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Quality Parameters of Soil Chemical Physics and Water Ecosystem in Indonesia

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***Abstract*—This research aimed to analyze the characteristics of coastal waters and the water and soil quality parameters using direct field observations or measurements and laboratory analysis. The results showed that the characteristics of the coastal waters include a 2.5 km coastline length in Tongke-Tongke Village, 1.2 average high tides, and 0-5 beach floor slope elevation degrees. The soil quality parameters include an average soil pH of 5.53, organic matter of 7.83 ppm, nitrogen of 0.19 ppm, phosphorus of 70.56 ppm, potassium of 220.80 ppm, the iron of 0.21 ppm, and soil texture of sandy mud with 45% dominated by watersheds, 40% by tides and waves, and 15% clay. Similarly, the water quality parameters include average water temperature at 29.780, 6.97pH, 30.40 ppt salinity, 4.06 ppm oxygen, 30.60 cm turbidity, and 0.87 ppm ammonia. The measurements and analysis of soil and water quality parameters were dynamic based on seasonal conditions. Therefore, the coastal waters of Tongke-Tongke Village were suitable as a research location due to the diverse flora and fauna. For tourism, the sedimentation volume from the watershed and the sea should be minimized through tides and waves. Floating net cages and other marine cultivation also need further development as tourist attractions. This setting is very suitable for educational endeavors due to its adherence to the optimal parameters required for aquaculture practices involving aquatic species that allow for implementing various instructional methods, such as using floating or fixed net cages and other systems, to educate visitors effectively.**

***Keywords*—Physical-chemistry; soil; and water.**

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I. INTRODUCTION

Indonesia is one of the world's largest archipelagic countries, with 17,508 large and small islands and an 81,000 km coastline [1]. Therefore, it is among the largest global exporters of fishery products, especially tiger prawns. The tiger prawns are obtained through aquaculture in ponds and at sea, making the country the largest global exporter by the end of the 1970s with increased annual demand from importing countries. The Presidential Decree Number 39 of 1980 Prohibiting Tiger Trawl Operations in Indonesian marine waters was issued to preserve fishery resources, especially tiger prawns, and its enactment decreased the tiger prawn's production cultivated in ponds and from the sea. Furthermore, the government implemented various efforts to increase production and meet the demand from importing countries through extensification or intensification [2].

These efforts have impacted the environment of various coastal water ecosystems through soil and water pollution. Intensification has decreased the environmental quality through soil pollution from excessive chemicals, such as fertilizers and drugs, that hardens the pond's bottom soil to become barren land due to intensive shrimp farming [3], [4]. This is experienced by various aquacultures, such as the north coast of Java Island and South Sulawesi's south coast, one of which is in Bantaeng District and is converted into idle land [5], [6]. Extensification decreased the mangrove forest area from 5,209,543 ha in 1982 to 2,346,414 in 1999, indicating a decline of 2,863,129 ha or 54% in 17 years. Furthermore, the remaining area of 2,346,414 ha, or 57.9%, is in critical condition due to human activities, such as aquaculture, ports, industries, and tourism [3], [4], [7].

The government implemented various efforts to restore the mangrove forest, including physical through planting mangroves along the coastline encroached for various purposes, and non-physical through regulations on environmental conservation, including Law No. 1990 on preserving the biodiversity of flora and fauna and their ecosystems [8], [9].

One of the restoration efforts by the government and the community is the Tongke-Tongke mangrove forest as one of

the brandings of Sinjai District. However, its condition is worsening annually, and it is viewed only as a coastal forest and managed for tourism purposes on a simple scale in recent years [10]. Mangrove forest conservation can be optimized by combining it with tourism and education activities [5]. Visitors can enjoy the characteristics of the beach while observing its panorama and natural phenomena, especially viewed from a distance with the nine islands cluster as a breakwater before the waves. This research analyzed the characteristics of coastal waters and the parameters of soil and water quality.

II. Materials and Method

A. Materials

This research used writing instruments, a ruler, a compass, a tidal scale pole, a water turbidity meter, a soil tester, a thermometer, a pH meter, a refractometer, a roller meter, a plastic bottle and bucket, and a camera. The applied materials included soil, water samples, and label paper. While primary and secondary data were applied through direct field observations for soil and water quality parameters and previous writings such as research results and book reports like village potential, sub-districts in numbers, districts in numbers, and local, national, and international journals, respectively.

B. Method

1) Research Setting: The research was conducted for six months, from March to August 2021, in the coastal waters of Tongke-Tongke Village, East Sinjai Sub-district, Sinjai District, and South Sulawesi Province, as shown in Figure 1.

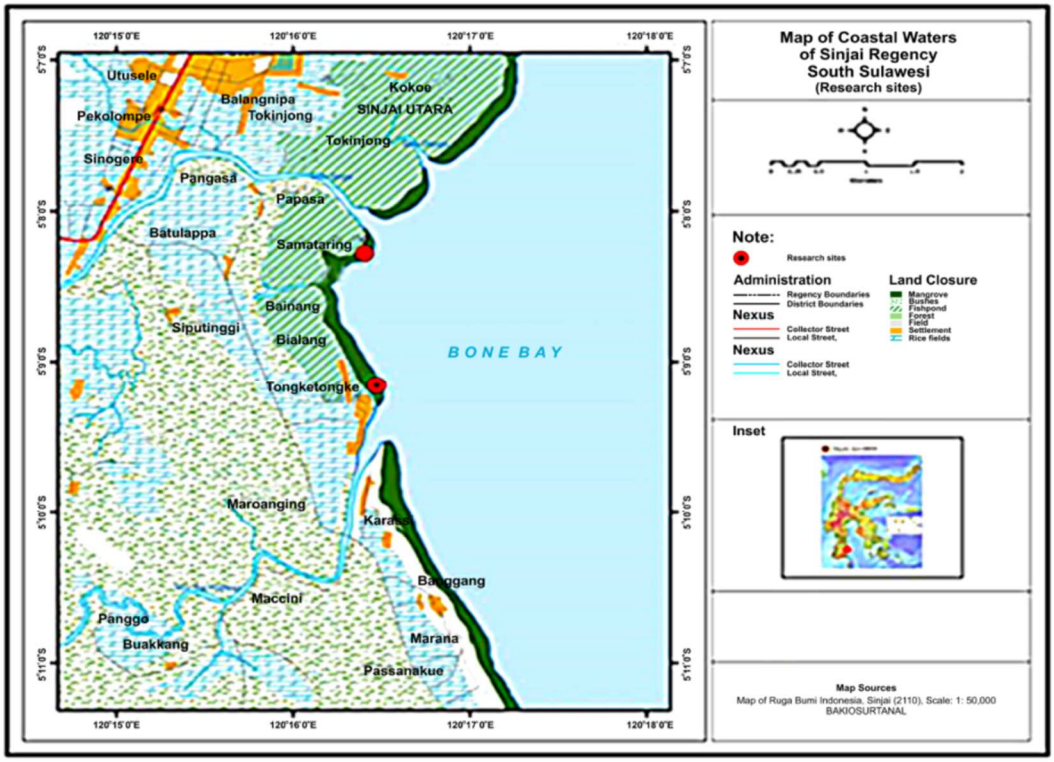

Fig. 1 Tongke-Tongke Village, East Sinjai Sub-district, South Sulawesi, Indonesia

2) Data Collection Techniques: The data were collected through two methods:

- Direct field observations of the characteristics of the coastal waters in Tongke-Tongke Village, such as tidal conditions and elevation.
- The soil quality parameters were sampled on three transects, each with three stations, and then analyzed in the laboratory.

Meanwhile, the water quality parameters were sampled on three transects with three stations, measuring some directly at the observation site, such as temperature, and the rest were analyzed in the laboratory. The transect location was in a straight line from land to sea. Hence, the ecological data represented the mangrove ecosystem.

3) Data analysis: Quantitative analysis was applied with a feasibility study of the coastal waters' characteristics and soil and water quality parameters. Furthermore, the quantitative data were analyzed descriptively and qualitatively to provide recommendations to all stakeholders on whether the location meets the ecological requirements for education and tourism.

III. Results and Discussion

A. General Description

Administratively, Tongke-Tongke Village is located in the East Sinjai Sub-district, Sinjai District. It is divided into five hamlets, Cempae, Babana, Maroangin, Baccara, and Bentenge. Furthermore, it is bordered by Samataring Village in the north, Bone Bay waters in the east, Panaikang Village in the south, and Batulappa in the west. Sinjai city is

approximately 7.5 km to the south, with asphalt roads accessed by two or four-wheeled vehicles in 5 minutes.

Geographically, it is directly adjacent to Bone Bay waters and is flanked by two major rivers, the Mangottong in the north and Baringang in the south, with a 2.5km coastline. There is a green line along the coastline as mangrove forest on the beach with an area of 350.50 ha or 25.10% of the total 1.351.50 ha forest area in Sinjai District [6]. At the same time, the rear or mainland consists of aquaculture lands and residential areas spread over five hamlets with 3.297 people, where 448 are fishermen [5].

One of the sources, a community leader and a civil servant at the Plantation and Forestry Service of Sinjai District, provided a brief history of the mangrove forests in Sinjai District, especially Tongke-Tongke Village, stating that their origin is not certain but have existed since the Dutch colonial era [1]. However, the mangrove area decreases annually because it is used for various purposes, especially aquaculture, due to the attractive prices of tiger prawns [11].

The large-scale conversion of these forests for various purposes threatens the coastal waters of Sinjai District, especially Tongke-Tongke Village, through waves and tornadoes, the annual loss of the poles of the houses due to abrasion, wells, and water. The community's wells change the fresh water to brackish and salty during the dry season, making the house roofs fly off from tornados because the residential areas lack mangrove forests as green lanes. Based on this, the population realized the importance of mangrove forests as a green line and gradually conducted self-help planting [10]. Furthermore, he received Kalpataru from the President due to his pioneering work in saving the coastal environment.

In saving the coastal environment, the Sinjai District's community planted 1.351.50 ha of mangrove across nine coastal villages and 350.50 ha or 25.90% in Tongke-Tongke Village in less than 25 years from 1986-2010. The observations of the mangrove forests' condition in 2010 showed a gradual death between 1-5% year-1 due to lack of maintenance because the community only viewed it from the ecological aspect, disregarding the economic and social aspects [6].

The mangrove forests can be optimized and sustained by management based on tourism and education; for example, tourism activities can show how an ecosystem should be maintained through aesthetics. Furthermore, educational activities can show an ecosystem's biodiversity, maintaining flora and fauna. Therefore, the Tongke-Tongke mangrove forest can be sustainable as an aesthetic and a natural laboratory function.

B. Water Characteristics

The coastal waters characteristics in Tongke-Tongke Village included the coastline length, average tide height, elevation, topography, and currents and waves, described as follows:

1) Coastline Length: Tongke-Tongke Village is among the coastal villages in the East Sinjai Sub-district, Sinjai District, with its coastline extending from North to South at approximately 2.5 km. Mangrove forests are spread along the coastline over 350.50 ha and an average width of 310 meters, inhabited by various types of fauna like a bird, fish, shrimp, shellfish, and crab species. These forests benefit the surrounding community through ecological, economic, and social functions.

2) Average Tide Height: The average tidal height observations and measurements of Tongke-Tongke Village coastal waters and its surroundings were 1.2 meters. Therefore, the embankments along the coastal waters of Sinjai District, especially Tongke-Tongke Village, were at least 1.5 or 0.3 meters above the high tide average. The morning and afternoon tidal period was similar to Bone Bay waters and Makassar Strait, with a slightly higher average tide height in the Bone Bay waters than in Makassar Strait and Flores Sea.

3) Elevation: The elevation or slope was between 0-5 degrees, facilitating the development of aquaculture land in the coastal waters of Sinjai District, especially Tongke-Tongke Village, with easy water management through gravity using tidal water. This indicates that pond management reduces the operational costs of the water management system with traditional technology and is semi-intensive. Furthermore, a traditional package with intensive and supra-intensive uses a management system with pumping.

4) Topography: The coastal topography was relatively flat, especially in tidal areas, but the land was quite steep and hilly. Furthermore, the rice fields in the Sinjai District, especially East Sinjai, were relatively narrow and terraced like pyramids following topographic conditions. This condition can attract tourists visiting the mangrove in Tongke-Tongke Village while enjoying a three-dimensional natural panorama, namely the expanse of green mangrove forest with various types of flora associated with mangrove vegetation and fauna [10]. Besides the beauty of the mangrove forest with aesthetic and educational value, the sea looks blue when viewed from the east with a cluster of nine islands like stars. In contrast, the view from the west shows green hills clusters with some surrounded by rice fields shaped like pyramids around the hills, adding to the aesthetic and educational value of the coastal nature.

5) Currents and Waves: Geographically, the coastal waters of Tongke-Tongke Village are directly opposite the Bone Bay waters, hence stronger wave currents, especially in the dry season because the wind blows from east to west. Therefore, the residential areas along the coast of Sinjai District experience tornadoes, increasing abrasion and causing two simultaneous natural disasters. This damages the roof, and the house floor formed as a stage due to the lack of the mangrove forest as a green line, losing and breaking the pillars from abrasion annually. Therefore, the community is enthusiastic about planting independent mangroves [12].

6) Soil Quality Parameters: The measurements and analysis of soil quality parameters were for educational activities, while the tourism activities were for aesthetic values such as smell and color, as shown in Table 1.

TABLE I
AVERAGE RESULTS OF MEASUREMENT AND ANALYSIS OF SOIL QUALITY PARAMETERS IN THE TONGKE-TONGKE COASTAL MANGROVE ECOSYSTEM

Measured Parameter	Transect			Average
	1	2	3	
Soil PH	4.50	5.85	6.25	5.53
Organic Ingredients	8.75	7.45	7.31	7.83
Nitrogen	0.25	0.19	0.15	0.19
Phosphor	53.57	94.15	63.95	70.56
Potassium	205.05	221.32	236.01	220.80
Iron	0.27	0.25	0.11	0.21
Soil Texture	L. Sandy	L. Sandy	L. Sandy	L. Sandy

7) Soil pH: pH is an abbreviation of potential hydrogen describing the acidity level or soil wetness at a research object location, indicating land productivity. Therefore, one of the soil quality parameters determines the growth rate of natural feeds such as moss, klekap, and plankton. The average soil pH analysis in the coastal waters of the mangrove ecosystem of Tongke-Tongke Village was acidic, as presented in Table 1. This was due to the low water circulation system in the mangrove ecosystem because the vegetation density reaches 12.000 trees ha^{-1}, causing organic matter from the decomposition process of leaves, flowers, and fruit between the mangrove roots [13]. The analysis showed a direct correlation between the three observation transects, with lower pH on the inner transect or land direction following the middle, outer transect, or sea direction. This was caused by lower water circulation on the mainland, accumulating organic matter with a stronger tidal influence than the middle and outer parts of the transect. Therefore, high water circulation can transport organic matter on the ground floor [14].

8) Organic Ingredients: Organic matter indicates the land's fertility level and is positively correlated with other nutrients as the main source of all nutrients. Most nutrients come from organic materials before changing their original shape, including macro and micro, turning into nitrogen elements, phosphorus, and potassium [8], [15]. Decomposed mangrove litter consisting of leaves, flowers, fruit, twigs, stems, and bark first forms organic matter before changing into macro and microelements. This explains the relationship between organic matter and other elements: high organic matter increases other elements, including macro and micro. The results showed that the organic matter in the Tongke-Tongke mangrove ecosystem positively correlated with other elements. In general, there were more nutrients in the land transect due to different water circulation systems in each transect [9], [14].

9) Nitrogen: The nitrogen elements abbreviated by N in the coastal water's ecosystems, especially mangrove ecosystems come from three sources, (1) organic materials from decomposed mangrove litters. (2) The sea through tides caused by various materials, such as garbage, animal carcasses, and volcanic eruptions after breaking down into various nutrients. (3) The atmosphere is caused by various mud particles in the air, including volcanic eruptions, forest fires, industrial pollution, and land, sea, and air transportation. The nitrogen element in the Tongke-Tongke mangrove ecosystem positively correlated with organic matter. It is among the elements needed for the growth of natural foods, such as *klekap* and plankton. However, excess plankton elements cause eutrophication, exploding in closed waters such as lakes, pools, and ponds [16] [17]. Mangrove ecosystems similar to open water are less likely to occur due to high tides, creating tourist sites.

10) Phosphor: Phosphorus is abbreviated by P and is caused by weathering of flora and fauna corpses. As a soil nutrient, it is essential for the growth of algae and other natural foods in ponds or pools. Furthermore, it is not always positively correlated with organic matter because the organic matter from mangrove litter contains less phosphorus than other elements like nitrogen. The analysis showed no correlation between transects and other nutrients such as nitrogen, organic matter, potassium, and iron. This was different from previous research [5], which stated that phosphorus positively correlates with iron, where areas with higher iron content have greater phosphorus. However, the phosphorus analysis on all transects was above the optimal limit for natural food growth in ponds or pools [18] [19].

11) Potassium: Potassium abbreviated by K is a nutrient required for plants, namely a macro element called NPK needed in large quantities, including natural food in waters such as algae, klekap, and plankton. The elements are needed by plants to form chlorophyll and are found in ponds or other coastal ecosystems from continuous high tides, causing higher circulation systems in coastal aquatic ecosystems than others such as ponds. The results showed that it did not positively correlate with the transect location nor other nutrients, such as organic matter and nitrogen, which are independent, such as phosphorus. These results were different from previous research [6], which found the optimal range for pond needs. This was because the previous research was conducted on pond ecosystems with closed waters, limiting the water circulation compared to mangrove ecosystems with open waters, allowing continuous water circulation. This results in dynamic environmental parameters, including soil and water quality [20], [21].

12) Iron: Iron is a microelement needed in small amounts to limit plant growth, including natural food in ponds or pools. Laibig's law states that the plants' growth determining factor is neither macronutrients nor quantity but their availability in small amounts, including iron [22]. The ideal amount of iron in the soil is 0.5 ppm because higher content can lower pH and bind phosphorus. Therefore, iron negatively correlates with soil pH and phosphorus. The analysis of the average iron on all transects showed that it was above the optimal range of 0.21 ppm, with a 0.5 ppm tolerable iron limit due to the low water circulation system in the mangrove ecosystem. The vegetation density of 12,000 trees causes this ha^{-1}. Hence, the bottom soil's organic matter is not distributed at high tide. The results were positively correlated with those of soil pH, where all transects were acidic but not correlated with phosphorus, as presented in Table 1. This was because phosphorus is sometimes independent and not correlated with other elements, such as nitrogen [23].

13) Soil Texture: Soil texture is essential during the pond construction, and the land should meet the technical

requirements [24], [25] that the ideal texture for aquaculture includes clay, loam, and sandy. Furthermore, it helps grow natural food because it contains clay and sand, facilitating high oxygen circulation in the soil [26]. The analysis showed sandy loam soil texture on all transects, including the texture lacking the requirements for aquaculture land. Furthermore, it was difficult to build ponds embankments, could not hold water, and lacked natural food growth. A good soil composition for aquaculture consists of 44% silt, 42% clay, and 15% sand and is ideal for bund making and the growth of natural food Fields[19]. The results of the average soil texture per transect are presented in Table 1.

14) Water Quality Parameters: The measured and analyzed water quality parameters, including temperature, soil pH, salinity, dissolved oxygen, brightness, and mania, as presented in Table 2.

TABLE II
AVERAGE RESULTS OF MEASUREMENT AND ANALYSIS OF WATER QUALITY PARAMETERS IN THE TONGKE-TONGKE COASTAL WATER MANGROVE ECOSYSTEM.

Measured Parameter	Transect			Average
	1	2	3	
Temperature	28.96	29.35	31.03	29.78
pH	6.85	6.91	7.15	6.97
Salinity	30.11	30.35	30.75	30.40
Dissolved Oxygen	3.95	3.99	4.25	4.06
Brightness	35.11	31.13	25.36	30.60
Ammonia	0.11	0.09	0.06	0.87

15) Water Temperature: The water temperature affects other parameters, especially oxygen and salinity, and is positively correlated with salinity, where higher temperature increases the salinity due to evaporation. In contrast, it is negatively correlated with oxygen, where higher temperature lowers the dissolved oxygen due to an increased metabolic process that utilizes oxygen. However, the analysis of temperature and oxygen did not correlate because the sampling was conducted in a mangrove ecosystem with similar temperatures due to desalination. The temperature measurements showed no significant difference among transects, indicating an optimal range for fish and shrimp farming in ponds. Besides reduced sunlight before reaching the waters, the relatively stable temperature in the mangrove ecosystem is due to the vegetation that affects aquaculture production. Some pond farmers stated that the mangrove ecosystem as a green line increases pond production because it stabilizes temperature, provides nutrients for the water entering the pond, and prevents pollutants because it contains a biofilter [5].

16) Water pH: Hydrogen potential measures the hydrogen ion concentration to indicate water alkalinity or acidity, using the pH scale from 0-14, with 7 as neutral. The analysis of water pH showed a correlation with the shoreline, where the deeper it goes inland, the lower the pH. Two factors cause this, a closer distance to the land lowers the water circulation and increases sediments as organic deposits. Therefore, the water pH level is determined by the circulation system. Water pH is directly related to tourism activities because it increases ammonia, emitting an unpleasant odor when lower. However, the coastal waters of Tongke-Tongke have a lower potential for ammonia increase because it is directly opposite the open sea, allowing continuous water circulation. Furthermore, the dynamic quality parameters, including pH and ammonia, differ from closed water ecosystems such as bays and estuaries with lower water circulation.

17) Salinity: Salinity is the concentration of dissolved matter in water expressed in mg liter-1 (ppt). It is a water quality parameter consisting of the physiological processes of aquatic organisms [27]. Salinity fluctuations limit organisms in maintaining life and growth because they affect the osmoregulation process, balancing aquatic organisms' external environment and internal conditions [28]. The difference in osmotic pressure between external and internal uses more energy, affecting survival and growth. Planting mangroves along the coastline can manage salinity fluctuations in aquaculture areas [29]. The mangrove vegetation in the dry season can overcome high salinity in coastal waters, including ponds, because the leaves have a desalination function, slowing freshwater evaporation and reducing salinity fluctuations. The development of fish and shrimp cultivation in Sinjai District has potential because the mangrove forest area is almost twice the pond area at 1,351.50 ha and 716.50 ha, respectively [5]. Therefore, salinity fluctuations are smaller throughout the year, allowing the cultivation of aquatic organisms, specifically fish and shrimp.

18) Dissolved Oxygen: Dissolved oxygen is the essential water quality parameter in fish, shrimp farming, and other aquatic organisms, causing mass death in the early morning [30]. This is due to the lack of dissolved oxygen reserves from the previous day used by aquatic organisms and plants at night [31]. Furthermore, oxygen production stops at night due to a lack of phytoplankton photosynthesis as the main source of dissolved oxygen. The fluctuation of dissolved oxygen is determined by phytoplankton, hence its positive abundance during the day as a producer and negative at night because it acts as a user. Consequently, this disturbs other aquatic organisms experiencing an oxygen crisis. The dissolved oxygen measurements and analysis on all transects were stable with smaller fluctuations, as presented in Table 2. The stability of dissolved oxygen in mangrove ecosystems is influenced by the mangrove vegetation, controlling temperature fluctuations. Hence, a silvofishery pond system is necessary to control the water temperature because it contains mangrove vegetation, providing nutrition and other ecological functions to stabilize water quality parameters [32] [33].

19) Brightness: Brightness indicates the amount of solid material floating in the water, hindering sunlight. The water brightness or turbidity is caused by plankton or other aquatic plants and mud particles from the water movement. This observation focused on the coastal waters of the Tongke-Tongke mangrove ecosystem as a tourist location, requiring water turbidity. The assessed coastal landscapes include water quality, flora, fauna, elevation, and topography. The results showed insignificant differences between the three transects and an optimal range for tourism designation. This strengthens the argument that the mangrove ecosystem traps and localizes sedimentation, stabilizing the water clarity for tourism purposes without interfering with swimming and fishing activities [34] [35].

20) Ammonia: Ammonia describes the water pollution level and is influenced by the accumulation of organic matter [36]. The results showed a positive correlation with the coastline location, where each transect differed, as presented in Table 2. One transect near the land had more ammonia than the others towards the sea due to higher water circulation in the sea directly from high tides and waves. Ammonia positively correlated with water brightness, where higher brightness is followed by increased ammonia concentration. However, it negatively correlated temperature, pH, and dissolved oxygen but related with salinity without affecting each other [37].

IV. Conclusion

The results showed that the coastal waters characteristics of Tongke-Tongke Village are suitable as a tourist location and educational activities due to attractive and aesthetic panoramas and educational value. The quality parameters were natural and above optimal for klekap, algae, and plankton growth, and without pollution. Therefore, tourism and educational activities through field practice for students and research, including Non-Governmental Organizations (NGOs), are ideal. Water quality parameters should be used as a tourism location because aesthetically, it lacks the potential for pollution, causing unpleasant odors and changes in watercolor. Additionally, it is ideal for educational activities because the parameters are within the optimal range for aquaculture designation of aquatic organisms, allowing floating or fixed net cages and other systems to educate the visitors.

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