Analysis of water quality in the coastal area of Padang Pariaman Regency, West Sumatra, Indonesia

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Abstract. One utilization of coastal areas with adverse effects on coastal environmental quality is shrimp farming. The negative impacts arise primarily from the common practice of clearing mangrove forests to make way for shrimp ponds, often leaving no green zones. The technology of shrimp farming has evolved from traditional to semi-intensive and intensive methods. The advancement of shrimp pond technology has raised concerns in coastal areas, particularly related to the high levels of organic waste generated by shrimp farming activities. The objective of this research is to analyze the water quality in the coastal area of Padang Pariaman Regency, West Sumatra, Indonesia. This study was conducted from July 2022 to January 2023 in the coastal areas of Padang Pariaman Regency, West Sumatra, Indonesia involving collection carried out in two seasons, namely summer and rainy season, at six stations with three repetitions. This study employed a survey and observational methods conducted at the research sites for data collection. The obtained data were analyzed descriptively based on the results obtained from both field and laboratory assessments. Based on the analysis of water quality in the coastal area of Padang Pariaman Regency, it can be concluded that offshore, parameters such as total suspended solids (TSS), chemical oxygen demand (COD), and turbidity exceed the tolerance limits for marine biota. According to the phytoplankton evenness index, the area falls into the category of lightly to moderately polluted. Consequently, the phytoplankton condition at each station indicates a fairly uniform distribution of individual species. The analysis of macrozoobenthos diversity index places the area in the moderately polluted category, indicating a relatively even distribution of species.
Key Words: coastal environmental quality, mangrove forests, polluted category, shrimp farming.

Introduction. Indonesia is a tropical nation situated in Southeast Asia, which is currently vigorously engaged in economic development efforts, particularly in the utilization of coastal resources. The planning and management of coastal resources for the purpose of economic advancement must be grounded in the enhancement of sustainably-based resources, ensuring that the process of coastal economic development does not result in environmental degradation (Listiyani et al 2018; Natalia & Pandjaitan 2019). The adverse consequences of inadequate coastal environmental management planning can lead to long-term environmental degradation, necessitating prolonged recovery periods and incurring substantial costs. Hence, it is imperative that in the management of coastal ecosystems, both physical and non-physical damage, such as environmental pollution, are effectively prevented (Garcia & Fonseca 2018; Listiyani et al 2018; Wu & Yang 2018).

The development of the coastal areas in western Sumatra has had adverse environmental impacts, one of which is experienced by the Padang Pariaman Regency in West Sumatra. This is attributed to the fact that Padang Pariaman Regency serves as a buffer zone for waves coming from the open sea. Changes in land cover in the region are a result of uncontrolled urbanization (Long et al 2014; Seto et al 2012). Shrimp farming utilization of coastal areas has detrimental effects on coastal environmental quality. The predominant negative impacts stem from the widespread practice of clearing mangrove forests to create space for shrimp ponds, frequently resulting in the absence of green zones. An example of unsustainable development can be seen in the northern coast of Java (Pantura), where the previously green mangrove belt has been entirely transformed into shrimp ponds. To preserve the sustainability of coastal areas, the development of coastal regions should not solely focus on developmental activities, including aquaculture, but should also encompass conservation and protected areas. These conservation and protected zones are instrumental for the maintenance and preservation of various ecobiological processes. In terms of physical, chemical, and biological functions, mangrove ecosystems serve to protect the coastline from erosion and sedimentation, act as pollutant absorbers, and function as spawning, feeding, and nursery grounds for various species (Lara et al 2009; Nahuelhual et al 2014).

The total shrimp pond area in Indonesia currently stands at approximately 3,759 hectares, which accounts for 0.43% of the potential 866,550 hectares available across the country. With a substantial area suitable for aquaculture development, the fisheries cultivation sector in Indonesia continues to expand. However, the consequences of ill-conceived and unsustainable plans have led to persistent issues. Mismanagement of land cover changes in the Padang Pariaman Regency is primarily due to a lack of alignment between the spatial planning and the actual utilization within the region, exceeding 25% (Maurinus Roy et al 2017). The transformation of the coastal forest area in Padang Pariaman Regency, which was originally consisted of 40% of the region, has now seen a substantial portion redefined for open shrimp pond areas. Uncontrolled changes in land use can lead to environmental degradation (Imamah et al 2013).

Shrimp farming technology has progressed from traditional to semi-intensive and intensive methods, sparking concerns in coastal areas, especially regarding the substantial organic waste produced in shrimp farming activities. This research aims to analyze water quality in the coastal region of Padang Pariaman Regency, West Sumatra, Indonesia.

Material and Method

Research timing and location. This study was conducted from July 2022 to January 2023 in the coastal areas of Padang Pariaman Regency, West Sumatra, Indonesia (Figure 1) involving data collection during two seasons, namely summer and rainy season, at six stations, each with three repetitions, as follows: seawater station, encompassing three sub-stations (A1, A2, and A3); coastal water station, with three sub-stations (B1, B2, and B3); the shrimp pond water station, categorized as intensive, semi-intensive, and traditional, comprising three sub-stations each (C1, C2, and C3); river water station, consisting of three sub-stations (D1, D2, and D3); estuary water station, including three sub-stations (E1, E2, and E3); outlet water station, with three sub-stations (F1, F2, and F3).

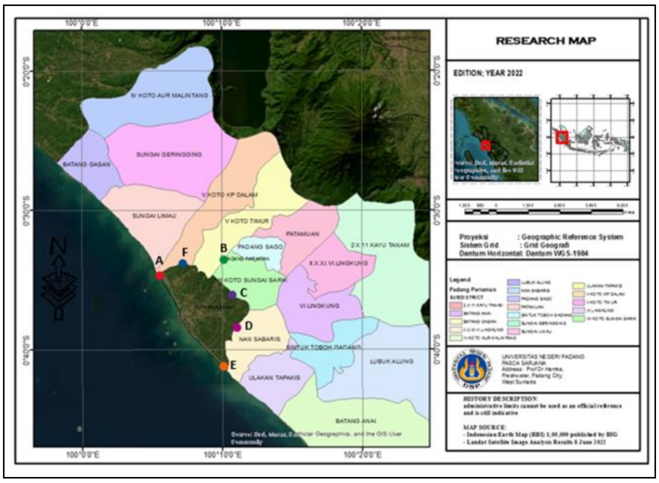

Figure 1. Location of research stations (map generated from Indonesian Earth Map - RBI).

Research methodology. This research utilized survey and observational methods conducted at the research sites to gather data. The positions of each station and sub-station for sample collection were determined using the global positioning system (GPS). Water quality sample collection for analysis was performed four times, including twice during the dry season (September and October) and twice during the wet season (December and January). Water quality analysis consisted of on-site measurements of temperature, turbidity, salinity, dissolved oxygen (DO), pH and total suspended solids (TSS). Laboratory determinations of biological oxygen demand (BOD_3), chemical oxygen demand (COD), total organic content (TOC), nephelometric turbidity (NTU), ammonia (NH_3), nitrate (NO_{3-}), nitrite (NO_{2-}), phosphate (PO_4^{3-}), copper (Cu), lead (Pb) and zinc (Zn), conducted at the water chemistry laboratory of the State University of Padang.

The measurement of water quality parameters aimed to establish the 'present status' of the water conditions, which can be associated with the level of shrimp pond cultivation productivity. The observed water quality parameters were focused on those that support shrimp farming productivity and describe pollution levels. The observed biological parameters in the water included phytoplankton and macrozoobenthos. To obtain phytoplankton samples, 75 liters of water were filtered using a no. 25 plankton net, reducing the volume to 30 ml, and then preserved with 10 ppm formalin. Identification of phytoplankton species was conducted in the laboratory using microscopes and identification guides (Sachlan 1982; Yamaji 1979). To collect macrozoobenthos, soil probes were taken using an Ekman grab with an opening size of 15 x 15 cm, then placed in a plastic bag and preserved with 10 ppm formalin. Identification of macrozoobenthos types is carried out in the laboratory using a microscope and identification books (Hyman 1955; Sahidin et al 2018)

Data analysis. Descriptive analysis was conducted for the results obtained from both field and laboratory assessments. To assess water quality in terms of the physical and chemical aspects, the field and laboratory data were compared with established seawater quality standards for marine organisms and shrimp cultivation criteria according to Boyd (1990) and Wedemeyer (1996) as cited in Conte (2004), and MENKLH (2003). To evaluate water quality based on biological aspects, specifically phytoplankton and macrozoobenthos as environmental quality indicators, species diversity indices and evenness indices were employed.

Results. The average values of the water quality measurements taken from each observation station in the coastal area of Padang Pariaman Regency, examined in this study, are shown in Table 1.

Table 1

Water quality measurements at each research station

No	Parameter	Station					
		Seawater (A)	*Coastal water (B)*	*Shrimp pond (C)*	*River water (D)*	*Estuary water (E)*	*Outlet water (F)*
1	Temperature (°C)	29.3±1.33	29.7±1.14	29.6±0.85	29.7±1.25	29.8±1.00	30.2±0.84
2	Turbidity (%)	74.04±8.37	73.39±2.97	42.21±2.29	50.83±21.97	32.66±9.67	33.21±10.9
3	Salinity (%)	31.18±1.33	31.2±1.56	27.88±1.95	0	8.92±4.22	30.25±1.22
4	Dissolved oxygen (ppm)	6.89±1.08	6.13±0.81	5.60±0.96	4.92±0.78	6.27±1.41	3.43±0.86
5	pH	8.11±0.07	8.07±0.88	8.16±0.19	7.87±0.24	8.05±0.08	8.06±0.12
6	TSS (ppm)	63.9±19.5	125±50.7	283.3±53.3	241.3±39.5	414.5±60.9	316.4±197.8
7	BOD_3 (ppm)	4.70±2.01	6.51±1.19	7.63±2.14	6.88±2.86	10.78±2.92	7.83±2.18
8	COD (ppm)	72.39±17.50	86.70±22.87	82.61±26.8	86.65±27.23	82.83±15.30	95.37±30.71
9	TOC (ppm)	7.39±17.36	17.08±12.65	51.76±29.83	37.72±29.76	42.12±22.06	37.64±15.11
10	Turbidity (NTU)	5.38±3.81	23.36±9.55	56.9±22.3	26.22±16.14	23.88±19.65	23.44±10.17
11	Ammonia (NH_3) (ppm)	0.071±0.112	0.128±0.007	0.404±0.148	0.136±0.135	0.225±0.168	0.872±0.506
12	Nitrate (NO_3) (ppm)	0.064±0.082	0.059±0.058	0.064±0.082	0.069±0.041	0.101±0.051	0.203±0.150
13	Nitrite (NO_2) (ppm)	0.074±0.82	0.094±0.057	0.228±0.147	0.099±0.065	0.214±0.292	0.0424±0.399
14	Phosphate (PO_4^{3-}) (ppm)	0.100±0.082	0.095±0.052	0.008±0.001	0.83±0.051	0.121±0.106	0.132±0.318
15	CU (ppm)	0.013±0.01	0.11±0.10	0.011±0.14	0.017±0.01	0.19±0.013	0.001±0.001
16	Pb (ppm)	0.003±0.003	0.08±0.009	0.001±0.016	0.015±0.013	0.08±0.006	0.03±0.002
17	Zn (ppm)	0.004±0.009	0.013±0.016	0.008±0.009	0.004±0.009	0.013±0.016	0.013±0.016

Based on Table 1, it is evident that several water quality parameters in the coastal area of Padang Pariaman Regency have exceeded the allowable standards for marine life, which include TSS (80 ppm), COD (80 ppm), and turbidity (30 NTU). At the coastal station, water quality parameters that exceed the permissible standards for marine life are TSS (125 ± 50.7 ppm) and COD (86.70 ± 22.87 mg/l). The high TSS levels at the coastal station are likely influenced by the discharge of waste from land-based shrimp farming activities. This is supported by the elevated TSS values at the intensive shrimp pond station, which are 283.3 ± 53.3 ppm, and at the outlet station, which are 316.4 ± 197.8 mg/l. Similarly, the elevated COD at the coastal station, especially, is presumed to originate from land-based agricultural activities that contain chemicals such as pesticides and domestic wastewater from residential areas. This is evident in the high COD values at the river and estuary stations, which are 86.56 ± 27.23 ppm and 82.83 ± 15.30 ppm, respectively, exceeding the permissible standards for marine life. These stations also serve as discharge points for agricultural and residential wastewater before entering the coastal area.

Based on the results of phytoplankton identification, it is evident that there are at least five classes of phytoplankton present in the coastal waters of Padang Pariaman Regency, namely Bacillariophyceae, Cyanophyceae, Dinophyceae, Chlorophyceae, and Euglenophyceae. The data showing the identification of phytoplankton species at different stations and sub-stations are presented in Table 2. The composition and abundance of phytoplankton species in the coastal waters of Padang Pariaman at different stations (seawater, coastal water, shrimp pond water, outlet water, and estuary water) can be observed in Table 2.

Table 2

Phytoplankton composition and abundance (ind/L) in the coastal waters of Padang Pariaman Regency

Station	*Species composition/abundance (ind/L)*				
	Bacillariophyceae	*Chlorophyceae*	*Cyanophyceae*	*Dinophyceae*	*Euglenophyceae*
Seawater	20583	6481	3488	1184	0
Coastal	54848	7996	3538	2606	600
Shrimp pond	86876	1440	2308	4144	0
Outlet	6078	2790	1308	2728	248
Estuary	6192	1908	10854	3016	712
Total	174577	20615	21496	13678	1560
%	75.3	8.9	9.3	5.9	0.7

Based on the identification of macrozoobenthos, it is evident that there are at least four classes of macrozoobenthos present in the coastal waters of Padang Pariaman Regency, which include the classes Gastropoda, Pelecypoda, Polychaeta, and Crustacea. Several species from the Gastropoda class, such as *Cerithidea* sp., *Terebralia* sp., and *Nerita* sp. were identified. Pelecypoda class species included *Modiolus* sp. and *Lithophaga* sp. Polychaeta class species like *Nereis* sp. and *Capitella* sp. were identified. From the Crustacea class, species such as *Balanus* sp., have been identified. The analysis of species evenness index (E) at each station ranged between 0.86 to 1.0, with an average value of 0.96. When E values approach 0, it indicates an uneven distribution of individuals among species. Based on the analysis of macrozoobenthos diversity index (H') at each observation station, a relatively even distribution of species is shown. Data regarding the identification of macrozoobenthos species at the observation stations are presented in Table 3.

Table 3
Composition of macrozoobenthos species and abundance (ind/m²) in the coastal waters of Padang Pariaman Regency

*Species composition/abundance (ind/*m²*)*	*Station*		
	Seawater	*Coastal water*	*Estuary water*
Phylum Mollusca			
Conus sp.	0.00	14.67	0.00
Cerithidea sp.	0.00	14.67	88.00
Terebralia sp.	44.00	0.00	0.00
Terebellum sp.	44.00	7.33	0.00
Littorina sp.	14.67	14.67	0.00
Melanoides sp.	0.00	0.00	44.00
Nassarius sp.	14.67	7.33	0.00
Nerita sp.	29.33	7.33	14.67
Mitra sp.	14.67	7.33	0.00
Class Pelecypoda			
Modiolus sp.	14.67	0.00	0.00
Lithophaga sp.	0.00	7.33	0.00
Perna sp.	14.67	14.67	0.00
Tellina sp.	0.00	22.00	0.00
Pitar striatum	0.00	0.00	14.67
Class Polychaeta			
Sabella sp.	0.00	14.67	14.67
Nereis sp.	0.00	36.67	14.67
Class Crustacea			
Balanus sp.	0.00	0.00	14.67
Leptognatha sp.	14.67	8.80	0.00

Discussion. The high TSS in intensive shrimp farming areas can be attributed to the presence of uneaten artificial feed, such as leftover feed and metabolic byproducts in the form of waste that is released into the water (Boyd 1999). It should be noted that in intensive aquaculture technology, the nutritional needs of the cultivated animals depend entirely on artificial feed. Thus, if a significant amount of the artificial feed can remain unused, and it can be a primary factor contributing to the high organic matter content in the ponds, subsequently elevating TSS levels in the water. Supporting this notion, another parameter is the high turbidity of water in the intensive pond stations (56.9 ± 22.1). According to studies by Paena et al (2020), Pantjara et al (2010) and Syah et al (2014), there is a positive relationship between suspended particle matter and water turbidity in a water body, meaning that the higher the suspended particle matter concentration, the higher the turbidity.

Phytoplankton, tiny floating plant organisms in water, play a pivotal role as primary organisms in the food chain and serve as a biological parameter for assessing water fertility (Iswanto et al 2015; Sihombing et al 2015). Based on Table 2, it can be observed that the Bacillariophyceae type constitutes 73.5% of the composition, Chlorophyceae accounts for 8.9%, Cyanophyceae for 9.3%, while Dinophyceae and Euglenophyceae contribute 5.9% and 0.7% respectively. When considering the different stations, it is evident that Bacillariophyceae dominates at the seawater, coastal, shrimp pond, and outlet stations. The high presence of Bacillariophyceae is likely influenced by the relatively high salinity levels at each station, ranging from 25 to 34 ppm. This is supported by the estuary station, where the salinity ranges from 5 to 18 ppm, which is primarily dominated by Cyanophyceae. As observed by Afif et al (2014), phytoplankton living in salinity ranges above 20 ppm are predominantly Bacillariophyceae, and salinity levels are also influenced by the competition with other phytoplankton species.

Some species of Bacillariophyceae (diatoms), such as *Chaetoceros* spp., *Nitzschia* spp., *Rhizosolenia* spp., and *Coccolithus* spp., are noteworthy for their high frequency of appearance and abundance. *Chaetoceros* spp. and *Nitzschia* spp. are particularly favored by shrimp. Commonly occurring Chlorophyceae species include *Oocystis* spp., *Coelastrum* spp., and *Ulothrix* spp. Among Cyanophyceae, species like *Spirulina* spp., *Oscillatoria* spp., and *Calothrix* spp. have been identified. From the Dinophyceae class, species like *Noctiluca* sp. and *Ceratium* spp. are frequently observed, and for the Euglenophyceae class, *Euglena* spp. is a common find.

To assess the level of pollution in aquatic environments, the qualitative and quantitative analysis of macrozoobenthos is often considered essential to complement the findings from physical and chemical analyses. In certain instances, the results of physical and chemical water analyses may be less precise and subject to variations influenced by transient conditions. In highly dynamic marine environments, biological analyses such as phytoplankton and macrozoobenthos can offer a clearer picture of the impact of pollutants on the community structure of organisms residing in the water. Additionally, benthic organisms like macrozoobenthos, due to their slow mobility, serve as indicators of the disappearance of specific species typically found in a particular environment, providing insights into environmental changes or indications of pollution in an aquatic environment. The calculated diversity index (H') across all stations fall within the range of 1.01 to 2.12. The lowest diversity index value is observed at the estuary station, while the highest is recorded at the seawater station. According to Odum and Barrett (1971), diversity values between 1 and 3 fall into the moderate category.

According to Lee et al (1978) as cited in Drira et al (2014), evenness index values between 1.0 and 2.0 indicate light pollution, and values exceeding 2.0 categorize the observed area in Padang Pariaman Regency as moderately even, suggesting that it is lightly to moderately polluted. Furthermore, the species evenness index (E) across all observation stations ranges from 0.5 to 1.0, indicating a relatively even distribution of individual species. The observations of macrozoobenthos at each station revealed a very low number of species, typically ranging from 1 to 5 species, with an average of 60 individuals/m^2. This situation indicates the dominance of certain macrozoobenthos species. This aligns with the findings of Indrawan et al (2007) and Nurcahyo (2018), who propose that when there is a sharp decrease in organism diversity within an environment to the extent that only specific dominant organisms remain, the environment has likely experienced pollution-induced stress, and these dominant populations are considered pollution indicators.

The analysis of macrozoobenthos diversity index at each observation station falls within the range of 0.64 to 1.70, with an average value of 1.06. According to Lee et al (1978), as cited in Drira et al (2014), a diversity index value between 1.0 and 1.5 is categorized as moderately polluted.

Conclusions. Analysis of water quality in the coastal area of Padang Pariaman Regency, shows that at the offshore station, parameters such as TSS, COD, and turbidity exceed the tolerance limits for marine biota. Based on the phytoplankton evenness index, this area falls into the category of lightly to moderately polluted. The phytoplankton condition at each station displays a fairly uniform distribution of species. Macrozoobenthos diversity index places the area in the moderately polluted category, with a relatively even distribution of species.

Conflict of interest. The authors declare that there is no conflict of interest.

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