Plankton indexes and heavy metal pollution in Kendal coastal waters, Indonesia

Hartanto, Agus Tjahjono

Engineering Department, Inland Water and Ferries Transport, Polytechnic of Palembang, Palembang, South Sumatera, Indonesia. Corresponding author: A. Tjahjono, a_agus_tjahjono70@yahoo.co.id

Abstract. Kendal port is regarded as a new economic area and an environmental regulation for a sustainable aquatic environment is needed. This research aimed to analyze the abundance of phytoplankton and zooplankton, the evenness index, diversity and dominance index, pollution index and environmental enforcement in 4 stations from the port. Based on the STORET method, it was found that stations 1 and 2 were classified as class D, poor, while stations 3 and 4 were classified as class C, meaning that the water quality was considered moderate. On the other hand, the results indicate that stations 1 and 2 are heavily polluted, whereas stations 3 and 4 are lightly polluted. Six classes of phytoplankton were found, while only 2 classes of zooplankton were discovered. The diversity index of phytoplankton showed that the water quality was moderate. However, the diversity index of zooplankton shows a heavily polluted water. In terms of evenness index, phytoplankton was relatively distributed, whereas the zooplankton evenness index was low. The dominance of phytoplankton was regarded as normal, but some species dominate in case of zooplankton. Thus, the regional government should strive for the enforcement of environmental regulations.
Key Words: Kendal coastal waters, phytoplankton, pollution index, zooplankton.

Introduction. Kendal Regency is a district in Central Java Province. It is located at 109°40'-110°18'E and 6°32'-7°24'S. Kendal Port, which is located in Kaliwungu subdistrict, can also be found in this regency (Siregar et al 2014). Kendal Regency consists of 20 subdistricts. It covers coastal areas, lowlands, highlands and mountains. It is also well-known for some major commodities such as milkfish (*Chanos chanos*), vannamei shrimp (*Litopenaeus vannamei*) and tiger shrimp (*Penaeus monodon*) (Ristiyani 2012; Prasetyo 2016). Kendal has a 2205.47 ha mangrove forests, located in Mororejo village, which can be used for ecotourism, and foreign investment has also been made in 10 subdistricts of Kendal (Fahrian et al 2015; Thirafi 2013).

Plankton are the primary producers in waters. Plankton is divided in two categories: phytoplankton (photosyntetic microorganisms) and zooplankton (species of animals found in fresh and marine waters). Zooplankton is the major link in energy transmission in waters. This phenomenon is an interesting object in the assessment of potential marine production (Russel 1935; Jeyaraj et al 2014). Aquatic fertility is characterized by the presence of nitrates, phosphates, chloriphyll-a, and high plankton abundance (A'in et al 2015). The abundance of zooplankton is influenced by environmental factors, physicochemical and temporal fluctuations. Thus, zooplankton can be used as a bioindicator in aquatic ecosystem (Ziadi et al 2015; Carrasco & Perissinotto 2015).

Some research has been previously conducted in the area. A research conducted in Garang watershed, which includes Semarang City, Kendal Regency, and Semarang Regency showed that the phytoplankton density ranged from 13 to 53 ind L^{-1}. It was also found that the number of species ranged from 4 to 8 individuals. The diversity index, which ranged from 1.07-2.06, showed that the waters are categorized as mildly polluted (Ujianti et al 2019). *Sardinella lemuru* is a dominant pelagic fish species found in Bali Strait, in which there is a positive significant correlation between the number of catches and the numbers of chlorophyll-a (phytoplankton) in 2006, with $r=0.71$, $p <0.005$ (Sartimbul et al 2010). Zooplankton distribution is influenced by pH and ammonia (Pratiwi et al 2016). The abundance of phytoplankton, which caused harmful algae bloom in Semarang bay, including Semarang, Kendal, and Demak waters ranged from 34420 to 36667 individuals L^{-1}. Moreover, it is positive that the genera which caused the harmful algae bloom were *Trichodesmium* and *Ceratium*. The abundance percentage was lower (<11%) than non-harmful algae phytoplankton (A'in et al 2017).

The fish diversity index in the Damar river, Kendal, reached 1.88, being categorized as moderate, with waters lightly polluted (Riharista et al 2013). As Kendal is part of the Kendal-Semarang-Demak corridor, some negative effects should be considered, like the conversion of lands and environmental damage (Wilonoyudho 2010). Marwah et al (2015) found that the content of cadmium reached 0.076 mgL^{-1} in Wakak river estuary, at Kendal coast, which means that the result had exceeded the quality standard (0.01 mg L^{-1}) (GR no. 82 2001). However, the content of lead was below the upper limit of the quality standard of 0.29 mg L^{-1}. Within the Waridin river estuary, the highest content of lead in the sediment was found near the mangrove area (9.339 mg kg^{-1}), whereas the lowest content was found at the estuary (4.709 mg kg^{-1}) (Garvano et al 2017).

The study also mentions that Blukar river was lightly polluted, after determining the BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) parameters, both surpassing the quality standards. The pollution index tended to decrease from upstream to downstream (Agustiningsih et al 2012). In water, lead can be found in a dissolved form and in a mixture of fuel, while cadmium is not soluble in water. The accumulation of lead and cadmium in the human body affects the function of kidneys (Effendi 2003). Heavy metal pollution, especially with cadmium, produces negative effects. Heavy metals are bioaccumulative in the body of water organisms. Research carried out on java barb red fish (*Puntius bramoides* C.V.) in Garang river showed that the accumulation of Cd in fish liver was greater than in the rest of its body (Prabowoet al 2016). The analysis of Cd content in water, sediments and green mussels (*Pernaviridis*) in Tanjung Mas Semarang waters showed that the sediments were lightly polluted. However, in the water and the clam meat itself, the findings were still in accordance with quality standards (Purba et al 2014).

This research aims to analyze the abundance of phytoplankton and zooplankton, evenness index, diversity index and dominance index of phytoplankton and zooplankton, and the pollution index according to the Ministerial Decree of the Ministry of Environment of Indonesian Republic no. 115/2003, and to the environmental enforcement efforts based on Kendal Regional Regulation no. 11 of 2012, with the STORET method.

Material and Method

Description of the studysites. The field research was carried out on September 5th, 2018 starting at 9:30 A.M., when the water level was at high tide and started to recede. The tide was at 5:12 A.M. and receded at 1:11 P.M. The highest tide reached 0.9 m while the lowest tide was 0.3 m.

Sampling was carried out at four stations. Station 1 ($6^0$55.857'S, $110^0$18.552'E) was located next to the plywood port and the estuary. Station 2 ($6^0$54.771'S, $110^0$17.282'E) was a part of Kendal port. Station 3 ($6^0$54.716'S, $110^0$16.068'E) was located west of the port. Station 4 ($6^0$54.672'S, $110^0$17.532'E) was located east of Kendal port (Figure 1).

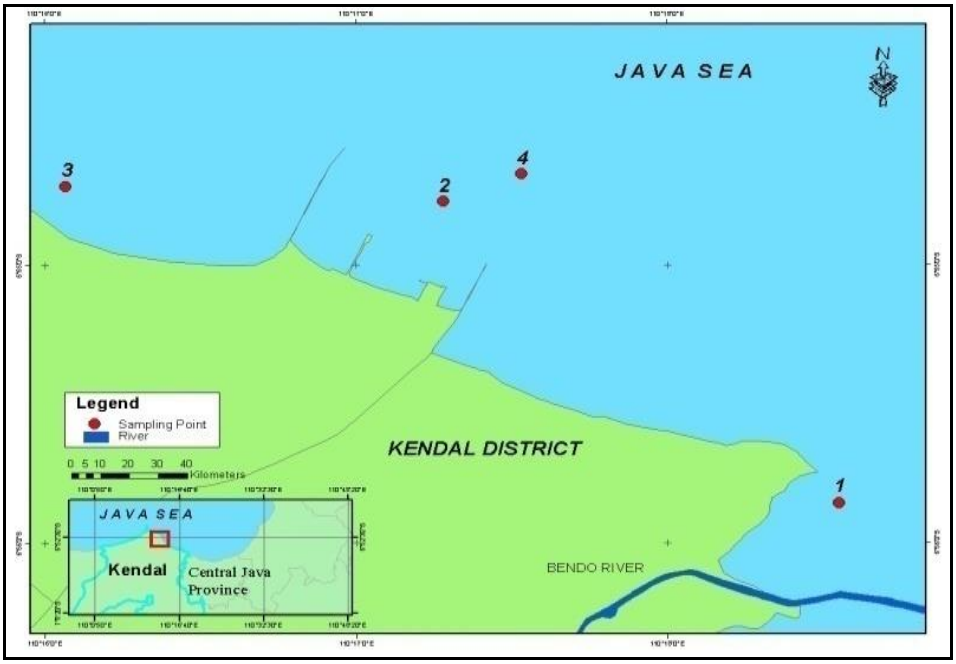

Figure 1. Research location.

Data collection methods. The research material consists in the samples of seawater, which included Pb and Cd content and sediment. In this research, the primary data which were directly obtained included sea water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), turbidity, salinity, stream velocity, brightness, and depth using the following: a thermometer, a pH meter, DO meter, a Turbidity Meter HF Scientific type DRT-15 CE, Salinity meter, TDS Digital Meter type TDS-3, Flowatch type FL 03, Sechi disc, and a scaling rope.

The determination of heavy metal (Pb, Cd) content in seawater. 500 mL of seawater were poured into a separator funnel and the pH reached 4 by adding diluted HCl. APDC (Ammonium Pyrrolidine Diti Carbamate) solution and NaDDC (Sodium Diethyldithiocarbamate) were then added and mixed for 1 minute. After that, 25 mL of MIBK (Methyl Isobutyl Ketone) solvent was poured and mixed for 30 seconds. The water phase was then separated. 10 mL of ion-free distilled water was then added into the upper layer phase. It was shaken and the water phase was separated. Then, 1 mL of concentrated HNO_3 was poured, shaken and left for 1 hour. Furthermore, 19 mL of ion-free distilled water was added and mixed. The water phase was collected. It was analyzed by applying AAS (Atomic Absorption Spectroscopy) using furnaces with argon gas and Pb and Cd lamps (Sitorus 2004; APHA 2012).

The determination of heavy metal (Pb, Cd) content in sediments. The sediment was dried at 105^oC for 24 hours. After cooling, 10-20 gr of the sediment was weighed and put in a centrifuge tube. 500 mL of ion-free distilled water was added and stirred. Then, it was centrifuged for 30 minutes at 2000 rpm. The water phase was removed and re-dried in an oven at 105^0C for 24 hours. The sediments were weighed and 1 gram was removed and put in a closed teflon beaker. 5 mL of aqua regia and 6 mL of HF were added and heated at 130^0C, until the solution was almost dry. Then, 9 mL of ion-free distilled water was poured. Finally, the solution was analyzed by applying AAS using furnaces with argon gas and Pb and Cd lamps according to the type of metal which was analyzed (Sitorus 2004; APHA 2012).

Data analysis. The water sample for the plankton was collected through filtration by using a plankton net (diameter of 30 cm, mesh of 300 µm, 1.8 m length). The water was collected near the substrate and was filtered through the plankton net. The sample was put into a 50 ml bottle and a drop of lugol was added. Then, the water sample was filtered into a counting chamber (1 mL). It was important to make sure that there was no air bubbles inside. The sample was observed using a microscope with low magnification in order to obtain the general description. The plankton was counted using 5 fields of view (5 columns) (Tjahjono et al 2018; Jeong et al 2013; Jeyaraj et al 2014). Genera on the field of view was identified and counted (Yamaji 1986).

The phytoplankton was analyzed by using the individual abundance (N), diversity index (H'), evenness index (E), and dominance index (D) (Anggoro 1988; Wibisono 2005; Effendi 2003).

The individual abundance (N) was determined using the following formula:

$$N = \frac{1}{A} \times \frac{B}{C} \times \frac{D}{E} \times F$$

Where: N - abundance (individual L^{-1}); A - the volume of filtered water (L); B - the volume of water in the sample (125 mL); C - the volume of preparations at identification (1 mL); D - area of glass cover (mm^2); E - field of view (mm^2); F - average number of observed individuals.

The diversity index and evenness index (equitability index) was determined with the following formula (Shannon & Weiner 1949; Effendi 2003):

$$H' = -\sum_{i=1}^{S} p_i (\ln p_i)$$

Where: H' – observed diversity index; p_i – proportion of the total count arising from the i^{th} functional group; S – total number of functional group.

Evenness index (E) (Wibisono 2005; Effendi 2003):

$$E = \frac{H'}{H'_{max}}$$

Where: E - evenness index or stability; H’ – diversity index ; $H'_{max} = \log_2 S = 3.3219 \log_{10} S$; S - number of taxa within a community.

In order to identify the dominance of a certain species within the waters, the Simpson dominance index can be used. The formula is as follows:

$$D = \sum_{i=1} S \left|\frac{n_i}{N}\right|^2$$

Where: D - Simpson dominance index; n_i- the i^{th} individual type; N - total number of individuals; S - number of genera.

If the dominance index ranges between 0-1; D=0, it means that there are no species dominating other species or that the community structure is stable. However, if D=1, it means that there are species that dominate other species or the community structure is labile due to ecological pressure.

The pollution status was determined using the pollution index based on the Ministerial Decree of the Ministry of Living Environment of Indonesian Republic no. 115 of 2003 on the determination guideline of water quality status (Nemerow & Sumitomo 1970).

$$IP_J = \sqrt{\frac{\left({C_i}/{L_{ij}}\right)_M^2 + \left({C_i}/{L_{ij}}\right)_R^2}{2}}$$

Where: IP_j - index pollution for j; C_i - concentration of water quality parameter i; L_{ij} - parameter quality stated in the water quality standard j; M – maximum; R - average.

There are four IP (Index Pollution) classes: 0≤IP≤1.0, meaning that it meets the quality standard; 1.0≤IP≤5.0, meaning that it is lightly polluted; 5.0≤IP≤10, meaning that it is moderately polluted; IP≥10, meaning that it is heavily polluted (Table 1). The water quality standard is based on the Ministerial Decree, Ministry of Living Environment of the Indonesian Republic, no. 51 of 2004 regarding seawater quality standard, including the quality standard for marine tourism and biota. Based on the quality standards of marine biota, some variables were obtained in determining the pollution levels, including physical parameters (turbidity, TDS), chemical parameters (pH, salinity, DO, nitrates) and dissolved metals in seawater (Pb, Cd).

Another method to determine the water quality status is STORET. It is a method applied to compare water quality data with water quality standards, which are adjusted in order to determine the water quality status. Determination of water quality status using US-EPA (United States-Environment Protection Agency) is classified in four categories: class A (very good, score 0); class B (good, score -1 to -10); class C (medium, score -11 to -30); class D (poor, score ≥-31) (US-EPA 1989).

Table 1

Determination of score systems to determine water quality status

Number of samples	*Score*	*Parameter*		
		Physical	*Chemical*	*Biological*
<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

Results and Discussion. The field research including the quality physical-chemical variables shows that the water temperature at the 4 stations ranged from 29 to 33^{0}C. The turbidity ranged from 4.94 to 537 NTU, which means that it had exceeded the quality standard for marine biota (quality standard <5 NTU). The level of suspended solids (TDS) ranged from 620 to 1000 mg L^{-1}, pH ranged from 7.9 to 8.3 and the DO level was 7.8-8.2 mg L^{-1}. The salinity ranged from 17.7 to 19 ppt. TDS variables had exceeded the quality standard (coral - 20 mg L^{-1}; mangrove- 80 mg L^{-1}; seagrass - 20 mg L^{-1}) (Table 2).

Table 2

Average and Standard Deviation (SD) for physical-chemical parameters of Kendal waters

Parameter/Station	*1*	*2*	*3*	*4*
Temperature (^{0}C)	32±1	32±0.58	30±1	20±0.5774
pH	8±0	8.1±0.15	8.13±0.06	5.6±0
DO (mg L^{-1})	7.87±0.12	8.1±0.1	8.13±0.12	5.4±0.1528
TDS (mg L^{-1})	1000±0	780±10	843±32.1	491±185.2
Turbidity (NTU)	153±234	184±305	17.5±10.5	9.8±30.263
Salinity (ppt)	18±0.25	18±0.12	17.5±10.5	13±0.1528
Current (m s^{-1})	0.043	0.053	0.063	0.085
Transparency (m)	0.7	0.7	0.7	1.5
Depth (m)	2.5	2.5	2.5	3

Note: DO – dissolved oxygen; TDS – total dissolved solids.

The contents of Pb and Cd at the 4 stations were 0.008 mg L^{-1} and 0.002 mg L^{-1}, respectively. Pb content met the quality standards, but Cd content slightly exceeded the required quality standard (Figure 2).

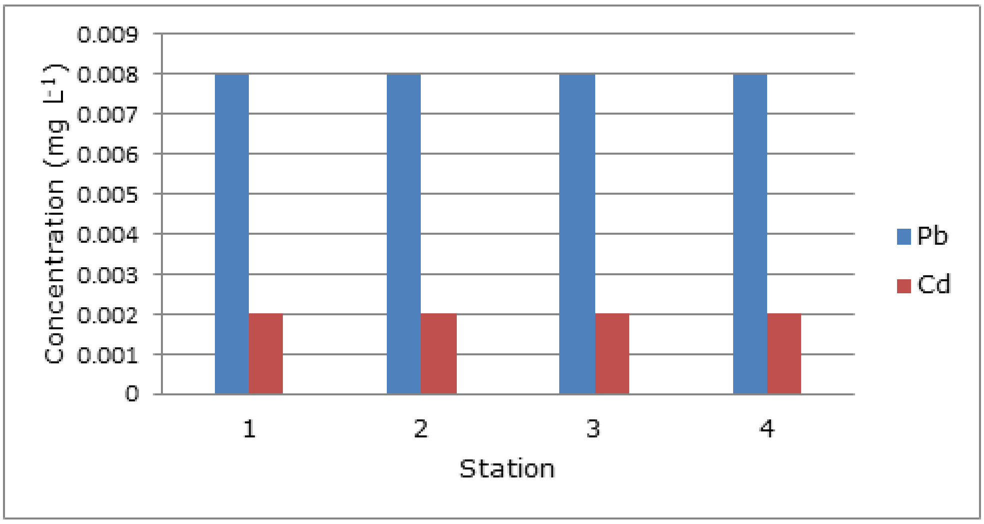

Figure 2. The content of Pb and Cd in Kendal waters

The nitrate content ranged from 0.2 to 0.85 mg L^{-1}, meaning that it had exceeded the quality standard for marine biota (0.008 mg L^{-1}) (Figure 3).

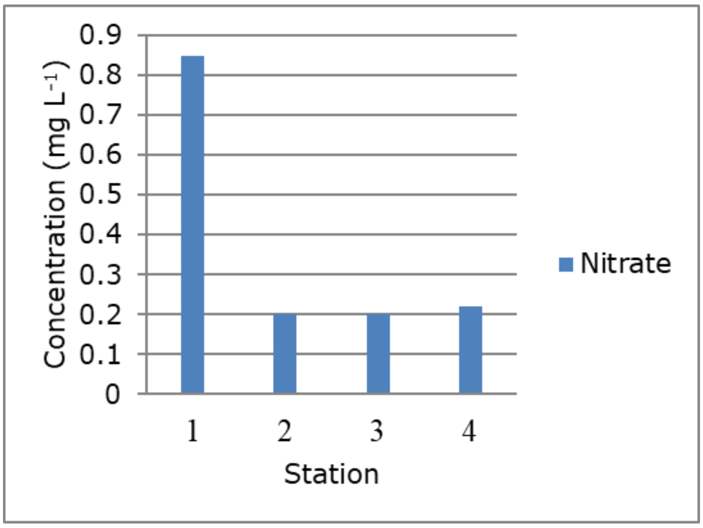

Figure 3. Nitrate content in Kendal waters.

The Pb content in the sediments of the 4 stations ranged from 0.406 mg kg^{-1} to 0.522 mg kg^{-1}, while the Cd content was 0.0021 mg kg^{-1}. The content of heavy metals was still below the quality standard set by CCME (Canadian Council of Ministers for the Environment) on surface sediment. Based on CCME, Pb and Cd quality standards are 30.2 mg kg^{-1} and 0.7 mg kg^{-1}, respectively (CCME 1999) (Figures 4 and 5).

Based on the calculation and analysis by using eight variables (physical and chemical variables), it was found that stations 1 and 2 were classified as class D, poor, while stations 3 and 4 were classified as class C, moderate (Tables 3, 4, 5 and 6).

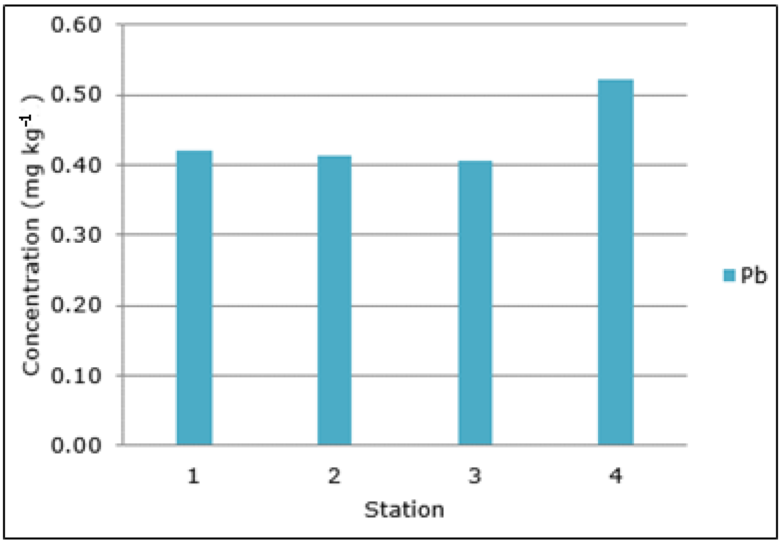

Figure 4. Pb content in surface sediments of Kendal waters.

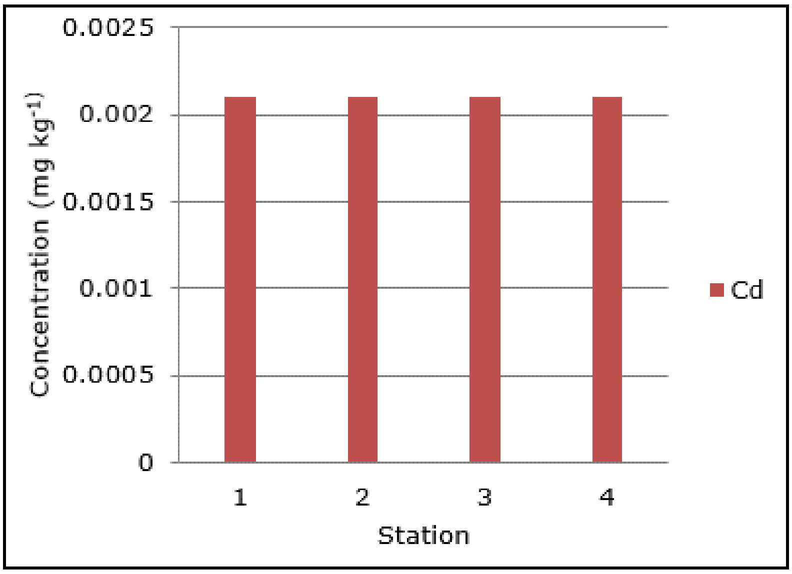

Figure 5. Pb content in surface sediments of Kendal waters.

Table 3

Pollution level based on STORET method at station 1

No	*Parameter*	*Unit*	*Quality Standard*	*Results*			*Score*			
				Max	Min	Average	Max	Min	Average	Total
	Physical parameter									
1	Turbidity	NTU	<5	423	13.1	152.5	-1	-1	-3	-5
2	Temperature	^{0}C	28-32	33	31	32	0	0	0	0
3	TDS	mg L^{-1}	80	1000	1000	1000	-1	-1	-3	-5
	Chemical parameter									
4	pH		7-8.5	8	8	8	0	0	0	0
5	DO	mg L^{-1}	>5	8	7.8	7.867	0	0	0	0
6	Cd	mg L^{-1}	0.001	0.002	0.002	0.002	-2	-2	-6	-10
7	Pb	mg L^{-1}	0.008	0.008	0.008	0.008	-2	-2	-6	-10
8	Nitrate	mg L^{-1}	0.008	1.31	0.46	0.85	-2	-2	-2	-6
										-36

Note: TDS – total dissolved solids; DO – dissolved oxygen; Max – maximum; Min – minimum.

Table 4

Pollution level based on STORET method at station 2

No	Parameter	Unit	Quality Standard	Results			Score			
				Max	Min	Average	Max	Min	Average	Total
	Physical parameter									
1	Turbidity	NTU	<5	537	5.15	184	-1	-1	-3	-5
2	Temperature	^0C	28-32	32	31	31.7	0	0	0	0
3	TDS	mg L^{-1}	80	790	770	780	-1	-1	-3	-5
	Chemical parameter									
4	pH		7-8.5	8.2	7.9	8.07	0	0	0	0
5	DO	mg L^{-1}	>5	8.2	7.9	8.07	0	0	0	0
6	Cd	mg L^{-1}	0.001	0.002	0.002	0.002	-2	-2	-6	-10
7	Pb	mg L^{-1}	0.008	0.008	0.008	0.008	0	0	0	0
8	Nitrate	mg L^{-1}	0.008	0.36	0.03	0.2	-2	-2	-6	-10
										-30

Note: TDS – total dissolved solids; DO – dissolved oxygen; Max – maximum; Min – minimum.

Table 5

Pollution level based on STORET method at station 3

No	Parameter	Unit	Quality Standard	Results			Score			
				Max	Min	Average	Max	Min	Average	Total
	Physical parameter									
1	Turbidity	NTU	<5	27.4	6.43	17.5	-1	-1	-3	-5
2	Temperature	^0C	28-32	31	29	30	0	0	0	0
3	TDS	mg L^{-1}	80	880	820	843	-1	-1	-3	-5
	Chemical parameter									
4	pH		7-8.5	8.2	8.1	8.13	0	0	0	0
5	DO	mg L^{-1}	>5	8.2	8	8.13	0	0	0	0
6	Cd	mg L^{-1}	0.001	0.002	0.002	0.002	0	0	0	0
7	Pb	mg L^{-1}	0.008	0.008	0.008	0.008	0	0	0	0
8	Nitrate	mg L^{-1}	0.008	0.22	0.19	0.2	-2	-2	-6	-10
										-20

Note: TDS – total dissolved solids; DO – dissolved oxygen; Max – maximum; Min – minimum.

Table 6

Pollution level based on STORET method at station 4

No	Parameter	Unit	Quality Standard	Results			Score			
				Maximum	Minimum	Average	Max	Min	Average	Total
	Physical parameter									
1	Turbidity	NTU	<5	61.3	4.94	27	-1	-1	-3	-5
2	Temperature	^0C	28-32	30	29	30	0	0	0	0
3	TDS	mg L^{-1}	80	990	620	810	-1	-1	-3	-5
	Chemical parameter									
4	pH		7-8.5	8.3	8.3	8.3	0	0	0	0
5	DO	mg L^{-1}	>5	8.1	7.8	8	0	0	0	0
6	Cd	mg L^{-1}	0.001	0.002	0.002	0.002	0	0	0	0
7	Pb	mg L^{-1}	0.008	0.008	0.008	0.008	0	0	0	0
8	Nitrate	mg L^{-1}	0.008	0.34	0.05	0.2233	-2	-2	-6	-10
										-20

Note: TDS – total dissolved solids; DO – dissolved oxygen; Max – maximum; Min – minimum.

According to the tests of index pollution, it was found that station 1 and 2 were regarded as heavily polluted, while station 3 and 4 were classified as lightly polluted. Station 2 was located in an estuary in which fishing activities often take place and was next to a mangrove ecotourism location. Therefore, the discharge of the fishing community possibly affected the water quality at station 1. On the other hand, station 2 was part of the port, where water quality also depends on the awareness of the port environment. It was found that stations 3 and 4 were lightly polluted. This condition was probably influenced by the distance to the stations and water flow at the time the samplings were conducted (Table 7).

Table 7

Index pollution test results

No	Parameter	1	2	3	4	L_{ij}	1	2	3	4
		$C_{i\ max}$					IP_j			
1	Turbidity	423	537	27.4	61.3	5	18.37	15.5	4	3.72
2	pH	8	8.2	8.2	8.3	7				
3	TDS	1000	790	880	990	80				
4	DO	8	8.2	8.2	8.1	5				
5	Salinity	18.2	18.2	18.7	19	34				
6	Cd	0	0.002	0	0	0.001				
7	Pb	0.01	0.008	0.01	0.01	0.008				
8	Nitrate	1.31	0.36	0.22	0.05	0.008				

Note: TDS – total dissolved solids; DO – dissolved oxygen, $C_{i\ max}$ – maximum concentration of water quality parameter i; L_{ij} – parameter quality stated in the water quality standard j; IP_j – pollution index for j.

There were six classes of phytoplankton found in Kendal waters: *Bacillariophyceae, Chlorophyceae, Cyanophyceae, Trebouxiophyceae, Dinophyceae* and *Chrysophyceae*. Within class *Bacillariophyceae*, *Chaetoceros* was the most dominant genus, followed by *Rhizosolenia* and *Guinardia* (Table 8).

Table 8

Average of phytoplankton abundance

No	*Genus*	*Station 1*	*Station 2*	*Station 3*	*Station 4*
		Bacillariophyceae			
1	*Bacteriastrum*	0	0	212.31	212.31
2	*Bacillaria*	425	425	0	0
3	*Biddulphia*	0	0	0	21
4	*Chaetoceros*	1199.66	1730.23	1089.8	1804.54
5	*Coscinodiscus*	594.643	431.543	413.97	580.087
6	*Cyclotella*	1911	21	0	0
7	*Gyrosigma*	806.977	700.445	1153.67	1111.4
8	*Mellosira*	637	0	0	0
9	*Naviculla*	244.5	201.655	431.627	425
10	*Nitzchia*	573.077	509.5	318.47	948.523
11	*Pinnularia*	1274	0	212.31	0
12	*Skeletonema*	2685.66	138.04	580.17	587.523
13	*Asterionella*	0	21.23	42	849.315
14	*Thallassiosira*	0	21	0	0
15	*Thallasiotrix*	212	0	0	0
16	*Eucampia*	0	0	849.26	424.655
17	*Guinardia*	735.977	1114.57	1924.83	1118.28
18	*Rhizosolenia*	1316.46	785.63	2370.82	1309.34
		Chlorophyceae			
19	*Schroederia*	42.46	212.155	0	212.31
20	*Tetraedron*	212	212	0	42
		Cyanophyceae			
21	*Oscillatoria*	1450.82	636.64	2176.14	1486.32
		Trebouxiophyceae			
22	*Chlorella*	0	42	0	0
		Dinophyceae			
23	*Ceratium*	0	127	212.31	0
		Chrysophyceae			
24	*Peridinium*	21.23	85	424.625	0
	Total	14342.46	7414.638	12412.31	11132.6

Only 2 classes of zooplankton were found, *Crustacea* and *Ciliata*, with 3 genera (Table 9).

Table 9

Average of zooplankton abundance

No	*Genus*	*Station 1*	*Station 2*	*Station 3*	*Station 4*
		Crustacea			
1	*Acartia*	1.27	7.005	1.27	19.11
		Ciliata			
2	*Tintinnopsis*	22.507	8.9167	8.9167	7.645
3	*Leprotintinnus*	0	1.27	12.74	0
	Total	23.777	17.192	22.927	26.755

The diversity index of phytoplankton (H') ranged from 1.854 to 2.018. It means that the stability of the biota community is moderate and the water is moderately polluted. Evenness index (E) ranged from 0.751 to 0.879, close to 1, which means that a normal distribution exists or the number of individuals of each species was relatively the same. Dominance index (D) ranged from 0.157 to 0.198, close to zero, which means that there were no species dominating other species or the community structures were stable (Fachrul 2007) (Figure 6).

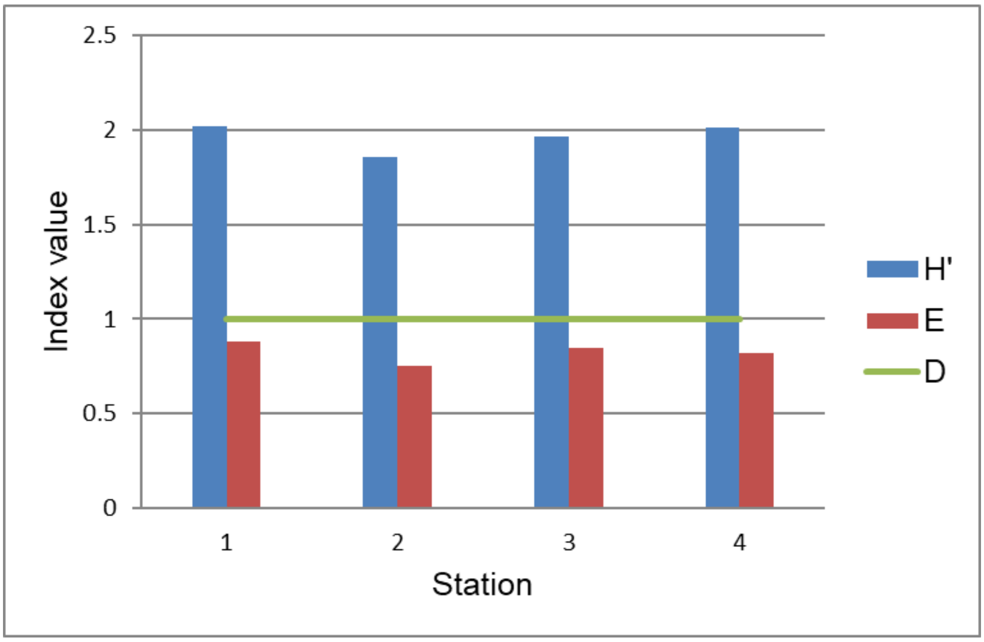

Figure 6. The diversity (H'), uniformity (E) and dominance (D) of phytoplankton.

The diversity index on zooplankton (H') ranged from 0.187 to 0.597, indicating that the zooplankton biota community was unstable or that the water was heavily polluted. Evenness index (E) ranged from 0.093 to 0.481, indicating that at stations 1, 3 and 4, evenness among species was low. On the other hand, at station 2, an even distribution was observed. Dominance index (D) ranged from 0.611 to 0.875, close to 1, which means that there were species that dominated other species or labile community structures were found due to ecological pressure (Fachrul 2007) (Figure 7).

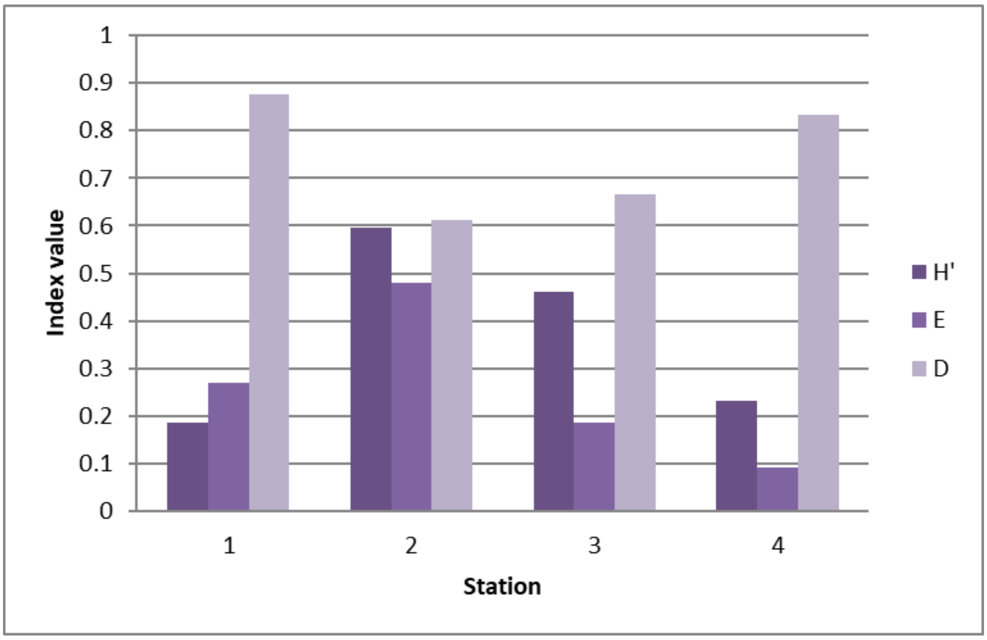

Figure 7. The diversity (H'), uniformity (E) and dominance (D) of zooplankton.

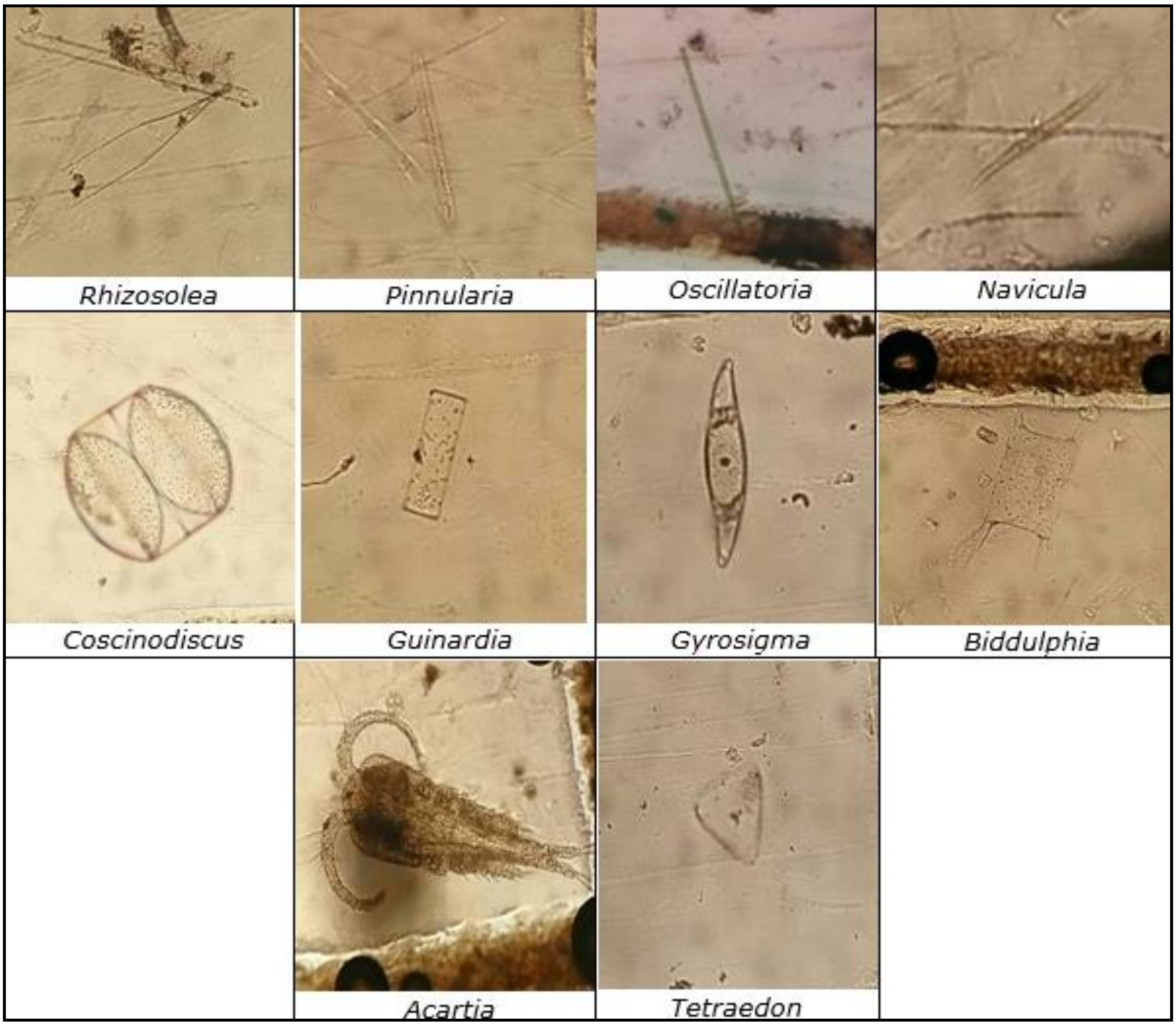

Figure 8. Some of the genera identified in Kendal waters.

The content of Pb and Cd in Kendal seawaters was at the threshold of quality standard for marine biota, 0.008 mg L^{-1}. On the other hand, Cd content exceeded the value of 0.001 mg L^{-1}. Pb and Cd, with the values of 30.2 mg kg^{-1} and 0.7 mg kg^{-1}, are still below the threshold of the quality standard (CCME 1999) (Table 10). Pb and Cd content in Citarum River were 27.5 and 3.5 times greater than the values from the present study. However, Pb and Cd content in the sediment were 2.75 smaller and 16.67 greater than in the current research. Cd content in the river had exceeded the class III of water quality standard at 0.01 mg L^{-1} (GR no. 82 of 2001). The high content of heavy metals found in these watersheds is dangerous for fish farming. It also affects the economic conditions of the society in Saguling reservoir. Moreover, it subsequently affects humans (Happy et al 2012; Mulyadi & Atmaja 2011).

The content of Pb and Cd in freshwater, and Cd sediments in the Mamberamo river, the largest river in Papua, was smaller than the results in this study. However, Pb sediment content was 26.48 higher than in the current study, since Papua contains a large quantity of mine material. Thus, water seepage takes place through the river flow (Tarigan et al 2003). Previous research showed that the content of Pb and Cd in seawater at Jakarta bay was 0.005-0.011 mg L^{-1} and 0.006-0.015 mg L^{-1}, respectively, classified as moderately polluted. On the other hand, the content of Pb and Cd in surface sediments was 14-58.1 ppm and 0.012-0.75 ppm, respectively, the sediments being classified as unpolluted (Permanawati et al 2013). However, in the next five years, the high content of Pb and Cd (with an increase of 3.9 and 6.1 times) in Muara Kamal waters, Jakarta Bay, will lead to abnormalities in the body of green shellfish due to the content of Pb, Hg and Sn (Riani et al 2018).

Heavily polluted water, as the Maros waters (between -50 and -88, IP_j>10), possibly caused heavy metals bioaccumulation in the body of shells. Pb content reached 6.13 ppm in the shells (Dahlifa & Indrawati 2017). Other studies in the Jeneberang region also showed that heavy metals can accumulate in shells (Amansyah & Syarif 2015).

The abundance of diatoms from the genus *Chaetoceros*, reaching 10^6 cells L^{-1} is believed to cause red tide. Red tide can cause mass fish mortality due to a blockage in the gills, which stop the fish from absorbing oxygen (Asriyana & Yuliana 2012).

In Tugu river, in the Semarang region close to Kendal waters, it was found that the abundance and diversity of benthic organisms decreased. This was influenced by three heavy metals, Cr, Pb and Cu. The correlation between the diversity of benthic organisms and heavy metals in sediments presented value of 0.92, while the correlation between the abundance of benthic organisms and heavy metals in sediments presented a r value of 0.99 (Suryono 2016). The diversity index in Bitung coastal waters was low, ranging from 0 to 1.79 for shells. It can be said that the coastal waters have been polluted by heavy metals (Mokoagouw 2008).

On the coast of South Sulawesi, Cd was found in surface sediments. It exceeded CCME quality standards. The content of Pb and Cd in these sediments was 60.3 and 1307.14 times greater than the standard, while the content of Pb and Cd in the seawater was 10.94 and 185 times greater than the results from the current research. This was because Tallo river estuary, Bone bay, Parepare Bay, and Tanjung Bunga beach have industrial areas, with tugboat activities near the port and port activities. The quantities of heavy metals found decrease in the following order Lead>Copper>Cadmium (Setiawan & Subiandono 2015).

Water quality in Barito waters exceeded the environmental carrying capacity and it was caused by the coal waste disposal. The condition leads to an accumulation of pollutants in Giant freshwater prawn (*Macrobrachium rosenbergii*). The content of Pb and Cd in Barito waters was 18.38 and 2.5 times higher than the value found in the current research (Sofarini et al 2010). Tapak River, which is located on the east side of Kendal waters, was also polluted by heavy metals. Pb content in Tapak River exceeded the quality standard, reaching 0.003 mg L^{-1}. The condition was related to the location of the river, which is close to the industrial area, aquaculture area and settlements (GR no. 82 of 2001; Pratama et al 2012). Cd content in Tapak River waters reached 0.004 mg L^{-1}. However, Cd content found in pond water on the northern coast of Semarang City reached 0.0045 mg L^{-1}. Thus, the condition affected the milkfish living in the fishpond (Martuti et al 2016).

The comparison of heavy metal content (Pb) in surface sediment found in Linggi estuary in Malaysia and Red River in Vietnam showed that the content was 119.54 and 150 times greater than in the current research. However, in Kelantan estuary in Malaysia, the content reached a level 0.95 times smaller than what was found in Kendal waters. Cd content in Linggi Estuary and Red River was 42.86 and 166.67 times greater than the value found in Kendal waters. On the other hand, the Cd content in Kelantan estuary was smaller compared to the findings from Kendal waters (Elias et al 2018; Wang et al 2017; Nguyen et al 2016).

The content of Pb and Cd in surface sediments found in Chinese waters in Sheyang estuary was 38.34 and 71.42 times greater than the value found in the current research. On the other hand, the content found in Yantze estuary was 69.41 and 400 times greater than in the current research. Cadmium is a major contributor to the pollution in Sheyang estuary. The pollution unfortunatelly caused ecological impacts. Heavy metal As, Cr, and Cd were major contributors to the pollution in Yantze estuary. The pollution was originally caused by the resident activities (Zhao et al 2018 Liu et al 2016).

Some researches on the heavy metal content in other Asian regions had been conducted. Research in Gorgan beach, Iran, found that the content of Pb and Cd reached values 18.58 and 51.42 times greater than the values found in the current research. The results showed a high concentration of Pb and Zn in the water and sediment (Tabari et al 2010). Research conducted in Sangu river, Bangladesh, found that the content of Pb in surface sediments was 44.5 times greater than the findings in the current research. The high levels were caused by Pb, which came from the fuel of boat engines (Hossain et al 2019).

Based on the Kendal Regency Regulation on Environmental Protection and Management, it is said that any waste disposal which includes B3 (Hazardous and Toxic Material) onto environmental media is prohibitted. Administrative sanctions will be applied to those responsible for the business and/or the activity, if any violation of the environmental permit is found (RR of Kendal no. 11 of 2012). However, due to it endangering the local flora and fauna, as well as human health, criminal sanctions should be considered for individuals, companies, and legal entities that violate the rules of quality standards for toxic and hazardous waste. The local government needs to make efforts to prevent the discharge of household waste by providing trash bins, waste disposal facilities, and transportation facilities. Moreover, waste processing installation facilities for households and industries is also required. In order to raise funds for environmental management, environmental taxes should be considered for households, industries and business entities in Kendal Regency.

The high Pb concentration in the waters could possibly affect the Pb metal content in the bodies of Juaro (*Pangasius polyuranodon*) and Sembilang fish (Plotosidae family) as it was found in Musi river. It was also found that the liver was mostly affected (Putri & Purwiyanto 2017). The content of Cd in waters possibly affected biota such as green mussels (*Pernaviridis*) as was found in Poncol waters, Jepara, where the BCF (Bio Concentration Factor) ranged from 1.44 to 1.57 (Rahma et al 2017). It was also found that the pollution in the north coast of Java affected tuna (*Euthynnus* sp.), in which the average Cd level reached 0.156 mg kg^{-1}, exceeding the maximum standard of 0.1 mg kg^{-1} (Hananingtyas 2017).

Table 10

The concentration of Pb and Cd in some Asian waters (mean ± SD)

Waters	*Concentration in Seawater (mgl^{-1})*		*Concentration in Surface Sediment ($mgkg^{-1}$)*		*References*
	Pb	Cd	Pb	Cd	
Kendal estuary	0.008	0.002	0.44±0.055	0.0021	Present study
Citarum river	0.022 ±0.021	0.007 ±0.003	0.16± 0.072	0.035 ±0.017	Happy et al 2012
Membramo estuary	0.004 ±0.0001	0.001	11.653 ±2.757	0.001	Tarigan et al 2003
Muara Kamal waters	0.0312 ±0.043	0.0122 ±0.008	NA	NA	Riani et al 2018
Coast of South Sulawesi	0.0875 ±0.0263	0.37 ±0.410	26.523 ±27.587	2.745 ±2.182	Setiawan & Subiandono 2015
Barito estuary	0.147 ±0.0979	0.005 ±0.0022	2.777 ±5.551	3.035 ±0.219	Sofarini et al 2010
Tapak river	0.4 ±0.436	NA	53.653 ±10.786	NA	Pratama et al 2012
Linggi estuary	NA	NA	52.6 ±3.536	0.09 ±0.066	Elias et al 2018
Kelantan estuary	NA	NA	0.4222 ±0.01474	0.00004 ±0.00002	Wang et al 2017
Red River	NA	NA	66±28	0.35 ±0.27	Nguyen et al 2016
Gorgan coast	0.1486 ±0.03374	0.10284 ±0.02602	NA	NA	Tabari et al 2010
Sheyang estuary	0.00055 ±0.00043	0.00012 ±0.00006	16.87 ±3.03	0.15 ±0.04	Zhao et al 2018
Yangtze estuary	NA	NA	30.538 ±13.492	0.84 ±1.32	Liu et al 2016
Sangu river estuary	NA	NA	19.58 ±7.017	BDL	Hossain et al 2019

Notes: NA - not available; BDL - below detection limit.

Conclusions. Based on the analysis using the STORET method, it was found that stations 1 and 2 were identified as class D, poor, while stations 3 and 4 were classified as class C, moderate. By using Nemerow and Sumitomo indices, stations 1 and 2 were classified as heavily polluted, while stations 3 and 4 were considered as lightly polluted. 6 classes of phytoplankton were found, while only 2 classes of zooplankton were found. The diversity index of phytoplankton showed that the water quality was moderate, while the diversity index of zooplankton showed that the water was heavily polluted. Moreover, the evenness index was evenly distributed, but the evenness of zooplankton was low. The dominance of the phytoplankton was at a normal level, while the zooplankton presented dominating species. Thus, it is recommended that the regional government should strive for environmental rules by providing and enforcing more legislation. The prevention of the discharge of household waste and the regulation of environmental taxes as efforts to manage environmental resilience should be considered.

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Authors:
Hartanto, Inland Water and Ferries Transport Polytechnic of Palembang, Engineering Department, Sabar Jaya 116 Perajin, Banyuasin I Regency, 30963 Palembang, South Sumatera, Indonesia, e-mail: hartantosatya@gmail.com
Agus Tjahjono, Inland Water and Ferries Transport Polytechnic of Palembang, Engineering Department, Sabar Jaya 116 Perajin, Banyuasin I Regency, 30963 Palembang, South Sumatera, Indonesia, e-mail: a_agus_tjahjono70@yahoo.co.id

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