

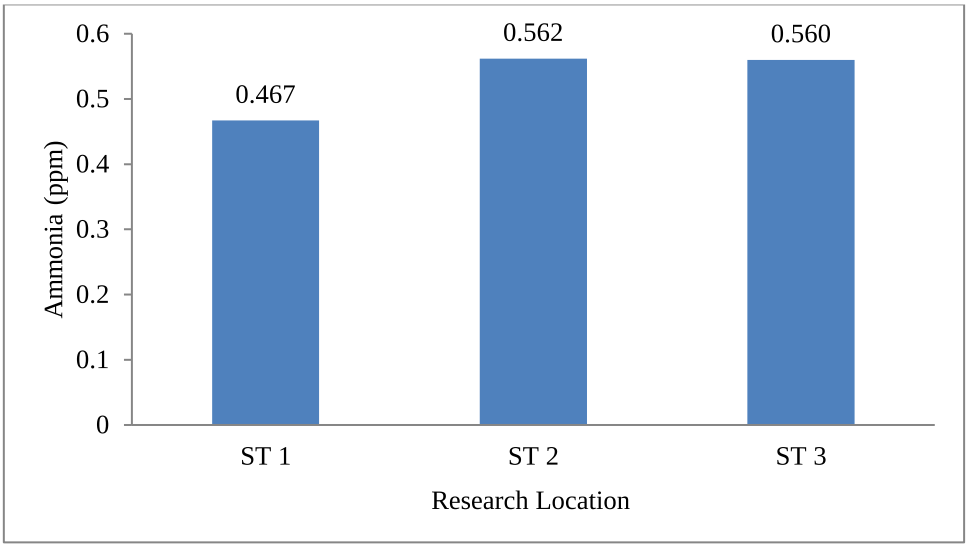

Figure 1. Ammonia Content of Substrate Soil

Nitrate (NO_3)

Nitrate is the primary form of N in natural waters and is a key nutrient for the growth of aquatic plants and algae. Nitrate is not toxic to aquatic organisms (Mustafa and Admi, 2014). Nitrate is the primary form of N in natural waters and is an important nutrient for pond cultivation because it is NO_3 that is utilized by aquatic plants and algae. Chu (1943) found that the optimum NO_3 content for plankton growth is 0.9-3.5 mg/L. Smayda (1983) stated that plankton generally prefer to utilize N in the form of NO_3, NO_2, and NH_3, so under these conditions, NO_3 is utilized first for its growth.

Figure 2 shows that the highest nitrate content in the substrate soil was at ST 1, at 4.3 ppm, and the lowest at ST 2, at 2.5 ppm. Nitrate is one of the three main forms of nitrogen compounds in seawater. This compound is often used as an indicator of water fertility. The oxidation of ammonia to nitrate and nitrite, which usually occurs under aerobic conditions, is known as nitrification and is an important process in the nitrogen cycle (Rizal et al., 2017). Generally, nitrate content in sediment tends to be low because nitrate is first utilized by phytoplankton and other organisms. This condition is because nitrate dissolves more quickly in water, resulting in fewer particles settling in the sediment (Rizal et al., 2017).

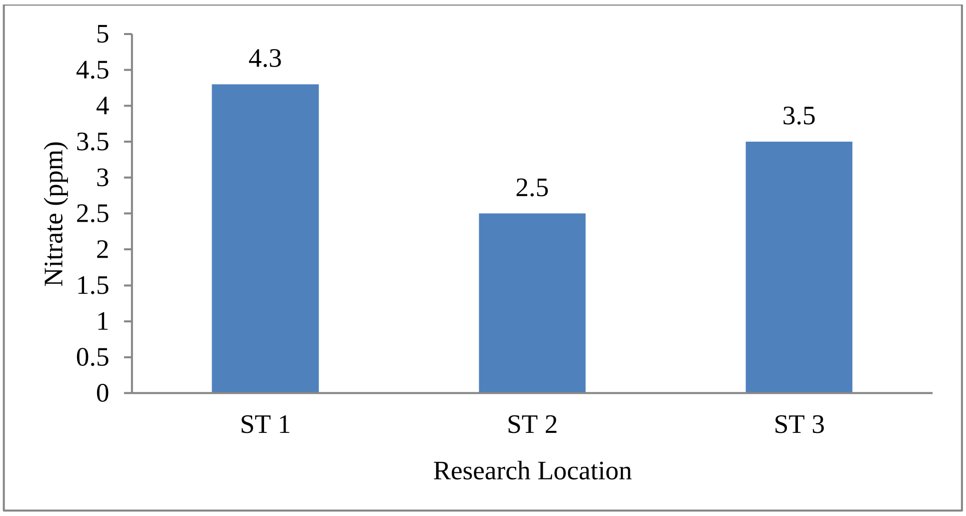

Figure 2. Nitrate Content of Soil Substrate

Soil Substrate pH

Acid sulfate soils commonly found in aquaculture areas in Indonesia have unique or specific properties, including being susceptible to changes due to natural disasters such as drought and human activities such as reclamation, land clearing, farming, and intensive agriculture. Therefore, in selecting soil quality criteria for aquaculture, variables are selected that have a significant impact on aquaculture but are stable or relatively difficult to change (Mustafa et al., 2008). Soil pH is related to nutrients and soil properties (Nazir et al., 2017). The potential for high soil acidity and low soil pH causes a higher solubility of various toxic compounds, which impacts the low availability of certain elements such as phosphorus (Ratnawati and Asaad, 2012).

A common indicator of the acidity or alkalinity of a land is its soil pH. Soil is said to be more acidic if its concentration of H+ ions is higher. Conversely, soil is more alkaline if it contains more H+ ions. Soil reacts neutrally (pH 6-7) if the concentrations of both ions are balanced (Agustina et al., 2022). Figure 3 shows that the pH value of the substrate soil ranges from 7.31 to 7.66, and all of these pH conditions indicate normal pH values. The pH of pond soil can reach above 6. This condition is thought to be caused by the high content of raw organic matter, which is the source of the pond soil's acidity (Hidayanto et al., 2004).

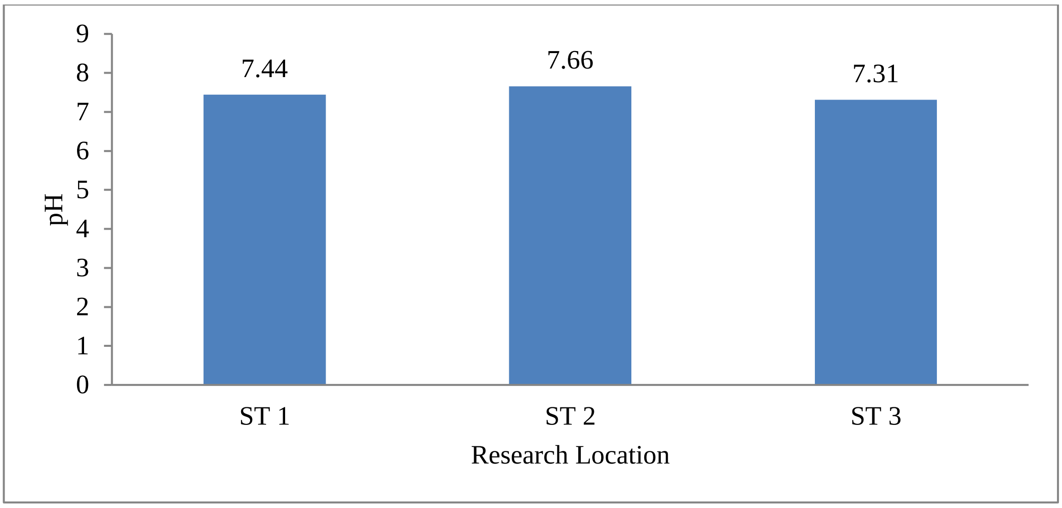

Figure 3. Soil pH Value

Nitrogen

Nitrogen is a macronutrient that is very beneficial for pond soil because it can support the growth of kelp and other aquatic plants that act as natural food. Nitrogen is a weak substance that functions to increase plant growth, nourish chlorophyll, increase protein levels in the plant body, and increase the proliferation of microorganisms that are important for the continued decomposition of organic matter (Sabang and Rahmiyah, 2012). Afrianto and Liviwati (1991) state that as nitrogen content is a measure of soil fertility, it is advised to check the nitrogen content of land that will be utilized for ponds. The amount of kelp that grows in the pond bottom soil increases with the amount of nitrogen in the soil.

Figure 4 shows that the highest nitrogen value of the substrate soil was at ST 1, which is located around the river mouth with a value of 4.3 ppm, and the lowest was at ST 2, a location located around the mangrove forest, which was 2.5 ppm. Most of the nitrogen (N) in the pond bottom soil is contained in organic matter. The results of research conducted by Mustafa and Admi (2014) in ponds in Demak Regency showed that the total N content of pond soil averaged 0.07%. According to Karthik et al. (2005), the total N content of pond soil greater than 0.05% (5 ppm) is considered good for pond cultivation.

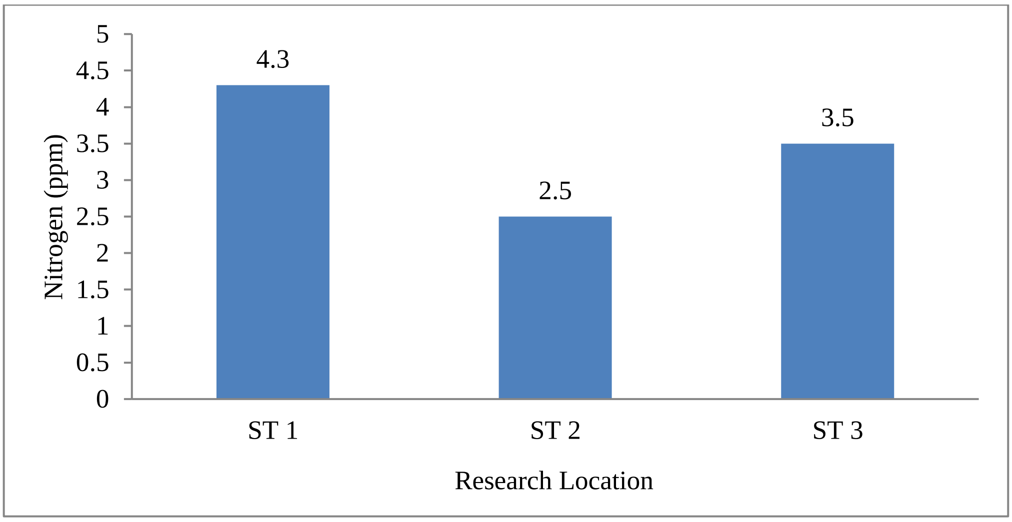

Figure 4. Substrate Soil Nitrogen

Phosphate (PO_4)

Pond primary productivity is constrained by phosphorus. Phosphorus is essential for a number of functions, including respiration, photosynthesis, energy storage and transfer, cell division, and cell expansion (Price, 2006). Water turbidity may rise on pond bottom soil with a high clay or silt percentage. Light penetration and oxygen transmission from the atmosphere into the body of water might be hindered by increased turbidity. Increased water turbidity can also make it difficult to see and interfere with the gills' ability to breathe, which can cause asphyxiation in aquatic life. Conversely, high sand content facilitates the management of excess organic matter from leftover feed or shrimp waste. In sandy sediments, nitrification rates are higher, as well as lower turbidity, ammonia, and bacterial populations (Bratvold & Browdy, 2001). Phosphate is an essential nutrient for the growth of aquatic organisms; high phosphate concentrations in water indicate the presence of pollutants. Nitrate levels are influenced by nitrate intake from the river. Nitrate originates from agricultural sources, including animal and human waste (Subiakto et al., 2019).

Figure 5 shows that the highest phosphate content is at ST 3, a location located near residential areas and fish farms, at 0.006 ppm. The high soil phosphate content at this location is thought to be due to its proximity to fish farms and the frequent fertilization of fish farms. However, the phosphate content at all study locations is relatively low compared to the opinion of Mustafa et al. (2008), who stated that phosphorus is an essential element as an energy source for many life forms. In aquatic systems, phosphorus is an essential element for primary production. Phosphate availability greater than 60 ppm in pond soil can be classified as slight or good with easily overcome limiting factors. PO_4 content greater than 60 ppm in pond soil can be classified as slight or good with easily overcome limiting factors (Karthik et al., 2005).

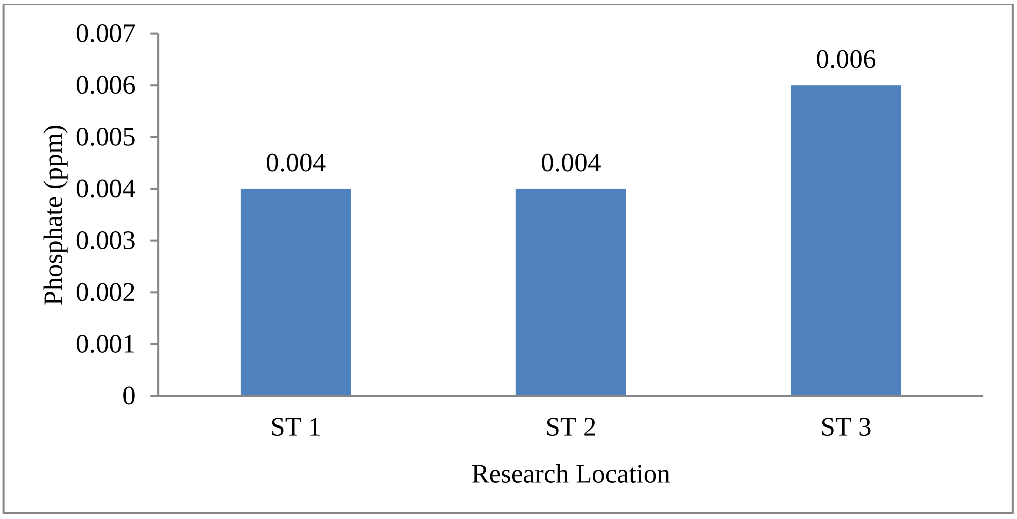

Figure 5. Phosphate (PO_4) in Substrate Soil

Soil Substrate Texture

Soil texture is the relative proportions of clay, silt, and sand in the soil (Mustafa et al., 2008). Sampling was conducted at the meeting point between seawater and rivers, where tidal currents carry fine-grained sediments out to sea and coarser sediments are deposited (Randa et al., 2021). Muddy sand is the most common form of sediment in places close to estuaries. This is due to the fact that when one gets closer to the estuary, the currents get smaller and eventually slow down, producing finer silt (Randa et al., 2021). According to Randa et al. (2021), sand sedimentation brought on by unstable current conditions can lead to mud and sand cross-pollination. Clay content up to 50% typically determines pond fertility (Hanafi and Badayos, 1989).

Table 1 shows that all research locations have a dusty texture. Good soil types for aquaculture are sandy loam, sandy clay, silty clay, and clay. Sandy loam soil is very suitable for the growth of natural food, while sandy and silty sand soils are very porous, so they cannot retain water and are poor in nutrients (Hidayanto et al., 2004). Sediment movement is greatly influenced by current speed; the larger the sediment grains, the greater the current speed required. Conversely, if the current velocity is weak, the sediment transported will be finer (Nursiani et al., 2020). High clay or silt content in pond bottom soil can increase water turbidity. Increased water turbidity can inhibit light penetration and oxygen transfer from the atmosphere into the water body. Furthermore, increased water turbidity will impede visibility and disrupt the respiratory system, namely the gills, resulting in asphyxiation in aquatic organisms. Conversely, high sand content facilitates the management of excess organic matter from leftover feed or shrimp waste (Mustafa et al., 2008). In sandy sediments, nitrification rates are higher, along with lower turbidity, ammonia, and bacterial populations (Bratvold & Browdy, 2001).

Table 1. Soil Texture of Substrate at Research Location

No.	Research Location	Texture of Substrate
1	ST 1	Dusty
2	ST 2	Dusty
3	ST 3	Dusty

CONCLUSION

The results showed that the highest substrate soil ammonia content was at ST 2 at 0.562 ppm, a station located around mangrove vegetation, and the lowest was at ST 1, a location around the Tamarupa River Estuary. Ammonia at the three research locations was classified as high because it was more than 0.1 ppm. The highest substrate soil nitrate content was at ST 1 at 4.3 ppm and the lowest at ST 2 at 2.5 ppm, and the nitrate content at the research locations was classified as low. The pH value of the substrate soil was within the normal range, ranging from 7.31 to 7.66. The highest nitrogen content was found in ST 1, a location near the river mouth, with a value of 4.3 ppm, a relatively low nitrogen content. The highest phosphate content was found in ST 3, a location near residential areas and fish farms, with a value of 0.006 ppm. Phosphate values for all study locations were still considered low. Furthermore, regarding the substrate soil texture, all study locations had a dusty texture.

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