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Study on water quality based on physicochemical parameters and distribution of waste in the waters of Kelapa Dua Island

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ABSTRACT

Kepulauan seribu archipelago is home to Kelapa Dua Island, a potential marine tourism destination and habitat for diverse marine life. The survival of marine biota hinges on suitable physical and chemical water parameters, encompassing temperature, pH, salinity, and dissolved oxygen (DO). This study aims to evaluate water quality and litter distribution on Kelapa Dua Island within Kepualauan Seribu National Park. Results reveal that the water quality largely aligns with established standards; however, specific points surpass limits, notably lower salinity at stasion 3 (26‰), and higher pH at station 2 (9.35). Despite meeting quality standards, the island's status as a populated area and tourist destination raises concerns about potential alterations to water quality. Furthermore, observations on litter distribution indicate a status categorized as B (0-4/m) and C (4-10/m), highlighting a relatively low level of litter presence. The interaction of human activities, both as inhabitants and visitors, may contribute to fluctuations in water quality. Understanding these dynamics is crucial for sustainable management, ensuring the preservation of Pulau Kelapa's ecological integrity as a cherished marine environment and tourist attraction. This study provides insights into the delicate balance between human interactions and environmental preservation in the context of Pulau Kelapa, Kepualauan Seribu.

Introduction

The marine waters have an extremely important role when viewed from the perspective of management and planning. Based on past observations up to the present time, marine areas have provided significant economic value beneficial to human life (Wang & Li 2022).

The benefits of well-preserved marine ecosystems include serving as a source of food such as fish, shellfish, crustaceans, and seaweed, which are important protein sources for humans (Costello *et al.,* 2013). Furthermore, marine ecosystems have a role in regulating the global climate and temperature, particularly coral reef and seagrass species that absorb carbon dioxide and influence ocean currents, which in turn affect thermohaline circulation (McLeod *et al.,* 2011). According to Duarte (2010), marine ecosystems also have a role in purifying and removing waste through biochemical and physical processes (water filtration, waste deposition, and organic matter decomposition). Well-preserved marine ecosystems can enhance the tourism sector and serve as a source of economic income (Cisneros *et al.,* 2015).

The benefits yielded are not only experienced by communities residing contiguous to maritime regions but are also perceived by certain inland communities situated at a considerable distance from maritime zones. Concurrently, with the passage of time, the increase in population inhabiting maritime territories such as islands is progressively expanding. This trend may entail consequences that exert pressure on maritime territories; with the growing population residing on islands, there is a corresponding

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expansion of maritime areas earmarked for habitation (Tjandraatmadja *et al.*, 2018). The situation clearly can have an impact on ecosystems located in marine waters. As the population increases, it cannot be denied that there will be an increasing amount of both organic and inorganic substances entering the water. The amount of waste production in certain areas will be directly proportional to the population, the number of activities or events, and the consumption levels of the community (Manik *et al.,* 2016; Akbar and Rahayu, 2023).

The Kepulauan Seribu Islands archipelago has one island named Pulau Kelapa, which has the potential to be a marine tourism attraction. The Pulau Kelapa sub-district has a population density second only to Pulau Panggang, yet the application of cultural values as a maritime nation has faded. According to Tahara (2018), as an ethnic group residing in maritime regions, the excavation of noble values within the community plays a very important role. This is necessary to cultivate maritime cultural values as a strength in implementing coastal community development with local wisdom. According to Noor & Jumberi (2008), to design intervention strategies towards local knowledge, which in this case is the knowledge possessed by a particular group of people in a specific area and for a certain period, it is important to understand their perspectives when interacting with their environment. How communities interact with their environment will significantly influence the sustainability of marine ecosystems.

Organic and inorganic substances or other components that enter water bodies from human activities will certainly change the quality of the water (Hamuna *et al.,* 2018). The input of these components can cause water quality to decline and not comply with established marine water quality standards. Incoming pollutants can also come from various sources, resulting in varying impacts on waters. The determined quality status is a comparison to determine whether a body of water is still in good condition or has been polluted. So it can be ensured that waters that have water quality that still meets quality standards will have a good impact on the life of the marine biota within it.

According to Hughes *et al.,* (2017), marine organisms rely on suitable water quality for their survival. Coral reefs and fish are interdependent, with coral reefs serving as habitats for fish. Fish inhabiting coral reef areas assist in controlling algae growth by consuming algae present on the reefs, thus helping to prevent algae blooming.

The sustainability of marine life necessitates suitable physical and chemical parameters of water, including temperature, pH, salinity, dissolved oxygen (DO), among others. Water quality assessment is an activity aimed at determining the quality of water at predefined locations (Boyd, 2015; Akbar *et al.*, 2023).

The aim of this research is to determine the water quality and distribution of waste on Kelapa Dua Island, Kepulauan Seribu National Park Hall. The water quality at that location is still appropriate or no longer in accordance with the determined quality standards. Apart from Kelapa Dua Island being an island that is inhabited and used as a tourist spot, it can allow for changes in water quality.

Materials and Methods

Location and time of research

This research was conducted in June 2023 on Kelapa Dua Island, within the Kepulauan Seribu National Park, DKI Jakarta Province. Water quality parameters were taken at three designated stations. In-situ measurements of seawater quality were conducted with two repetitions at each station. The selection of measurement stations was based on cardinal directions, namely north, south, and east. The reference standards for seawater quality adhere to Appendix VIII of Republic of Indonesia Government Regulation Number 22 of 2021 concerning Environmental Protection and Management. The types of physical and chemical parameters tested in this study, as well as the measurement methods and analysis standards utilized, are detailed in Table 1.

Table 1. Water Quality Measurement Parameters

No.	Parameter	Unit	Analysis Type	Analysis Tools/Method Spesifications
		Physical Parameter		
1	Temperature	^0C	*In situ*	YSI Pro20 Dissolved Oxygen Meter
		Chemical Parameter		
1	Salinity	%o	*In situ*	Atago Hand Refractometer
2	pH	-	*In situ*	WQM Horiba
3	*Dissolved Oxygen* (DO)	*mg/L*	*In situ*	YSI Pro20 Dissolved Oxygen Meter

The method used to determine the distribution of waste on Kelapa Dua Island is a survey method by going around Kelapa Dua Island and determining the coordinates for locations where there is an abundance of waste and conducting interviews with waste cleanup parties regarding waste processing that has been carried out on Kelapa Dua Island. . The location points that have been obtained with a large amount of waste will be included in the waste distribution map created using the ArcGis 10.4 application

The Condition of Waste Due to Tourism Activities in the Waters of Kelapa Dua Island

The weight of waste per square meter (m^2) is the total weight of waste per square meter.

$$M = \frac{total\ weight\ of\ waste\ (gr)}{w\ .\ l}$$

The composition of beach waste is calculated based on the percentage which is defined as the weight of each type of waste in each total waste in the transect box.

$$Percentage\ (\%) = \frac{X}{\sum_{i=1}^{n} Xi}\ 100\%$$

Waste density is the amount of waste of each type per square meter

$$K = \frac{amount\ of\ waste\ each\ type}{w\ .\ l}$$

M is the weight of the waste, X is the weight of the waste per type, K is the density of the waste, w is the transect width (m), and l is the transect length (m). The length of the transect at Station 1 and Station 2 is 100 meters, then the length of the transect at Station 3 is 235 meters, while the width of Station 1 is 48 meters, Station 2 is 50 meters, and Station 3 is 10 meters.

The Level of Waste Pollution Due to Tourism Activities in the Waters of Kelapa Dua Island

The level of waste pollution on beaches is classified based on the quantity of waste (all types of waste) per meter of research area (Earll *et al.,* 1997; Araujo and Costa, 2006) as presented in Table 2.

Table 2. Quantitative Criteria for Determining the Degree of Beach Pollution by Waste

Level	Description	Items/m	Information
A	*Absent*	0	There was no evidence of trash anywhere
B	*Trace*	>0-4	Most of the area is free from rubbish, there are only a few small items
C	*Unacceptable*	>4-10	Some at intervals, distribution waste is widespread, but accumulated small
D	*Objectionable*	>10	The area has lots of rubbish strewn about, with lots of accumulation

Data analysis

This research uses a comparative descriptive data analysis, by collecting water quality data in the field. The collected data will be compared with the quality standards for seawater quality in Appendix VIII of Republic of Indonesia Government Regulation Number 22 of 2021 concerning Environmental Protection and Management. The seawater quality standard reference table can be seen in Table 3.

Table 3. Sea Water Quality Standards

No	Parameters	Unit	Quality Standards
Physical Parameter			
1	Temperature	^0C	28-30
Chemical Parameters			
1	Salinitas	‰	33-34
2	pH	-	7 – 8.5
3	*Dissolved Oxygen* (DO)	mg/l	>5

Results

Water Quality

The quality of seawater, which serves as the habitat for numerous marine organisms and activities, undoubtedly necessitates standards in physical, chemical, and biological parameters. Values of water quality that surpass the established standards can be classified as polluted waters. The results of measurements conducted in situ will be presented in Table 4.

Table 4. Results of Water Quality Measurements

No	Parameters	Unit	Quality Standards	Measurement Results St. 1	St. 2	St. 3
Physical Parameter						
1	Temperature	^0C	28-31	31	32.2	30.1
Chemical Parameters						
1	Salinity	‰	33-34	27	28	26
2	pH	-	7-8.5	8.51	9.35	-
3	*Dissolved Oxygen* (DO)	mg/L	>5	6,2	6	5.7

Temperature

Temperature is a critical physical parameter for the sustenance of marine life. It can significantly

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impact the metabolism of aquatic organisms. Factors influencing temperature fluctuations include water depth, air temperature, seasonality, and time of day. Temperature elevation can lead to water stratification, wherein stratified layers affect water mixing and are essential for oxygen distribution, thereby preventing anaerobic conditions at the bottom layer (Hamuna *et al.*, 2018). The temperature measurement results are in the range of 30.1-32.2 ^{0}C.

pH (Acidity Level)

Measurements of acidity levels conducted in situ could not be performed at all designated locations due to limitations in available equipment. Nevertheless, the obtained values can serve as an indication of seawater quality. The measurements indicate discrepancies between northern and southern points. The pH values obtained at the northern point is 8.51, while at the southern point, it is 9.53.

Salinity

Observations indicate that surface seawater salinity in this area ranges from 26 to 28 parts per million (ppm). The salinity values of these waters do not meet the quality standards outlined in Appendix VIII of Republic of Indonesia Government Regulation Number 22 of 2021 concerning Environmental Protection and Management. The seawater quality, which specify a range of 33-34 ppm, with allowable variations of up to <5% in seasonal average salinity. According to Sadili *et al.,* (2015), Coral thrives in a salinity range between 34 and 36o/oo.

Dissolved Oxygen (DO)

Based on observations conducted at each sampling point, the obtained DO values showed no significant variation, ranging from 5.7 mg/L to 6.2 mg/L. These values comply with the quality standards outlined in in Appendix VIII of Republic of Indonesia Government Regulation Number 22 of 2021 concerning Environmental Protection and Management. The seawater quality, which specify a minimum DO level of >5 mg/L. According to Subarijanti (2005) in Kadim *et al.* (2017), the ideal oxygen content in waters is between 3 – 7 mg/L.

Waste Distribution

Waste management presents an enduring environmental challenge characterized by difficulties in containment. Kelapa Dua Island, situated within the Kepulauan Seribu archipelago, is subject to human habitation and tourism, thereby inevitably generating waste. Upon conducting site assessments of Kelapa Dua Island, various areas exhibiting substantial waste accumulation were pinpointed in Figure 1.

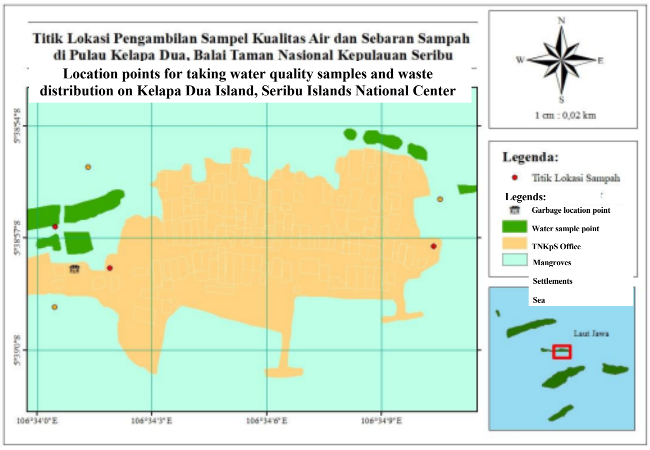

Figure 1. Map of Research Location

The accumulated total amount and weight of waste found in Kelapa Dua can be seen in Table 5.

Table 5. Amount and Weight of Garbage in Kelapa Dua Island

No	Location	Type of Water		Amount of Waste (items)	Waste weight (gr)
E1.	Statiun 1 (Mangrove area)	Organic	Leaves and Branches	140	300
		Inorganic	Glass Bottles	4	3,430
			Mineral water packaging	123	
			Food Packaging	350	
			Straws	100	
			Cigarette butt	56	
22.	Statiun 2 (Tourism area)	Organic	Palm fronds	3	10.4
			Paper	4	
		Inorganic	Food packaging	23	45
			Straws	15	
			Cigarette butt	30	
			Cloth	5	
33.	Stasiun 3 (Tourism area)	Organic	Coconut	204	112.450

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		Leaves and Branches	200	
		Food remnants	234	
		Paper/Cardboard	34	
	Inorganic	Mineral water packaging	57	
		Styrofoam	3	
		Food packaging	12	
		Straws	34	34.400
		Rubber	23	
		Glass bottles	67	
		Cigarette butts	80	
		Cloth	8	

Level of Garbage Pollution due to Activities on Kelapa Dua Island

Type of Waste Distribution

Observations conducted within the environment of Kelapa Dua Island, Kepulauan Seribu, revealed several locations with considerable waste accumulation. The waste found predominantly consists of discarded household items, sacks, ropes from discarded fishing nets, and is predominantly composed of plastic waste. The origin of the waste varies, with some originating from Kelapa Dua Island itself and others carried by currents passing through the island from neighboring islands. Waste was also found in mangrove areas, where it becomes entangled in the roots of mangrove trees as the tide recedes. Mangroves serve as waste accumulation sites in several coastal areas due to the root structures that trap waste (Hastuti *et al.*, 2014).

Table 6. Waste Contamination Levels by Category (Earll *et al.*, 1997)

No.	Location	Total Amount of Waste (items)	Items/m	Category
1.	Station 1	773	7.73	C
2.	Station 2	80	80	B
3.	Station 3	956	956	D

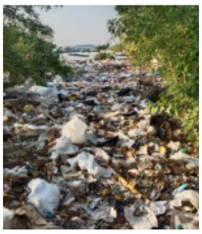

Figure 2. Garbage Pile Behind Kindergarten

Figure 3. Eastern Trash Heap

Waste management on Kelapa Dua Island is adequately structured for the handling of plastic, wood, and organic waste. Plastic waste collected at waste banks on the island is sorted based on plastic bags and plastic bottles. According to interviews with sanitation authorities, plastic bottles are collected and transported to the mainland for recycling. Meanwhile, plastic bags are processed into biofuel through pyrolysis techniques. Pyrolysis is a decomposition process of a substance at high temperatures without the presence of air or with limited air, involving chemical decomposition through heating without oxygen (Miandad *et al.,* 2019). The pyrolysis process produces solid fuel in the form of carbon, liquid in the form of tar mixture, and some other substances. In this process, waste is first sorted to obtain suitable types for conversion, including HDPE (High-Density Polyethylene), PET (Polyethylene Terephthalate), and PS (Polystyrene) plastics. Then, the waste is vacuumed to eventually transform into fuel. This process only requires a box-shaped container and gas as the burner, heating the waste above 400°C without oxygen. Typically, pyrolysis takes place over 4-7 hours (Miandad *et al.,* 2019). At such temperatures, plastic melts and produces solid fuel in the form of carbon, liquid in the form of tar mixture, and other substances. The pyrolysis process yields three types of products: solid (charcoal), gas (fuel gas), and liquid (bio-oil). According to sanitation authorities, the pyrolysis process cannot yet be implemented on Kelapa Dua Island due to the absence of the necessary machinery on the island. However, islands such as Pulau Pramuka and Pulau Harapan already have pyrolysis machines. As for wood waste and dry leaves, they are utilized as organic fertilizer, while some are incinerated before use, as indicated in Figure 4.

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Figure 4. Waste Processing

Discussion

The quality of seawater, crucial for supporting diverse marine life and activities, requires adherence to standards encompassing physical, chemical, and biological parameters. Changes in sea surface temperature can significantly impact these parameters and influence marine ecosystem dynamics (Kusumaningtyas *et al.*, 2014). Elevated sea surface temperatures disrupt ecological balance and affect climate, altering hydrological cycles and precipitation intensity (Wibisana *et al.*, 2018).

Direct measurements (in situ) around Kelapa Dua Island show slight variations in water temperature, ranging from 30.1 to 32.2°C, within the typical range of 28 to 31°C (Nontji, 2005). Variations may be attributed to solar radiation disparities affecting water heat absorption. The lowest temperatures in the eastern location likely result from afternoon readings when the sun is nearer to the western horizon (Officer, 1976). Atmospheric conditions, weather patterns, solar radiation intensity, geographical factors, and current dynamics significantly influence water temperature distribution (Pond and Pickard, 1978). Comparison with marine life quality standards, as per Appendix VIII of Republic of Indonesia Government Regulation Number 22 of 2021 on Environmental Protection and Management, indicates that all stations meet acceptable temperature levels for marine life around Kelapa Dua Island.

Water acidity, reflected by pH, is a critical indicator of water quality, influenced by factors like photosynthesis, temperature, and ionic composition (Siburian et al., 2017). Extremes in pH disrupt aquatic organism metabolic processes. Fish and aquatic life generally tolerate pH values from 4.0 to 11.0 (Jones, 1964; Swingle, 1968). While pH values at the northern point align with standards, those at the southern point do not (Edward and Tarigan, 2003). pH levels of 7 to 8.5 support aquaculture and recreation, while coral reef environments typically prefer pH ranges of 6 to 9.

Salinity, representing dissolved salt concentrations, influences osmotic pressure in water (Widiadmoko, 2013; Gufran and Baso, 2007). In accordance with Appendix VIII of Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning Environmental Protection and Management the salinity value is still below the standard quality threshold with a salinity value range of 26-28 o/oo while the standard quality value is 33-34 o/oo. Indonesian waters generally have salinity levels of 28 to 33 o/oo (Nontji, 2002), influenced by factors like freshwater inflow, rainfall, and seawater mixing (Banjarnahor, 2000).

Dissolved Oxygen (DO) is crucial for marine life, influenced by respiration and organic decomposition (Hutabarat and Evans, 1985). In accordance with Attachment VIII of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning Environmental Protection and Management, the dissolved oxygen value is in accordance with the standard quality limit with a range of dissolved oxygen values of 5.7 mg/L- 6.2 mg/L with a standard quality of >5 mg/L. Oxygen levels of 5 mg/L at 20-30°C support aquatic life (Rivai, 1983). Adequate DO supports biological processes and indicates water quality suitability for organisms (Salmin, 2005).

Waste concentration around Kelapa Dua Island is notably high at tourist areas (station 3), though managed effectively by local authorities and communities (Nontji, 2005). Waste management challenges persist due to inadequate awareness among residents and non-designated disposal areas (Indarmawan, 2014). Proper waste utilization, like organic waste for fertilizer and maggot feed, demonstrates structured waste management efforts (Indarmawan, 2014). Daily household waste collection and categorization by sanitation authorities contribute to waste control and environmental sustainability.

The waste management system in Pulau Kelapa Dua has effectively categorized and processed waste, ensuring that the water quality in the surrounding waters remains within established standards. Despite Kelapa Dua's status as a tourist destination, local waste banks have efficiently managed plastic waste using pyrolysis technology, which presents a significant advantage compared to other regions, such as the Pangandaran Waste Bank, which still relies on plastic shredding and pelletizing equipment. The use of pyrolysis technology also generates economically valuable products, reduces dependency on other petroleum-based resources, and enhances energy efficiency. This aligns with Sari's (2017) statement that the advantages of the pyrolysis process compared to incineration include the reduction of exhaust gases by up to 20 times, and the fact that the products generated from pyrolysis are more flexible in their utilization and easier to manage.

Conclusion

The water quality of Kelapa Dua Island, Kepulauan Seribu, which measure physical parameters such as temperature and chemical parameters such as pH, dissolved oxygen, and salinity. The values obtained for the physical and chemical parameters mostly comply with the quality standards set by the Ministry of Environment. However, salinity values do not meet the established standards, possibly due to the influence of ocean waves. Accumulated waste distribution on Kelapa Dua Island is found only at specific points. The waste management system on Kelapa Dua Island efficiently categorizes and processes plastic, wood, and organic waste, with plastic bottles being sent to the mainland for recycling, and wood waste and dry leaves repurposed as organic fertilizer or incinerated.

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