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Research Article

Seawater Quality Analysis in Mantehage Island for Integrated and Sustainable Marine Tourism Development

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Abstract

Background and Objective: There is a growing interest to significantly explore more opportunities in the coastal environment. For this reason, adequate progressive strategies appear very essential. The purpose of this study was to analyze seawater quality as a database for developing integrated and sustainable marine tourism in Mantehage Island, Indonesia. **Materials and Methods:** The present paper applied descriptive and quantitative methods to sample 20 observation points around the selected location. In addition, the seawater content was directly measured and stored in the laboratory for further analysis. Consequently, certain parameters were evaluated, including salinity, temperature, turbidity, pH, total suspended solids, dissolved oxygen, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$. The subsequent data were also compared to the related quality standards of the Minister of Environment, Decree No. 51 of 2004. **Results:** Based on the results, Mantehage water quality demonstrated an excellent condition and is also believed to support the proposed marine tourism development. **Conclusion:** The values of salinity, temperature, turbidity, pH, total suspended solids, dissolved oxygen, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$, the condition of Mantehage water quality obtained a suitable category within the specified standards of the Minister of Environment Decree No. 51 of 2004. Several parameters known to exceed these provisions, including nitrate and phosphate content, indicate the instantaneous value during measurement.

Key words: Seawater quality, marine tourism, development, biodiversity, turbidity, salinity, dissolved oxygen

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The quality of seawater greatly determines the feasibility of an underwater tourism area, diving and snorkelling activities require good seawater conditions, this greatly affects the comfort and safety of tourists. Bunaken National Park exhibits high biodiversity, particularly in the Coral Triangle along the Asia Pacific region. The number of tourists visiting has a real connection with extensive coral cover. An increase in the number of tourist arrivals will affect the broad decline in coral cover and vice versa. Otherwise, the decline in coral cover will cause the number of tourists to decrease¹. The underwater view is famous to foreign tourists around the world and encompasses 5 minor islands, including, Bunaken, Siladen, Manado Tua, Mantehage and Nain. These 5 landmasses are divided into 2 administrative regions, including Manado city and North Minahasa Regency. Mantehage is a major outermost island in Indonesia with the greatest mangrove area in North Sulawesi, the mangrove flora in Bunaken National Park was floristically rich with at least 27 species and the broader northern distribution limit of *L. littorea* and *L. racemosa*, *C. philippinense*, *S. ovata* was confirmed². The mangroves community structure shows that it is unstable with low values of diversity and evenness, while the value of domination and species richness is high. The highest density of the mangroves found in station 9 is *C. tagal*. In general, mangroves species richness is found in the moderate category³. Moreover, the nature of the coral reef ecosystem serves as a potential underwater tourist attraction^{4,5}. The condition of the coral reefs in Mantehage island seen from the percentage of coral cover ranging from 20-40%, the condition of hard coral substrates accompanied by good water quality will support this island as a new marine tourism area⁵. This island also has a good seagrass ecosystem with an average cover percentage of 33%, there are 4 species of seagrass including *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *Halophila pinifolia*⁶. As far as can be ascertained, the marine biodiversity of Bunaken National Park is notably high. However, there seems to be a lack of a more comprehensive assessment, especially in Mantehage Island. To date, no comprehensive studies have been done on other marine fauna such as sea snakes, turtles, shorebirds and marine mammals⁷. Another factor might be the establishment and management histories of BNP since management was principally initiated by the Indonesian National Government (top-bottom approach) unlike in other well-known cases (e.g. Apo Island Reserve in the Central Philippines) where protection was initiated and even to this day actively participated by the local communities⁸. Some

important water quality parameters include salinity, temperature, turbidity, pH, total suspended solids, dissolved oxygen, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$. Information about these parameters will be very helpful in the development of tourist areas. This research is probably a consideration for policymakers in determining the direction and strategies related to the management of coastal and marine resources, particularly for marine tourism development in Mantehage.

The purpose of this study was to analyze the seawater quality as a database for the prospective development of marine tourism. In addition, The Minister of Environment Decree No. 51 of 2004 poses as a reference for the seawater quality standards.

MATERIALS AND METHODS

Study area: This research was conducted in Mantehage Island, Wori District, North Minahasa Regency, North Sulawesi Province, within Bunaken National Park from March-May, 2021.

Research protocol: Descriptive and quantitative methods with purposive sampling were employed in determining the observational base. Each station possesses coordinate points for easy monitoring and is evenly distributed.

Parameters measurement: The measured seawater parameters were salinity, temperature, turbidity, pH, total suspended solids, dissolved oxygen, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$. However, the sampling technique and data analysis adopted the methods^{9,10}.

Instruments used: The instrument used in this study is Horiba U-50 series multi-parameter water quality checker that enables to measure and indicate the monitoring result simultaneously up to 11 parameters with one unit. Considering user-friendly field monitoring on-site, such as river, groundwater, drainage water, etc. bring together feature of function and performance, which makes simple operation for everybody. Multiple sensors allow for the measurement of 11 parameters simultaneously (pH, pH (mv), Oxidation-Reduction Potential (ORP), Dissolved Oxygen (DO), Conductivity (COND), Salinity, Total dissolved solids (TDS), Seawater Specific Gravity, Temperature, Turbidity, Water Depth). For $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$ analysis, seawater samples were put into glass bottles, then brought to the laboratory for further analysis. Subsequently, the results were compared to the Minister of Environment Decree No. 51 of 2004 as a reference for seawater quality standards.

RESULTS AND DISCUSSION

Salinity: Salinity is described as the total amount of dissolved salt in seawater. The unit is generally accepted in mg L^{-1} but also occurs in ppt (parts per thousand) or percentage and Practical Salinity Unit (PSU). Freshwater salinity values are typically <0.5%, brackish waters 0.5-30% and seawaters 30-40%. Meanwhile, the estimate for coastal waters is strongly influenced by freshwater input from rivers. However, salinity potentially instigates osmotic pressure in seawater biota. The salt content in the aquatic cells occurs close to the surrounding seawater salinity. As the salinity changes, an osmoregulation mechanism is then required in balancing the salt levels between the cells and the environment. Mantehage Island shows a salinity range of 28-31 PSU, with an average of 29.15 PSU (Table 1). This value varies based on the climate/weather during measurement. In the dry season, seawater salinity rises above 30 PSU. Rainy weather condition was observed on the day before sampling, resulting in a lesser salinity value but showing a good category, according to seawater quality standards. This salinity condition is not only good for tourism activities but also for the sustainability of the surrounding aquatic biota.

Temperature: Temperature influences the metabolic activity and reproduction of marine organisms. This factor is used in a certain tourist destination to determine the potential and existence of coral reef growth¹¹. In marine life development, the optimal average temperature is expected in the range of 23-35 with tolerance limits between 36-40°C. The seawater temperature of Mantehage Island occurs from 28-31 °C with an average value of 29.15°C (Table 1). Furthermore, a similar condition was observed in the coastal waters of Labuhan Haji, East Lombok Regency, with a range of 30-32°C¹¹. However, temperature variations tend to influence the life of coral reefs. Based on the Minister of Environment Decree No. 51 of 2004, the water temperature for marine tourism is expected at natural temperature. An appropriate range for coral reef areas exists in the range of 28-30 and 28-32°C for Mangrove regions. Discontinue *in situ* temperature measurement is a natural temperature with a change tolerance <2°C (Minister of Environment Decree No. 51 of 2004). However, the biota in tropical waters naturally resides in the upper limit of the highest temperature. These variations possibly interfere with the physiological processes known to endanger the biota. In the value range >28°C, sea surface temperature in the western equator appears very warm¹². Moreover, the condition is considered natural as Indonesia is a tropical region. Based on

the water depth, extensive seawater surface temperatures are observed, in comparison to a certain depth, probably due to the high intensity of sunlight.

Turbidity: Lower turbidity increases the light intensity capable of penetrating the water depth. Therefore, the resulting value is expected to exist under normal conditions, where water transparency is inversely proportional to the turbidity, believed to significantly influence oxygen content. Turbid water possibly interferes with the respiration process and decreases oxygen levels. The seawater turbidity condition of Mantehage Island ranges between 2.2-4.7 NTU (Nephelometric Turbidity Unit), with an average value of 3.58 NTU (Table 1), indicating an appropriate category and in line with the quality standards. Therefore, the site is suitable as a potential tourist attraction. This condition is supported by data on Mantehage Island coral reef cover in the range of 19-30%, with an average live coral cover of 29.10%⁵. Furthermore, turbidity describes inadequate water transparency, due to colloidal and suspended materials, including mud, organic and inorganic materials as well as aquatic microorganisms.

pH level: Inconsistencies in the water pH level probably influence biota existence to a certain extent of varying pH¹³. The water pH value depends on carbon dioxide and ion concentrations. Moreover, the parameter plays a significant role in the solubility of particular compounds, although appears minimal in the morning, compared to the afternoon period. Subsequently, the pH of Mantehage Island seawater ranges from 7.1-7.9, with an average value of 7.51, indicating an appropriate category for tourism development and aquatic life support (Table 1). This value also corresponds to a pH in Labuhan Haji beach between 7.6-7.9¹¹. These variations depend on geographic position and water injection from the environment. In addition, it is also affected by the season as related to local rainfall and climate.

Total Suspended Solid (TSS): The TSS of Mantehage Island waters ranged from 28.24-36.25 mg L^{-1} with an average value of 32.39 mg L^{-1} , corresponding to the quality standard for biota survival (Table 1). However, in-depth study and sampling of other seasons are required for tourism development, particularly underwater ecotourism, considering the present research was only conducted in one season without repetition. This high TSS value is due to the greatest mangrove forest in Bunaken National Park and therefore sedimentation in certain segments is inevitable. This varies from the TSS of Pria Laot waters at the range of 14-31 mg L^{-1} , with an average

Table 1: Seawater quality parameters in Mantehage Island

Stations	Coordinate Latitude	Longitude	Temperature 28-32 alami C	Turbidity NTU	TSS (mg L ⁻¹)	pH	Salinity PSU	DO (mg L ⁻¹)	NO ₃ -N (mg L ⁻¹)	PO ₄ -P (mg L ⁻¹)	Parameters Biota quality standards Tourism quality standards Unit quality standards Decree of the Minister of Environment of the Republic of Indonesia No 51 of 2004
1	1°42'49.04"N	124°43'44.57"E	29	3.21	31.20	7.2	30.21	5.23	0.005	0.010	
2	1°42'27.10"N	124°44'10.46"E	30	4.25	29.25	7.6	31.26	5.47	0.025	0.011	
3	1°42'5.66"N	124°44'28.58"E	28	3.2	33.65	7.4	31.25	5.65	0.045	0.016	
4	1°41'49.04"N	124°44'54.55"E	29	2.2	35.25	7.8	30.45	5.14	0.006	0.018	
5	1°41'39.27"N	124°45'22.47"E	30	3.2	30.56	7.5	29.45	5.98	0.068	0.014	
6	1°41'29.02"N	124°45'49.90"E	28	4.7	32.00	7.4	30.87	6.12	0.065	0.013	
7	1°41'37.80"N	124°46'31.55"E	28	3.6	33.63	7.6	32.14	3.24	0.058	0.015	
8	1°41'59.04"N	124°47'48.3"E	28	2.8	32.63	7.9	30.45	6.35	0.009	0.019	
9	1°42'29.46"N	124°47'1.90"E	30	4	34.24	7.1	31.56	5.21	0.004	0.018	
10	1°43'9.12"N	124°46'41.67"E	30	4.1	32.13	7.4	30.25	5.98	0.008	0.017	
11	1°43'35.87"N	124°46'26.20"E	30	3.2	33.26	7.5	31.25	5.87	0.025	0.009	
12	1°44'29.95"N	124°46'15.18"E	29	4.5	31.00	7.6	30.87	5.46	0.054	0.008	
13	1°44'58.36"N	124°45'57.12"E	30	2.5	31.27	7.1	31.63	5.21	0.066	0.016	
14	1°45'19.63"N	124°45'38.18"E	31	3.8	33.36	7.5	32.65	5.69	0.042	0.014	
15	1°45'51.74"N	124°45'15.50"E	29	4.7	36.25	7.8	32.4	5.19	0.061	0.018	
16	1°46'14.93"N	124°44'9.69"E	28	3.5	35.21	7.5	31.25	5.38	0.019	0.016	
17	1°45'24.98"N	124°43'48.02"E	30	3.4	28.24	7.6	30.65	5.67	0.048	0.014	
18	1°44'51.67"N	124°43'41.78"E	28	2.8	29.25	7.6	31.45	5.43	0.065	0.013	
19	1°44'18.76"N	124°43'32.41"E	29	3.6	32.25	7.6	30.14	5.28	0.008	0.017	
20	1°43'37.56"N	124°43'34.43"E	29	4.5	33.25	7.5	30.86	5.17	0.007	0.014	
Average			29.15	3.58	32.39	7.51	31.052	5.43	0.034	0.015	
Minimum			28	2.2	28.24	7.1	29.45	3.24	0.004	0.008	
Maximum			31	4.7	36.25	7.9	32.65	6.35	0.068	0.019	

TSS: Total suspended solid, NTU: Nephelometric Turbidity Unit, PSU: Practical Salinity Unit and DO: Dissolved Oxygen

of 21.83 mg L⁻¹. Similarly, the TSS of Labuhan Haji beach also demonstrated a fairly higher content, ranging from 14-31 mg L⁻¹, with an average of 21.83 mg L⁻¹. This value is also above the quality standard allowed for marine tourism (20 mg L⁻¹) and marine life (coral and seagrass at 20 mg L⁻¹ and mangroves at 80 mg L⁻¹)¹¹.

Dissolved Oxygen (DO): The dissolved oxygen source in water originates from the diffusion of oxygen from the air, water currents or flow through rainwater, as well as photosynthetic activity by aquatic plants and phytoplankton. Generally, aquatic creatures, e.g fish, shrimp, shellfish and other animals, including microorganisms, e.g bacteria, require oxygen. Dissolved Oxygen (DO) regulates the metabolism of organisms to grow and reproduce. Fish need water with an oxygen content of at least 5 mg L⁻¹. The DO values in Mantehage waters ranged from 3.24-6.35 mg L⁻¹, with an average of 5.43 mg L⁻¹ (Table 1). This indicates a suitable oxygen content capable of supporting marine biota. Moreover, seawater quality standards for tourism and healthy ecological activities require DO values above 5 mg L⁻¹. The condition supports the seagrass survival, covering 33% of the island⁸ and also matches the results of Dissolved Oxygen (DO) measurements performed at Labuhan Haji beach, where the total stations obtained a yield range of 6 mg L⁻¹. Also, the value shows an excellent water condition and relatively suffices the seawater quality standards¹¹. Furthermore, dissolved oxygen describes the relative concentration of the element in water within the range of 4.28-10 mg L⁻¹¹⁴. The measured DO value of Pria Laot Sabang ranged from 4.4-4.69 mg L⁻¹, with an average of 4.53 mg L⁻¹. However, at sea level, DO values are influenced by the diffusion of oxygen from the air and the photosynthetic rate by marine plants¹⁵.

Salinity: A particular salinity level is required for coral reefs and seagrass survival towards attracting marine tourism objects, including snorkelling and diving. The salinity range of Mantehage Island waters occurs between 29.45-32.65‰, with an average value of 31.05‰ (Table 1). This estimation indicates a suitable category within the applicable quality standards. Salinity plays an essential role in supporting marine biota and the water level varies based on geography and time, where the increase in the parameter is caused by evaporation and the result of freezing sea ice, while the decrease is instigated by precipitation and freshwater input from rivers. This outcome slightly varies from the measurement results at

Labuhan Haji beach, showing a salinity range of 32-35‰¹¹. However, the salinity value to promote coral reef life is expected to range from 30-36‰¹¹. This difference is influenced by geographical position and water type. Furthermore, stable salinity in the archipelago tends to be achieved, due to inadequate water inflow from the mainland. In addition, the value is also greatly impacted by evaporation and precipitation rates.

Nitrate: The nitrate content in the Mantehage waters ranges from 0.004-0.068 mg L⁻¹ at an average of 0.034 mg L⁻¹ (Table 1). This value exceeded the quality standard of the Minister of Environment and Forestry Decree No. 51 of 2004, estimated at 0.008 mg L⁻¹. In addition, the extreme result is influenced by the mangrove ecosystem located on the coastal part of the island, where sedimentation is very extensive during the rainy season. An additional indicator is also due to poor mangrove management, leading to free waste from anthropogenic activities entering the aquatic environment. The high concentration of nitrate is probably due to input from land and surrounding factors in the form of liquid waste, both due to agricultural operations. Moreover, the primary ingredient of fertilizers is nitrogen, known to utilize a biophysicochemical process to become a compound. In marine waters, six types of nitrogen are formed, termed N₂, NO₃, NO₂, NH₃, NH₄, organic N and particulate N. This outcome corresponds to the analysis results of the NO₃ at Labuhan Haji beach, with similar content of 0.036 mg L⁻¹. Also, the nitrate (NO₃) at Labuhan Haji appears relatively high due to community activities on the coast/land, where unwanted materials are directly and inappropriately disposed into the sea. In addition, the existence of river water flowing into the beach also serves as a transportation medium for agricultural waste and other human activities related to the sea¹¹.

Phosphate: The phosphate content in Mantehage waters ranges from 0.008-0.019 mg L⁻¹ at an average of 0.015 mg L⁻¹ (Table 1). This value is under the specified quality standard for marine tourism at 0.015 mg L⁻¹, based on the Minister of Environment Decree No. 51 of 2004. However, the estimate varied from the measurement results in Moyo Hilir and Lape sub-districts, between 0.03-0.3 mg L⁻¹. Extensive land activities are believed to trigger the phosphate content beyond the quality standard, including livestock, agricultural operations and the landfill existence in the coastal areas. This research implies that the involvement of academics through

this study is very helpful for policymakers in developing strategies for developing Mantehage island tourism areas. The data of this study can be applied in determining the best location for snorkelling and diving areas, Mantehage Island is very feasible to be developed as a marine tourism location because it is supported by very good water conditions and follows environmental quality standards. This study has limitations in research time, where the sample is only taken in one season, does not represent another season, besides that this study has not studied the overall condition of the oceanographic parameters.

CONCLUSION

Based on the values of salinity, temperature, turbidity, pH, total suspended solids, dissolved oxygen, $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$, the condition of Mantehage water quality obtained a suitable category within the specified standards of the minister of the Environment Republic of Indonesia. Several parameters known to exceed these provisions, including nitrate and phosphate content, indicate the instantaneous value during measurement. Therefore, an in-depth study, sufficient interval and sampling location to represent the spatial and temporal conditions of the entire island are greatly required. This outermost island generally appears suitable as a marine tourism attraction, particularly snorkelling and diving. Furthermore, the beauty of coral reefs is believed to be a major tourist object with the need for further encouragement. Mantehage Island is very feasible to be developed as a marine tourism area, especially for snorkelling and diving activities, underwater beauty, high biodiversity and supported by good water conditions make this island attractive to tourists.

SIGNIFICANCE STATEMENT

This study discovered the condition of the seawater quality of Mantehage Island which can be developed as an underwater tourism location, the good status of coral reefs supported by underwater beauty makes Mantehage Island worthy of development, that can be beneficial for the government, researchers and the people of Mantehage Island in developing tourism. This study will help the researchers to uncover the critical areas of the outermost small island of Indonesia that many researchers were not able to explore. Thus a new theory on the condition of seawater quality for the development of marine tourism may be arrived at.

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