Environmental management approach: The impact of a wastewater treatment plant for shrimp ponds on Carocok Anau River water quality

[1,3]Rahmiana Zein, [2,3]Jabang Nurdin, [3]Dewa R. Rianto, [1]Putri Ramadhani

[1] Laboratory of Environmental Analytical Chemistry, Department of Chemistry, Andalas University, Padang, Indonesia; [2] Ecology Laboratory, Department of Biology, Andalas University, Padang, Indonesia; [3] Environment Science Study Program, Postgraduate Program, Andalas University, Padang, Indonesia. Corresponding author: R. Zein, rzein@sci.unand.ac.id

Abstract. The high demand for shrimp has made the development of intensive shrimp pond areas more widespread, not least in Indonesia. Shrimp farming has caused a great deal of global concern, and much of the literature points to negative impacts on the environment and ecosystems. Around the Carocok Anau River, West Sumatra, there are intensive shrimp ponds with vannamei shrimp (*Litopenaeus vannamei*), which possibly pollute with organic matter in rivers and the sea. Since the existence of shrimp farming activities, the community has begun to complain about the unpleasant smell of the Carocok Anau River water. The community is worried about the pollution from the wastewater of the shrimp ponds. The purpose of this study was to determine the quality of the waters of the Carocok Anau River based on physical, chemical, and biological parameters and the status of water quality with a pollution index. The physical, chemical, and biological parameters used in this study included temperature, color, total dissolved solids (TDS), total suspended solids (TSS), turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), pH, ammonia, nitrate, nitrite, total phosphate, sulfate, cadmium (Cd), chromium (Cr), lead (Pb), total coliform count and plankton abundance. From the parameter data obtained, the Pollution Index (IP) was determined. The results showed that the TDS, DO, BOD, COD, ammonia, lead (Pb), and total coliform count values obtained were above the quality standards, with the highest values in the shrimp pond waste channel. The IP showed that all research points fall into the moderately polluted category.
Key Words: physical-chemical-biological parameters, plankton, pollution, water.

Introduction. In recent years, shrimp farming has expanded significantly around the world, especially in southeast Asia (Li et al 2019). Indonesia is one of the largest shrimp-producing countries in the world. Shrimp farming is divided into intensive cultivation, semi-intensive cultivation, extensive cultivation and shrimp-plant systems (Dien et al 2019). Pond aquaculture currently uses intensive systems, with high stocking densities, highly nutritional feed, and high water exchange rates to increase production. Unfortunately, the rapid growth and expansion in shrimp farming have also resulted in the degradation and pollution of the aquaculture fields and surrounding environment. Typically, more than 70% of nutrient inputs end up in sediments, while yields represent only a small fraction of primary production (Haque et al 2016; Kumar et al 2017; Dien et al 2019). Shrimp farming has caused a great deal of global concern, and much of the literature points to negative impacts on the environment and ecosystems (Kabir et al 2016; Morshed et al 2020). Many studies explain that cultivated land has experienced environmental degradation, which has an impact on organisms (Han et al 2018; Qiu et al 2018; Xu et al 2018; Lou et al 2019). The development of aquaculture always has challenges, but also benefits for society that can be obtained in a sustainable manner (Firdaus et al 2022).

Pesisir Selatan Regency is one of the regencies/cities in West Sumatra Province with a great potential to be used by the citizens. Pesisir Selatan Regency has 23 rivers, consisting of large rivers and small rivers (BPS-Statistic of Pesisir Selatan Regency 2022). Rivers in Pesisir Selatan Regency are used by the community to support household needs, agriculture, aquaculture or industries. Along with the increasing population and industrial development, the coastal area is the largest waste recipient. Water quality and environmental carrying capacity have decreased due to community activities that have the potential to produce waste, such as industrial waste, domestic waste, and others (Arivalagan et al 2014; Taiwo et al 2016; Abazi et al 2022).

The Carocok Anau River is one of the estuary waters in Pesisir Selatan Regency used for many activities. One of the activities is the cultivation of vannamei shrimp (*Litopenaeus vannamei*) in a shrimp pond with intensive cultivation technology. Since intensive shrimp farming activities around the Carocok Anau River have appeared, the community began to complain about the unpleasant smell of the Carocok Anau River water. The community is worried about the pollution from the wastewater of the shrimp ponds. Organic waste from leftover feed and metabolic waste from shrimp farming activities reach river waters through a water exchange process. Shrimp pond waste produces residues that cause poor environmental quality, especially residues from intensive shrimp ponds (Ramos e Silva et al 2017). Residual feed causes a decrease in water quality in shrimp pond areas. Dead shrimp have a lesser effect than leftover feed and feces on water quality (Dunca 2018). Although shrimp pond residues are not as bad as industrial residues, they will accumulate in large quantities and have a negative impact on the environment (Ferreira & Lacerda 2016; Ramos e Silva et al 2017). Wastewater discharge from shrimp ponds will affect the physical, chemical, and biological conditions of the surrounding aquatic environment as waste recipient (Khalil et al 2010).

The way to determine the occurrence of water pollution is to analyze the water quality parameters. Physical, chemical and biological parameters of water quality can provide an overview on the growth of organisms in their natural habitat (Prasetiyono et al 2022). Aquatic biota can be used as a bioindicator of water quality. Plankton is one of the organisms that are important for the aquatic environment (Yuan et al 2014). The water parameters play a role in the distribution and community structure of the plankton (Hoang et al 2018). Therefore, plankton can be used as a bioindicator to determine the quality of the aquatic environment (Gao et al 2016).

This study aims to determine the environmental conditions of the waters of the Carocok Anau River based on physical, chemical, and biological parameters and to determine the status of water quality based on the Pollution Index (IP) as the basis for environmental management strategies to preserve the environment of the river waters.

Material and Method

Sampling. The research location and water sampling were carried out in the Carocok Anau Koto XI Tarusan River, Pesisir Selatan Regency. The time of study was from July to September 2022. The determination of the research locations was done by using the purposive sampling method. The researcher determines the sampling stations by setting special characteristics that follow the research objectives, being expected to answer research problems. The location was determined based on the consideration of the source of the waste and adjusted to Indonesian National Standard 6989.57:2008. Figure 1 shows the map of the sampling locations (six points) in the Carocok Anau River.

Data analysis. Water samples were collected in this study from 6 points and repeated 2 times (Table 1). Water sampling was carried out in accordance with each Indonesian National Standard. The research material used for the study was represented by the water samples from the mouth of the Carocok Anau Koto XI Tarusan River, Pesisir Selatan Regency. The water samples were used for the analysis of the physical, chemical, and biological parameters (Table 2). Water samples in different amounts, according to the method used, were transported to the Environmental Laboratory of Pesisir Selatan

Regency for parameter analysis. At the same time, 25 mL of water from each sampling point were used for plankton analysis at the Andalas University Biology Laboratory.

Figure 1. Map of sampling locations (Source: Google Earth).

Table 1

Research location points

Point	*Coordinate*	*Description*
1	S 1°14'35" E 100°26'49"	Location before the input from the intensive shrimp pond wastewater treatment plant (WWTP) water flow
2	S 1°14'35" E 100°27'1"	The location of the outlet from the intensive shrimp pond WWTP, near houses.
3	S 1°14'19" E 100°27'15"	The location where the water flow of the Carocok Anau River meets with the intensive shrimp pond WWTP aliran
4	S 1°14'37" E 100°26'42"	The location is next to soil excavation activities. The location has received water from the intensive shrimp pond WWTP.
5	S 1°14'42" E 100°26'36"	The location is under a bridge and around the dock for tourist boats in the Mandeh Islands. The location has received the intensive shrimp pond WWTP water flow.
6	S 1°14'49" E 100°26'33"	The location is next to the Carocok Anau Tourism Information Center and around the Mandeh Archipelago tourist boat pier, a location for water use.

All data obtained during observations in the Carocok Anau River were analyzed descriptively. The data obtained were also compared with the quality standards set by the government in Government Regulation of the Republic of Indonesia Number 22/2021 Attachment VI concerning the Implementation of Environmental Protection and Management. The government issues and implements environmental regulations and environmental quality standards to prevent environmental pollution arising as a result of a development (Tepe & Temel 2018).

Analysis of the plankton samples obtained. The plankton samples obtained were identified using a glass object and a microscope, using the following references: Bold & Wynne (1985), Prescott (1978) and Yamaji (1970).

Table 2

Analysis of physical, chemical, and biological water parameters

No	*Parameters*	*Unit*	*Measurement location*	*Measurement method*
A	Physical			
1	Temperature	°C	*In situ*	Indonesian National Standard 6989.23-2005
2	Color	Pt-Co	Laboratory	Indonesian National Standard 698980-2011
3	TDS	mg L^{-1}	Laboratory	Indonesian National Standard 6989.27:2019
4	TSS	mg L^{-1}	Laboratory	Indonesian National Standard 6989.3:2019
5	Turbidity	NTU	Laboratory	Indonesian National Standard 698925-2005
B	Chemical			
1	DO	mg L^{-1}	*In situ*	Indonesian National Standard 6989.14-2004
2	BOD	mg L^{-1}	Laboratory	Indonesian National Standard 6989.72_2009
3	COD	mg L^{-1}	Laboratory	Indonesian National Standard 6989.2:2019
4	pH		*In situ*	Indonesian National Standard 6989.2:2019
5	Ammonia	mg L^{-1}	Laboratory	Indonesian National Standard 6989.30:2006
6	Nitrate	mg L^{-1}	Laboratory	Indonesian National Standard 6989.79:2011
7	Nitrite	mg L^{-1}	Laboratory	Indonesian National Standard 6989.9-2004
8	Total phosphate	mg L^{-1}	Laboratory	Indonesian National Standard 6989-31_2021
9	Sulfate	mg L^{-1}	Laboratory	Indonesian National Standard 6989.20:2019
10	Cadmium (Cd)	mg L^{-1}	Laboratory	Indonesian National Standard 6989.16:2009
11	Chromium (Cr)	mg L^{-1}	Laboratory	Indonesian National Standard 6989.17-2004
12	Lead (Pb)	mg L^{-1}	Laboratory	Indonesian National Standard 6989.8:2009
13	Salinity	‰	*In situ*	
C	Biological			
1	Total Coliform Count	MPN 100 mL^{-1}	Laboratory	Standard methods
2	Plankton		Laboratory	

Note: TDS - total dissolved solids; TSS - total suspended solids; DO - dissolved oxygen; BOD - biological oxygen demand; COD -chemical oxygen demand; MPN - most probable number.

Plankton abundance. The total abundance of plankton was determined using the formula:

$$K = \frac{a x c}{l}$$

Where: K is the number of individual plankton obtained per liter (ind L^{-1}), a is the average number of individuals of a plankton species in 1 mL, c is the sample concentrate volume (mL), and 1 is the volume of filtered water (L) (Michael 1984).

Plankton diversity index. Plankton diversity was determined using the Shannon-Wienner's diversity index:

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where: H is the diversity index, In is the natural logarithm, pi is the number of individuals of a species and s is the number of all species (Michael 1984).

The diversity index classification is: H'<1, low diversity; 1<H'<3, medium diversity; H'>3, high diversity.

Plankton evenness index. The evenness index was calculated using the following formula:

E=H'/Hmax

Where: E is the evenness Index (E ranges from 0-1); H' is the Shannon-Wienner diversity index, Hmax is ln s, and s is the number of all species (Michael 1984). The evenness index ranges from 0 to 1, a closer value to 1 showing a more even distribution of individuals and no domination from a species (Odum 1971).

Plankton dominance index. The calculation of the dominance index was carried out using the dominance index formula (Brower et al 1990):

$$C = \frac{\sum ni\,(ni-1)}{N\,(N-1)}$$

Where: C is the dominance index, ni is the total number of individuals of the I species, and N is the total number of individuals of all species. If the domination index is close to 1, there are dominating species.

Water quality status. The analysis of water quality in this study used the Pollution Index (IP) method according to the Decree of the Minister of the Environment of the Republic of Indonesia No. 115/2003 on determining the water quality status for the level of river pollution. IP provides a single assessment score on the environmental parameters and it will be analyzed to interpret the water quality (Popovic et al 2016). The pollution index can be used to determine the level of water pollution in coastal areas. The results of the pollution index calculation can advise the decision-makers to assess the quality of water and improve it if there is a reduction due to the existence of pollutant compounds (Tanjung et al 2019). To determine the level of pollution in rivers, the following formula was used:

$$Pij = \sqrt{\frac{\left(\frac{Ci}{Lij}\right)^2 M + \left(\frac{Ci}{Lij}\right)^2 R}{2}}$$

Where: Pij is the IP for allotment (J), Ci is the concentration of water quality parameters listed in the water designation quality standard (J), Pi is the concentration of water quality parameters in the field, (Ci/Lij)M is the maximum Ci/Lij value, (Ci/Lij)R is the average Ci/Lij value. This method relates the pollution level of waters used for a specific designation with the value of certain parameters, as shown in Table 3.

Table 3

Relationship of the Pollution Index value with water quality status

No	*Pollution Index value*	*Water quality*
1	$0<IP\leq 1$	Standard/Good quality
2	$1.1<IP\leq 5$	Lightly polluted
3	$5<IP\leq 10$	Moderately polluted
4	$IP>10$	Heavily polluted

Note: source: Minister of Environment Decree No. 115 of 2003.

Results and Discussion

Water quality. All the analyses of physical, chemical, and biological parameters are presented in Table 4. The value of TDS, DO, BOD, ammonia, Pb, and total coliform count at each point always exceeded the river quality standard class II Government Regulation of the Republic of Indonesia 22/2021.

TDS content. Based on the laboratory analysis results, the TDS value at each point ranged from 18.859 to 29.088 mg L^{-1} with an average value of 23.879 mg L^{-1} (Table 4). The TDS content at all these points is higher than the existing quality standard of 1 mg L^{-1} (RI Government Regulation 22/2021). The highest TDS value is at point 3, on the shrimp pond WWTP waste channel. The TDS values in the Carocok Anau River are similar to those reported by Anggraini et al (2016) in the Bedog River, where the highest value was found at the point of disposal of shrimp pond wastewater. Research by Anggraini et al (2016) showed that the waters of the Bedog River had a TDS value above the quality standard. One reason is the activity of shrimp ponds, which dispose of waste water in the Bedog River. As mentioned by Irshad et al (2011), the high TDS value indicates that the waste's organic matter has not been completely degraded. The decrease in the TDS value was due to the dissolved particles being converted into a gaseous form released as a by-product of the biodegradation process by microorganisms (Irshad et al 2011). Aquaculture activities produce waste containing organic matter, plankton, dissolved solids, suspended solids, which can reduce the quality of the surrounding aquatic environment (Tepe & Temel 2018).

DO content. The DO value at each point ranged from 1.612 to 3.02 mg L^{-1}, with an average value of 2.34 mg L^{-1} (Table 4). The DO content at all points was below the existing quality standards, namely >4 mg L^{-1} (RI Government Regulation 22/2021). The lowest DO value was at point 3, right at the WWTP waste channel for shrimp ponds. The DO values in the Carocok Anau River are similar to those obtained by Harianja et al (2018) in the Kembung River, where the DO values were below the quality standard. Both of these rivers receive input from shrimp pond wastewater. The low value of DO is evidenced by the BOD values from all points of the research location, which were relatively high, even above the quality standard, ranging from 4.325 to 10 mg L^{-1}. The low DO values were due to the high oxygen demand of decomposing microorganisms in the decomposing organic matter. Waters are polluted and have DO levels below 4 mg L^{-1}. Nutrient enrichment in coastal estuaries, brought about by traditional intensive shrimp farming, might have long-range consequences in the estuarine system, such as eutrophication and the ensuing consumption of DO (Oestreich et al 2016). DO concentrations in waters are heavily influenced by environmental factors such as chemical reactions, decomposition processes and residual respiration of aquatic organisms (Hoang et al 2018).

Table 4

Comparison of water quality values according to the quality standards of RI Government Regulation 22/2021 Attachment VI on the Implementation of Environmental Protection and Management

No	*Parameter*	*Unit*	*Quality standards Class II*	*Point*					
				1	*2*	*3*	*4*	*5*	*6*
	Physical								
1	Temperature	°C	Dev 3	28	30	29	28	28.8	29.3
2	Color	Pt-Co	50	17.4	18.7	18.15	16.45	20.2	18.85
3	TDS	mg L^{-1}	1000	18859	25358	29088	22756	22952	24264
4	TSS	mg L^{-1}	50	5.7	25.1	12.05	8.9	5.3	8.4
5	Turbidity	NTU		9.445	8.045	11.25	4.985	7.46	7.04
	Chemical								
1	DO	mg L^{-1}	> 4	2.315	2.565	1.612	2.415	2.115	3.02
2	BOD	mg L^{-1}	3	4.325	8.51	10	5.135	6.995	5.64
3	COD	mg L^{-1}	25	18.6	29.65	25.55	22	15.5	20.9
4	pH		6-9	6.7	7.055	7.26	6.775	6.865	7.085
5	Ammonia	mg L^{-1}	0.2	0.334	0.5205	0.647	0.4305	0.398	0.431
6	Nitrate	mg L^{-1}	10	0.0765	0.1595	0.3935	0.0935	0.067	0.1335
7	Nitrite	mg L^{-1}	0.06	0.021	0.049	0.0945	0.026	0.025	0.0345
8	Total phosphate	mg L^{-1}	0.2	0.036	0.2315	0.3265	0.1455	0.08375	0.3185
9	Sulfate	mg L^{-1}	300	48.5	50.35	42.8	36.05	41.7	45
10	Cadmium (Cd)	mg L^{-1}	0.02	0.007	0.00345	0.0085	0.00445	0.00185	0.002
11	Chrome (Cr)	mg L^{-1}	0.05	0.012	0.008	0.0115	0.007	0.007	0.0065
12	Lead (Pb)	mg L^{-1}	0.01	0.519	0.8945	0.698	0.663	0.6645	0.682
13	Salinity	mg L^{-1}		18	18	23.5	23.5	23.5	24.5
	Biological								
1	Total Coliform Count	APM 100 mL^{-1}	5000	67500	43000	160000	56500	44500	94000

Note: TDS - total dissolved solids; TSS - total suspended solids; DO - dissolved oxygen; BOD - biological oxygen demand; COD -chemical oxygen demand; MPN - most probable number.

BOD content. The BOD value at each point ranged from 4.325 to 10 mg L^{-1}, with an average value of 6.77 mg L^{-1} (Table 4). The BOD content at all of these points was higher than the existing quality standard of 3 mg L^{-1} (RI Government Regulation 22/2021). The highest BOD values were at point 3, at the WWTP waste channel for shrimp ponds, while the lowest BOD value was at point 1, in a stream that has not received input from the WWTP for shrimp ponds. The BOD vaues in the Carocok Anau River are similar to those in the Kembung River, obtained by Harianja et al (2018), where the highest value was found at the point where the shrimp pond wastewater was being discharged. The Kembung River has a higher BOD value than the Carocok Anau River, reaching 28.7 mg L^{-1}. The high content of BOD in the waters is thought to come from active aquaculture, the remaining feed from aquaculture being a source of organic matter. The high value of BOD indicates that the oxygen demand of decomposing microorganisms when breaking down organic matter is relatively high. This is evidenced by the DO levels from all research points, which were low, even below the quality standard, which ranges between 0.604–3.92 mg L^{-1}. The difference between DO and BOD is that DO is the amount of oxygen dissolved in water while BOD is the oxygen requirement by organisms for the biodegradation process. Therefore, when the BOD value is high, it causes the DO value to decrease (Islam et al 2013).

COD content. COD represents the need for chemical oxygen for the oxidation process of materials disposed of in water. COD is one of the parameters that is widely used to determine the quality of waters (Jouanneau et al 2014). COD values at each point ranged from 15.5 to 29.65 mg L^{-1}, with an average value of 22.03 mg L^{-1} (Table 4). At some points, the COD content was higher than the existing quality standard of 25 mg L^{-1} (RI Government Regulation 22/2021). The highest COD values were at points 2 and 3, both points being at the WWTP waste channel for shrimp ponds. The COD values in the Carocok Anau River are similar to those obtained by Mutmainah et al (2022) in the Bogowonto River, where the highest value was found at the point of disposal of shrimp pond wastewater. The Bogowonto River has higher COD values than Carocok Anau River, reaching 96.47 mg L^{-1}. The high value of COD in waters can be caused by the degradation of organic and inorganic materials from community activities around the river and waste disposal produced by human activities. The high content of COD in waters will affect the decrease in DO, causing a decrease in water quality. A further consequence is that the level of productivity of aquatic resources also decreases. COD is an important parameter in pollution control and environmental management, which describes the level of pollution and organic matter content in waters (Prambudy et al 2019).

Ammonia content. Based on the laboratory analysis results, the ammonia value at each point ranged from 0.334 to 0.647 mg L^{-1}, with an average value of 0.46 mg L^{-1} (Table 4). The ammonia content at these points was higher than the existing quality standard of 0.2 mg L^{-1} (RI Government Regulation 22/2021). The highest ammonia value was observed in point 3, in the shrimp pond WWTP waste channel, while the lowest ammonia value was determined in point 1, in a stream that did not receive input from the shrimp pond WWTP. Ammonia values in the Carocok Anau River were similar to those determined by Mutmainah et al (2022) in the Bogowonto River, where the highest value was found at the point of disposal of shrimp pond wastewater. According to Mutmainah et al (2022), the high ammonia in the Bogowonto River is influenced by the amount of organic matter from shrimp pond cultivation activities. The high ammonia content in waters is due to the high organic matter that can come from agricultural activities, domestic waste, and industrial waste around the waters. Ammonia in surface water comes from urine, feces, and microbiological decomposition of organic substances from natural water, industrial wastewater, or domestic waste. The low DO value is evidence of the high content of ammonia. At high DO levels, ammonia is rarely found. Ammonia in waters is also the result of the metabolism of aquatic organisms and the remaining organic matter breakdown after breakdown by aquatic bacteria (Lemonnier et al 2017). Ammonia is one of the limiting factors in crustacean cultivation activities. In addition, ammonia is also the dominant pollution factor in waters, being one of the parameters that must be measured to reflect the level of water pollution (Xiao et al 2019). It has influence on important physiological and pathophysiological processes including in crustaceans (Cui et al 2017). If the amount of ammonia exceeds the quality standard limits it will become toxic to the aquatic environment (Tanjung et al 2019).

Lead content. The concentration of Pb at each point ranged from 0.519 to 0.8945 mg L^{-1} with an average value of 0.687 mg L^{-1} (Table 4). The Pb content at all these points was higher than the existing quality standard of 0.01 mg L^{-1} (RI Government Regulation 22/2021). The highest Pb value was observed at point 2, while the lowest Pb value was at point 1. The Pb content in the Carocok Anau River is similar as that obtained by Salahuddin et al (2012) in the Mahakam Estuary, where the value was above the quality standard. Both rivers have a higher Pb concentration downstream compared to upstream, possibly due to the impact of industrial waste entering the waters. Pb content in waters can come from residual pesticide residues that enter water bodies through water flows. Pb pollution in waters that exceeds the threshold concentration can cause death for aquatic biota. In humans, ingestion of lead (Pb) compounds in high concentrations can cause symptoms of poisoning such as vomiting, stomach pain, and diarrhea (Islam et al 2013).

Total coliform content. Based on the laboratory analysis results, the total coliform count at each point ranged from 43000 to 160.000 APM 100 mL^{-1}, with an average value of 77583 APM 100 mL^{-1} (Table 4). The total coliform count at all points was higher than the existing quality standard of 5000 APM 100 mL^{-1} (RI Government Regulation 22/2021). The total coliform count in the Carocok Anau River was similar to that determined by Widyaningsih et al (2016) in the Kali Wiso Estuary, where the values were above the quality standard. The value in the Carocok Anau River was 77583 MPN 100 mL^{-1}, while in the Kali Wiso Estuary it was 110000 MPN 100 mL^{-1}. Both of these waters receive the input of shrimp pond wastewater. The highest total coliform count was at point 2. The presence of coliform bacteria in high numbers is thought to occur from the input of the shrimp pond waste around the Carocok Anau River. Waste that enters the waters carries nutrients and organic compounds that can affect the number of coliform bacteria in these waters. Organic matter can increase the growth and activity of microorganisms, including aquatic bacteria.

Plankton composition. Changes to water quality can also be seen from the plankton composition and other variables. The values of abundance, diversity index, uniformity and dominance of plankton are biological parameters that can be used to reflect the quality of waters. Plankton plays an important function in balancing aquatic ecosystems (Acevedo-Trejos et al 2015). Based on the results of plankton research conducted in the waters of the Carocok Anau River, 125 species of plankton were found. The species found belong to 49 families and 16 classes, each class having a different percentage of individuals (Figure 2). The results obtained were similar to those of Yuliana et al (2023) in the Kastela waters, where Bacillariophyceae was found more commonly than other plankton classes. The abundance of Bacillariophyceae in the waters of the Carorok Anau River and Kastela waters is caused by a salinity value above 20‰. As stated by Sachlan (1982), species from the class Bacillariophyceae include plankton species that can live and develop well at salinities above 20‰.

Bacillariophyceae class had the highest percentage of individuals, of 38.02%, with 349 individuals. Diatoms or Bacillariophyceae are a group of phytoplankton characterized by the presence of a cell wall made of silicate called frustule (Lin et al 2020). Diatoms are highly adaptable to various environmental conditions such as temperature, pH, light period and salinity and can achieve higher growth rates compared to other phytoplankton groups (Yi et al 2017). The highest presence of diatoms in the Carocok Anau River was found at points 2 and 3, where levels of nitrate and phosphate were high. The existence of autotrophic organisms such as diatoms is limited by the presence of nutrients in the waters. Nitrate is preferred by most of the diatom group. An increase in nitrate in the waters will increase the growth rate of diatoms (Mochemadkar et al 2013).

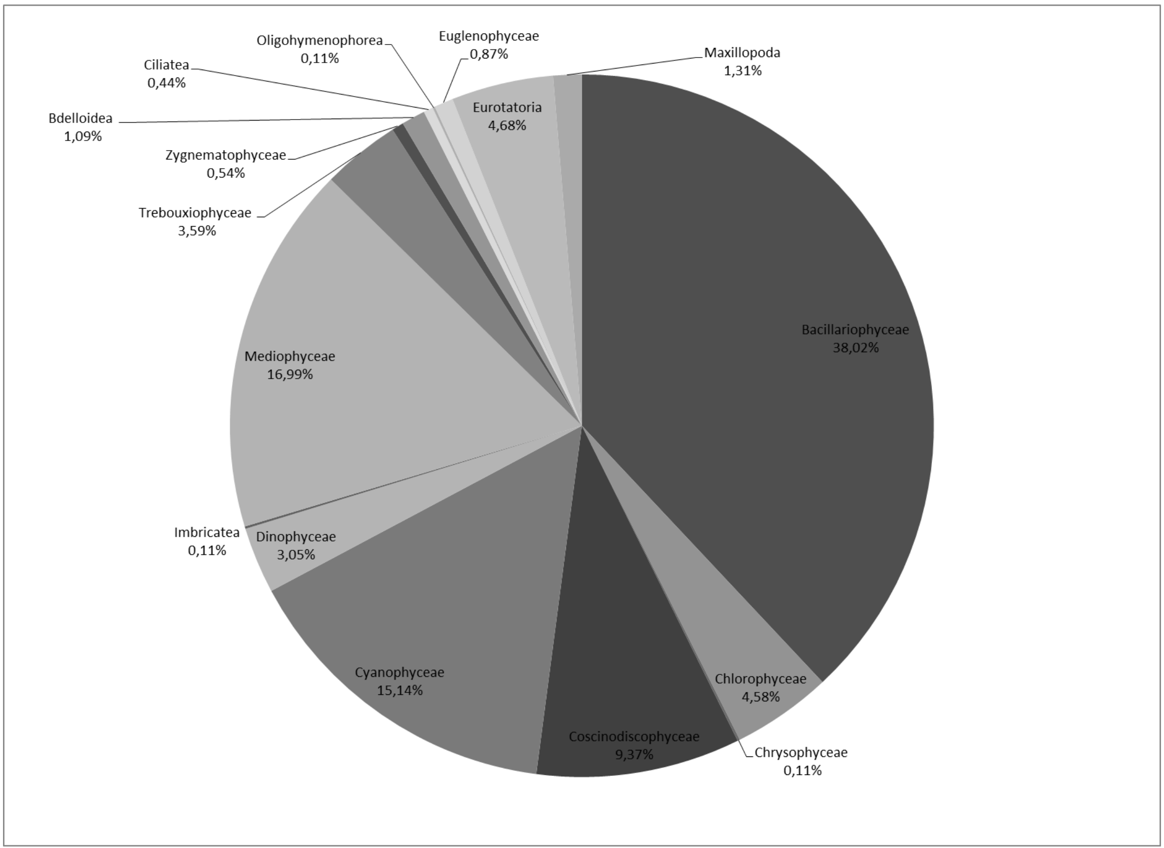

Figure 2. Abundance of plankton in the waters of the Carocok Anau River.

The family and species composition obtained in this study included Bacillariophyceae (16 families and 58 species), Chlorophyceae (6 families and 7 species), Chrysophyceae (1 family and 1 species), Coscinodiscophyceae (2 families and 6 species), Cyanophyceae (5 families and 17 species), Dinophyceae (3 families and 5 species), Imbricatea (1 family and 1 species), Mediophyceae (5 families and 15 species), Trebouxiophyceae (1 family and 2 species), Zygnematophyceae (1 family and 1 species), Bdelloidea (1 family and 1 species), Ciliatea (1 family and 2 species), Oligohymenophorea (1 family and 1 species), Euglenophyceae (1 family and 1 species), Eurotatoria (1 family and 3 species), Maxillopoda (3 families and 4 species) (Figure 3).

Bacillariophyceae is the class of phytoplankton with the highest number of species. Phytoplankton found in the waters are Bacillariophyceae, Dinophyceae and Cyanophyceae. This is because Bacillariophyceae have a faster growth compared to other classes of plankton and can adapt well to changes in the water environment (Qiao et al 2020).

Plankton density. The total density of plankton in the Carocok Anau River ranges from 3.4-7.3 ind L^{-1}. The Carocok Anau River is dominated by the Bacillariophyceae class. The results obtained are similar to those of Yuliana et al (2023) in Kastela waters, where the abundance of Bacillariophyceae was found to be higher than that of other plankton classes. The abundant presence of Bacillariophyceae in the waters is an advantage, because it is a natural feed that supports shrimp farming (Mulis & Habibie 2022). The waters of the Carocok Anau River have a plankton density that varies in each point between 3.4-7.3 ind L^{-1} (Figure 4).

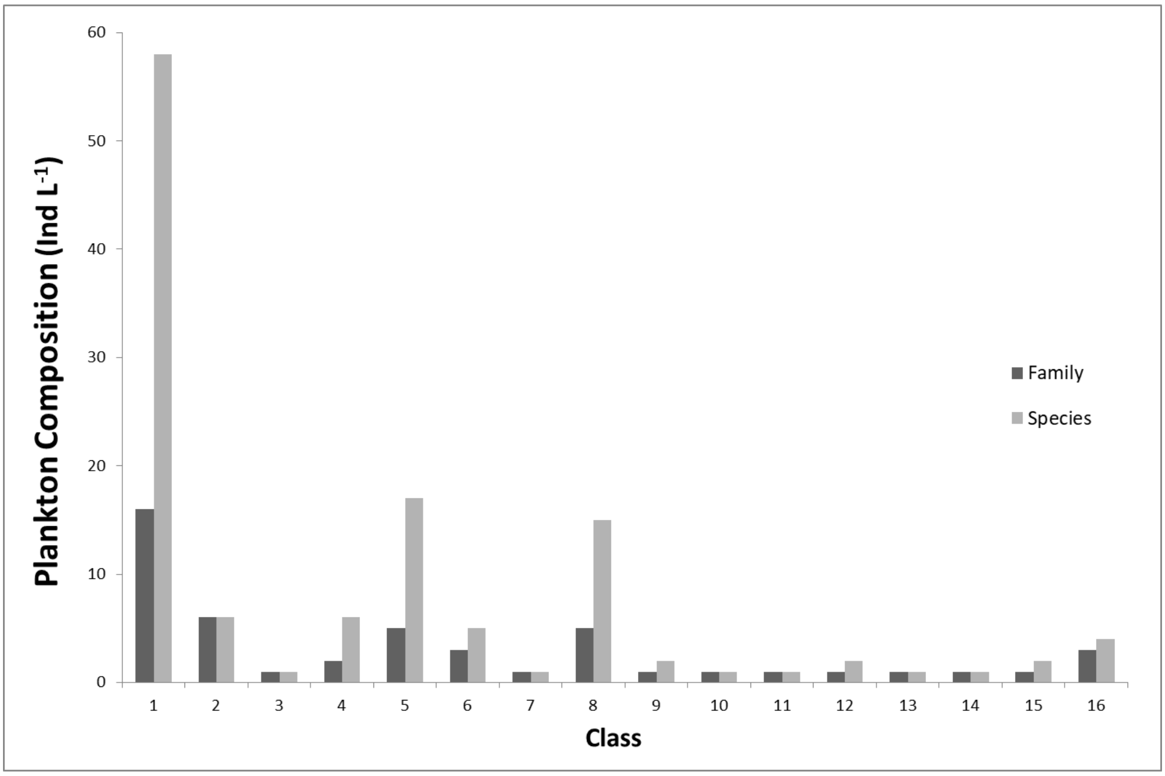

Figure 3. Plankton composition; 1 - Bacillariophyceae; 2 - Chlorophyceae; 3 - Chrysophyceae; 4 - Coscinodiscophyceae; 5 - Cyanophyceae; 6 - Dinophyceae; 7 - Imbricatea; 8 - Mediophyceae; 9 - Trebouxiophyceae; 10 - Zygnematophyceae; 11 - Bdelloidea; 12 - Ciliatea; 13 - Oligohymenophorea; 14 - Euglenophyceae; 15 - Eurotatoria; 16 - Maxillopoda.

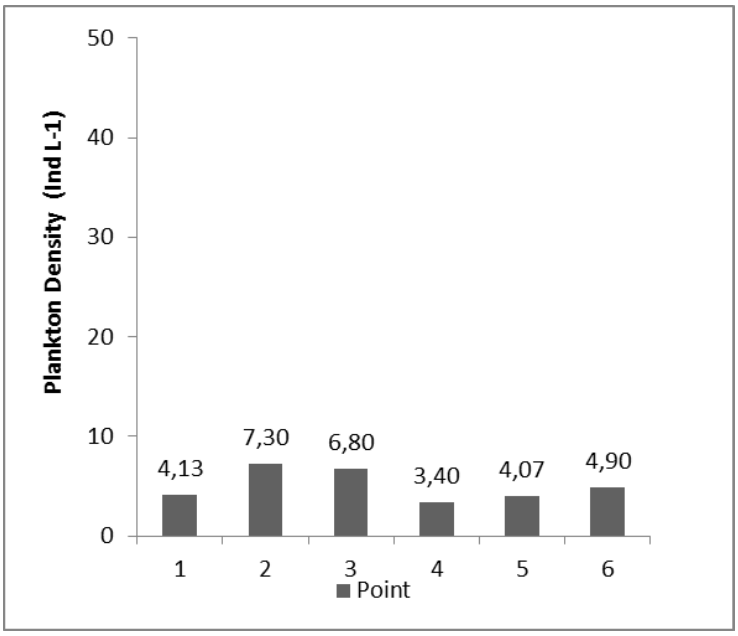

Figure 4. Plankton density at each point in the waters of the Carocok Anau River.

The plankton species with the highest density in the waters of the Carocok Anau River was *Coscinodiscus lineatus*. The plankton density in the Carocok Anau river is low. Poor water quality can affect this condition. The growth of plankton in a water is influenced by the physical and chemical parameters of the waters. Parameters such as water temperature, brightness, organic matter and eutrophication affect the abundance of plankton in an aquatic ecosystem (Gao et al 2016). Pollution due to poor aquatic environmental management practices can result in physiological changes to the growth and survival of aquatic organisms (Xu et al 2017). Plankton, aside from being primary producers, can also be used as bioindicators in the assessment of an aquatic environment because it is sensitive to changes in the aquatic environment (Jamshid et al 2016).

Plankton diversity index (H'). The structure of the plankton community in a water can be described using the diversity Index. The diversity index (H') at each point ranged from 2.64 to 3.35, with an average value of 2.97 (Figure 5).

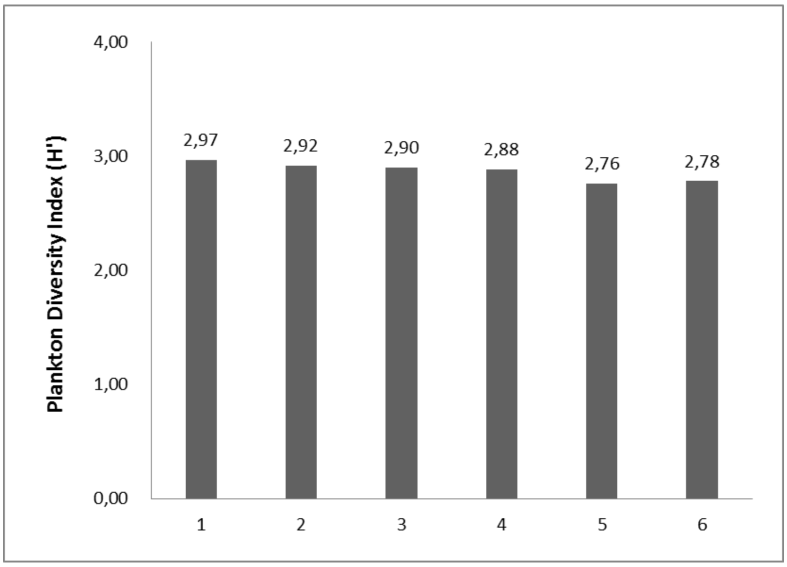

Figure 5. Diversity Index (H') at each study point in the Carocok Anau River.

In contrast to the results of Iswanto et al (2015), which showed that the plankton diversity index in the Jali River and Lereng River was low (1.57), the plankton diversity index in the Carocok Anau River waters was classified as moderate. This shows that the aquatic ecosystem of the Carocok Anau River is not seriously polluted. The plankton diversity index in the waters of the Carocok Anau River is classified as medium, indicating that the waters' ecosystem is not badly polluted. To obtain high quality water production, it is necessary to have good aquatic ecological conditions. The quality of water and diversity of plankton can describe the quality of an aquatic environment (Qiao et al 2020).

Plankton evenness index (E). The evenness index (E) at each point ranged from 0.87 to 0.94, with an average value of 0.89 (Figure 6). The evenness index of plankton in the waters of the Carocok Anau River is relatively high, indicating that no individual species dominates. This is different from the results of Iswanto et al (2015) in the Jali River and Lereng River, where the plankton evenness index value was moderate (0.59). The plankton evenness index in the waters of the Carocok Anau River is better than that of the Jali River and Lereng River.

Plankton dominance index (C). To determine whether or not there is a dominating plankton species in a water, the dominance index is used. The dominance index (C) at each point ranged from 0.04 to 0.09, with an average value of 0.07 (Figure 7). The results obtained are similar to those of Rahmatullah et al (2016) in the Kuala Rigaih Estuary, where the domination index obtained was low. In the Kuala Rigaih Estuary, the domination index was 0.21. The dominance index in the waters of the Carocok Anau River is close to zero. It can be assumed that there are no plankton species that dominate these waters.

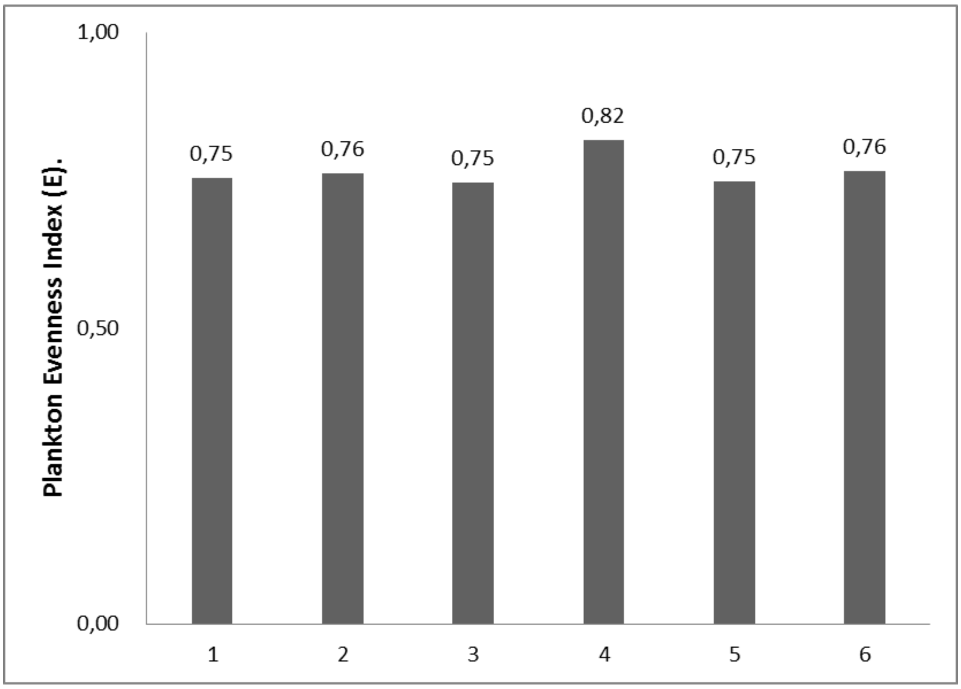

Figure 6. Evenness Index (E) at each study point in the Carocok Anau River.

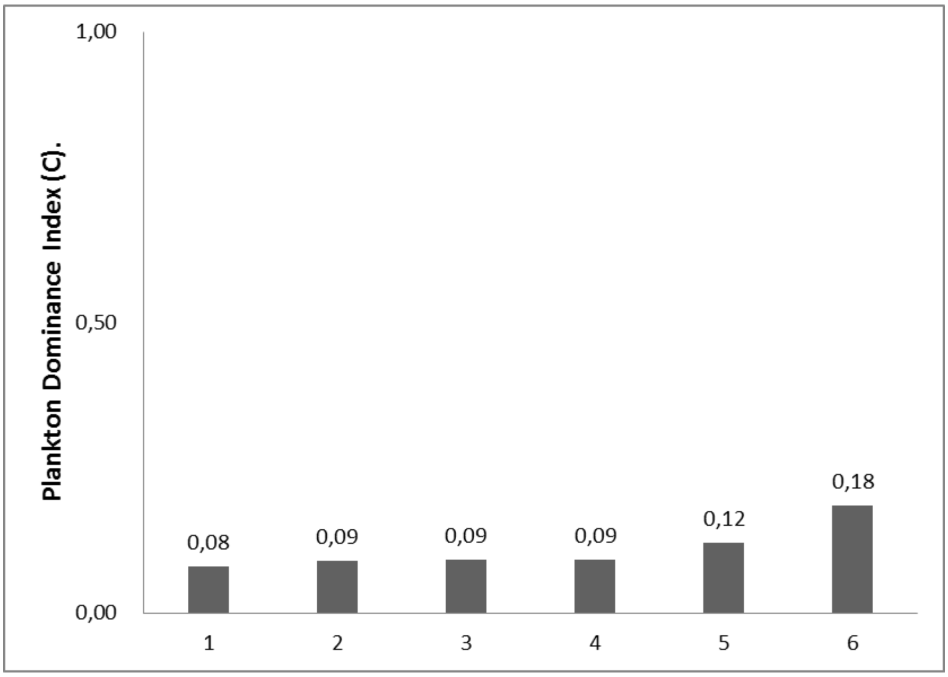

Figure 7. Dominance Index (C) at each point in the waters of the Carocok Anau River.

Pollution Index (IP). At each point, the IP ranged from 6.55 to 7.91, with an average value of 7.38 (Figure 8). The highest IP value was at point 2, and lowest at point 1. The IP in the waters of the Carocok Anau River is in the moderately polluted class. The condition of the waters can be caused by many activities around the aquatic environment such as households, agriculture, fisheries, industry, and community development (Jahan & Strezov 2017).

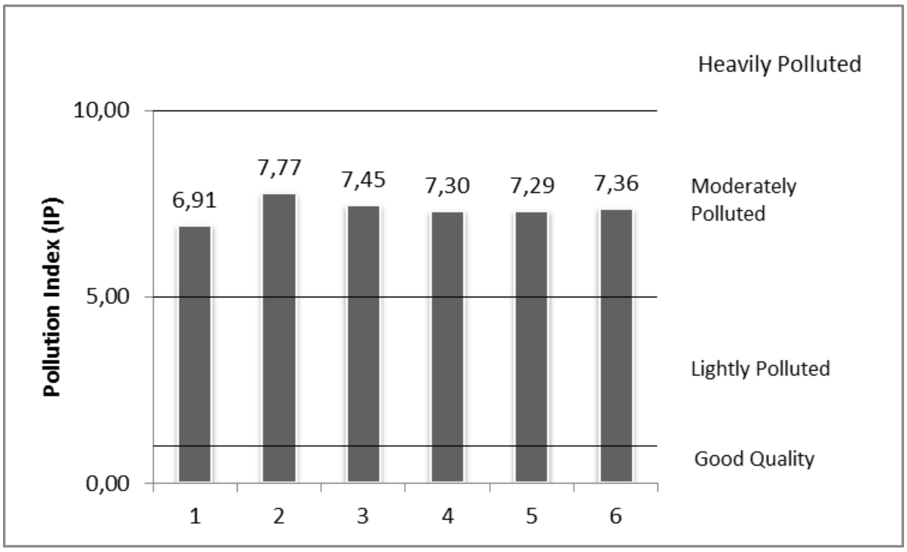

Figure 8. Pollution Index at each point in the waters of the Carocok Anau River.

An alternative strategy for sustainable shrimp aquaculture. Good water quality is very important for productive and sustainable shrimp farming activities. One way to maintain good water quality is by water exchange, which can reduce the concentration of ammonia and organic matter. The exchange of water leaves waste that has the potential to pollute the environment (Mulis & Habibie 2022). Pollution by shrimp pond waste must be handled properly. One way is through a shrimp farming wastewater treatment system, which is very important for a recirculating culture system. A sedimentation process and mechanical separation by using static and rotating micro screens can help speed up the process of settling and separating the sediment from the waste water (Tepe & Temel 2018).

In addition to mechanical separation technology, shrimp pond waste treatments can use constructed wetlands. The treatment of aquaculture effluents with constructed wetlands has evolved over the last two decades by creating complex effluent treatment systems. Constructed wetlands have many advantages compared to other aquaculture waste treatment systems, such as low maintenance cost, easy operation and cost efficiency (Abou-Elela et al 2013). Recovery of water quality in the sewage treatment systems using constructed wetlands can be carried out together with physical, chemical and biological processes (Wu et al 2015), which can degrade water pollutant in aquaculture waste water (Abou-Elela et al 2013; Bilgin et al 2014).

There are many innovative, environmentally friendly and sustainable technologies that can be used to prevent environmental pollution due to shrimp pond activities (Tong et al 2021). One effective way is optimizing the use of natural resources and better cultural environment such as water plants *in-situ* and *ex-situ* (Mariscal-Lagarda & Páez-Osuna 2014). The use of aquatic plants to degrade organic matter from shrimp ponds is becoming a trend and has been applied throughout Asia (Burford et al 2020). This innovation is considered more effective, environmentally friendly and sustainable without any negative impacts (Boock et al 2016). However, the use of this innovation is mostly used in simple aquaculture systems, where shrimp is not the main product (Li et al 2019) or applied to freshwater aquaculture and rarely used in brackish water aquaculture with intensive systems (Li et al 2018).

Conclusions. From the analysis that has been carried out, the results show that the values of TDS, DO, BOD, COD, ammonia, lead (Pb), and total coliform count consistently exceed the quality standards. Based on the structure of the plankton community, it can be concluded that these waters are in an unfavorable condition, because the total value of plankton abundance in these waters is very low, even though there are no plankton species that dominate. From the assessment of water quality using the Pollution Index, the waters of the Carocok Anau River are in a moderately polluted condition. The results of the study indicate that the condition of the waters is not good. This is thought to be a consequence of intensive shrimp pond activities around the Carocok Anau River. Environmental pollution can disrupt the sustainability of the aquatic environment and can have a negative impact on humans. Under these conditions, activities around the Carocok Anau River must carry out wastewater treatment before being discharged into these waters in accordance with applicable laws and regulations.

Acknowledgements. The authors would like to thank the Postgraduate Program of Andalas University, Padang, Indonesia, which has funded this research by the Basic Research Scheme (RD) research contract number: B 5/UN16.16 DIR/PT.01.03/2022 in the fiscal year 2022.

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

References

Abazi A. S., Gashi B., Spahiu M. H., Bytyçi P., Dreshaj A., 2022 Analysis of the impact of ferronicel industrial activity on Drenica River quality. Journal of Ecological Engineering 23(7):312-322.
Abou-Elela S. I., Golinielli G., Abou-Taleb E. M., Hellal M. S., 2013 Municipal wastewater treatment in horizontal and vertical flows constructed wetlands. Ecological Engineering 61:460-468.
Acevedo-Trejos E., Brandt G., Bruggeman J., Merico A., 2015 Mechanisms shaping size structure and functional diversity of phytoplankton communities in the ocean. Scientific Reports 5:8918.
Anggraini A., Sudarsono, Sukiya, 2016 [Plankton abundance and productivity in Bedog River]. Journal of Biology 5(6):1-10. [In Indonesian].
Arivalagan P., Singaraj D., Haridass V., Kaliannan T., 2014 Removal of cadmium from aqueous solution by batch studies using *Bacillus cereus*. Ecological Engineering 71:728-735.
Bilgin M., Şimşek I., Tulun Ş., 2014 Treatment of domestic wastewater using a lab-scale activated sludge/vertical flow subsurface constructed wetlands by using *Cyperus alternifolius*. Ecological Engineering 70:362-365.
Bold H. C., Wynne M. J., 1985 Introduction to the algae : Structure and reproduction. 2nd Edition. Prentice-Hall, New Jersey, 720 p.
Boock M. V., Marques H. L. A., Mallasen M., Barros H. P., Moraes-Valenti P., Valenti W. C., 2016 Effects of prawn stocking density and feeding management on rice-prawn culture. Aquaculture 451:480-487.
Brower J. E., Zar J. H., von Ende C., 1990 Field and laboratory methods for general ecology. WCB Publishers, Dubuque, 288 p.
Burford M. A., Hiep L. H., Sang N. V., Khoi C. M., Thu N. K., Faggotter S. J., Stewart-Koster B., Condon J., Sammut J., 2020 Does natural feed supply the nutritional needs of shrimp in extensive rice-shrimp ponds? – A stable isotope tracer approach. Aquaculture 529:735717.
Cui Y., Ren X., Li J., Zhai Q., Feng Y., Xu Y., Ma L., 2017 Effects of ammonia-N stress on metabolic and immune function via the neuroendocrine system in *Litopenaeus vannamei*. Fish and Shellfish Immunology 64:270-275.
Dien L. D., Sang N. V., Faggotter S. J., Chen C., Huang J., Teasdale P. R., Sammut J., Burford M. A., 2019 Seasonal nutrient cycling in integrated rice-shrimp ponds. Marine Pollution Bulletin 149:110647.
Dunca A. M., 2018 Water pollution and water quality assessment of major transboundary rivers from Banat (Romania). Journal of Chemistry 2018:9073763.
Ferreira A. C., Lacerda L. D., 2016 Degradation and conservation of Brazilian mangroves, status and perspectives. Ocean & Coastal Management 125:38-46.

Firdaus M., Hatanaka K., Shimoguchi N. N., Saville R., Zamroni A., 2022 Key actors in Indonesia’s sustainable mariculture enterprises: the power and influence of actors in the case of mariculture in Lampung and Bali. AACL Bioflux 15(6):2798-2812.
Gao W., Tian L., Huang T., Yao M., Hu W., Xu Q., 2016 Effect of salinity on the growth performance, osmolarity and metabolism-related gene expression in white shrimp *Litopenaeus vannamei*. Aquaculture Reports 4:125-129.
Han S., Wang B., Liu M., Wang M., Jiang K., Liu X., Wang L., 2018 Adaptation of the white shrimp *Litopenaeus vannamei* to gradual changes to a low-pH environment. Ecotoxicology and Environmental Safety 149:203-210.
Haque M. M., Belton B., Alam M. M., Ahmed A. G., Alam M. R., 2016 Reuse of fish pond sediments as fertilizer for fodder grass production in Bangladesh: Potential for sustainable intensification and improved nutrition. Agriculture, Ecosystems & Environment 216:226-236.
Harianja R. S. M., Sofia A., Mubarak, 2018 [Analysis of pollution load for shrimp ponds around the Kembung River, Bantan Bengkalis District]. Indonesian Environmental Dynamics 5(1):12-19. [In Indonesian].
Hoang H. T. T., Duong T. T., Nguyen K. T., Le Q. T. P., Luu M. T. N., Trinh D. A., Le A. H., Ho C. T., Dang K. D., Némery J., Orange D., Klein J., 2018 Impact of anthropogenic activities on water quality and plankton communities in the Day River (Red River Delta, Vietnam). Environmental Monitoring and Assessment 190:67.
Irshad M., Malik N., Khan T., Faridullah, 2011 Effect of solid waste on heavy metal composition of soil and water at Nathiagali-Abbottabad. Journal - Chemical Society of Pakistan 33(6):830-834.
Islam M. S., Tusher T. R., Mustafa M., Mahmud S., 2013 Effects of solid waste and industrial effluents on water quality of Turag River at Konabari Industrial Area, Gazipur, Bangladesh. Journal of Environmental Science and Natural Resources 5(2):213-218.
Iswanto C. Y., Sahala H., Pudjiono W. P., 2015 [Water fertility analysis based on plankton biodiversity, nitrate and phosphate in Jali River and Lereng River Keburuhan Village, Purworejo]. Diponegoro Journal of Maquares 4(3):84-90. [In Indonesian].
Jahan S., Strezov V., 2017 Water quality assessment of Australian ports using water quality evaluation indices. PLoS ONE 12(12):e0189284.
Jamshid K. A., Mohsenizadeh F., Omidi S., 2016 Effects of environmental parameters and nutrients on phytoplankton communities around the shrimp farm complexes in Bushehr Province, in the Persian Gulf. Iranian Journal of Fisheries Sciences 15(3):1044-1054.
Jouanneau S., Recoules L., Durand M. J., Boukabache A., Picot V., Primault Y., Lakel A., Sengelin M., Barillon B., Thouand G., 2014 Methods for assessing biochemical oxygen demand (BOD): A review. Water Research 49:62-82.
Kabir M. J., Cramb R., Alauddin M., Roth C., 2016 Farming adaptation to environmental change in coastal Bangladesh: shrimp culture versus crop diversification. Environment, Development and Sustainability 18:1195-1216.
Khalil B., Ouarda T. B. M. J., St-Hilaire A., Chebana F., 2010 A statistical approach for the rationalization of water quality indicators in surface water quality monitoring networks. Journal of Hydrology 386(1-4):173-185.
Kumar S. V., Pandey P. K., Anand T., Bhuvaneswari R., Kumar S., 2017 Effect of periphyton (aquamat) on water quality, nitrogen budget, microbial ecology, and growth parameters of *Litopenaeus vannamei* in a semi-intensive culture system. Aquaculture 479:240-249.
Lemonnier H., Hochard S., Nakagawa K., Courties C., Rodier M., 2017 Response of phytoplankton to organic enrichment and shrimp activity in tropical aquaculture ponds: A mesocosm study. Aquatic Microbial Ecology 80(2):105-122.
Li F., Sun Z., Qi H., Zhou X., Xu C., Wu D., Fang F., Feng J., Zhang N., 2019 Effects of rice-fish co-culture on oxygen consumption in intensive aquaculture pond. Rice Science 26(1):50-59.

Li G., Tao L., Li X., Peng L., Song C., Dai L., Wu Y., Xie L., 2018 Design and performance of a novel rice hydroponic biofilter in a pond-scale aquaponic recirculating system. Ecological Engineering 125:1-10.

Lin Z., Li J., Luan Y., Dai W., 2020 Application of algae for heavy metal adsorption: A 20-year meta-analysis. Ecotoxicology and Environmental Safety 190:110089.

Lou F., Gao T., Han Z., 2019 Effect of salinity fluctuation on the transcriptome of the Japanese mantis shrimp *Oratosquilla oratoria*. International Journal of Biological Macromolecules 140:1202-1213.

Mariscal-Lagarda M. M., Páez-Osuna F., 2014 Mass balances of nitrogen and phosphorus in an integrated culture of shrimp (*Litopenaeus vannamei*) and tomato (*Lycopersicon esculentum* Mill) with low salinity groundwater: A short communication. Aquacultural Engineering 58:107-112.

Michael P., 1984 Ecological methods for field and laboratory investigations. McGraw-Hill Education, 574 p.

Mochemadkar S., Gauns M., Pratihary A., Thorat B., Roy R., Pai I. K., Naqvi S. W., 2013 Response of phytoplankton to nutrient enrichment with high growth rates in a tropical monsoonal estuary – Zuari estuary, India. Indian Journal of Geo-Marine Sciences 42(3):314-325.

Morshed M. M., Islam M. S., Lohano H. D., Shyamsundar P., 2020 Production externalities of shrimp aquaculture on paddy farming in coastal Bangladesh. Agricultural Water Management 238:106213.

Mulis, Habibie S. A., 2022 Analysis of water quality and plankton community of *Litopenaeus vannamei* ponds in the coast of Tomini Bay, Mootilango Village, Gorontalo, Indonesia. AACL Bioflux 15(4):1630-1638.

Mutmainah A., Bambang S., Arif R., 2022 [Water quality status analysis of the Bogowonto River, Yogyakarta]. Sea Sand Journal 6(1):33-42. [In Indonesian].

Odum E. P., 1971 Fundamentals of ecology. 3rd Edition. W.B. Sounders, Philadelphia, 574 p.

Oestreich W. K., Ganju N. K., Pohlman J. W., Suttles S. E., 2016 Colored dissolved organic matter in shallow estuaries: Relationships between carbon sources and light attenuation. Biogeosciences 13(2):583-595.

Popovic N., Đuknic J., Canak Atlagic J., Rakovic M. J., Marinkovic N., Tubic B., Paunovic M., 2016 Application of the water pollution index in the assessment of the ecological status of rivers: A case study of the Sava River, Serbia. Acta Zoologica Bulgarica 68(1):97-102.

Prambudy H., Supriyatin T., Setiawan F., 2019 The testing of chemical oxygen demand (COD) and biological oxygen demand (BOD) of river water in Cipager Cirebon. Journal of Physics: Conference Series 1360:012010.

Prasetiyono E., Nirmala K., Supriyono E., Sukenda, Hastuti Y. P., 2022 Analysis of environmental quality, production performance and economic feasibility of *Anadara granosa* cultivation in Sukal, Bangka Belitung Province. AACL Bioflux 15(6):2881-2891.

Prescott G. W., 1978 How to know the freshwater algae. W.C. Brown, 355 p.

Qiao L., Chang Z., Li J., Chen Z., 2020 Phytoplankton community succession in relation to water quality changes in the indoor industrial aquaculture system for *Litopenaeus vannamei*. Aquaculture 527:735441.

Qiu L., Shi X., Yu S., Han Q., Diao X., Zhou H., 2018 Changes of ammonia-metabolizing enzyme activity and gene expression of two strains in shrimp *Litopenaeus vannamei* under ammonia stress. Frontiers in Physiology 9:211.

Rahmatullah M., Sarong A., Sofyatuddin K., 2016 [Diversity and dominance of plankton in Kuala Rigaih, Aceh Jaya District]. Jurnal Ilmiah Mahasiswa Kelautan Perikanan Unsyiah 1(3):325-330. [In Indonesian].

Ramos e Silva C. A., Sternberg L. S. L., Dávalos P. B., Souza F. E. S., 2017 The impact of organic and intensive farming on the tropical estuary. Ocean & Coastal Management 141:55-64.

Sachlan M., 1982 [Planktonology]. Direktorat Jenderal Perikanan, Departemen Pertanian, Jakarta, 178 p. [In Indonesian].

Salahuddin, Chafid F., Eko S., 2012 [Study of environmental pollution in the Mahakam Delta shrimp pond]. Technoscience Journal 2(1):32-47. [In Indonesian].
Taiwo A. M., Gbadebo A. M., Oyedepo J. A., Ojekunle Z. O., Alo O. M., Oyeniran A. A., Onalaja O. J., Ogunjimi D., Taiwo O. T., 2016 Bioremediation of industrially contaminated soil using compost and plant technology. Journal of Hazardous Materials 304:166-172.
Tanjung R. H. R., Hamuna B., Alianto, 2019 Assessment of water quality and pollution index in coastal waters of Mimika, Indonesia. Journal of Ecological Engineering 20(2):87-94.
Tepe Y., Temel F. A., 2018 Treatment of effluents from fish and shrimp aquaculture in constructed wetlands. In: Constructed wetlands for industrial wastewater treatment. Alexandros S. (ed), John Wiley & Sons, pp. 105-126.
Tong Y., Liao Z., Yang Q., Chen X., Zeng D., Yang C., Ma H., Hu T., Lv M., 2021 Effect of a prawn (*Macrobrachium rosenbergii*)-plant eco-symbiotic culture system (PECS) on intestinal microbiota, organic acids, and ammonia. Aquaculture Reports 20:100647.
Widyaningsih W., Supriharyono, Niniek W., 2016 [The analysis of total coliform bacteria in Kali Wiso estuary, Jepara]. Diponegoro Journal of Maquares 5(3):157-164. [In Indonesian].
Wu H., Zhang J., Ngo H. H., Guo W., Hu Z., Liang S., Fan J., Liu H., 2015 A review on the sustainability of constructed wetlands for wastewater treatment: Design and operation. Bioresource Technology 175:594-601.
Xiao J., Li Q. Y., Tu J. P., Chen X. L., Chen X. H., Liu Q. Y., Liu H., Zhou X. Y., Zhao Y. Z., Wang H. L., 2019 Stress response and tolerance mechanisms of ammonia exposure based on transcriptomics and metabolomics in *Litopenaeus vannamei*. Ecotoxicology and Environmental Safety 180:491-500.
Xu C., Li E., Liu Y., Wang X., Qin J. G., Chen L., 2017 Comparative proteome analysis of the hepatopancreas from the Pacific white shrimp *Litopenaeus vannamei* under long-term low salinity stress. Journal of Proteomics 162:1-10.
Xu Z., Regenstein J. M., Xie D., Lu W., Ren X., Yuan J., Mao L., 2018 The oxidative stress and antioxidant responses of Litopenaeus vannamei to low temperature and air exposure. Fish & Shellfish Immunology 72:564-571.
Yamaji I., 1970 Illustrations of the marine planktons of Japan. Hoikusha Publishing Co., 537 p.
Yi Z., Xu M., Di X., Brynjólfsson S., Fu W., 2017 Exploring valuable lipids in diatoms. Frontiers in Marine Science 4:17.
Yuan M., Zhang C., Jiang Z., Guo S., Sun J., 2014 Seasonal variations in phytoplankton community structure in the Sanggou, Ailian, and Lidao Bays. Journal of Ocean University of China 13:1012-1024.
Yuliana, Mutmainnah, Irfan M., Nasir A., Djamhur M., 2023 Phytoplankton quality based on species composition in the Kastela waters, Ternate, North Maluku, Indonesia. AACL Bioflux 16(2):743-752.
*** BPS-Statistic of Pesisir Selatan Regency, 2022 [Pesisir Selatan Regency in figures 2022]. [In Indonesian].
*** https://earth.google.com/web/
*** Indonesian National Standard 6989.14:2004
*** Indonesian National Standard 6989.2:2019
*** Indonesian National Standard 6989.2:2019
*** Indonesian National Standard 6989.20:2019
*** Indonesian National Standard 6989.23:2005
*** Indonesian National Standard 6989.25:2005
*** Indonesian National Standard 6989.27:2019
*** Indonesian National Standard 6989.3:2019
*** Indonesian National Standard 6989.31:2021
*** Indonesian National Standard 6989.72:2009
*** Indonesian National Standard 6989.79:2011
*** Indonesian National Standard 6989.80:2011
*** Indonesian National Standard 6989.16:2009

*** Indonesian National Standard 6989.17:2004
*** Indonesian National Standard 6989.30:2006
*** Indonesian National Standard 6989.8:2009
*** Indonesian National Standard 6989.9:2004
*** Ministry of Environment Decree No 115/2003 Concerning Guidelines for Determining Water Quality Status in the Republic of Indonesia.
*** Regulation of the Government of Indonesia Number 22 of 2021, Appendix VI concerning the Implementation of Environmental Protection and Management, Republic of Indonesia.

Received: Received: 27 January 2023. Accepted: 18 April 2023. Published online: 30 May 2023.
Authors:
Rahmiana Zein, Laboratory of Environmental Analytical Chemistry, Department of Chemistry, Andalas University, Limau Manis, 25163 Padang, West Sumatra, Indonesia, e-mail: rzein@sci.unand.ac.id
Jabang Nurdin, Ecology Laboratory, Department of Biology, Andalas University, Limau Manis, 25163 Padang, West Sumatra, Indonesia, e-mail: jabang-nurdin@yahoo.com
Dewa Restu Rianto, Environment Science Study Program, Postgraduate Program, Andalas University, Limau Manis, 25163 Padang, West Sumatra, Indonesia, e-mail: dewarestu99@gmail.com
Putri Ramadhani, Laboratory of Environmental Analytical Chemistry, Department of Chemistry, Andalas University, Limau Manis, 25163 Padang, West Sumatra, Indonesia, e-mail: putriramadhanikimia11@gmail.com

How to cite this article:
Zein R., Nurdin J., Rianto D. R., Ramadhani P., 2023 Environmental management approach: The impact of a wastewater treatment plant for shrimp ponds on Carocok Anau River water quality. AACL Bioflux 16(3):1531-1548.