Jurnal Ilmu Kelautan
SPERMONDE (2020) 6(2): 1-9

P-ISSN: 2460-0156
E-ISSN: 2614-5049

THE STATUS OF ORGANIC POLLUTION AND THEIR SPATIAL DISTRIBUTION IN THE WEST COAST OF SOUTH SULAWESI

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Submitted: December 22, 2020 Accepted: March 3, 2021

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ABSTRACT

Aquaculture activities produce organic wastes that are discharged into coastal waters and may impact the water quality. This research aimed to study the status of organic pollution and its spatial distribution on the west coast of South Sulawesi, Indonesia. Water was sampeld from two locations (Punaga Village, Takalar Regency (an open water system), and Bojo Village, Barru District (in a bay, a semi-closed water system)). Water quality was assessed by using the STORET index. Whilst to assess the spatial distribution of organic waste, an interpolation technique was used. Results showed that the water quality was categorized as highly polluted by organic pollution. The distribution of the organic pollutant, however, showed a different spatial pattern between the two locations. The difference was may be due to the different origin of the pollutant and geomorphology of the sampling locations.

Keywords: Organic pollution, water quality status, spatial distribution, West coast of South Sulawesi

INTRODUCTION

Anthropogenic activities on land are the main source of organic pollutants in coastal waters and may impact the water quality (Garno, 2004). The increasing number of anthropogenic activities on land, such as aquaculture, industrial, mining, and domestics, trigger the increasing amount of organic matter entering the coastal waters (Golterman, 2004; Amin et al, 2017).

The organic matter discharged into coastal waters is influenced by several factors, such as river runoffs, rainfall, and the intense use of organic matter on land (Seyhan, 1977; Lihan et al, 2008; Chazottes et al, 2008). Apart from that, the increasing human population in the catchment area (Davies, 2004) and the oceanographic condition (Lihan et al., 2008) may also take part in organic pollution discharged into coastal waters. Furthermore, the intensity of organic matter discharged into coastal waters is higher in the wet season compares to the dry season.

In certain conditions, a big amount of organic wastes end up in coastal waters. These may create problems in coastal areas. Such problems include a huge amount of decomposed matter, oxygen depletion, toxic gases, deaths of biota (Garno, 2004) as well as an ecosystem imbalance (Costa et al., (2006). Considering several anthropogenic activities, especially aquaculture, it is important to study the water quality status in various regions. Organic pollutions can be determined by measuring the water quality parameters such as Total Organic Matter (TOM), NO_3^- (Nitrate), and PO_4^- (Phosphate). Waterbodies are considered polluted when the value of the pollutant load is greater than the water quality standards (Garno, 2004; Wulandari, 2018).

South Sulawesi is a province with aquaculture as its main commodity, especially fish cultured in ponds. The area of fish ponds in South Sulawesi covers 49,679 hectares where most of them (i.e. 30,436 hectares or 61% of the total pond area) are located on the west coast (BPS, 2020). Having aquaculture as its main commodity, it showed that the west coast of South Sulawesi has a relatively high concentration of organic pollution, especially in river estuaries (Faizal, 2012), where shrimp pond outlets are located (Paena et al., 2020).

Based on these, it is necessary to study the organic pollutions in the waters of the west coast of South Sulawesi. Hence, this research aimed to know the status of water quality, to map the spatial distribution of the organic pollutions on the west coast of South Sulawesi, and provide information on the distribution patterns of organic pollution in this area. To map the distribution pattern of the organic pollutions, we applied geographic information systems on the results of the organic pollution parameter (Wiriani & Hutwan Yarifudin, 2018). This research was conducted to provide information about the impacts of organic pollution produced by aquaculture activities on the water quality on the west coast of South Sulawesi, i.e. a semi-closed or bay area of Bojo

Village, Barru Regency, and open water areas in Punaga Village, Takalar Regency.

MATERIALS AND METHODS

Study Sites

Preliminary observations and sampling were in June-December 2020 in the waters of 1) Punaga village, District of Mangarombobang, Takalar Regency (119° 26’ 13.808” LS; 5° 35’ 22.038” BT) and 2) Baji village, District of Mallusetasi, Barru Regency ((119° 36’ 55.300” LS; 4° 5’ 28.590” BT) (Fig. 1). There were 4 stations at each site, and sampling was conducted with three replications at each station at 10:00 – 12:00 pm (mean sea level -0.2 – 0.2 m) (Fig. 2). Samples were analyzed at the laboratory of chemical oceanography, Faculty of Marine Science and Fisheries, Hasanuddin University

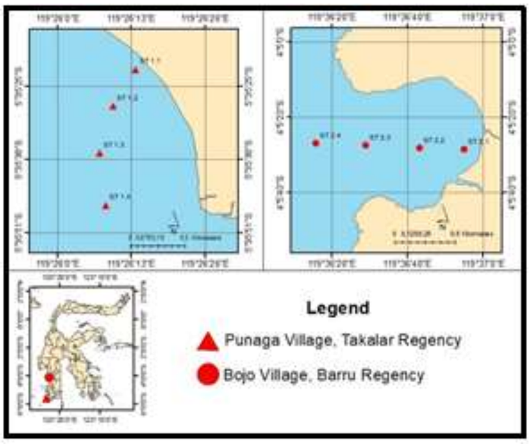

Figure 1. Map showing study sites in Punaga and Bojo villages, west coast of South Sulawesi

Water Sampling

Sampling was conducted following Salimin (2005) by using *Kemmerer water* sampler. Water temperature, salinity, pH, and Dissolved Oxygen (DO) were measured i*n* situ, whereas Total Organic Matter (TOM), NO_3^- (Nitrate), and PO_4^- (Phosphate) were analyzed further in the laboratory using the spectroscopy method.

Data Analysis

To compare the mean values of the water quality between the two locations, a *t-test* was conducted. Whereas to assess the status of organic pollution, STORET Analysis (Walukow, 2010) was used, with several steps: (a) comparing each water quality parameter with the standard quality value; (b) Results that conform or less than the standard values, were scored 0; (c) Results that disagreed or higher than the standard values, were scored as shown in Table 1; (d) Negative values from all measured parameter were summed and based on the score gained, we could then determine the status of the water quality; (e) The water quality were then classified by comparing them with the standard quality values for marine organisms (Tabel 2) (Kadim et al., 2017).

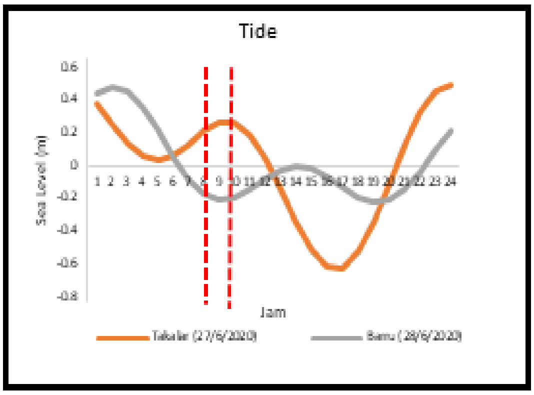

Figure 2. Sea level (m) during sampling

Lastly, the spatial distribution of water quality was conducted by applying the interpolation technique with the Kriging method (Aswant, 2016). These data then overlayed with oceanographic data to show the spatial distribution pattern (Wisha dan Kusumah 2019).

Tabel 1. Assesssment system used in determining the water quality status (Walukow, 2010)

Number of samples	Values	Parameters		
		Physical	Chemical	Biological
<10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Mean	-3	-6	-9
>10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Mean	-6	-12	-18

Table 2. Classification on water quality based on STORET index, class and water quality standard value (Canter, 2007 in Keputusan Menteri Negara Lingkungan Hidup, 2003)

Total Score	**Quality level**	**Class**	**Standard values**
0	Very Good	A	4
-1 to -10	Good	B	3
-11 to -30	Moderate	C	2
< -30	Bad	D	1

RESULTS AND DISCUSSION

Water Quality

Water quality measurement was the main parameter to determine the water quality status and to produce organic pollution distribution.

Results from the water quality measurement in the villages of Punaga (Takalar regency) and Bojo (Barru Regency) are shown in Table 3

Tabel 3. The water quality in the villages of Punaga (Takalar Regency) and Bojo (Barru regency).

Variable	Location	Min	Max	Mean	SE	Standard values
Temperature (°C)	Takalar	27	28	28a	0.149	28-30*
	Barru	26	29	27a	0.288	
Salinity (‰)	Takalar	34	36	35a	0.149	33-34*
	Barru	34	35	35a	0.151	
pH	Takalar	7.86	10.39	9.386a	0.167	7-8.5*
	Barru	7.54	8.61	8.077b	0.052	
DO (mg/l)	Takalar	7.938	10.094	8.967a	0.259	>5*
	Barru	4.018	5.978	4.949b	0.217	
TOM (mg/l)	Takalar	14.852	107.440	62.832a	5.016	80**
	Barru	34.444	147.260	79.325b	5.647	
Nitrate (mg/l)	Takalar	0.114	0.608	0.231a	0.023	0.008*
	Barru	0.129	0.487	0.224a	0.018	
Phosphate (mg/l)	Takalar	0.004	0.029	0.016a	0.001	0.015*
	Barru	0.012	0.034	0.021b	0.001	

The t-test showed that temperature, salinity, and NO_3^- (Nitrate) showed no significant differences between the two locations ($\alpha = 95\%$), except pH, DO, TOM and PO_4. It also showed that the mean values of salinity and Nitrate in both locations, pH and DO in Takalar, were higher mean than the water quality standards. Current velocity was in the range of 0-4 m/s and categorized as weak (Faizal *et al.*, 2020 and Daruwedho *et al.*, 2016) (Table 4)

Tabel 4. Mean current velocity and direction of the study sites

Location	Mean Current velocity (m/s)	Current direction
Punaga village (Takalar Regency)	0 – 0.5	Current dominated from the north (Makassar Strait) entering Laikang bay and heading to the Flores Sea. (Faizal et al., 2020)
Bojo village (Barru Regency)	0 – 4	East monsoon influenced the current from east heading to the West. (Daruwedho et al., 2016)

Temperature affects the metabolism of marine biota. This study showed the mean value of temperature was 28°C in Punaga village, Takalar regency, and the maximum value (29°C) was in Bojo village, Barru Regency, especially in station 1, and showed no significant differences in temperature between the two villages. Referring to the standard values 28-30°C, water temperature in both locations was still tolerable by marine biota. Jalil et al., (2020) also found similar mean water temperature in Punaga village in June and mean water temperature (29°C) in Bojo village (Basis Data Lingkungan Hidup Daerah Kabupaten Barru, 2006).

Mean water salinity in both locations were the same (35‰). However, they were relatively higher than the standard values (33 – 34‰), which may be due to the sampling time in the afternoon where evaporation was high (Nybakken, 1992 in Samawi et al, (2016).

pH is an important parameter, amongst others, in monitoring water quality. In this study, the mean pH in both locations was significantly different (Tabel 3). Moreover, pH in Punaga and Bojo villages (9.39 and 8.08, respectively) was relatively higher than the standards for the living of marine biota (7 – 8.5).

The mean pH in Takalar Regency was significantly higher than the standard values for marine biota. This may be due to the different morphological characteristics of the location. Punaga village (Takalar Regency) was open waters facing the Flores Sea, and they tended to have higher pH than bays (Schaduw, 2018).

Dissolved Oxygen is required for decomposing organic material. DO standard value for marine biota should be >5 mg/l. In this study, it showed that DO in Bojo village (4.949 mg/l) was relatively suitable for marine biota. However, the mean DO in Punaga village, Takaler Regency (8.967 mg/l) was significantly higher than in Bojo village. Jalil et al., (2020) and Basis Data Lingkungan Hidup Daerah Kabupaten Barru (2006) also found suitable DO values for Punaga and Barru villages (6.7 mg/l and 5.6 mg/l, respectively). DO in Bojo village was below the standard values for marine biota. This may be due to the geomorphology of the area. Some observers suggested that a high concentration of organic matter can be found in bays than in open seas Santoso (2005). When DO in a waterbody decreased, it may indicate a high organic matter concentration in that waterbody (Simbolon, 2016).

Total organic matter (TOM) indicates the concentration of organic matter in water which consists of dissolved and suspended organic matter and colloid (Sembel & Manan, 2018). Results showed that the mean concentration of TOM in the villages of Bojo (79.325 mg/) and Punaga (62.832 mg/l) were relatively lower than the standard value for marine biota (80 mg/l). However, these were relatively higher than Asaf et al., (2016) found in Punaga (28.67–56 mg/L) and Paena et al., (2020b) found in Labuange bay, a sub-district of Mallusetasi (51- 60 mg/l). A high concentration of TOM was may be due to the proximity of the sampling locations to fishponds outlet (Paena et al., 2015) as in Punaga village, and close to river estuaries (Paena et al., 2015) as in Bojo village.

Nitrate (NO3) is needed by phytoplankton and aquatic plants in a certain acceptable range. *T-test* showed no significant differences in Nitrate mean concentration in the villages of Punaga (0.231 mg/l) and Bojo (0.224 mg/l). Even though Asaf et al., (2016) also showed relatively the same results in Punaga village (0.101–0.2387 mg/l), and by ((Paena et al., 2020) in Labuange Bay, Mallusetasi Sub-district 0.07–0.21 mg/l). However, those values were higher than the standard values for marine biota (0.008 mg/l). This may be due to the impact of organic waste from ponds discharged into the waters (Samawi et al., (2015) since both sampling locations were relatively close to fishponds.

Phosphate is an essential nutrient for the growth of aquatic organisms (Simbolon, 2016). Mean concentration of phosphate in Punaga village was significantly lower (0.016 mg/l) than in Bojo (0.021 mg/l). Asaf et al., (2016) however, found a relatively higher phosphate concentration of 0.1578 mg/l in Punaga village and a relatively lower concentration range (0.05-0.01 mg/l) in Labuange Bay, Barru Regency (Paena et al., 2020). The standard of Phosphate for marine biota is 0.015 mg/l. Results showed that phosphate concentration in Punaga village, Takalar regency exceeded this value. Bojo village, Barru Regency, however, showed a higher concentration than in Punaga village. This was probably due to the pollutants that are usually accumulated higher in bays (Bojo village) than in open waters (Punaga village) due to water circulation (Ikhsani et al., (2016). Moreover, sampling was conducted in the east monsoon that is generally characterized by a low-speed current (Sukuryadi, 2018).

Water Quality Status

STORET index is an assessment used to determine the status of water quality. This method showed that the more water quality parameter used in the assessment, the better the result (Mantaya et al., 2016). In this study, four (DO, BOT, NO_3^-, and PO_4^-) of 7 parameters measured represented organic pollutions that may affect the water quality status (Tabel 5 and 6). Locations of the study were the villages of Punaga (Takalar Regency) and, Bojo (Barru Regency) were both in Class D, with the status of highly polluted/ Bad (Tabel 2). Comparing with the scores resulted from the STORET index, Bojo village had a lower score (-42) than in Gorontalo bay (-39) Kadim et al., (2017). Meanwhile, Punaga village had a total score of -37

Table 5. Results of the Punaga village water quality measurement, analyzed using STORET index

Variable	**Standards**	**Min**	**Max**	**Mean**	**Min Score**	**Max Score**	**Mean Score**	**Sub-Total**
Temperature (ºC)	28-30	27	28	28	-1	0	0	-1
Salinity (‰)	33-34	34	36	35	0	-2	-6	-8
pH	7-8.5	7.86	10.39	9.386	0	-2	-6	-8
DO (mg/l)	>5	7.938	10.094	8.967	0	0	0	0
TOM (mg/l)	80	14.852	107.440	62.832	0	-2	0	-2
Nitrate (mg/l)	0.008	0.114	0.608	0.231	-2	-2	-6	-10
Phosphate (mg/l)	0.015	0.004	0.029	0.016	0	-2	-6	-8
Total score								-37

Table 6. Results of the Bojo village water quality measurement, analyzed using STORET index.

Variable	**Standard**	**Min**	**Max**	**Mean**	**Min Score**	**Max Score**	**Mean Score**	**Sub-Total**
Temperature (ºC)	28-30	26	29	27	-1	0	-3	-4
Salinity (‰)	33-34	34	35	35	0	-2	-6	-8
pH	7-8.5	7.54	8.61	8.077	0	-2	0	-2
DO (mg/l)	>5	4.018	5.978	4.949	-2	0	-6	-8
TOM (mg/l)	80	34.444	147.260	79.325	0	-2	0	-2
Nitrate (mg/l)	0.008	0.129	0.487	0.224	-2	-2	-6	-10
Phosphate (mg/l)	0.015	0.012	0.034	0.021	0	-2	-6	-8
Total score								-42

These total scores recorded was due to most of the water parameters that exceeded the quality standard value for marine biota. These parameters were DO and TOM in Bojo village and Nitrate and Phosphate in both study sites. Hence, both locations are loaded with organic pollution, which may be due to aquaculture activities and may affect the surrounding waters (Putri et al., 2014). Any aquaculture type will result in organic pollution due to biological activities, such as excretion and urination by the cultured biota (Arfiati et al., (2018).

DO concentration in Punaga village was relatively higher than the standard quality value, which indicated lower organic material. This confirms with TOM concentration, which was below the quality standard value. Naturally, DO would decrease to zero due to organic material decomposition (Yuningsih et al., 2014). The more organic waste in a waterbody, the less DO available. Moreover, DO depletion is influenced by increasing temperature, salinity, respiration, a boundary layer on water surface, easily oxidized compounds, and atmospheric pressure (Patty et al., 2015).

In Bojo village, Barru Regency, however, DO mean concentration was lower than the standard quality value. This confirmed the higher TOM concentration than the standard quality value (Pusarpedal, 2011 in Yuningsih et al. 2014). It also showed that decomposing organic matter removed DO.

Nitrate concentrations in both study areas were higher than the water quality standards, even though they were still in a mesotrophic state. Phosphate concentrations were also in the mesotrophic and oligotrophic state, though higher than the water quality standards. This indicated that both waterbodies could still tolerate organic pollution. However, there is a need for a water management strategy by monitoring to prevent an excess of wastes discharged into these waterbodies. Especially that organic wastes may result in eutrophication. Nitrate exceeded 0.2 mg/l may trigger alga blooming and kill the marine organisms (Effendi (2003) in Hamuna et al., (2018). Moreover, high phosphate concentration may result in similar conditions.

Organic Pollution Spatial Distribution

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The spatial distribution of organic pollution between Punaga village and Bojo showed a different pattern (Fig. 3). In Punaga village, Takalar Regency, based on the spatial distribution of organic pollution, there was an increase from station 1 to station 4. Whereas in Bojo, Barru Regency, the organic pollution accumulated in the bay, centrally

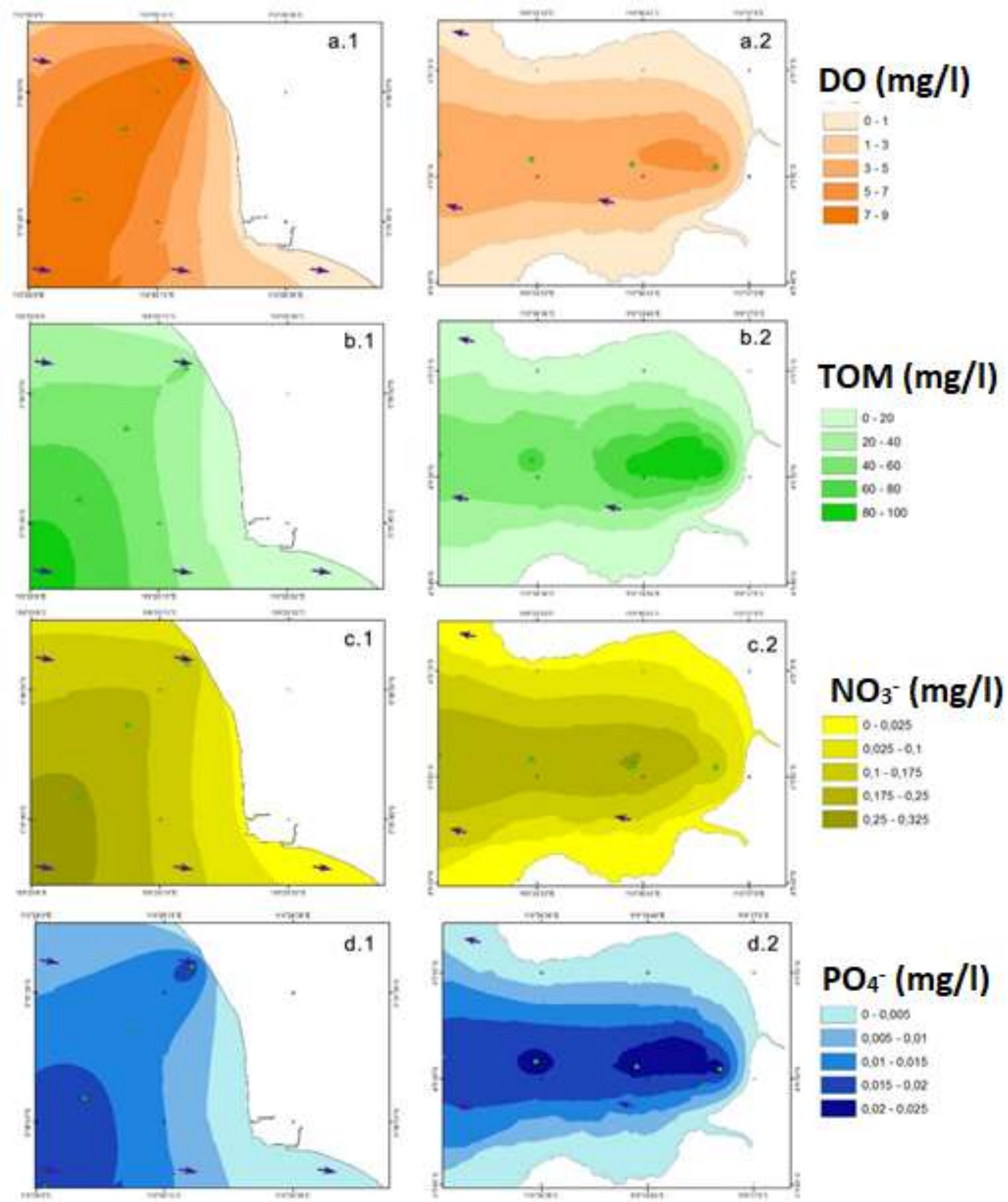

Figure 3. Spatial distribution of water parameters affected by organic pollution. Letters a,b,c, and d indicated different parameters measured (DO, TOM, Nitrate and Phosphate, respectively. Numbers 1 and 2 indicated Punaga village (Takalar Regency) and Bojo village (Barru Regency), respectively. Arrows indicated current directions

DO concentration in Punaga village, Takalar Regency showed an uneven spatial distribution, where it was bigger than 7mg/l. TOM, nitrate, and

phosphate concentrations showed an increase heading south-west. The low concentration of organic pollution in stations 1 and 2 showed that they were not affected by organic pollution.

Spatial distribution of the organic pollution in Bojo village, Barru Regency, showed a relatively centralized pattern due to the area's geomorphology. The highest DO concentration found was in the range of 5 – 7 mg/l, indicating a lower value than the standard quality value. The spatial distribution pattern of TOM, Nitrate, and Phosphate in Bojo village also showed a relatively centralized pattern, with a higher concentration in the bay, centrally. Particularly for Phosphate, which showed a higher concentration (> 0.02 mg/l) than found in Punaga village and accumulated in the center of the bay with a centralized spatial distribution pattern.

The organic pollution distribution in Punaga village showed an extended pattern due to the increasing number of sampling stations further offshore, yet approaching the outlet of a shrimp pond. This resulted in an opposite pattern found by Yuningsih et al., (2014) that organic material composition decreased along with the sampling stations further offshore. The organic pollution distribution in Bojo village showed a centralized pattern where they accumulate in the middle of the bay. With the semi-closed condition, bays are prone to receiving pollutants from rivers, outlets, or wastes directly discharged into the bays (point and non-point source). Physically and chemically, bays are highly influenced by hydrologic cycle, hydrodynamic, topography, spatial and intensive use of the bay area (Sembel & Manan, 2018). Water mass circulation in semi-closed areas tends to be slow resulting in an increasing concentration of nutrients in the bay (Grundle et al., 2009).

Based on all the conditions mentioned, it is suggested that bay waters and offshores are different in their potential in receiving pollutants. Considering bays are semi-closed systems, they are highly potential in receiving and accumulating pollutants in the central of the bay, which may exceed their capacity (Yudo, 2007).

CONCLUSIONS

The status of the water quality in Punaga and Bojo villages was bad/highly polluted. Based on the STORE index, the total score for Bojo village was -42, whilst Punaga was -37. The spatial distribution of organic pollution in Punaga village showed a higher concentration at the outer sampling site due to its proximity to shrimp pond outlets. In Bojo village, however, the organic pollution spatial distribution was influenced by its geomorphological condition.

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