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Assessment of water quality status in Bondet Estuary, Cirebon

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ABSTRACT

The coast is a water area that gets a lot of environmental pressure from human anthropogenic activities. As a result, many coastal areas are in a polluted condition, is no exception Bondet Estuary. An assessment of the condition and status of water quality needs to be carried out, as an effort to conserve coastal resources. This research aims to know the condition of water quality and determine the water quality status of the Bondet Estuary using the STORET method and the pollution index (IP). This study used survey method, where the determination of the sampling location is based on the purposive sampling method. Based on the STORET method, the water quality status of the Muara Sungai Bondet was moderately polluted with a score of -14 to -18, while the results of the assessment with the pollution index showed that it was lightly polluted with a value of 2.54 - 4.05. Several parameters that contribute to the condition of water quality degradation are salinity, TSS, and Pb. Based on these results, a sustainable management plan for the Bondet Estuary area is needed to reduce the negative impact on the environment due to various human activities.

INTRODUCTION

Coastal areas are the most important ecosystems and have abundant resources for human life (Bierman et al., 2011), and provide environmental services derived from mangrove ecosystems, coral reefs, seagrass and estuaries (Effendy, 2009; Pramudyanto, 2014; Rahmayani, 2015; Miteva et al., 2015). Coastal ecosystems are the most productive and important habitats for many fish and other organisms, which are a source of food for humans and a vital component of marine ecosystems. These interactions between coastal and marine ecosystems provide nutrients and supportive conditions for primary producers, who serve as the basis of the food chain. Therefore, water quality in the coastal environment is very important for several things, from protecting marine ecosystems and organisms to public welfare and health (Bierman et al., 2011).

Coastal waters have become a major concern, because of their value for socio-economic development and human health (Wu et al., 2010). However, with higher population growth and rapid development activities, causing ecological pressure on coastal ecosystems and resulting in changes in water quality and biodiversity, loss of critical habitat, and a decrease in the quality of life of local residents as a whole (Effendy, 2009; Herrera-Silveira & Morales-Ojeda, 2009).

The threat of changes in water quality can be caused by increased nutrients (N and P) from anthropogenic activities. This condition can result eutrophication and algal blooms phenomenon, especially if dominated by Dinoflagellates and Cyanophyceae (*Trichodesmium erythraeum*) (Anderson et al., 2002; Kumar et al., 2020; Garno, 2020). Changes in water quality in coastal areas are also caused by an increase in pollutants such as heavy metals (Arifin et al., 2012; Anas, 2011; Gao et al., 2014), oil (Islam & Tanaka, 2004; Effendy, 2009; Pramudyanto, 2014), and pathogenic microorganisms such as *Escherichia coli* and *Enterococcus* sp. from fecal contamination, especially from humans (Kucuksezgin et al., 2010; Vignesh et al., 2012).

Currently, most of the world's coastal areas have been reported to be damaged, and have a significant impact on commercial coastal and marine fisheries (Islam & Tanaka, 2004). The Bondet Estuary is a coastal area in Cirebon Regency which is reported to have changed water quality. The results of the research by Sudirman and Husrin (2014) showed that the condition of the waters on the coast of Cirebon was polluted from low to heavy. The input of sediment and waste from rivers into the estuary causes high turbidity, while dense residential conditions add to the burden of waste input from household and fishing activities.

Monitoring of water quality pollution is an urgent need as an effort to sustainably manage and conserve water resources (Islam & Tanaka, 2004). Rapid water quality assessment to determine the level of pollution is necessary. Therefore, the selection of an effective monitoring and assessment index such as the water pollution index is useful for providing the results of an initial assessment of the status of water quality (Effendi, 2016; Liu et al., 2012). In general, the determination of the status of water quality is by comparing the data of water quality parameters (physics, chemistry, and biology) with the quality standard of water designation (Saraswati et al., 2014). The STORET method and the pollution index (IP) can be used to determine the water quality status on the coast, which is based on Ministry of Environment and Forestry Decree number 115 of 2003 concerning Guidelines for determining the status of water quality. The research aims to examine the condition of water quality and determine the status of the water quality of the Bondet Estuary using the STORET method and the pollution index (IP).

MATERIAL AND METHODS

Research area and sampling. The research was conducted in September 2020 at the Bondet Estuary, Mertasinga Village, Gunungjati District, Cirebon Regency. Geographically, the Bondet Estuary is a coastal area located at 6°30'–7°00' South Latitude and 108°40'-108°48' East Longitude (Haidar et al., 2021).

The research was conducted by survey method, where the determination of the sampling location was based on the purposive sampling method. A total of four sampling locations were used for water quality analysis. The four sampling locations were stated as station 1, station 2, station 3, and station 4 (Figure 1). Station 1 is waters with a depth of 2.5 m and little community activity, station 2 has a depth of 2.3 m, and is a densely populated area and fishing boat activity, station 3 is the waters towards the mouth of the estuary, with a depth of 2.5 m and there is a fish auction site. while station 4 is close to the sea with a depth of 1 m.

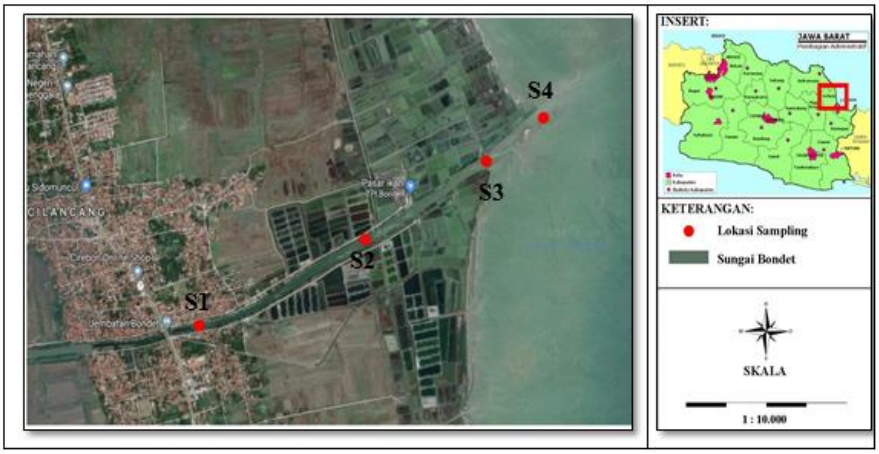

Figure 1. Study site. The red dot (●) indicates the location of water quality sampling at Bondet Estuary

Water sampling was carried out directly by the grab sampling method using vandorn. The water sample obtained was then stored in a 250 ml sample bottle and put into an ice box. Measurements of physical and chemical parameters of waters carried out directly in the field include temperature, salinity, dissolved oxygen, and pH of the water, while the parameters measured in the laboratory are TSS and BOD. Sample analysis procedure refers to guidelines American Public Health Association (APHA) in 2017.

Water quality assessment using the storet method. Based on Ministry of Environment and Forestry Decree Number 115 of 2003 concerning guidelines for determining water quality status, the principle of determining water quality status using the STORET method is to compare each water quality parameter with the quality standard. The quality standard in this study refers to Ministry of Environment and Forestry Decree Number 51 of 2004 for marine life. If the measurement result is in accordance with the water quality standard value (measurement result < quality standard) then it is given a score of 0; if the measurement result does not meet the water quality standard value or (measurement result > quality standard) then it is given a score as listed in Table 1.

Table 1. Determination of the value system to determine the status of water quality

Amount Example	Mark	Parameter		
		Physical	Chemical	Biology
< 10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

Source: Ministry of Environment and Forestry Decree No. 115 of 2003

Determination of water quality status using a value system from the US-EPA (Environmental Protection Agency) by classifying water quality into four classes as listed in Table 2

Table 2. Water quality classification

No	Category		Score	Status
1	Class A	Very well	0	Quality standards
2	Class B	Well	-1 to -10	Lightly polluted
3	Class C	Currently	-11 to -30	Medium polluted
4	Class D	Bad	>-30	heavily polluted

Source: Ministry of Environment and Forestry Decree No. 115 of 2003

Water quality assessment using the pollution index (IP). The pollution index method is based on two indices, namely the average index (IR) which shows the average level of pollution in one observation, while the maximum index (IM) indicates the type of dominant parameter that causes a decrease in water quality in one observation (Hermawan, 2017).

Assessment of water quality status using the IP method refers to Ministry of Environment and Forestry Decree number 115 of 2003 concerning guidelines for determining the status of water quality, with the following equation (Ministry of Environment and Forestry Decree, 2003):

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

Where IP is the pollution index, Ci is the concentration of water quality parameters (i) obtained from the analysis results, Lij is the concentration of water quality parameters listed in the quality standard of a water designation (j), (Ci/Lij)M is the maximum value of Ci/Lij, while (Ci/Lij)R is the average value of Ci/Lij. Evaluation of pollution index value with water quality status is presented in Table 3.

Table 3. Evaluation of pollution index value with water quality status

Pollution index	Water quality status
0 IP 1.0	Quality standards
1.0 < IP 5.0	Lightly polluted
5.0 < IP 10	Medium polluted
IP > 10	heavily polluted

Source: Ministry of Environment and Forestry Decree No. 115 of 2003

Data analysis. The water quality data obtained were tested by ANOVA to determine the differences between stations, then a 5% Duncan test was carried out using the SPSS statistical software package.

RESULTS AND DISCUSSION

Area description. The waters and the area around the Bondet Estuary are widely used by the community for various activities such as green mussel cultivation, fishing, fishing boats to lean on, fish auction activities, aquaculture, agriculture, and other activities. These activities produce both liquid and solid wastes that have the potential to pollute the surrounding waters. River flows from upstream that are carried to the sea also add to the burden of water pollution.

Water quality analysis. Water quality that does not in accordance with the physical, chemical and biological standards will affect the life of aquatic biota, and ultimately have an impact on human health. This is the reason for the importance of monitoring water quality in the Bondet Estuary. The analysis of water quality was carried out in situ and ex situ, and then the measurement results were compared with sea water quality standards for marine biota. The results of water quality analysis for physical and chemical parameters are presented in Table 4.

Temperature. The results of water temperature measurements in this study showed uniform variations between stations, which ranged from 30.8-31.5 ^{o}C. During the duration of the study, there was no sudden increase in water temperature, however, a higher temperature was observed at station 4, presumably due to the shallower water depth (1 m) compared to other stations. One of the factors that affect the temperature in the waters is the depth of the water body (Effendi, 2003), where in shallower waters the penetration of sunlight is easier to enter to the bottom of the waters compared to deeper waters (Sidabutar et al., 2019). The influence

of currents and strong winds causes a more optimal mixing process in shallow waters, so that a more homogeneous water temperature is formed. Higher temperatures were also observed in the shallower waters of Dhamra Estuary, India due to the high solar insolation in summer (Swain et al., 2021). In general, the water temperature at each station is relatively high, this can also be caused by the intensity of the sun and strong wind speed. According to Suhana (2018), several factors that also affect the temperature at sea level are precipitation, evaporation, humidity, temperature, wind speed and sunlight intensity.

Table 4. Results of measurement of physical and chemical parameters of the Bondet Estuary

No	Parameter	Quality standards[1)]	Measurement results[2)]			
			S1	S2	S3	S4
1	Temperature (°C)	28-32	$30.8^{a} \pm 0.2$	$31.2^{b} \pm 0.7$	$31.1^{ab} \pm 0.2$	$31.5^{c} \pm 0.3$
2	Salinity (ppt)	up to 34	$32.8^{a} \pm 0.5$	$34.0^{b} \pm 0.3$	$36.2^{c} \pm 0.2$	$33.7^{ab} \pm 1.4$
3	TSS (mg/L)	80	$132.7^{a} \pm 17.0$	$216.3^{a} \pm 51.9$	$154.0^{a} \pm 42.8$	$401.3^{b} \pm 75.1$
4	water pH	7-8.5	$7.1^{a} \pm 0.35$	$6.9^{b} \pm 0.0$	$7.2^{c} \pm 0.0$	$7.4^{d} \pm 0.2$
5	Dissolved oxygen (mg/L)	>5	$7.3^{a} \pm 0.2$	$5.8^{b} \pm 0.1$	$5.2^{c} \pm 0.1$	$5.5^{bc} \pm 0.9$
6	BOD (mg/L)	20	$2.7^{a} \pm 0.3$	$4.5^{b} \pm 0.5$	$4.7^{b} \pm 0.2$	$5.5^{c} \pm 0.2$
7	Pb in water (mg/L)	0.008	$0.024^{a} \pm 0.002$	$0.031^{b} \pm 0.003$	$0.030^{b} \pm 0.003$	$0.024^{a} \pm 0.004$

[1)] Ministry of Environment and Forestry Decree Number 51 of 2004; [2)]Data analysis for 2020; Different letters showed significantly different results ($P < 0.05$)

The results of the Anova test showed that the temperature between stations was significantly different ($p<0.05$). Further test results showed that stations 1 and 4 were significantly different, while stations 2 and 3 showed no difference. Meanwhile, based on the sea water quality standard for marine biota in Ministry of Environment and Forestry Decree No. 51 of 2004, the water temperature in the Bondet Estuary is still suitable for mangrove ecosystems and marine biota, one of which is green mussels which are widely cultivated in the surrounding waters. According to Zahroh et al. (2019) a good temperature range for the growth of green mussels is 27–37 °C.

Salinity. The results of the salinity measurement at each station show different value, where station 1, station 2, and station 4 show variations in values that are not much different. Meanwhile, the salinity value at station 3 showed the highest result, which was 36.2 ppt. The high salinity value at the station is influenced by the topography of the river, where station 3 is a water area surrounded by land which is quite high, so that the influence of input from land is lower than other stations. According to Suhana (2018), the shape of the regional topography will affect the salinity in a water area, this is related to the level of input from land. In addition, station 3 is a wider water area with calmer current conditions than other stations, so that the mixing and dilution rate of the water mass is lower. Meanwhile, the low salinity at station 1 (32.8 ppt) is influenced by the input of freshwater flow from upstream of the river and the location of the waters closer to the mainland. According to Sidabutar et al. (2019), river flows from upstream carry fresh water with a lower water mass, causing the salinity of marine waters to decrease.

Based on the ANOVA test for salinity, it is known that there are significant differences at each station ($p<0.05$). Further test results showed that station 3 had a significantly different salinity. As for station 1, station 2, and station 4, the salinity was not significantly different. Meanwhile, if the salinity value is compared with the sea water quality standard for marine biota in Ministry of Environment and Forestry Decree No. 51 of 2004, then the salinity at station 3 is no longer suitable for marine biota and mangrove ecosystems around the waters.

Total suspended solid (TSS). The TSS value in the Bondet Estuary fluctuates with a range between 132.7–401.3 mg/L, with the highest TSS value at station 4 and the lowest at station

1. Station 4 is the estuary waters which is the deposition area for particles from the river flow. The existence of tidal and current conditions as well as strong winds at station 4, resulted in the sediment at the bottom being lifted back to the surface so that it had an impact on increasing the TSS value at that station. The sediment resuspension process becomes more optimal due to the shallow water depth at station 4. According to Swain et al. (2021), Tidal currents cause sediment resuspension from the bottom of the water, thus affecting the TSS value. While the low TSS value at station 1 is influenced by relatively calm current conditions,

The results of the Anova test showed differences in TSS for each station ($p<0.05$). Further test results showed that station 4 had significantly different TSS, while station 1, station 2, and station 3 were not significantly different. When compared to sea water quality standard for marine biota in Ministry of Environment and Forestry Decree No. 51 of 2004, then the salinity value at all stations is no longer suitable for the ecosystem and life of marine biota. The results of Nyanti et al. (2018) showed that high concentrations of TSS have a negative impact on the survival of native fish species in Malaysia, due to environmental stress, especially on the respiratory system of fish.

pH. The results of pH measurements at the study site showed a uniform value at each station, with an increasing trend towards the sea. The highest average pH value at station 4 is associated with the influence of seawater. According to Damayanti (2013) seawater acts as a buffer to prevent large pH fluctuations, so that the pH value is in a stable condition. Meanwhile, the lowest pH value at station 2 is associated with the input of organic matter originating from activities and discharges around the location. Station 2 is a water location with dense settlements, and piles of garbage along the river shoulder. According to Swain et al. (2021), the decrease in pH in the waters is influenced by organic matter that enters the system. Furthermore, Su et al. (2014) explained that organic matter that enters the system will be decomposed by microbes,

Based on the Anova test on the pH value,there was a significant difference in pH for each station ($p<0.05$). Further test results showed that each station had a significantly different pH. Meanwhile, when compared to the quality standard of sea water for marine biota in Ministry of Environment and Forestry Decree No. 51 of 2004, the pH of the water at each station is still suitable for ecosystems and biota life, except for station 2. According to Hamuna et al. (2018), pH values that are too acidic or alkaline have a negative impact on the survival of aquatic biota due to metabolic and respiratory disorders.

Dissolved oxygen (DO). The dissolved oxygen value obtained during the measurement ranged from 5.2 to 7.3 mg/L. At station 1, fishermen and community activities are less than other stations, so the dissolved oxygen value in these waters tends to be higher. While stations 2, 3 and 4 are water areas leading to the estuary with various anthropogenic activities, so that dissolved oxygen tends to be lower with uniform value variations. According to Amira et al. (2017), anthropogenic activities contribute a large amount of organic matter that pollutes the waters. Such conditions encourage the use of dissolved oxygen to decompose organic matter, and cause its concentration in the waters to decrease.

Based on the Anova test, it is known that there is a significant difference in dissolved oxygen for each station ($p<0.05$). Further test results showed that stations 1 and 3 had significantly different dissolved oxygen, while stations 2 and 4 were not significantly different. When compared to the quality standard sea water for marine biota in Ministry of Environment and Forestry Decree No. 51 of 2004, the dissolved oxygen at each station is suitable for the life of ecosystems and marine biota.

Biologica oxygen demand (BOD). The BOD value obtained during sampling fluctuated between 2.7-5.5 mg/L. The lowest BOD value is at station 1, then tends to increase at station 2, 3 and the highest is at station 4. This result is in line with the concentration of dissolved oxygen at each station, where the more input of pollutants from anthropogenic activities causes an increase in the use of oxygen for decomposition activities. According to Su et al.

(2014), presence of organic pollutants anthropogenic activities can directly or indirectly increase the use of water as a waste storage area. This condition will decrease dissolved oxygen while increasing biochemical oxygen demand. The presence of a layer of oil at stations 2, 3 and 4 originating from fishing boats also inhibits reaeration on the surface of the water, thereby reducing the concentration of dissolved oxygen while increasing the need for biochemical oxygen because it is organic.

Based on the Anova test, it is known that there are differences in BOD for each station ($p<0.05$). Further test results showed that stations 1 and 4 had significantly different BOD compared to stations 2 and 3. While stations 2 and 3 did not show significantly different results. The BOD value in all stations is still below the maximum threshold based on quality standards of Ministry of Environment and Forestry Decree No. 51 of 2004 for marine biota, so that the BOD value is still safe and suitable for marine ecosystems and life.

Heavy Metal (Pb). Based on the measurement results of heavy metal Pb in water, it is known that the concentration at each station is between 0,024-0,031 mg/L. The highest concentration is found at station 2, which is thought to be related to inputs from land and heavy fishing boat activity at that location. Meanwhile, the lowest concentration of heavy metal Pb at stations 1 and 4 was influenced by the location of station 1 which was quite far from community activities and fishing boats. Station 4 is an estuary area near the sea with strong currents, so that the mixing and dilution of the water mass is strong. According to Permanawati et al. (2013) and Ahmed et al. (2017), high and low concentrations of heavy metals in waters are influenced by discharges from anthropogenic activities such as industrial waste, household waste, and spilled fuel containing Pb.

The results of the ANOVA test showed that there were significant differences in heavy metal Pb at each station ($P<0,05$). Further test results showed that the concentration of Pb at station 1 had a significant difference with stations 2 and 3, but stations 1 and 4 did not show significantly different results, as well as stations 2 and 3. When compared with sea water quality standards, the concentration of heavy metal Pb at all stations has exceeded the threshold value based on the Ministry of Environment and Forestry Decree No. 51 of 2004 for marine biota.

Water quality based on the STORET method. Based on the results of the analysis using the STORET method, it is known that the water quality for all stations is in the moderately polluted category (-14 to -18). The results of the analysis of water quality in the Bondet Estuary using the STORET method can be seen in Figure 2. The highest total score is at station 3 (-18), and the lowest is at stations 1 and 4 (-14), but overall the physical and chemical parameters that contribute on water quality conditions are salinity, TSS and Pb. Based on these parameters, the waters of the Bondet Estuary are not suitable for marine ecosystems and life based on Ministry of Environment and Forestry Decree No. 51 of 2004 for marine biota.

The results of the assessment of water quality status using the STORET method in this study were similar with the results in Cilincing Estuary and Berikat Nusantara area, which were moderately polluted with a score of -28 (Simbolon, 2016), and the Socah Estuary of Bangkalan Regency with moderate to heavily polluted conditions with a score of - 27 to -35 (Yusnita & Triajie, 2021). However, the results of the assessment of water quality status in this study were lower when compared with the results of the calculation of water quality status using STORET in Gorontalo Bay which shows heavily polluted conditions with a score of -39 (Kadim et al., 2017).

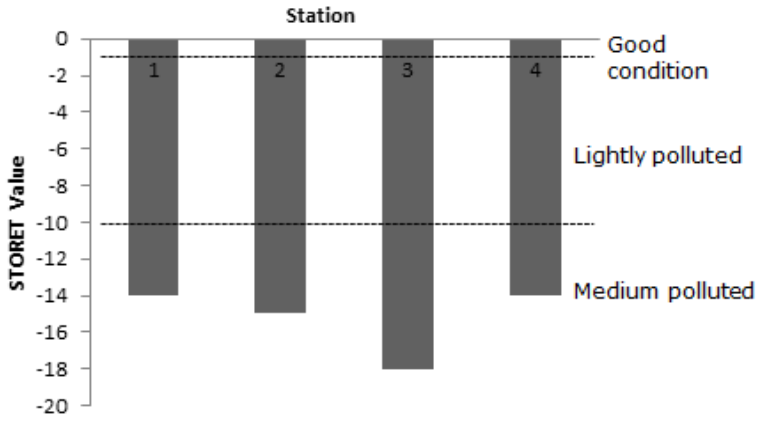

Figure 2. Water quality status based on STORET method in Bondet Estuary

***Water quality based on the pollution index (IP)*.** The results of the water quality status in Bondet Estuary using the pollution index method are presented in Figure 3. Based on Ministry of Environment and Forestry Decree No. 115 of 2003 show that all stations are in a polluted condition with a mild category. The highest IP value is at station 3 (4.05), while the lowest is at station 1 (2.54). Based on the location of the station, it is known that station 1 is a water area before the estuary which is quite far from activities and residential areas. This can be shown from several parameters such as salinity, TSS, BOD, and Pb whose concentration is lower than other stations. Stations 1 and 2 are densely populated areas and community activities and fishermen, so the influence of land and fishing activities is higher. Meanwhile, station 4 is an estuary area which is a place for accumulation of waste both from land and sea.

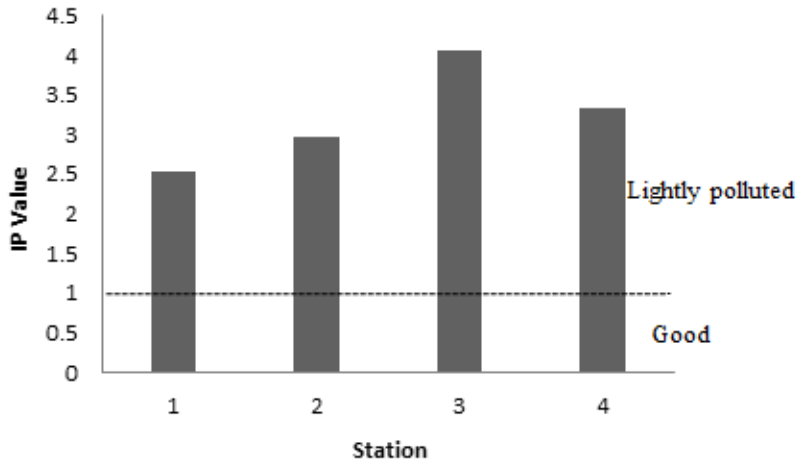

Figure 3. Water quality status based on IP method in Bondet Estuary

Most of the parameters that have exceeded the quality standard based on Ministry of Environment and Forestry Decree No. 51 of 2004 for marine biota include salinity at station 3, TSS and heavy metal Pb at stations 1, 2, 3 and 4. When compared with the results of other research, the water quality status based on IP in the Bondet Estuary is similar to the Madong Estuary of Tanjungpinang City, which is 1.87 with a lightly polluted category (Razai et al., 2018). However, the IP value in this study was lower when compared with the water quality status at Bulumanis Kidul Beach, Pati Regency, namely 5.67 - 8.22 with moderately polluted categories (Damayanti, 2013), Depapre District Estuary, Jayapura, which was 6 .25 – 7.69 (Hamuna et al., 2018), and the White Sand Waters of Situbondo with an IP value of 7.94 – 9.43 (Pahlewi & Rahayu, 2020).

CONCLUSION

Water quality status at the Bondet Estuary using the STORET method was the moderately polluted category with a value of -14 to -18, while based on the assessment of the pollution index included in the polluted condition with a light category (2.54-4.05). Several parameters that exceed the quality standard and affect the status of water quality in the Bondet Estuary are salinity, TSS, and Pb. Overall, both with the STORET method and the pollution index, the condition of the water quality in the Bondet Estuary has decreased in water quality, so that pollution control efforts are needed considering that future activities have the potential to cause increased pollution.

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