Analysis of water quality in the river estuary as source water for tiger shrimp farming in ponds in Bulungan Regency, Province of North Kalimantan, Indonesia

[1]Muhammad Amien, [2]Widiatmaka, [3]Kukuh Nirmala, [4]Setyo Pertiwi, [5]Wiwin Ambarwulan

[1] Doctoral Program of Department of Natural Resources and Environmental Management, IPB University, Bogor 16680, Indonesia; [2] Department of Soil and Land Resources, Faculty of Agriculture, IPB University, Bogor 16680, Indonesia; [3] Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University, Bogor 16680, Indonesia; [4] Department of Agricultural Engineering, Faculty of Agricultural Technology, IPB University, Bogor 16680, Indonesia; [5] Geospatial Information Agency, Bogor 16911, Indonesia. Corresponding author: Muh. Amien, amin.fpikubt@gmail.com

Abstract. River estuary is a part of the estuary ecosystem which includes semi-closed waters affected by the tidal processes and receives fresh water flow from the mainland. This study aimed to analyze the river water quality as source water for tiger shrimp (*Penaeus monodon*) farming in the ponds in the Bulungan Regency, Indonesia. This research used a quantitative descriptive method by using primary data to describe the quality of river estuary water and compared it to the Ministerial Regulation of Marine Affairs and Fisheries No. 72 of 2016 concerning Guidelines for Enlargement of Tiger and Vaname Shrimps Farming in Ponds. Analysis of determining the status of water pollution in river estuary in Bulungan Regency used the Pollution Index (PI) referring to the Decree of the Minister of the Environment No. 115 of 2003 concerning Guidelines for Determination of Water Quality Status. The results showed that the parameters of alkalinity, ammonia, nitrite and phosphate did not fulfill the quality standard, while the parameters of water temperature, salinity, water pH, dissolved oxygen, nitrate, H_2S, Pb, Cd, and Hg still fulfilled the quality standard. The status of river estuary pollution in Bulungan Regency was in the category of lightly and moderately polluted with pollution index ranging from 4.271 to 7.347.

Key Words: category pollution, ecosystem, pollution index, shrimp, water quality standart.

Introduction. Bulungan Regency is one of the regencies that has the largest tiger shrimp (*Penaeus monodon*) ponds in North Kalimantan Province, which is ±94,030.64 Ha and has seven main rivers that flow into the estuary region, namely Kayan, Bandan, Sesayap, Pimping, Sekatak, Jelarai, and Linuang Kayan. The river estuary is a part of the estuary ecosystem which is affected by the tidal processes and receives fresh water flow from the mainland, as well as the meeting place between sea water and fresh water (Daborn & Redden 2016; Kennedy et al 2020). Various community activities along river basins or river estuary in Bulungan Regency include oil palm plantations, coal mining, settlements, agriculture, river and sea transportation, speed boat ports, sand collection, fishing, and shrimp ponds. Due to these activities, it results in a decrease in water quality if the resulting waste is discharged directly into water bodies, so that it is no longer suitable as a source of raw water, fisheries, tourism and so on. The quality of river and sea water depends on community activities performed in the upstream and downstream rivers (Parker & Oates 2016; Purnaini et al 2018). Activities in the upstream river areas such as agriculture, plantations, industry and settlements can threaten the sustainability of river water resources.

The monitoring results of Kayan river water quality from the Environmental Agency (DLH) of Bulungan Regency in 2016-2018 revealed that river water quality parameters such as total suspended solid (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD) and iron (Fe) passed the quality standard based on Government Regulation No. 82 of 2001 concerning Water Quality Management and Water Pollution Control. BOD and COD parameters are indicators of the presence of organic pollutant sources in rivers originating from agricultural activities and domestic waste (Venkatesharaju et al 2010). Agricultural, urbanization and industrial activities affect the parameters of pH, TSS, BOD, COD, nitrates and phosphorus in rivers (Yadav & Rajesh 2011; Ijeoma & Achie 2011). According to Pramaningsih et al (2017), the activities of settlements, home industries, tofu and tempe industries, urban areas, markets, hospitals and malls increase the contents of BOD, COD and TSS in the Karang Mumus river. Considering that the river estuary waters in Bulungan Regency are used as source water for tiger shrimp farming and obtain water input from seven main rivers, as well as limited research data in the study area, this study was conducted to analyze the quality of river estuary water as source water for tiger shrimp farming in the ponds in Bulungan Regency.

Material and Method

Description of the study site. This research was conducted in the coastal waters of the Bulungan Regency, Indonesia. The research was carried out from November 2018 to January 2019. Water samples were taken at 9 stations in the river estuary with 2 replications. The location and sampling stations are shown in Figure 1.

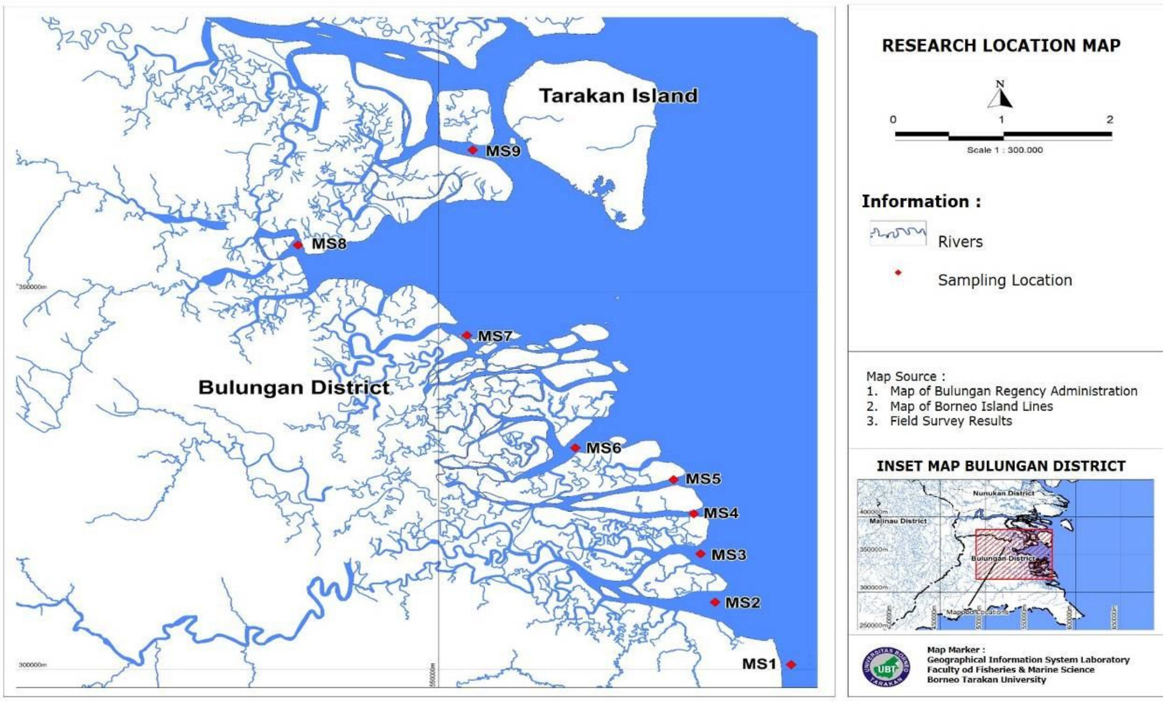

Figure 1. Sampling locations in the river estuaries in Bulungan Regency.

Experimental design. Sampling of river estuary water at each station was performed directly using a sample bottle at ±30 cm depth with the amount of 1000 mL, and 10 drops of HNO_3 were added. Next, the sample bottle was put into a cool box that was filled with ice cubes. The analysis of water pH, temperature, dissolved oxygen (DO), and salinity was conducted by in situ measurements. Meanwhile, the analysis of alkalinity, ammonia, nitrate, nitrite, phosphate, hydrogen sulfide (H_2S), mercury (Hg), cadmium (Cd) and lead (Pb) was conducted at the Laboratory of Water Quality at the University of Borneo Tarakan, Tarakan City, North Kalimantan and Mulawarman University Samarinda, East Kalimantan.

Data analysis. The results of measurement or analysis of physico-chemical parameters at each station are compared with the values recommended by the Ministerial Regulation of Marine Affairs and Fisheries No. 72 of 2016 concerning General Guidelines for Enlargement of Tiger and Vaname Shrimps in Ponds.

Determination of the water pollution status. Pollution Index (PI) is used to determine the status of water pollution in the estuary in Bulungan Regency by referring to the Decree of the Minister of Environment No. 115 of 2003 on Guidelines on Water Quality Status Determination. The steps to determine the status of water quality are as follows:

$$PIj = \sqrt{\frac{(Ci/Lij)_M^2 + (Ci/Lij)_R^2}{2a}} \quad (1)$$

where: PIj = PI of the j^{th};

Ci = measurement results of the concentration of the i^{th} water quality parameters;

Lij = the concentration of the i^{th} water quality parameters listed in the j^{th} designation quality standard;

$(Ci/Lij)_M$ = maximum value of Ci/Lij;

$(Ci/Lij)_R$ = average value of Ci/Lij

Conditions that must be considered in calculating PI values are as follows:

Increased pollution caused by the increased parameter contents such as parameters other than DO and pH, then the calculation of Ci/Lij uses the following formula:

$$(Ci/Lij)_{measurement\ results} = \frac{Ci}{Lij} \quad (2)$$

Increased pollution caused by the decreasing contents of parameters such as DO, the calculation of Ci/Lij uses the following formula:

$$(Ci/Lij)_{new} = \frac{Cim - Ci}{Cim - Lij} \quad (3)$$

If a parameter has a range on the L_{ij} value such as pH, then it must determine the $(Lij)_{average}$. If the value of $C_i \le (L_{ij})_{average}$, then the formula used is formula 4), whereas if the value of $C_i > (Lij)_{average}$ then the formula used is formula 5).

$$(C_i/L_{ij})new = \frac{[C_i - (L_{ij})average]}{[(L_{ij})min - (L_{ij})average]} \quad (4)$$

$$(C_i/L_{ij})new = \frac{[C_i - (L_{ij})average]}{[(L_{ij})max - (L_{ij})average]} \quad (5)$$

If the measurement value is greater than 1, the value used is $(Ci/Lij)_{new}$ value with the following formula:

$$(C_i/L_{ij})_{new} = 1{,}0 + P.\log10(Ci/Lij)_{measurement\ result} \quad (6)$$

C_{im} value is saturated DO value, and P is constant as the standard value for comparison. Generally, the value used is 5.

An evaluation of the PIj value and its pollution criteria is shown in Table 1.

Table 1

Evaluation of PI values and its pollution criteria

PI range value	*Pollution criteria*
$0 \le PIj \le 1.0$	Fulfilled quality standards
$1.0 < PI\ j \le 5.0$	Lightly polluted
$5.0 < PIj \le 10$	Moderately polluted
$PIj > 10$	Heavily polluted

Source: Decree of Minister of Environment (2003).

Results and Discussion

Physical and chemical parameters. The analytical results of the physical and chemical parameters of Bulungan Regency estuary water are presented in Table 2.

Table 2 shows that water quality parameters such as water temperature, salinity, pH, DO, nitrate, phosphate, Cd, and Hg fulfilled the quality standards, while parameters such as ammonia, nitrite, and Pb at MS. 1 station did not meet the quality standards based on Ministerial Regulation of Marine Affairs and Fisheries No. 72 of 2016. For more details, water quality parameters observed at each sampling station are described as follows.

Water temperature plays a vital role in the speed of metabolic rate and respiration of aquatic biota and metabolic processes in aquatic ecosystems. Direct measurements result of water temperature in the field ranged from 28.8 to 31.6°C. According to Chaitanawisuti et al (2013), temperature range of 29-30°C supports the life and development of tiger shrimp postlarvae. The range of temperature tolerance for growth and development of tiger shrimp ranges from 20 to 28°C (Pushparajan & Soundarapandian 2010).

The measurements result of the average salinity content at each station ranged from 5 to 25 ppt. Optimal salinity contents for shrimp survival is ranging from 10 to 30 ppt (Boyd & Lichtkoppler 1979). The optimal salinity content for tiger shrimp growth is 10-35 ppt (Zacharia & Kakati 2004). Surbakti (2012) mentioned that high salinity means that the mass of seawater is greater than the mass of freshwater.

The value of Power of Hydrogen (pH) of water greatly influences the biochemical processes in the waters, such as the nitrification process, which will lower the pH value. The measurement result of the average pH in the estuary ranged from 7.2 to 7.9. The pH value is one of the water quality parameters that determine the suitability of an aquatic environment for shrimp (Zafar et al 2016). Yuliastuti (2011) stated that a fluctuation in the pH value is influenced by organic and inorganic waste discharged into rivers.

Water alkalinity serves as a buffering capacity for the decreasing pH. The higher the alkalinity, the higher the water's ability to buffer, thus pH fluctuation is lower. The analytical result of the average alkalinity content in the estuary ranged from 16.7 to 156 mg L^{-1}. The range of alkalinity required by the water quality standard for tiger shrimp farming in ponds is 100-250 mg L^{-1}. Based on the result, the station that matches the quality standard is MS. 8, whereas stations MS. 1 - MS. 7 and MS. 9 had alkalinity content lower than 100 mg L^{-1}. The measured alkalinity content is higher than the results of Bintoro & Abidin (2014), which reported that the alkalinity content in the estuary in Indragiri river ranged from 25 to 127.5 mg L^{-1} $CaCO_3$. The alkalinity value in natural waters is 40 mg L^{-1} $CaCO_3$ (Daneshvar 2015).

Dissolved oxygen (DO) functions as an indicator of physical, chemical, and biological activities in the water. The primary sources of DO are diffusion of oxygen from the air and photosynthetic activity (Bouaoun & Nannout 2016). The measurement result of the DO contents at each station fulfilled the quality standards with the range of 5-5.6 to 5.7-8.8 mg L^{-1}. This value shows that Bulungan Regency estuary waters are suitable to be used as source water for the farming of tiger shrimp.

The analytical results of the average phosphate content ranged from 0.015 to 0.18 mg L^{-1}. Stations that have lower phosphate content than the quality standard were MS. 1, MS. 4 - MS. 6, and MS. 8 - MS. 9. Meanwhile, stations that have higher phosphate content than the quality standard were MS. 2, MS. 3, and MS. 7. Phosphate contents that are required in source water for tiger shrimp farming should have a minimum value of 0.1 mg L^{-1}. The phosphate contents are lower than the results of Sheftiana et al (2017) in Gelis River, Kudus Regency, which ranged from 0.5 to 0.84 mg L^{-1}.

Table 2

Average results of physical and chemical analysis of Bulungan Regency estuary water

Parameters	*Standard**)	*Sampling station*								
		MS.1	*MS.2*	*MS.3*	*MS.4*	*MS.5*	*MS.6*	*MS.7*	*MS.8*	*MS.9*
Physical										
Temperature (^oC)	28-32	31.6±0.142	30.3±0.425	28.8±0.07	29.25±1.061	29.1±0.99	29.45±0.071	29.7±0.22	31.25±1.061	30.3±1.839
Salinity (ppt)	5-40	20±7.071	12.5±10.6	20±2.829	5±2.829	5±1.415	17±4.243	6.5±2.122	18.5±2.122	25±4.243
Chemical										
pH	7.5-8.5	7.45±0.637	7.83±0.439	6.86±0.198	7.9±0.538	7.77±0.701	7.7±0.121	7.2±0.043	7.37±0.022	7.7±0.142
Alkalinity (mg L^{-1})	100-250	16.7±0.28	75.6±35.28	70.9±81.94	26.9±33.64	51.9±68.929	66.4±89.72	86±20.77	156±35.14	45.2±42.82
DO (mg L^{-1})	> 3	5.4-6±0.425	5-5.6±0.425	5.5-7.2±0.8544	5-5.6±0.4243	5-6.8±1.273	5-7.9±2.051	5.7-8.8±2.19	5-6±0.71	5.5-6.6±0.78
Phosphate (mg L^{-1})	0.1	0.083±0.013	0.18±0.007	0.13±0.057	0.023±0.003	0.056±0.049	0.061±0.044	0.14±0.099	0.08±0.057	0.09±0.071
Ammonia (mg L^{-1})	< 0.01	0.089±0.017	0.27±0.092	0.152±0.088	0.412±0.111	0.24±0.138	0.727±0.331	0.32±0.382	0.28±0.354	0.22±0.071
Nitrite (mg L^{-1})	< 0.01	0.028±0.02	0.0125±0.01	0.025±0.021	0.017±0.005	0.07±0.022	0.01±0.007	0.02±0.015	0.07±0.015	0.02±0.015
Nitrate (mg L^{-1})	0.5	0.085±0.036	0.27±0.118	0.1325±0.01	0.069±0.008	0.233±0.052	0.17±0.163	0.148±0.138	0.16±0.088	0.32±0.227
H_2S (mg L^{-1})	-	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cd (mg L^{-1})	0.01	0.01	< 0.002	0.004	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Pb (mg L^{-1})	0.03	0.12	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Hg (mg L^{-1})	0.002	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003

*) Ministerial Regulation of Marine Affairs and Fisheries No. 72 of 2016 concerning General Guidelines for Enlargement of Tiger and Vaname Shrimps in Ponds.

Analytical results of the average ammonia content (NH_3-N) in the estuary ranged between 0.089 and 0.727 mg L^{-1}. Those values are higher than the quality standard as source water for tiger shrimp farming activities, which is a maximum of < 0.01 mg L^{-1}. This value shows that the estuary waters of the Bulungan Regency are classified as unsuitable as source water for the farming of tiger shrimp. The high contents of ammonia at each station can indicate the presence of organic pollutants from domestic waste, industrial waste, and runoff of agricultural fertilizer that enters the river waters. For comparison, Prianto et al (2010) reported that ammonia contents in the Banyuasin Coast region in 2010 were in the range of 0.025-4.25 mg L^{-1}.

Nitrite (NO_2-N) content in waters is usually found in very small amounts than nitrate because they are unstable in the presence of oxygen. The analytical results of the average nitrite content in each station ranged from 0.01 to 0.07 mg L^{-1}. The nitrite content in the river estuary has exceeded the quality standard of source water for tiger shrimp farming activities, which is a maximum of < 0.01 mg L^{-1}. The high nitrite content was caused by the activity of decomposing bacteria due to disposal of household, agricultural, and industrial waste into river waters. According to Kasnir et al (2014), the limit of nitrite content recommended for shrimp farming activities is < 0.25 mg L^{-1}.

Nitrate (NO_3-N) is the result of oxidation of nitrogen or ammonia compounds in waters under aerobic conditions carried out by the *Nitrobacter* bacteria. The results of the average nitrate content at each station ranged from 0.085 to 0.27 mg L^{-1}. The nitrate content was smaller than the quality standard used, which is a maximum of 0.5 mg L^{-1} (Table 2). As a comparison of research results by Utami et al (2016) it was reported that nitrate contents in Karangsong waters obtained a range between 0.42 and 2.5 mg L^{-1}. According to Effendi (2016), nitrate contents > 0.2 mg L^{-1} can cause eutrophication (enrichment) of waters and subsequently stimulate the growth of algae and aquatic plants rapidly (blooming).

Hydrogen sulfide (H_2S) is a gas that is very dangerous for the survival of aquatic biota and produces a foul odor. This is as a result of the decomposition process of organic material by anaerobic bacteria. The analytical results of H_2S content at each station were not detected. In contrast to the research results of Oulyscya & Harianto (2004) it was mentioned that the Porong river has high H_2S contents ranged between 0.028 and 0.032 mg L^{-1}.

The analytical results of the average cadmium (Cd) content at each station ranged from < 0.002 to 0.01 mg L^{-1}. At MS.1 station, it showed the same Cd content as water quality standards of the source, which was 0.01 mg L^{-1}, while the other stations were below the water quality standard. However, it needs to be a concern at the MS. 1 station, because the average Cd content is the same as the quality standard.

The analytical results of the average lead (Pb) metal content at each station ranged from < 0.003 to 0.12 mg L^{-1}. Furthermore, from the 9 sampling stations, the MS. 1 station had a Pb content that exceed the quality standard, which was 0.03 mg L^{-1}. As a comparison, the research results by Songca et al (2013) reported that the content of Pb heavy metal in the estuary of the South African Umzimvubu river ranged from 9.8 to 20.2 mg L^{-1}. Meanwhile, according to Putri et al (2014), the Pb heavy metal content in the estuary waters of the Manyar river in Gresik Regency, Indonesia was around 0.31-0.57 mg L^{-1}. Pb can originate from coal-fired power plant waste and coal loading and unloading at the port (Fitriani & Dini 2014).

Mercury or hydrargyrum (Hg) metal pollution originates from agriculture, mining, municipal and industrial waste water disposal, and coal combustion activities. The analytical results of the average Hg content at each station were < 0.0003 mg L^{-1}. The Hg content was smaller than the quality standard, which was 0.002 mg L^{-1}. Unlike elsewhere, heavy metal Hg in river estuary waters was detected and even passed quality standards, such as the research results of Tilaar (2014) that reported Hg metal content in the estuary of the Tondano river ranged from 0.000231 to 0.000268 mg L^{-1}. According to Sari et al (2017), Hg metal content in the coastal waters of Wonorejo, East Coast of Surabaya ranged between 0.015 and 0.017 mg L^{-1}. Meanwhile, according to Barus (2017), the Hg metal content in the Banyuasin river estuary on average ranged between < 0.001 and 0.002 mg L^{-1}.

Analysis of pollution index (PI). The PI is used to determine the relative pollution level to permitted water quality parameters. The water pollution index was determined based on a single assessment score on environmental parameters and was analyzed to interpret water quality (Popovic et al 2016). The results of the PI calculation in the river estuary in Bulungan Regency is shown in Figure 2. The results of the PI of the river estuary waters in Bulungan Regency were in the category of lightly to moderately polluted with a pollution index ranged from 4.271-7.347. Station MS.1 had a pollution index value classified as lightly polluted, while MS.2-MS.9 were classified as moderately polluted. The PI values are not too different from the research results by Tanjung et al (2019), which ranged from 3.51 to 6.95.

After calculating the PI at each station, the parameters of ammonia, nitrite, phosphate and alkalinity became the parameters that provide the highest contribution to the pollution of river estuary waters in Bulungan Regency. Ammonia and nitrite parameters at each sampling station have passed the water quality standard based on the Ministerial Regulation of Marine Affairs and Fisheries No. 75 year 2016.

The input of organic material into the waters can result in high contents of ammonia and nitrite. Effendi (2016) mentioned that increased ammonia content in the ocean are closely related to the entry of biodegradable organic matter (whether containing nitrogen or not). It is further stated that the source of ammonia in waters is the result of decomposition of organic nitrogen (protein and urea) and inorganic nitrogen present in water, also it is derived from the decomposition of organic matter (dead aquatic plants and biota) carried out by microbes and fungi.

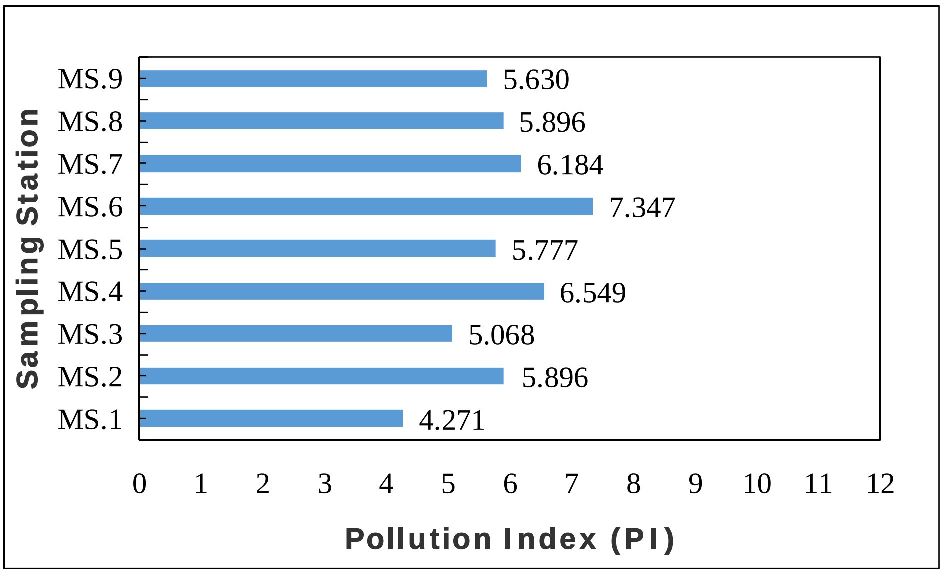

Figure 2. Water pollution index of river estuaries in Bulungan Regency.

Conclusions. This research was conducted in the river estuary waters of Bulungan Regency, Indonesia, where the source water for the farming of tiger shrimps in ponds came from river waters or river estuaries. The analytical results of the river estuary water quality indicated that the parameters of ammonia, nitrite, alkalinity (station MS. 1 - MS. 7, MS. 9), phosphate (MS. 1, MS. 4 - MS. 6, MS. 8 - MS. 9), and Pb (MS. 1) did not fulfill or has passed water quality standards, while the parameters of water temperature, salinity, water pH, DO, phosphate, nitrate, H_2S, and Hg, Pb, Cd metals were below the quality standard based on the Ministerial Regulation of Marine Affairs and Fisheries No. 75 year 2016, indicating the status of pollution was classified in the class category of lightly to moderately polluted.

Acknowledgements. The first author thanks to BUDI - LPDP, Republic of Indonesia.

References

Barus B. S., 2017 [Analysis of heavy metal cadmium (Cd) and mercury (Hg) in water and sediment at Banyuasin Estuary]. Maspari Journal 9(1):69-76. [in Indonesian]

Bintoro A., Abidin M., 2014 [Pengukuran total alkalinitas di perairan estuari sungai indragiri Provinsi Riau]. Buletin Teknik Litkayasa Sumber Daya Dan Penangkapan 12(1):11-14. [in Indonesian]

Bouaoun D., Nannout R., 2016 Study of physical and chemical parameters of Oustouan River, North Lebanon. Journal of Coastal Zone Management 9(3):1-8.

Boyd C. E., Lichtkoppler F., 1979 Water quality management in pond fish culture. International Center for Aquaculture 22:1-30.

Chaitanawisuti N., Santhaweesuk W., Wattayakorn G., 2013 The combined effects of temperature and salinity on survival of postlarvae tiger prawn (*Penaeus monodon*) under laboratory conditions. Agricultural Sciences 4(6A):53-56.

Daborn G. R., Redden A. M., 2016 Estuaries. In: The wetland book. pp. 1-19.

Daneshvar E., 2015 Dissolved iron behavior in the Ravenglass Estuary waters, an implication on the early diagenesis. Universal Journal of Geoscience 3(1):1-12.

Decree of Minister of Environmental, 2003 [Keputusan Menteri Negara Lingkungan Hidup Nomor 115 Tentang Pedoman Penentuan Status Mutu Air]. In Jakarta: Menteri Negara Lingkungan Hidup, pp. 1-15. [in Indonesian]

Effendi H., 2016 River water quality preliminary rapid assessment using pollution index. Procedia Environmental Sciences 33:562-567.

Fitriani A., Dini I., 2014 [Analysis of lead (Pb) content in sediment and windy shrimp (*Penaeus monodon*) from Biringkassi Beach in Bungoro district, Pangkep regency]. Jurnal Sainsmat 3(2):191-202. [in Indonesian]

Ijeoma K., Achie O. K., 2011 Industrial effluents and their impact on water quality of receiving rivers in Nigeria. Journal of Applied Technology in Environmental Sanitation 1(1):75-86.

Kasnir M., Harlina H., Rosmiati R., 2014 Water quality parameter analysis for the feasibility of shrimp culture in Takalar Regency, Indonesia. Journal of Aquaculture Research and Development 5:273.

Kennedy D. M., McSweeney S. L., Mariani M., Zavadil E., 2020 The geomorphology and evolution of intermittently open and closed estuaries in large embayments in Victoria, Australia. Geomorphology 350:106892.

Oulyscya F. A., Harianto B., 2004 Pengaruh pembuangan lumpur lapindo di sungai porong terhadap pencemaran air tambak kecamatan jabon kabupaten sidoarjo. Swara Bhumi E-Journal Pendidikan Geografi FIS Unesa 3(3):256-264. [in Indonesian]

Parker H., Oates N., 2016 How do healthy rivers benefit society? A review of the evidence. Working Paper 430:1-73.

Popovic N. Z., Duknic J. A., Atlagic J. Z. Č., Rakovic M. J., Marinkovic N. S., Tubic B. P., Paunovic M. 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.

Pramaningsih V., Suprayogi S., Setyawan Purnama I. L., 2017 Kajian persebaran spasial kualitas air sungai karang mumus, samarinda, kalimantan timur. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 7(3):211-218. [in Indonesian]

Prianto E., Husnah H., Aprianti S., 2010 Karakteristik fisika kimia perairan dan struktur komunitas zooplankton di estuari sungai banyuasin, Sumatera Selatan. BAWAL Widya Riset Perikanan Tangkap 3(3):149-157. [in Indonesian]

Purnaini R., Sudarmadji, Purwono S., 2018 Tidal influence on water quality of Kapuas Kecil River downstream. E3S Web of Conferences 31:1-5.

Pushparajan N., Soundarapandian P., 2010 Recent farming of marine black tiger shrimp, *Penaeus monodon* (Fabricius) in South India. African Journal of Basic and Applied Sciences 2(1-2):33-36.

Putri Z., Wulandari S., Maslukah L., 2014 Studi sebaran kandungan logam berat timbal (pb) dalam air dan sedimen dasar di perairan muara sungai manyar Kabupaten Gresik, Jawa Timur. Jurnal Oceanografi 3(4):589-595.

Sari S., Kirana J., Guntur, 2017 Heavy metal content analysis of Hg and Cu dissolved in coastal waters of Wonorejo, East Beach Surabaya. Jurnal Pendidikan Geografi 22(1):1-9.

Sheftiana U. S., Sarminingsih A., Nugraha W. D., 2017 [Determination of river water quality status based on pollution index method as environmental quality control (case study: Gelis river, Kudus Regency, Central Java)]. Jurnal Teknik Lingkungan 6(1):1-10. [in Indonesian]

Songca S. P., Seteni B., Oluwafemi O. S., 2013 Heavy metals found at Umzimvubu River Estuary in the Eastern Cape, South Africa. African Journal of Environmental Science and Technology 7(5):236-244.

Surbakti H., 2012 [Tidal characteristics and flow patterns at the Musi River Estuary, South Sumatra]. Jurnal Penelitian Sains 15(1):35-39. [in Indonesian]

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.

Tilaar S., 2014 [Analysis of heavy metal polution in river Mouths and estuaries Tondano and Sario in Manado City, North Sulawesi]. Jurnal Ilmiah Platax 2(1):32-39. [in Indonesian]

Utami T. M. R., Maslukah L., Yusuf M., 2016 [Nitrate (NO_3) and phosphate (PO_4) distribution in Karangsong waters, Indramayu regency]. Buletin Oseanografi Marina 5(1):31-37. [in Indonesian]

Venkatesharaju K., Ravikumar P., Somashekar R., Prakash K., 2010 Physico-chemical and bacteriological investigation on the River Cauvery of Kollegal Stretch in Karnataka. Kathmandu University Journal of Science, Engineering and Technology 6(1):50-59.

Yadav S., Rajesh K., 2011 Monitoring water quality of Kosi River in Rampur District, Uttar Pradesh, India. Advances in Applied Science Research 2(2):197-201.

Yuliastuti E., 2011 [Kajian kualitas air sungai ngringo karanganyar dalam upaya pengendalian pencemaran air]. Tesis, Program magister ilmu lingkungan program pasca sarjanauniversitas diponegoro Semarang. pp. 1-127

Zacharia S., Kakati V. S., 2004 Optimal salinity and temperature for early developmental stages of *Penaeus merguiensis* De Man. Aquaculture 232(1-4):373-382.

Zafar M., Haque M., Aziz M., Alam M., 2016 Study on water and soil quality parameters of shrimp and prawn farming in the Southwest region of Bangladesh. Journal of the Bangladesh Agricultural University 13(1):153-160.

Received: 15 November 2019. Accepted: 19 January 2020. Published online: 20 March 2020.
Authors:
Muhammad Amien, Doctoral Program of Department of Natural Resources and Environmental Management, IPB University, Bogor 16680, Indonesia, e-mail: amin.fpikubt@gmail.com
Widiatmaka, Department of Soil and Land Resources, Faculty of Agriculture, IPB University, Bogor 16680 Indonesia, e-mail: widi.widiatmaka@yahoo.com
Kukuh Nirmala, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University, Bogor 16680, Indonesia, e-mail: kukuhnirmala@yahoo.com
Setyo Pertiwi, Department of Agricultural Engineering, Faculty of Agricultural Technology, IPB University, Bogor 16680, Indonesia, e-mail: setyo_pertiwi@yahoo.com
Wiwin Ambarwulan, Geospatial Information Agency, Bogor 16911, Indonesia, e-mail: wiwin.ambarwulan@big.go.id

How to cite this article:
Amien M., Widiatmaka, Nirmala K., Pertiwi S., Ambarwulan W., 2020 Analysis of water quality in the river estuary as source water for tiger shrimp farming in ponds in Bulungan Regency, Province of North Kalimantan, Indonesia. AACL Bioflux 13(2):618-626.