Condition of Waters in Pejarakan Mangrove Ecosystem, Buleleng, Bali Based on Water Quality Status

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Abstract. Pejarakan mangrove ecosystem area, Bali is one of the largest mangrove forests in Buleleng Regency and is managed for conservation and education. The input of anthropogenic waste or farming activities around the area can affect changes in water quality. This study aims to evaluate the condition of the waters which includes several physical and chemical parameters as a basis for determining the status of water quality in the area. The research was conducted in Pejarakan mangrove area, Bali at 6 station points since September 2022, January 2023, September 2023, and January 2024. The analysis method used is the pollution index (IP). Based on the observation results, pH (7.47-8.49), DO (3-7.6 mg/L), turbidity (0.17-18.75 mg/L), TSS (2.8- 38.6 mg/L), nitrate (0.02-0.05 mg/L), ammonia (0.05-0.5 mg/L), total phosphate (0.01- 0.75 mg/L), temperature (28.7-37.4°C), were obtained, generally the waters were mildly polluted for the pollution index (IP) method.

1 Introduction

Mangrove ecosystems are one of the coastal areas that have an important role for humans and biota. These ecosystems based on their ecology have several functions as services that include nursery ground, spawning ground, and become one of the producers in the marine food chain or feeding ground for aquatic organisms [1]. The ecological function of mangroves is related and continuous with other coastal areas which include seagrasses and coral reefs as coastal stability from abrasion. Humans can benefit from mangroves indirectly, namely as a wave breaker [2]. While directly becoming a source of building wood or firewood, as well as the capture of aquatic organisms caught around mangroves for the welfare of the community because this area is one that is rich in marine biota resources [3].

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The coastal area of Pejarakan, Buleleng, Bali is one of the largest mangrove forests in Buleleng Regency (160 ha) which is managed by Nature Conservation Forum Putri Menjangan 2016 for conservation and tourist education as well as ecotourism [4]. The mangrove in Pejarakan coastal area has 13 mangrove species that can grow well. The mangrove species include *Avicennia* sp., *Excoecaria* sp., *Rhizophora* spp. *Aegiceras* sp., *Ceriops* spp., *Lumnitzera* sp., *Bruguiera* sp., *Sonneratia* sp., and several associated plants [5]. Management of mangroves in Pejarakan, Bali has been carried out through reforestation activities to expand and improve mangrove [6]. Activities in the vicinity of the study site, including shrimp and salt farming, as well as agriculture and lobster farming, are expected to have an impact (e.g., waste input) on the mangrove ecosystem. This mangrove area is also utilized as ecotourism with its resource characteristics that are relied upon for conservation purposes as well as the tourism industry, so it can be one of the factors for the amount of waste entering in addition to its location adjacent to the farm [7].

However, quality status research in determining water conditions has not been conducted in the Pejarakan mangrove area, Bali. Therefore, observations of water quality both physically and chemically in the mangrove area in Pejarakan Bali need to be done to determine the status of water quality as supporting information and evaluation of the impact of activities around the mangrove area for local managers. This research aims to analyze the status of water quality using the pollution index method in the waters of Pejarakan mangrove area, Buleleng, Bali in order to know the condition of the waters along with appropriate management suggestions. This research is expected to provide basic information for the people of Pejarakan, Buleleng, Bali regarding the status of pollution and water quality in the waters of Pejarakan mangrove area, Buleleng, Bali as an evaluation material and suggestions for proper management in the future.

2 Materials and methods

2.1 Time and Location

Sampling was conducted in September 2022, January 2023, September 2023, and January 2024 in the mangrove area and its surroundings, Pejarakan Village, Buleleng, Bali. This water sampling time is expected to represent the season in the tropics. Water sampling was conducted at a six location point that represents the Pejarakan mangrove area, Bali using purposive sampling. Station 1 is the outlet sampling point of the farm, while station 6 is the inlet of the farm. Station 4 and station 5 are sampling points that are opposite the open sea. Station 2 is part of the canal and includes an inlet adjacent to the mangrove. Station 3 is a sampling point in the middle of the mangrove ecosystem (Figure 1).

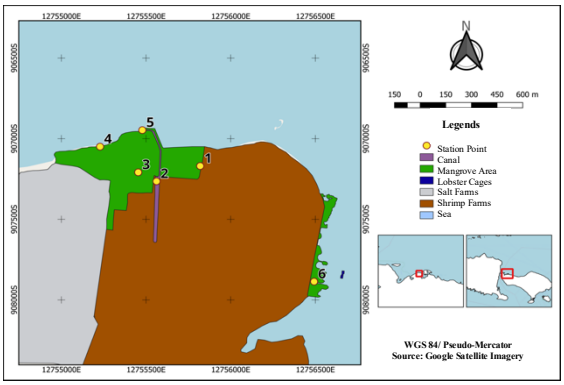

Fig. 1. Location map of Pejarakan mangrove area, Buleleng, Bali

2.2 Material and Equipment

This research requires tools and materials used in analyzing the pollution index and water quality status both ex situ and in situ. Direct measurements in the field or in situ using measuring instruments, namely multiparameters used to measure dissolved oxygen (DO), temperature, conductivity, salinity, and pH. Water sampling requires a 100mL sample bottle mixed with sulfuric acid (H_2SO_4) as a preservative to store samples that will be analyzed further include measure nitrate and ammonia, while 250 mL without preservatives to store samples that will be analyzed further include total suspended solid (TSS), nitrite, turbidity, and total phosphate [8]. Water samples will be analysis in the laboratory or ex situ, so labels are needed so that the bottles of each sampling point are not mixed up and coolboxes as a place to store water samples so that they are not contaminated and change.

2.3 Data Collection

Data collection in the form of primary data. Primary data includes water collection of physical and chemical parameters using multiparameters and further analysis in the laboratory (BIMA 1 MSP and BDP Environment, FPIK, IPB University). Water quality parameters used in determining the condition and status of water quality in Pejarakan mangrove area, Bali along with analysis methods and measuring instruments are presented in Table 1.

Table 1. Measured water quality parameters

Parameters	Unit	Measurement tool/Analysis method
Physics		
Temperature	°C	Multiparameter/ visual
Turbidity	NTU	Multiparameter/ *nephelometric method*
Total Suspended Solid (TSS)	mg/L	Balance sheet/ gravimetry
Chemical		
pH	-	Multiparameter/ visual
Dissolved Oxygen (DO)	mg/L	Multiparameter/ visual
Nitrate (NO_3)	mg/L	Spectrophotometry/ *cadmium reduction method*
Nitrite (NO_2)	mg/L	Spectrophotometry/ *sulfanilamide method*
Ammonia (NH_3)	mg/L	Spectrophotometry/ *phenate method*
Total Phosphate	mg/L	Spectrophotometry/ *ascorbic acid method*

2.4 Descriptive Analysis

The research data obtained were processed and analyzed descriptively. Descriptive analysis is a description and explanation of research results in accordance with scientific principles [9]. The value of water quality parameters obtained will be compared with the quality standards according [10] concerning the implementation of environmental protection and special management of water quality standards for marine biota [11]. The results of the analysis obtained will be used in determining the pollution index and as a form of strategy recommendations in the management of Pejarakan mangrove area, Buleleng, Bali.

2.5 Similarity of Characteristics between Research Stations based on Water Quality

The similarity of characteristics between research stations based on water quality was analyzed using Minitab22 software with the cluster analysis method. Water quality parameters included in this analysis include all chemical and physical parameters measured. Cluster analysis is a statistical method used in the clustering process. This process needs to use a distance measure in order to describe the similarity between data to represent a simple cluster structure from complex data. The distance measure that is often used is the euclidean

measure [12]. Single linkage is one of the cluster methods of hierarchical analysis (development whose structure resembles a branched tree) by grouping two data that have the closest distance. The result of using single linkage analysis with euclidean distance is a dendrogram. Dendrogram is a branching tree diagram used to illustrate similarities between data [13].

2.6 Pollution Index (PI)

The Pollution Index (PI) is the methods used to determine the status of water quality [14]. The level of water quality condition is indicated by its water quality status by comparing the existing and established quality standards. The water quality data obtained will be analyzed using PI according to [15] on the determination of water quality status. Determination of the level of pollution of mangrove areas with the following formula.

$$PI_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)^2 M + \left(\frac{C_i}{L_{ij}}\right)^2 R}{2}} \quad (1)$$

Description:

PI_j = pollution index for designation j
Ci = concentration of water quality parameter i
L_{ij} = concentration of water quality parameter i specified in the quality standard for water designation j
M = Maximum
R = Average

Determination of the level of pollution is done using four ranges of values from the results of the pollution index obtained. The following PI classes are presented in Table 2.

Table 2. Water class based on Pollution Index (PI) method

Pollution Index Value	Waters Class
$0 \leq IP_j \leq 1{,}0$	Meet Quality Standard
$1{,}0 \leq IP_j \leq 5{,}0$	Lightly Polluted
$5{,}0 \leq IP_j \leq 10$	Moderately Polluted
$IP_j > 10$	Heavily Polluted

Source: KEPMEN LH No. 115 Year 2003

3 Results

3.1 Aquatic Environmental Conditions in Pejarakan Mangrove Area Bali (physical and chemical parameters

Water quality data in the Pejarakan mangrove area, Bali obtained from observations for 4 months, including September 2022, January 2023, September 2023, and January 2024. The results of this water quality parameter test vary and in order to determine the value of parameters that either meet the quality standards for biota in mangroves, there is an average value and standard deviation. Determination of the quality standards of water quality parameters [10]. The test results of water quality parameters both physical and chemical temporally are presented in Table 3.

Table 3. Minimum, maximum, mean, and standard deviation values of water quality in Pejarakan mangrove area, Bali (physical and chemical parameters) in September 2022, January 2023, September 2023, and January 2024

Parameters	Unit	Quality Standard	Month			
			Sep-22	Jan-23	Sep-23	Jan-24
Physics						
Temperature	°C	28-32	30.70-27.60 (29.43±1.15)	32.80-30.90 (31.77±0.77)	34.40-29.80 (31.58±1.52)	37.40-29.70 (31.73±2.89)
Turbidity	NTU	5	18.75-0.17 (4.07±7.24)	5.50-2.30 (4.08±1.32)	8.10-0.40 (4.13±2.58)	18.70-1.30 (9.6±8.32)*
TSS	mg/L	80	38.60-5.60 (12.48±12.88)	22.00-9.20 (16.33±5.26)	16.20-2.80 (8.60±4.62)	37.40-3.50 (19.68±16.09)
Chemical						
pH	-	7-8,5	8.49-7.48 (8.08±0.43)	8.30-8.10 (8.25±0.08)	8.41-7.90 (8.18±0.20)	8.35-7.47 (7.92±0.35)
DO	mg/L	>5	7.60-5.00 (6.48±1.13)	6.50-5.20 (5.68±0.49)	6.70-4.00 (5.38±1.07)	7.30-3.00 (5.12±1.64)
Nitrate	mg/L	0,06	0.03-0.02 (0.02±0.004)	0.05-0.03 (0.04±0.01)	0.03-0.03 (0.03±0.002)	0.03-0.02 (0.03±0.001)
Nitrite	mg/L	-	0.15-0.01 (0.04±0.06)	0.44-0.17 (0.33±0.12)	0.05-0.02 (0.03±0.01)	0.36-0.06 (0.16±0.11)
Ammonia	mg/L	0,3	0.50-0.05 (0.25±0.18)	0.30-0.20 (0.23±0.04)	0.28-0.13 (0.19±0.06)	0.10-0.06 (0.08±0.01)
Total Phosphate	mg/L	-	0.60-0.01 (0.20-±0.22)	0.33-0.02 (0.15±0.14)	0.35-0.03 (0.16±0.14)	0.75-0.19 (0.40±0.21)

The results of the average temporal analysis of both chemical and physical water quality parameters show that there is one parameter that does not meet the established quality standards. The parameter that does not meet is turbidity in January 2024 with an average of 9.60 NTU. The highest average value is the temperature parameter in January 2024 at 31.73°C. The lowest average value is for the nitrate parameter in September 2022 at 0.02 mg/L. Physical or chemical parameters each have a minimum (lowest) and maximum (highest) value based on data per month.

Parameters with varied values can be seen from the minimum, maximum, average, and standard deviation values, in the physical parameters analyzed include temperature, turbidity, and TSS. The highest temperature value obtained was in January 2024 at 37.40°C, while the lowest temperature value was in September 2022 at 27.60°C. The highest and lowest turbidity levels obtained were at the same time in September 2022 with values of 18.75 NTU and 0.17 NTU. The highest TSS value obtained was in September 2022 at 38.60 mg/L, while the lowest TSS value was in September 2023 at 2.80 mg/L. However, the highest or lowest values of turbidity and TSS do not differ much between months.

The values of the analyzed chemical parameters include pH, DO, nitrate, nitrite, ammonia, and total phosphate. The highest pH value obtained was in September 2022 at 8.49, while the lowest value was obtained in January 2024 at 7.47. The highest DO value obtained in September 2024 was 7.46, while the lowest value was in January 2024 at 3. The highest nitrate concentration obtained was in January 2023 at 0.05 mg/L, while the lowest concentration was in September 2022 and January 2024 at 0.02 mg/L. The highest nitrate concentration obtained in January 2023 was 0.44 mg/L, while the lowest concentration was in September 2022 at 0.01 mg/L. The highest ammonia concentration obtained in September 2022 was 0.5 mg/L, while the lowest concentration was obtained in January 2024 with a value of 0.06 mg/L. The highest total phosphate concentration obtained was in January 2024 at 0.75 mg/L, while the lowest concentration was in September 2022 at 0.01 mg/L. The results of water quality analysis tests for both physical and chemical parameters are also presented geographically or per station in Table 4.

Table 4. Minimum, maximum, mean, and standard deviation values of water quality in Pejarakan mangrove area, Bali (physical and chemical parameters) in station 1-6

Parameters	Unit	Quality Standard	Station					
			1	2	3	4	5	6
Physics								
Temperature	°C	28-32	32.80-29.80 (30.98±1.46)	31.40-29.40 (30.4±0.91)	31.80-29.40 (30.4±0.91)	37.40-30.40 (33.65±2.99)*	31.10-28.70 (30.10±1.12)	31.80-30.70 (31.33±0.49)
Turbidity	NTU	5	18.70-0.17 (6.22±8.45)*	18.75-2.90 (10.24±7.49)*	18.20-0.94 (7.74±7.57)*	5.20-0.53 (2.43±2.05)	5.50-0.40 (2.66±2.24)	4.90-1.90 (3.54±1.54)
TSS	mg/L	80	37.40-5.60 (20.15±15.07)	38.60-10.20 (22.20±13.71)	36.40-6.90 (18.58±12.57)	20.80-3.50 (8.98±7.96)	22.00-2.80 (9.80±8.41)	19.60-5.80 (11.49±10.33)
Chemical								
pH	-	7-8,5	8.40-8.30 (8.36±0.04)	8.49-8.16 (8.29±0.15)	8.20-7.48 (7.78±0.33)	8.30-7.61 (7.99±0.31)	8.30-7.47 (7.97±0.36)	8.41-8.10 (8.25±0.17)
DO	mg/L	>5	7.60-5.50 (6.78±0.93)	6.60-5.20 (5.83±0.64)	6.00-3.40 (4.6±1.14)*	7.00-5.50 (6.13±0.75)	5.30-3.00 (4.43±1.07)*	7.50-5.60 (6.25±0.86)
Nitrate	mg/L	0,06	0.03-0.03 (0.03±0.00)	0.04-0.02 (0,03±0,01)	0.05-0.02 (0.03±0.01)	0.03-0.02 (0.03±0.00)	0.05-0.02 (0.03±0.01)	0.05-0.03 (0.03±0.01)
Nitrite	mg/L	-	0.17-0.02 (0.12±0.07)	0.37-0.01 (0.19±0.20)	0.44-0.03 (0.14±0.20)	0.21-0.01 (0.10±0.11)	0.41-0.01 (0.15±0.18)	0.42-0.01 (0.14±0.19)
Ammonia	mg/L	0,3	0.50-0.07 (0.25±0.18)	0.40-0.07 (0.26±0.14)	0.25-0.08 (0.15±0.07)	0.30-0.06 (0.19±0.10)	0.20-0.05 (0.12±0.06)	0.24-0.10 (0.15±0.07)
Total Phosphate	mg/L	-	0.60-0.04 (0.34±0.23)	0.33-0.16 (0.23±0.07)	0.35-0.02 (0.24±0.15)	0.19-0.01 (0.08±0.08)	0.75-0.05 (0.31±0.32)	0.55-0.01 (0.18±0.25)

The results of the average test analysis of water quality parameters both chemical and physical based on the station show that there are several parameters that do not meet the quality standards [10]. Parameters that do not meet include temperature, turbidity, and DO. The highest average value is for the temperature parameter at station 4 of 33.65°C. Turbidity levels that do not meet are at stations 3, 4, and 6 with an average value range of 6.22-10.24 NTU. DO values that do not meet quality standards are found at stations 3 and 5 at 4.60 mg/L and 4.43 mg/L. The lowest average value is in the nitrate parameter at all stations of 0.03 mg/L. Physical and chemical water quality parameters each have maximum (highest) and minimum (lowest) values based on data per station. Physical parameters analyzed include temperature, turbidity, and TSS.

The highest temperature value is at station 4 of 37.40 °C, while the lowest value is at station 5 of 28.70 °C. The highest turbidity level obtained is at station 2 of 18.75 NTU, while the lowest value is at station 1 of 0.17 NTU. The highest TSS value obtained was at station 2 of 38.60 mg/L, while the lowest value obtained was at station 5 of 2.80 mg/L. The chemical parameters analyzed include pH, DO, nitrate, nitrite, ammonia, and total phosphate. The highest pH value obtained was at station 2 of 8.49, while the lowest value was at station 5 of 7.47. The highest DO value obtained was at station 1 of 7.60 mg/L, while the lowest value was at station 5 of 3 mg/L. The highest nitrate concentration obtained was at stations 3, 5, and 6 by 0.05 mg/L, while the lowest concentration obtained was at stations 2, 3, 4, and 5 by

0.02 mg/L. The highest nitrite concentration obtained was at station 3 of 0.44 mg/L, while the lowest concentration obtained was at stations 2, 4, 5, and 6 of 0.01 mg/L. The highest ammonia concentration obtained is at station 1 of 0.5 mg/L, while the lowest concentration obtained is at station 5 of 0.05 mg/L. The highest total phosphate concentration obtained at station 5 was 0.75 mg/L, while the lowest concentration obtained at stations 4 and 6 was 0.01 mg/L.

3.2 Similarity of Characteristics between Research Stations based on Water Quality

The similarity of characteristics between stations was analyzed based on the average water quality status per station. The average data from each parameter was inputted and then analyzed using Minitab22 software to obtain the results in the form of a dendrogram. The following is a dendrogram of the similarity of characteristics between research stations based on water quality in the Pejarakan mangrove area, Bali presented in Figure 2.

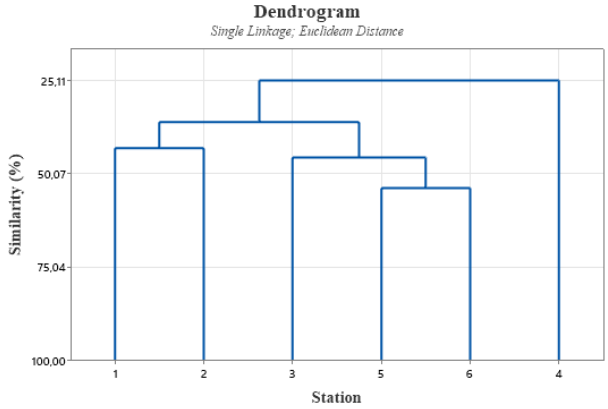

Fig. 2. Dendrogram of similarity characteristics between research stations based on water quality parameters in Pejarakan mangrove area, Bali

Based on the grouping results, it is known that there are two clusters formed. Station 4 has the lowest similarity value compared to other stations, which is 25.11%. The highest characteristic similarity value is between station 5 and station 6 with a value of 53.97%. The similarity value of 36.31% forms two clusters, namely between station 1 and station 2 with station 3, station 5, and station 6. The similarity value of 43.26% is between station 1 and station 2, while the similarity value of 45.82% is between station 3, station 5, and station 6.

3.3 Water Pollution Index (PI)

The calculation of the pollution index (PI) method is based [15] concerning the determination of water quality status. The results of using the PI method are presented in graphical form. The value of the PI of Pejarakan mangrove area waters, Bali temporally can be seen in Figure 3.

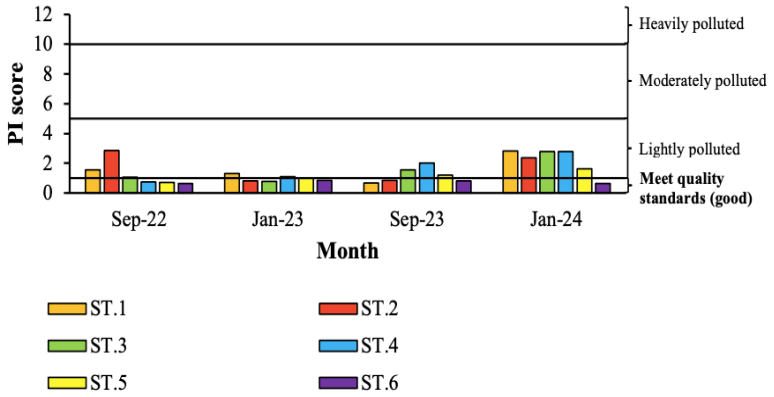

Fig. 3. Graph of water quality status using the pollution index (PI) method in the waters of the Pejarakan mangrove area, Bali in September 2022, January 2023, September 2023, and January 2024.

The results of the water quality status test using the temporal-based PI method show that the waters of the Pejarakan mangrove area, Bali are dominated by lighly pollution status. The average value per month is around 1.40 which is slightly different from the maximum score of the good category. The lowest value of temporal PI was found in September 2022 and January 2024 at station 6 at 0.65. The highest value of temporal PI was in September 2022 at station 2 at 2.85. The average high value of the PI at all stations was in January 2024 at 2.18, while in January 2023 the PI value at all stations was low with an average of 0.98. The results of pollution status using the PI method were analyzed geographically or per station presented in Figure 4.

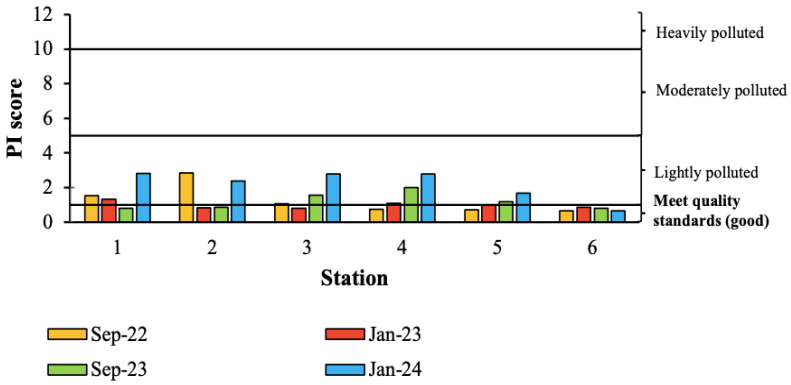

Fig. 4. Graph of water quality status using the pollution index (IP) method in the waters of the Pejarakan mangrove area, Bali in station 1-6

The results of the water quality status test using the PI method per station show that the waters of the Pejarakan mangrove area, Bali are dominated by good condition status. The average value per station is around 1.40 which is slightly different from the maximum score of the good category. The lowest value of PI per station was found in September 2022 and January 2024 at station 6 at 0.65. The highest value of PI temporally was in September 2022 at station 2 at 2.85. The highest average PI value based on each station is at station 2 of 1.73, while the lowest average is obtained at station 6 of 0.74.

4 Discussion

Pejarakan, Bali is one of the villages included in TNBB or West Bali National Park, where most of the small-scale fishermen's livelihoods depend on TNBB waters [16]. Pejarakan coastal waters have a mangrove ecosystem with a high diversity of mangrove species and good condition of 13 species [5]. Mangrove areas are very important for aquatic organisms as a habitat for breeding and growth. Several pond conversion areas in Pejarakan, Bali have been converted to mangrove planting sites. The mangrove area in this location also coexists with two other ecosystems which include seagrass ecosystems and coral reef ecosystems [17].

The main medium in the life of organisms such as fish to grow and develop is water. Water quality is a measure of the condition of a body of water relative to the needs of living things or humans [18]. The development and growth of good living things in a water body cannot escape the support of its water quality [19]. Water quality is very important to analyze to determine strategies in more appropriate control as ecotourism and the tourism industry [20]. Research in the Pejarakan Bali mangrove area based on parameters measured in situ or ex situ includes physics and chemistry. Seasonal effects can affect the value of water quality in a body of water taken and measured. January is a transition period from the rainy season to the dry season, September which represents the rainy season characterized by high precipitation [21].

The results of the analysis of the similarity of characteristics between stations based on water quality showed that none of the stations were similar with a similarity value of <80%. This is because each research station has different characteristics apart from the water quality parameters. However, between station 5 and station 6 which has the highest similarity value of 53.97% is because these two stations are meeting places with the open sea without any barriers. This is different from station 4, although the station point also intersects with the high seas, but there is a barrier between mangroves and the high seas, namely piles of sand that form a road as an abrasion barrier, so that even though the tide is not as much as the other stations and shallow. The characteristics of the waters at station 4 are also different, namely very turbid water and blackish brown in color. Stations 1 and 2 are included in the same cluster with a similarity value of 43.26% having similar geographical characteristics, namely turbid and greenish brown water, so parameters such as turbidity and TSS have values that tend to be the same. Station 3 is included in the same cluster as station 5 and station 6 with a similarity value of 45.28%, this is because between the three stations have similar geographical characteristics, namely adjacent and directly adjacent to the mangrove ecosystem.

The measured water quality parameters are found at several points that represent the geography of the study site and water sampling is done at high tide. The results of water quality parameters in the waters of Pejarakan Bali mangrove area measured and analyzed found that a few average values that do not meet the quality standards of seawater biota. Parameters that do not meet include temperature, turbidity, ammonia, and DO. Water quality parameters in several mangrove water areas in Indonesia based on research show that the measured results do not meet the quality standards [10]. Water quality data analyzed by several studies in mangrove water areas in Indonesia can be seen in Table 5.

Table 5. Water quality data from several mangrove water area studies in Indonesia

No.	Research Location	Parameter								References
		Temperature (°C)	Turbidity (NTU)	TSS (mg/L)	pH	DO (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Total phosphate (mg/L)	
1	Teluk Banten	28.40-37.50	0.00-38.00	0.40-10.00	6.63-	6.63-8.20	0.00-0.38	-	3.30-7.50	Adnina (2023)

					8.20					
2	Sagara Anakan, Cilacap	28.10-30.50	-	77.40 - 148.00	6.60-6.80	3.20-3.40	-	-	-	Priska *et al*. (2020)
3	Perancak, Bali	29.08-30.50	-	-	7.99-8.13	1.75-3.54	0.14-0.40	0.05-0.14	-	Susiana (2015)
4	Nusa Penida, Bali	28.00	-	55.20	7.50	3.50	0.560	-	0.35	Heriyanto dan Suharti (2019)

Based on the table above, it is known that at several research locations the values of physical and chemical parameters including temperature, turbidity, ammonia, and DO did not meet the predetermined quality standards. There are thresholds of seawater quality standards for marine biota that are still allowed according to the Decree of the State Minister of Population and Environment Number 2 of 1988 [22]. One of them is the threshold allowed for the turbidity parameter, which is 30 NTU, while the desired / best turbidity level is 5 NTU. Turbidity is included in physical water quality parameters whose characteristics can be known using the sense of sight [23].

Turbidity is a parameter that measures the relative clarity of a body of water. The expression of the amount of light scattered when sunlight enters a water sample or the optical characteristics of water is the definition of turbidity. Increased turbidity in a body of water will prevent sunlight from entering so that it can affect aquatic organisms and plants that need it [24]. High turbidity values are influenced by suspended inorganic and organic materials in the form of fine particles and colloids [25]. The results of turbidity and TSS values in the Pejarakan Bali mangrove area show a similar distribution both temporally and geographically. The turbidity parameter is closely related to total suspended solid (TSS), the higher the concentration of TSS in the water, the more absorption of solar heat energy will be [26]. This is in line with the turbidity concentration which will also increase and result in disturbed light penetration.

TSS (total suspended solid) is a suspended solid consisting of microorganisms, fine sand, and mud. Sediment that is lifted into the water column is also a factor in increasing suspended solids levels [27]. Measurement of total suspended solids can be used to determine the status of pollution of waters from domestic waste and the efficiency of seawater management units, especially in mangrove areas [28]. The TSS value obtained in the waters of the Pejarakan Bali mangrove area is in the range of 2.80-38.60 mg/L, which means that it is far from the threshold of sea water quality standards intended for mangrove marine biota of 80 mg/L.

Temperature is a physical parameter in a body of water influenced by latitude, sea level, season, stratification and depth flow of the water body, and time of day. Temperature data collection is not comprehensive for a period of time in days because each time has its own characteristics, but rather prioritizes the number of sampling points in order to represent the Pejarakan Bali mangrove area and structured repetition (September and January). Temperature values observed during the observation were in the range of 28.70-37.40°C with a varied distribution of values. The increase in temperature in January 2024 at station 4 to 37.40°C was due to the time of data collection in the morning before noon. The waters at station 4 were shallower than other stations, in accordance with the research in mangrove ecotourism area Sungai Tanah [29] which states that large changes in water temperature are found in shallow waters rather than deep waters. This also affects the increase in turbidity and TSS levels, so that changes in metabolic rate as a result of respiration or oxygen consumption by aquatic organisms decrease [30].

Dissolved oxygen (DO) is the concentration of the amount of oxygen (O_2) dissolved in a body of water [31]. Dissolved oxygen is used as a process of decomposing organic into inorganic by microorganisms and respiration by aquatic organisms [32]. DO as a water quality parameter can indicate the degree of impurity of raw water in a body of water [33]. DO values obtained in the range of 3.00-7.60 mg/L with a distribution of values that tends to vary slightly. These results are relatively similar to research in Banten Bay [34], Segara Anakan [35], Perancak [36], and Nusa Penida [37] which ranged from 1.75-8.20. The DO values analyzed contained data that did not meet the established quality standards. This can be influenced by the decomposition process, with the decay or decomposition of organic matter by microorganisms in the waters requiring oxygen and carbon to accelerate the process [38].

Potential hydrogen (pH) includes chemical water quality parameters to determine the level of hydrogen ions in water [39]. The pH value can be used to express the basicity of a solution [40]. Land organic matter that is flowed through river currents to the high seas can affect the acidity (pH) value of the water around mangroves. The pH value measured in the Pejarakan Bali mangrove area is relatively good with a range of 7.47- 8.49 with a slightly varied distribution of values. These results are comparable to research in Banten Bay [34], Segara Anakan [35], Perancak [36], and Nusa Penida [37] which ranged from 6.63-8.20. The value range is still within the threshold of seawater quality standards for biota. Aquatic biochemical processes such as nitrification of aquatic organisms are influenced by changes in pH values [41].

Nitrate, nitrite, and ammonia are chemical compounds and are called nutrients in the pollution index. Nitrate is a nutrient that is utilized by phytoplankton (an indicator of water quality status and fertility of a water body) in its metabolism and growth. Nitrate is formed from the decomposition process of the remains of dead organisms and plants or the decomposition / weathering process [42]. Nitrate is the main form of nitrogen in compound waters so it is important for protein synthesis of aquatic plants and animals, including in mangrove waters [43]. The nitrate concentration of Pejarakan Bali mangrove area analyzed in the range of 0.02-0.05 mg/L and the distribution is not varied. These concentrations meet the established quality standards. The nitrate concentration results obtained are relatively low compared to research conducted in Banten Bay [34], Segara Anakan [35], Perancak [36], and Nusa Penida [37] which ranged from 0.00-0.56 mg/L. High or low nitrate concentrations will affect the pollution index, so it needs to be known and analyzed.

Nitrite is an intermediate form or transition from the nitrification process, namely ammonia to nitrate and the denitrification process, namely nitrate to nitrogen gas. The amount of nitrite compounds in marine waters tends to be very small due to its unstable nature in the presence of oxygen [44]. The nitrite concentration obtained was in the range of 0.01-0.44 with a very varied distribution of values. The high level of nitrite compounds in a water body will cause disruption to aquatic organisms in it. This is because nitrite compounds easily bind to the blood hemoglobin of an aquatic organism and are toxic [45]. However, according to [46], the nitrite content of 0.01 can still be tolerated by mangroves and the waters of the Pejarakan mangrove area, Bali are near the farm, so there is input of waste flowing into the waters.

Ammonia can be toxic and non-toxic which is influenced by the pH of a water body. Ammonia that is not ionized or unionized due to waters having an alkaline atmosphere (high pH) can be toxic, and vice versa. Ammonia is easier to be absorbed by aquatic organisms into their bodies so that it can interfere and toxicity to aquatic organisms is higher. Ammonia values analyzed were obtained in the range of 0.05-0.50 mg/L with a varied distribution of values. Ammonia concentrations at station 1 and station 2 in September 2022 were above the threshold of seawater quality standards. High ammonia concentrations can be found in anoxic

areas, especially at the bottom of the waters [47]. This is in line with the location of the two stations at the outlet of the farm.

Phosphate is a nutrient compound that plays a role in the metabolic process and growth of both phytoplankton and other aquatic organisms. The forms of phosphate compounds that exist in marine waters are particulate phosphate and dissolved organic and inorganic [43]. The value of total phosphate concentration is influenced by ocean currents and physical and chemical water quality parameters [48]. Phosphate values in the Pejarakan Bali mangrove area analyzed were in the range of 0.01-0.75 mg/L with a varied distribution of values. The concentration of total phosphate in the sea has a less stable condition because it is vulnerable to the process of dilution, weathering, and erosion [43]. The concentration of total phosphate exceeding 0.096 mg/L in the sea has entered the high level classification [49]. However, this value can be caused by the lifting of high phosphate content from the bottom to the sea surface due to the turbulence of water masses and currents. This is in accordance with the total phosphate results at station point 5 which is close to the open sea, so that the total phosphate value reaches 0.75 in January 2024.

Pollution index (PI) is a method utilized in determining the status of a water body by using formulas that have been included [15]. Based on the results of the calculation of the pollution index or IP, it is known that the status of waters both temporally and geographically in the Pejarakan mangrove area, Bali is dominated by lightly polluted. These results are comparable to research on the East Coast of Surabaya City which states the results of station indices 2, 3, and 5 as part of the mangrove area are also lightly polluted [50]. Mangroves include biofilter plants, so the pollution index value obtained is still optimal for the ecosystem and the biota in it. The status of the waters at station 6 per month shows good conditions, because the station is an inlet of aquaculture.

Based on the results of the PI method used, the waters of the Pejarakan mangrove area, Bali are categorized in good to lightly polluted conditions. This is influenced by several parameters, especially ammonia which can be toxic to waters. Ammonia content that exceeds the quality standard is at the research station located at the outlet of the farm, so that management suggestions can be made by monitoring and supervising the disposal of waste from the farm which is carried out in a structured and periodic manner. The advice also applies to waters with good conditions in an effort to maintain healthy and safe waters of the Pejarakan mangrove area, Bali. Collaborative efforts and support also need to be made between related parties such as the government and local communities.

The government in question is not only the scope of the local village, but from the government of Gerokgak District and Buleleng Regency should also be able to pay attention to the mangrove area with proper supervision and legal determination for the management of this area. Such management includes evaluating the process of waste runoff from ponds into the sea on a regular basis, so that the value of water quality parameters that do not meet current quality standards can be degraded. Basic education also needs to be conducted for local communities and tourists regarding environmental care for mangrove ecosystems that have a major role in the waters and surroundings, so that collaborative efforts are more effective and easy to implement due to increased enthusiasm. Collaboration with pond owners and academics that has been carried out in the form of mangrove reforestation activities also needs to be improved so that polluting factors can be controlled. This is because rehabilitation can accelerate the restoration of a mangrove ecosystem and sustainable management in this area can be realized.

5 Conclusion

The condition of the waters of the Pejarakan mangrove area, Bali based on the status of water quality that has been analyzed using the pollution index (PI) method is generally lightly

polluted status. Based on the results of the status obtained, management advice that can be done is by monitoring and supervising the disposal of waste from farming, as well as collaborative efforts and support in mangrove area management needs to be done between related parties such as government and local communities so that polluting factors can be controlled.

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