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Relationship Population Density of Aquatic Sediment Macrozoobenthos to River Water Quality Parameters: Case Study of Upstream Citarum River in Bandung Regency

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Abstract: The increase in anthropogenic activities occur along the upstream of Citarum River Basin (CRB) in Bandung regency had a negative impact to the water quality caused by the presence of human activity, it will be able to be a disruption to the ecosystem aquatic. The purpose of this study was to determine the relationship of the physical and chemical parameters of water and sediment to the presence of macrozoobenthos populations. Based on the result of Pearson Correlation Analysis (PCA), the parameters of COD, TOC and silt composition were the highest correlation to the macrozoobenthos population density, the value were 0.966, 0.865 and 0.576. Although PCA analysis is used to determine the relationship between the parameters of water, sediment and sediment particle distribution, the result showed that the water parameters were the mayor component affected the density of macrozoobenthos. While based on the composition of sediment, it is found that substrate as silt, clay and gravel and phosphate parameter affected the density of macrozoobenthos. The measurement of water quality also were calculated by Biotic Monitoring Working Party-Average Score Per Taxon (BMWP-ASPT) index showed that the quality were polluted condition, although by Pollution Index (IP) method showed as a light polluted category.

Key words: Citarum upstream, correlation, sediment, macrozoobenthos, water quality.

1. Introduction

The increase in anthropogenic activities along the upstream of Citarum River has a negative impact on water quality. There are many kinds of land-use in the surounding of the upstream segment at the Citarum River Basin (CRB), such as municipal, industry, agriculture and farming area. At the upstream of Citarum River, located in GnWayang, it closes to the Citarum River springs, the disposal of waste from livestock activities are discharged through the sewers that flow into the water bodies subsidiary of Citarum River. As a result of the increase in the load of waste which enters to the water body, it will cause the water quality decline, also lead to the disruption of living in the aquatic ecosystem [1].

Macrozoobenthos is a biotic component of river ecosystem, and also it can be used as a bioindicator to determine the impact of anthropogenic activity. As an aquatic biota, it could be an important component in the biological assay (bioassessment) in order to evaluate the overall quality of water resources, ecological functions, as well as the specific influence of anthropogenic activities. Disruption that occurred in the biota due to contamination toxic pollutants may be physiological disorders, such as increased respiration, defect morphology, and there is a larger scale ecological balance disturbance [2]. Chopra, G. et al. [3] told that the river has brought the industrial waste, urban sewage, fertilizer runoff from agriculture and

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water carried out by the current, organism affected from such pollution is macrozoobenthos. Research done by Muntalif, B. S. et al. [4] indicates that there has been a decline in water quality in the upper Citarum River flowing along with the flow in the downstream direction that passes through residential areas, dairy farming and agriculture, which contributes to advise the burden of residual waste by the human activity and entered to the river.

This study was conducted to determine the distribution of macrozoobenthos populations that occur along the upstream of Citarum River, including population density and species composition of macrozoobenthos. This study would be used as information and efforts concerned on decision-making for water management according to the welfare along the upstream segment of Citarum River Basin in Bandung area.

2. Methodology

The study was conducted at July and September 2013, located in the upper segment of Citarum River Basin (CRB) at the Bandung Regency. The classification area sampling was determined as natural condition for 4 stations sampling as a refference sites, located in G. Wayang (SR-1), G. Guha (SR-2), G. Puncakcae (SR-3) and G. Halimun (SR-4). The other sampling stations determined depend on land use of the area such as agriculture area at Cikitu village (ST-1), domestic area at Babakan village (ST-2) and mining industry area at Wangisagara village (ST-3) is shown in Fig. 1. The measurement of physical and chemical parameters of water was conducted in situ and in ex-situ. Water parameters to be measured is temreature, turbidity, flow-rate, TDS, TSS, pH, DO, COD, BOD, pH, NTK and total Phosfat. The water sample is taken by composite method, preservatived and stored in the cold box.

Sampling of benthos was conducted by random sampling using a Surber net (30 × 40 cm^2), size 500 μm. The preservation of the macrozoobenthos samples used 4% formalin solution. Sediment composition was analyzed to determine the component of sediment such as particles, total organic carbon content (%), total nitrogen (%) and phosphate (mg/kg).

The calculation of macrozoobenthos population density was measured by counting the number of biota per cm^2 [5]. Furthermore, the Biotic Monitoring Working Party-Average Score Per Taxon (BMWP-ASPT) index is a method to determine the water quality score method based on the sensitivity of macrozoobenthos family to the water pollutant as well as the Pollution Index (IP) as a comparison [6, 7]. Relationship between the water parameter, sediment particle and the distribution of the biological parameters used the PCA. The test is used to determine the relationship between the parameters of water, sediment and sediment particle distribution (gravel (%), sand (%), silt (%) and clay (%)) on the abundance of macrozoobenthos. PCA determine the relationship between density of macrozoobenthos, water quality parameter and sediment parameters in the upstream Citarum River. The calculation of the statistical analysis performed using SPSS software ver. 20 (2014).

3. Results and Discussion

3.1 Physical and Chemical Parameters of River Water Bodies

The result of physical and chemical parameters measurement for the water samples taken in July (I) and September (II) along the 7 stations is described in Table 1.

In Table 1, it can be seen that the physical and chemical parameters of water quality are different between reference sites stations SR-1-4, and sites test stations ST-1-3 shows that the water temperature measured at the sites test stations ranged between 22.2 ^oC to 22.7 ^oC.

The water temperature at reference sites SR-1-3 is higher than other sites, located at the downstream as an open area and covered by riparian vegetation growth

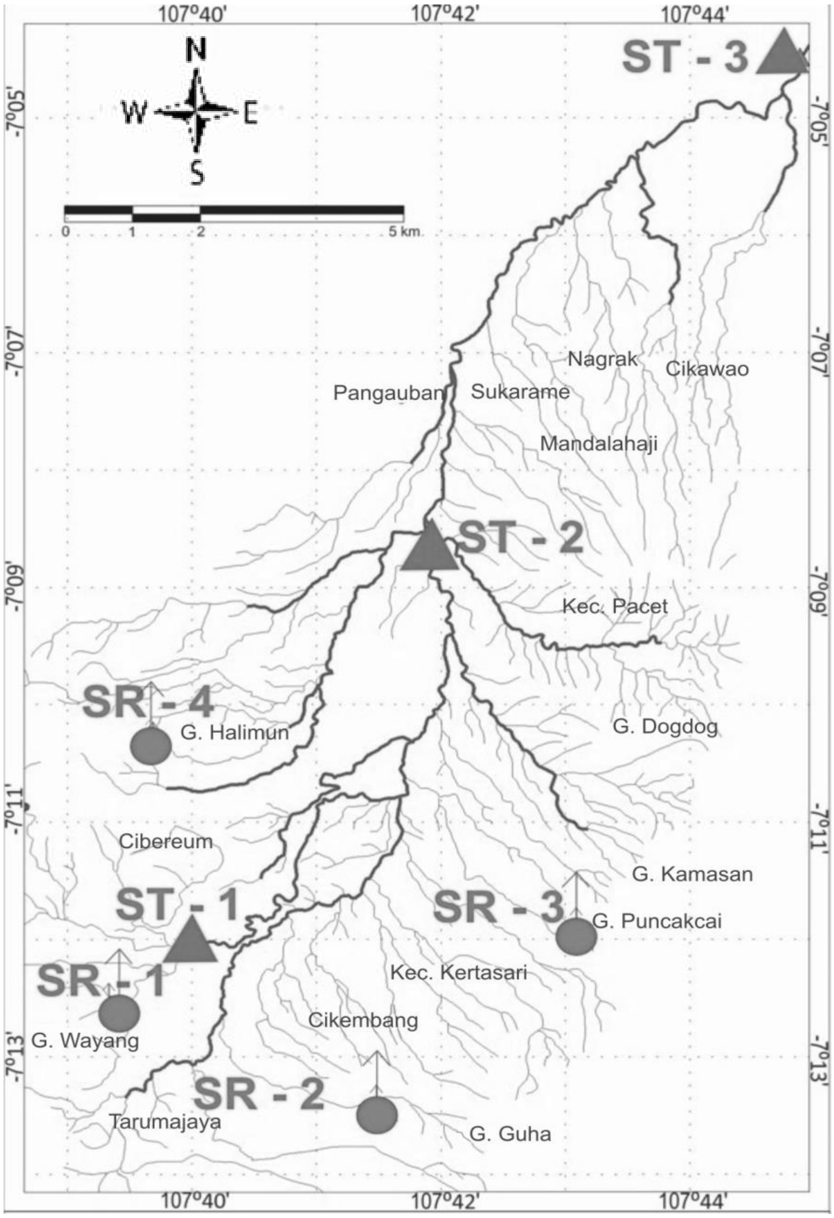

Fig. 1 Sampling site map.

Table 1 Physical and chemical parameters of water.

Parameter		Station													
		SR-1		SR-2		SR-3		SR-4		ST-1		ST-2		ST-3	
	Unit	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Temperature	°C	19.8	20.3	16.4	16.4	18.1	17.6	20.7	24.5	22.3	22.4	22.2	24.0	22.7	26.1
Turbidity	NTU	15.4	16.7	13.7	10.2	22.7	3.3	34.3	53.2	126.0	29.2	90.1	32.1	76.3	21.6
Flow-rate	m/s	1.08	0.2	2.1	0.2	0.4	0.3	2.1	0.2	0.5	0.4	1.2	0.4	0.9	0.5
TDS	mg/L	167	221	94	32	41	21	81	7	123	183	93	123	112	106
TSS	mg/L	> 1	10	11	16	> 1	14	> 1	29	225	38	106	34	93	23
pH		7.8	7.5	7.4	6.2	7.2	7.1	8.0	7.7	8.1	7.6	8.5	8.2	8.3	7.8
DO	mg/L	7.9	7.3	8.1	8.1	8.0	6.9	7.9	7.6	7.5	7.8	6.8	7.9	8.1	7.9
COD	mg/L	11.2	7.6	22.3	7.6	11.2	7.6	11.2	30.4	89.3	53.2	11.2	15.2	27.9	38
BOD	mg/L	-	4.7	-	4.6	-	4.5	-	13.7	-	24.7	-	7.3	-	18.5

through the river flows, which caused sunlight penetrate into the surface water. According to Whitehead, P. G. et al. [8], an increase in water temperature will affect the chemical reactions and is associated with a reduction in water quality and ecological status of freshwater. The high level of TSS concentration at sites test stations caused by run-off make a different function into open land, such as in area for agriculture, residential, traditional sand mining and ranching. Similarly, the turbidity values at this sites stations ST-1-3 are higher than the reference stations SR-1-4. The turbidity value is presumably due to differences flow velocity in each section of the river. The effect of a lower flow-rate causes the accumulation of material suspended solids is greater.

Increase of nitrogen concentration in each station presumably because the number of inputs of organic matter that comes from agricultural areas, which due to the use of nitrogen fertilizer around the river carried away during run-off. Moreover, domestic waste from human settlements and farms also contribute to the increase of the nitrogen concentration.

The highest COD concentration is located at station ST-1 with an average concentration of 89.3 mg/L. High concentration of COD at this location due to the input loading of organic material from the human settlement area, a dairy farm and agriculture around the river. It is similar with the statement of Al-Shami, S. A. et al. [9] that high concentration COD in the water is caused by a number of contaminants that enter to the waters, especially organic pollutants from household waste, industrial, rice fields and aquaculture.

3.2 Distribution of Sediment Particles

Aquatic sediment is main factor for growing up and spreading of macrozoobenthos activity. The compositions of particle sediment such as gravel, sand, clay and silt are used to determine the type of behavior makrozoobenthos in the aquatic ecosystem. The result of distribution sediment particle composition along the sampling station is shown in Fig. 2.

Data of Fig. 2 indicates the distribution of sediment particles, it is found that sand particles is the highest content of sediment fractions at all stations. The highest of sand fraction is found at station ST-3 (83%), while the lowest one in station SR-1 is about 51%. Nybakken, J. W. [10] stated that the sand media could not be served as a good nutrient and water holding material, but is better as media for infiltration and aeration process. Therefore, the number of benthos growing in this substrate is fairly well correlated to the water circulation that regulates moisture and supplies oxygen and nutrients.

In addition, the organic matter content in the sediment at the sampling location ranged from 33.85%-47.63%, where the lowest percentage found in station ST-2 and the highest one at station SR-2. The NTK content

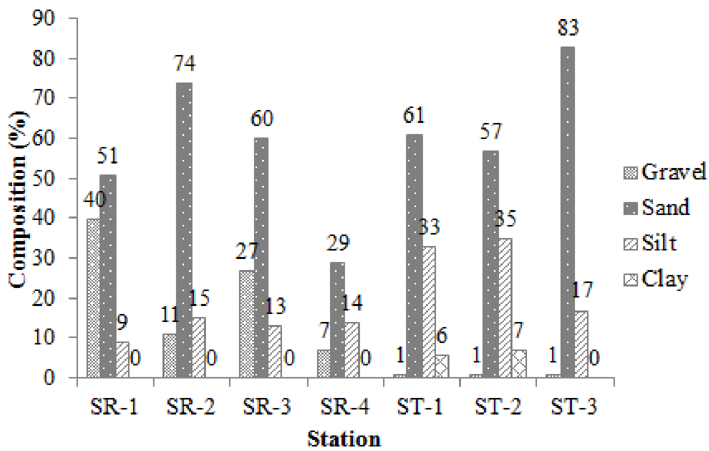

Fig. 2 Distribution of sediment particles.

ranged from 1.03%-1.22%, the lowest percentage is found at station SR-4 and highest at station ST-2. While the phosphate content ranged from 316.42-1,002.19 mg/kg, with the lowest content foundn at stations SR-3 and highest at station SR-1.

3.3 Macrozoobenthos

Based on observations of macrozoobenthos in the upstream of Citarum River during 2 periode samplings, it was found 87 genera, which is 68 genera of the class *Insecta*, 3 genera of the class *Hirudinae*, 3 genera of the class *Oligochaeta*, 5 genera of the class *Gastropoda*, 5 genera of the class *Malacostrac*a, one genera of the class *Bivalvia*, 1 genera of the class *Adenophorea* and 1 genera of the calss *Diplopoda*.

The number of individual macrozoobenthos data is shown in Fig. 3. It can be seen that at SR-1, it has found 32 genera, so as the location with the highest number of macrozoobenthos, meanwhile, the least number is found about 12 genera at the station ST-2. The lack genera found in this station is affected by the type sediment content, when there are dominated by rocky substrate, so that only certain types of macrozoobenthos are able to live on that substrate.

The most species of macrozoobenthos were found at station SR-1, which indicates that water quality at this station is still good, so the growing up of the various species aquatic biota will be supported. Meanwhile, the least number has been found at station ST-2, describing the condition of the water in bad quality, because it is only in some kind of macrozoobenthos which were tolerant to this water conditions.

Fig. 4 shows the result of density of population macrozoobenthos in the aquatic habitat. It can be seen that the highest population density was found at

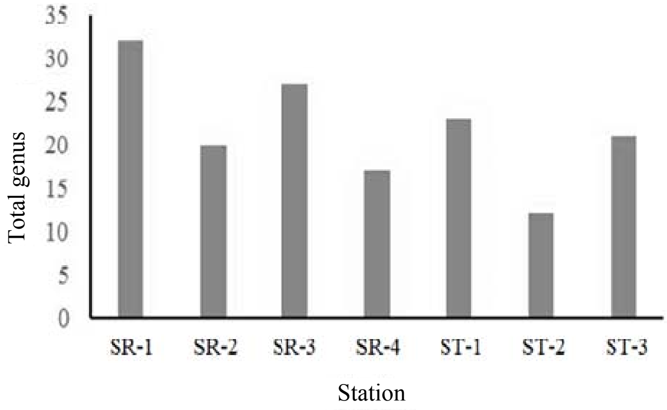

Fig. 3 Number of species macrozoobenthos.

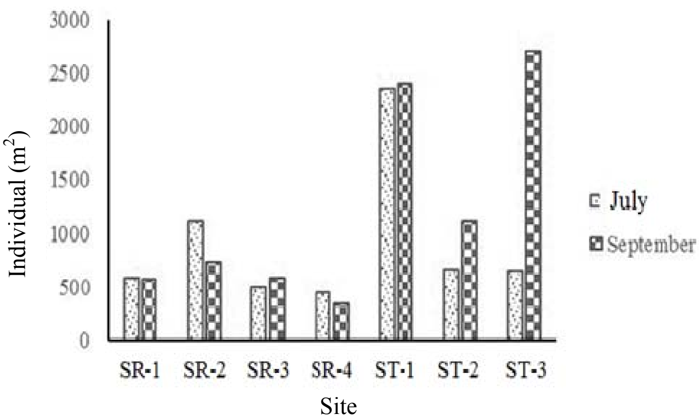

Fig. 4 Population density of macrozoobenthos.

station ST-1 and station ST-3, while at the station SR-1 as a location with the least density population. Two species dominantes of macrozoobenthos found at that location are the genera of *Chironomus* and *Polypedilum*. Both genera are known in the taxonomy nomenclature as a part of *Chironomidae* family, known as the species could be able to adapt to the water quality condition with high pollution levels. Also it can be said that species were supported by the ability to form colonies, and as the most reproductive compare to the other species in same family [11].

Diversity index (H') indicated by number of species and its density of macrozoobenthos for each station, the result found at the station SR-1 shown as a location with the highest index score were 2.48. In this station, there were 2 species dominant come from *Chironomidae* and *Simullidae*. While at the station ST-2 and ST-3 show the diversity index value for 0.49 and 0.40 and it was found 12 genera but only from family *Chironomidae* as a species dominant.

3.4 River Water Quality Assessment

Biotic indices are used for measuring the status of water quality assessment when it is used Biotic Monitoring Working Party-Average Score Per Taxon (BMWP-ASPT). Based on that score index calculated at all stations, the value was between 2.91 and 5.86, showing that the river water quality was at the level between light and heavy pollution category. The lowest index was at station ST-2 as a location with least number species formed by genera of the family *Chironomidae*, *Hirudinae*, *Oligochaeta* and *Gastropoda*, known as organism cosmopolitan and tolerant to various environmental conditions [12].

Pollution Index (IP) obtained from the seven stations ranged from 1.62 to 4.13. The highest IP value obtained at station ST-1 and the lowest at station SR-3. The high IP value at station ST-1 was done by some parameters, such as BOD and COD that exceed water quality standards. Sewage that comes from around the sampling station contributes to decrease the amount BOD and COD concentration, especially the waste which comes from a dairy farm. However, the value of IP is still included in the group lightly polluted.

3.5 Relationship between Biological Parameters to Water and Sediment Parameters

Pearson Correlation Analysis between the diversity of macrozoobenthos to water quality and sediment parameters within two sampling times (Tables 2 and 3) was obtained that parameters with the highest positive correlation value was the total phosphate (+0.33), TDS (+0.78) and substrate gravel (+0.91), while the parameters with the highest negative correlation value is pH (-0.75), DO (-0.5) and the sand substrate (-0.69).

At the first sampling, it is found that the total phosphate is the highest positive correlation value. However, when viewed from the significance value which is more than 0.05, it mean that parameters have not significantly relationship to diversity of macrozoobenthos. At the second sampling, TDS is known as the parameter with the highest correlation value. It has a significance which is less than 0.05, so it can be said that these parameters have a significant and strong relationship to diversity of macrozoobenthos. Data shown in Tables 4 and 5 are result of Pearson Correlation Analysis between density of macrozoobenthos and type of particulate, and biodeiversity of macrozoobenthos found that gravel has highest the significance value which is 0.05. So, it meant that the relationship between the diversity of macrozoobenthos and gravel parameters is very strong and significant.

Pearson Correlation Analysis between density of macrozoobenthos to water and sediment parameters (Tables 4 and 5) was calculated that parameters with the highest positive correlation values was COD (+0.97), TOC (+0.89) and silt substrates particles (+0.58), while the parameters with the highest negative correlation values were the total phosphate (-0.69), pH (-0.85) and gravel substrate (-0.59).

Table 2 Results of PCA between diversity of macrozoobenthos to water parameters.

	Flow-rate	Temperature	TDS	TSS	pH	DO	Turbidity	NTK	Total P	COD	TOC	BOD
Diversity (1)	-0.14	-0.57	0.02	-0.42	-0.75	0.31	-0.54	-0.54	0.33	-0.17	-0.34	
Significant (1)	0.77	0.18	0.96	0.26	0.05	0.5	0.22	0.21	0.47	0.72	0.45	
Diversity (2)	-0.06	-0.57	0.78	-0.38	0.17	-0.50	-0.19	-0.19	0.14	-0.14	0.10	-0.12
Significant (2)	0.89	0.86	0.04	0.41	0.71	0.25	0.68	0.68	0.77	0.77	0.85	0.80

Table 3 Results of PCA between diversity of macrozoobenthos to sediment parameters.

	C organic	NTK	Phosfat	pH	Gravel	Sand	Silt	Clay
Diversity (1)	0.34	0.01	-0.56	0.12	0.91	0.31	-0.50	-0.34
Significant (1)	0.45	0.98	0.19	0.8	0.01	0.5	0.25	0.45
Diversity (2)	0.67	-0.63	0.70	-0.32	0.73	-0.50	-0.25	-0.06
Significant (2)	0.10	0.13	0.08	0.41	0.06	0.25	0.59	0.90

Table 4 Results of PCA betweem density of macrozoobenthos to water parameters.

	Flow-rate	Temperature	TDS	TSS	pH	DO	Turbidity	NTK	Total P	COD	TOC	BOD
Density (1)	-0.43	0.21	0.27	0.81	0.21	-0.19	0.66	0.02	-0.69	0.97	0.50	
Significant (1)	0.34	0.66	0.56	0.03	0.79	0.11	0.11	0.98	0.09	0.00	0.25	
Density (2)	0.62	0.53	0.40	0.47	0.30	0.01	0.01	0.52	0.11	0.77	0.90	0.8
Significant (2)	0.14	0.24	0.37	0.3	0.51	0.99	0.99	0.23	0.82	0.04	0.01	0.03

Table 5 Results of PCA betweem density of macrozoobenthos to sediment parameters.

	C organic	NTK	Phosfat	pH	Gravel	Sand	Silt	Clay
Density (1)	0.18	0.25	0.48	-0.9	-0.4	-13	0.58	0.54
Significant (1)	0.70	0.59	0.27	0.02	0.40	0.78	0.36	0.21
Density (2)	-0.03	-0.54	-0.36	0.3	-0.6	0.27	0.49	0.36
Significant (2)	0.95	0.22	0.43	0.5	0.17	0.56	0.26	0.43

Correlation value, either COD or TOC, to population density of macrozoobenthos showed a very strong relationship, and the significance of each value less than 0.05 can be considered as a significant relationship. In addition, the negative correlation value of pH sediment has a very strong relationship to population density of macrozoobenthos and the significance value of 0.05 resulted in a significant relationship.

Principle Component Analysis (PCA) is statistical analysis to determine the influence of environment such as water and sediment parameter to the population density of macrozoobenthos with reduction some variables into several formed factors. The percentage of the form factor representing each independent variable can be seen from the value of communality.

The results of PCA analysis of water parameters in July showed that only one factor was formed from four water parameters. Based on Table 6, it shows that the turbidity and TOC is a variable that has the highest communality value of 4 parameters. For variable turbiditya, it obtains a value of 0.962. It shows that about 96.2% turbidity variable can be explained by factor formed. For variable TOC, it obtains a value of 0.883. It shows that about 88.3% TOC variable can be explained by formed factor.

The results of PCA analysis of water parameters in September showed that the water of 5 variable parameters only formed one factor. Based on Table 7, it is known that the BOD and COD are the variables with the highest commonality value with the formed factor. For BOD variables, it obtains a value of 0.789. It shows that about 78.9% BOD variable can be explained by formed factor. For COD variables, it obtains a value of 0.818. It shows that about 81.8% COD variable can be explained by formed factor.

Table 6 Communality value of water parameters (July) on formed factor.

Communalities	Initial	Extraction
Tempearture	1.000	0.764
TSS	1.000	0.877
Turbidity	1.000	0.962
TOC	1.000	0.883

* Extraction method: principal component analysis.

Table 7 Communality value of water parameters (September).

Communalities	Initial	Extraction
Tempearture	1.000	0.762
COD	1.000	0.818
BOD	1.000	0.789
pH	1.000	0.567
TSS	1.000	0.726

* Extraction method: principal component analysis.

Tabel 8 Communality value of sediment parameters (July) on formed factor.

Communalities	Initial	Extraction
C organic	1.000	0.764
pH	1.000	0.877
Silt	1.000	0.962
Clay	1.000	0.883

* Extraction method: principal component analysis.

Tabel 9 Communality value of sediment parameters (September) on formed factor.

Communalities	Initial	Extraction
C organic	1.000	0.632
Phosfat	1.000	0.897
Gravel	1.000	0.829
Silt	1.000	0.592

* Extraction method: principal component analysis.

The results of PCA analysis of sediment parameters in July indicates that from 5 variables of sediment parameters, there were only one factor formed. Based on Table 8, it is known that variable silt and clay are the variables with the highest commonality value to the formed factor. For variable silt, it obtains a value of 0.966. It shows that about 96.6% mud variable can be explained by factors that are formed. For variable clay, it obtains a value of 0.968. It shows that about 96.8% TOC variable can be explained by factors that are formed.

The results of PCA analysis of sediment parameters in September are shown in Table 9, from the four variables of sediment parameters, there were only one formed factor. It is found that total phosphate and gravel are variable with the highest communality value with the formed factor. The value for total phosphate obtained was 0.897. It shows that about 89.7% of total variable phosphate can be explained by factors formed. The value for gravel obtained 0.829. It shows that about 82.9% gravel variable can be explained by factors formed.

4. Conclusions

Based on PCA, it is known that COD and TOC have the highest correlation positive values to macrozoobenthos population density of +0.966 and +0.895, whereas, for sediment sludge parameters, it has the highest correlation value of +0.576. In addition, total phosphate and TDS parameters have positive correlation value to macrozoobenthos diversity of +0.33 and +0.78. While for the gravel and sediment parameters, phosphate has the highest correlation value of +0.91 and +0.696. Environmental parameters that most influence on the population density of macrozoobenthos and based on the analysis of PCA are water temperature, TSS, turbidity, TOC, COD, BOD and water pH. The influence of sediment parameters such as gravel, clay substrat and the total phosphate in sediment affect the density of macrozoobenthos. Conditions waters assessed from biotic index BMWP-ASPT in 6 stations were in lightly to moderate polluted, except in station 5 with heavily polluted conditions. Whereas, if assessed from Pollution Index (IP), those 7 stations were in lightly polluted state.

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