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The biophysical environment of Separi River on Kutai Kartanegara District

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Abstract — *This study was conducted at six sampling sites in Separi River flow area. Results showed that at all sampling sites the diversity of water biota (as nekton, plankton and benthos) was categorized low to moderate, its homogeneity was low to evenly distributed, and both dominant and not dominant species were found. Linear regression equation to show the relationship between fish species, plankton species and benthos species with some water quality parameters as temperature (X1), TSS (X2), TDS (X3), colour (X4), and turbidity (X5) was applied. The equation to show relationship with fish species is Y = 8,657–0,101 X1 -0,002 X2 –0,013 X3 -0,008 X4+ 0,021 X5 (r = 0,792; R = 62,48 %); with plankton species is Y = 2551,355 - 69,582 X1 - 0,101 X2 + 0,256 X3 + 0,128 X4- 0,362 X5 (r = 0,372; R = 0,139%); and with benthos species is Y = 1356,461–21,310 X1- 0,816 X2+0,153 X3+0,012 X4 -0,248 X5 (r = 0,444; R = 19,7 %). Relationship between fish species and some other water quality parameters as pH (X1), DO (X2), COD (X3), and BOD5 (X4) is shown by equation Y = - 8,503 –1,105 X1 + 2,054 X2 + 0,043 X3 + 3,501 X4 (r = 0,648; R = 41,9 %). Phytoplankton from the class of Chlorophyceae, Cyanophyceae, and Crysophyceae can be used as bio-indicators to predict water pollution. The quality status of water at all sample sites based on physical, chemical, and biological parameters in average was included in Class 4 which means that the water can only be utilized for crop irrigation or for other uses with similar requirements*

Keywords — *Biophysical environmen; Water Environment; Separi River*

I. Introduction

Sources of water pollution might come from industrial activities such as small scale industries, agriculture, and mining[1]. Most rivers in Asia are highly polluted with domestic, agricultural, and industrial wastes[2]. Indonesia water resources contribute approximately 6 percent from the world water resources or about 21 percent from the total water resources in the Asia Pacific region. However, the availability of clean water in Indonesia has been being a very serious problem. Large number of people is still using river water for drinking, bathing, and washing. Large number of households disposes their domestic wastes directly to the river body [1]. In 2008 the majority of rivers in Indonesia had been monitored and based on Storet method, water quality criteria Class 2, and Government Regulation No 82/2001 were included as heavily polluted. Other rivers were in slightly to moderately polluted [3]. Thus, the study on the characteristic, dynamic and ecology of river environment becomes very important in Indonesia.

Separi River is a tributary of Mahakam River located in the District of Kutai Kartanegara (Fig.1). The river provides water source for clean water and to irrigate crop production centres. As an impact of land use changes from forest to non forest utilization, the watershed area of Separi River has been degraded and uncovered, and unable to provide enough water during dry season but flooded during rainy season. Local community uses Separi River for domestic, fishery, agriculture, and other activities. Clear cutting vegetation in the watershed area gave impact on the deterioration of river water quality, declining the function of river, and changing the water status. Land clearing for coal mining activities in watershed area of Separi River directly evoked the increase of water turbidity. Apparently, Separi River has been polluted by waste materials from various activities occurring along riparian area, and bringing about negative impacts to the water environment, welfare of the biota, and human health.

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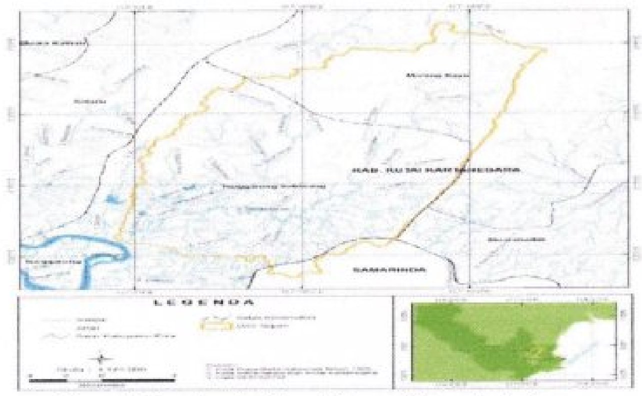

Figure 1. Map showing Separi River and its watershed area in the District of Kutai Kartanegara

The existing of certain species of water biota may become a bio-indicator for the status of water quality[4; 5; 6]. The changes of benthos density may be caused by the increase of human activities, addition of wastes, water temperature, input of detergents, low transparency, high conductivity, and high hardness. Many benthic species are unable to tolerate to the changes of environmental condition and pollution[7]. The objectives of this study are to identify species of fish, plankton, and benthos and their diversity as bio-indicator to know the condition of water quality; to analyze and determine water quality status and to identify the source of pollutants and their effect to the quality of river water.

II. METHODOLOGY

A. Location and Period

This study was conducted at six sampling sites in Separi River flow area in the District of Kutai Kartanegara for about 14 months started from April 2011 to May 2012. It consisted of pre-survey, field samplings carried out every 2 months for six periods; and water quality and biota analysis done in situ and ex situ at the laboratory.

B. Object and Procedure

1. Sampling for Biophysical Parameters

Water quality parameters measured in this study are referred to [8;9;10] for water quality analysis and procedure (Table 1).

Benthos was collected from the river bottom with Eikman-dredge 3 times at each six sampling sites. The benthos mixed with mud was put in a plastic bag, and then sieved with benthos screen for the purpose of identification. Water samples for plankton analysis were collected with plankton net and preserved in glass bottles. Benthos and plankton was identified in the Laboratory of Environmental Aquaculture, Faculty of Fisheries and Marine Science, Mulawarman University and the identification was referred to[10; 11; 12, 13].

Fishes were caught using gill net, casting net, fishhook, and scoop net; documented and identified in situ. Fishes that were unable to identify in situ, were preserved using ice and identified in the laboratory. Identification was referred to [4; 15; 16].

Table 1. Parameter, Method, Unit, Class (K) and Location of Analysis

No	Parameter	Method	Unit	K_1	K_2	K_3	K_4	Location
A	**Physical**							
1	Temperature	Potentiometric	°C	Dev. 3	Dev. 3	Dev. 3	Dev. 5	in situ
2	TSS	Gravimetric	mg/l	50	50	400	400	Laboratory
3	TDS	Gravimetric	mg/l	1000	1000	1000	2000	Laboratory
4	Colour		Pt.Co	100	180	200	250	Laboratory
5	Turbidity	Spectrophotometric	NTU					Laboratory
B	**Chemical**							
1	pH	Potentiometric	-	6 – 9	6 – 9	6 – 9	5 – 9	in situ
2	DO	Potentiometric	mg/l	6	4	3	0	in situ
3	BOD	Winkler	mg/l	2	3	6	12	Laboratory
4	COD	Titrimetric	mg/l	10	25	50	100	Laboratory
5	Ammonia	Spectrophotometric	mg/l	0.5	(-)	(-)	(-)	Laboratory
6	Nitrite (NO_2)	Spectrophotometric	mg/l	0.06	0.06	0.06	(-)	Laboratory
7	Nitrate (NO_3)	Spectrophotometric	mg/l	10	10	20	20	Laboratory
8	Phosphate (P)	Spectrophotometric	mg/l	0.2	0.2	1	5	Laboratory
9	H_2S	Titrimetric	mg/l	0.002	0.002	0.002	(-)	Laboratory
C	**Microbiological**							
1	Fecal Coli	MPN	100 ml	100	1000	1000	2000	Laboratory
2	*E. coli*	MPN	100 ml	1000	5000	10000	10000	Laboratory

Source : (8)

2. Storet Method

Storet method is applied to identify parameters that comply or do not comply with the water quality standard issued [9]. In principle, Storet method is used to define the quality status of water by comparing the actual measured values of water quality parameters with the values listed in the water quality standard [17]. The quality status of water was determined using value system developed by EPA (US Environment Protection Agency) that classified the quality status of water in four classes [18]. See Table 2 below.

Table 2. Classification of water quality status determined using Storet Method.

No.	Class	Category	Scores	Explanation
1.	A	Very Good	0	Standard quality
2.	B	Good	-1 s/d -10	Slightly polluted
3.	C	Moderate	-11 s/d -30	Moderately polluted
4.	D	Worse	≥ -31	Severely polluted

Source: [9]

The measured value of a parameter that is lower than the value in the water quality standard is scored zero. If the measured value does not comply with the value in the water quality standard (measured value > standard value), the score is negative and determined according to the rule. Total negative values of all parameters are counted and the water quality status is determined using EPA value system (Table 3). The characteristic of aquatic biota inhabiting the water of Separi River was analyzed using index of diversity, index of homogeneity, index of dominance, and Simpson's reciprocal index of diversity.

Table 3. EPA value system to determine the quality status of water

Number of parameter per sample [1]	Value	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

Source: [18; 19]

Note: [1] Total parameter per sample used to determine the water quality status

Multiple regression analysis was applied to know the relationship between the number of fish species, plankton species, or benthos species (Y) and some water quality parameters (X).

a. Index of Diversity

Formula from Shannon-Wiener (H') was applied to observe the diversity of species as follows[20]:

$$H' = -\sum \left[\frac{ni}{N}\right] \log \left[\frac{ni}{N}\right]$$

The diversity of species is determined using the following criteria:

H' < 1: low species variation, unstable community

H' 1-3: moderate species variation, moderate community

H' > 3: high species variation, stable community

b. Index of Homogeneity

Index of homogeneity illustrating the distribution of inter-specific individuals in a community was determined according to formula from Odum[20]. The E value is used considering that some species of aquatic biota have an adaptive behavior to a certain level of pollution. Index of homogeneity is shown by the following equation:

$$E = \frac{H'}{\ln(S)}$$

The value of E is ranging from 0 to 1. If E is approaching 1, the inter-specific individuals are evenly distributed. And in contrary if E is 0, the inter-specific individuals in community are not well distributed. The following criteria are used to define the homogeneity of species:

$0.00 < E \leq 0.50$: community in stress condition

$0.50 < E \leq 0.75$: community in unstable condition

$0.75 < E \leq 1.00$: community in stable condition

c. Index of Dominance

Index of dominance is used to show the domination of certain species in a community and in this study Simpson's index of dominance was applied[20 dan 21], as follows:

$$D = \sum \frac{(ni)^2}{N^2}$$

D value ranges from 0 to 1, and the interpretation is if:

D close to 1: certain species is dominant in community

D close to 0: no dominant species in community

d. Simpson's Reciprocal Index of Diversity

Simpson's reciprocal index of diversity is applied to indicate the level of pollution in the water. The equation is[21]:

$$(1 - D) = 1 - \sum \frac{(ni)^2}{N^2}$$

Based on this index, the level of water pollution can be classified in three levels [20] i.e.:

1 - D > 0.8 : slightly polluted

1 - D = 0.6-0.8 : moderately polluted

1 - D < 0.6 : heavily polluted

e. Multiple Regression Analysis

Multiple linear regression is used to know the relationship between the number of fish species, plankton species, or benthos species (Y) and some water quality parameters (X_1, X_2, X_3, X_4, X_5). The multiple linear regression was applied according to[22] and[23]: $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$

III. RESULT

A. Biophysical Condition

In the last decade, many coal mining companies developed in Separi area, since in fact the earth of Separi contains large coal resources. Wastes from coal mining activities contaminated water resources and paddy fields. The turbidity of river water and sedimentation in paddy fields was increasing. Coal mining activities surrounded most villages and operated in between river flow. Coal mining operation starting with land clearing and destroying land covering vegetations gave negative impacts to the increasing rate of erosion and to the extinction of wild species.

The increasing rate of run-off debit during rainy season will be followed with the increasing intensity of ground surface erosion, water turbidity, and river bottom sedimentation. Coal mining activity for long term period will bring about accumulative negative impacts to the environment in the form of natural resources degradation, pollution, increasing turbidity of river water and sedimentation.

1. Temperature

Water temperature (Fig. 2) in all sample sites complied with the water quality standard. Temperature did not fluctuated more than 2 ^{0}C, except in Sampling Site 2 that the fluctuation was recorded more than 3 ^{0}C. This may be caused by the fact that the water debit in Sampling Site 2 was low and no trees grown in river bank to protect the river water from direct sunlight during day time.

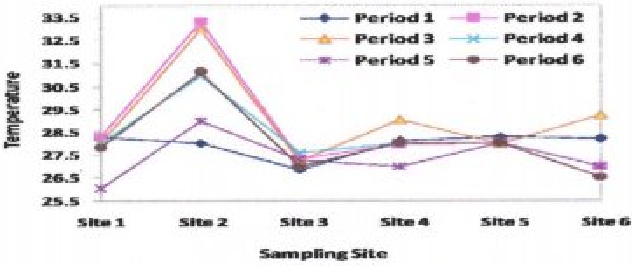

Figure 2. Fluctuation of water temperature at all sampling sites in Separi River flow

2. Total Suspended Solids (TSS)

TSS consists of suspended organic and inorganic particulates, and suspended colloids. Concentration (Fig. 3) of TSS at Sample Site 2 was recorded high (400 mg/L) and exceeded the value listed in the water quality standard Class 4 indicating that the water is only able to be utilized for any purposes after treated with multilayer treatments[8].

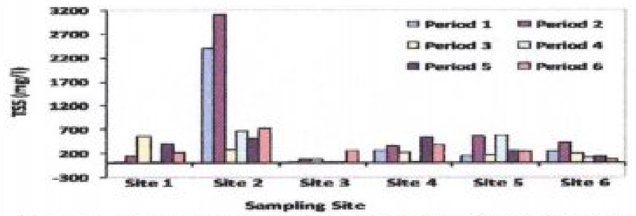

Figure 3. Concentration of TSS at all sampling sites in Separi River flow

3. Total Dissolved Solids (TDS)

The maximum allowable concentration of TDS (Fig. 4) for water criteria Class 1 to Class 3 is 1000 mg/L, and for Class 4 is 2000 mg/L[8]. Concentration of TDS in water may be derived from rock weathering, soil erosion, and from anthropogenic sources.

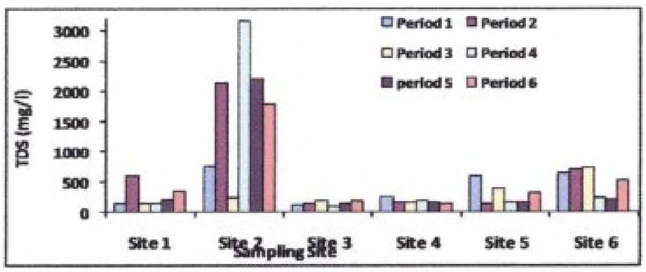

Figure 4. Concentration of TDS at all sampling sites in Separi River flow

The concentration of TDS exceeding the water quality standard Class 4 was only detected in Sampling Site 2. This site is located in between community settlements, paddy fields, and coal mining operation. The river flow in this site received wastes from villages, and coal mining activities. The value of parameters from other sampling sites still in ranges complied with the water quality standard.

4. Colour and Turbidity

The concentration of colour (Fig. 5) and turbidity in Sampling Site 2 was measured high exceeded the value allowable for the water quality criteria Class 4. The increase in turbidity was parallel with the changing of water colour. High turbidity will limit the existence of aquatic biota in water, because it hinders phytoplankton photosynthesis, disturbs respiration of fish, and even causes fish death.

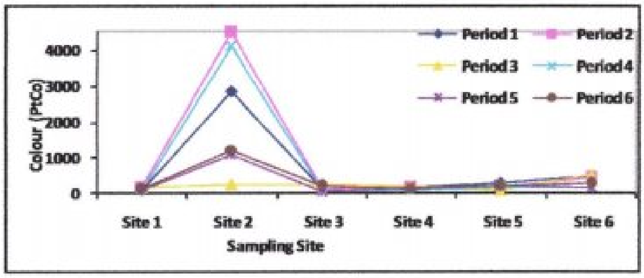

Figure 5. Fluctuation of water colour at all sites in Separi River flow

Turbidity caused by suspended soil particles seldom gives direct and prompt effect on fish population. Turbidity caused by clay will hamper light penetration for photosynthesis and have bad effect to productivity[24]. Particles deposited on the bottom will cover fish egg and benthos community.

5. pH

In situ measurement of pH showed that the value of pH in all sampling sites ranged from 6 to 8, except in Sampling Site 4, the pH value was 5-6. Referring to Government Regulation No. 82/2001, pH value in Sampling Site 4 was recorded lower than the value in the water quality criteria Class 1, 2,and 3 (pH 6-9) but it conformed with water quality criteria Class 4 (pH 5 - 9). The low pH is indicating acidity caused by the increase of carbon dioxide concentration released from the decomposition of organic matters.

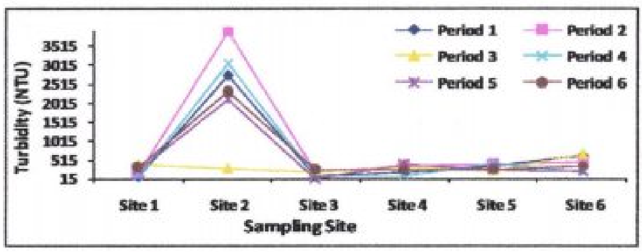

Figure 6. Water turbidity at all sites in Separi River flow

6. DO, BOD_5, and COD

Comparing to the water quality standard Class 1 and 2, the concentration of DO in all sampling sites was still in ranges of allowable minimal value. The value of COD in almost all sampling sites was still in the value range of water quality criteria Class 1, 2, and 3. But COD concentration in Sampling Site 2 was bad and included in the category of Class 4. Standard acceptable value of COD according to [8] is > 50 - < 100 mg/L for Class 4.

River should provide enough oxygen to decompose waste organic substances chemically. COD indicates the total oxygen consumed for the oxidation of easily degradable organic substances and more resistant organic matters to release CO_2 and H_2O. High concentration of COD was detected in the water from Sampling Site 2 with bad water quality condition.

7. NH_3, NO_3, and NO_2

The concentration of ammonia (NH_3-N) was detected lower than the allowable maximal value listed in the water quality standard according to [8], i.e. 0.5 mg/L. Nitrite (NO_2) concentration detected was also lower than water quality standard Class 1-3, i.e. 0.06 mg/l. Nitrate concentration in all sampling sites complied with maximum allowable concentration written in the water quality standard Class 1 – 4 i.e. 10 – 20 mg/L. The covering of vegetation along riparian area may function as natural biological filter.

8. PO_4-ortho and H_2S

The concentration phosphate measured at all sample sites was increasing exceeding the maximal allowable value according to the water quality standard of Government Regulation No. 82/2001. The highest concentration was recorded in Sampling Site 3 where the riparian area near this site was utilized for agriculture activities by local community.

Concentration of hydrogen sulphide in all sample sites was generally low and in the range of tolerable concentration i.e. < 0.1 mg/L. Hydrogen sulphide is bad smell gas and harmful to aquatic organism released from anaerobic decomposition of organic substances.

9. Coliform and E.coli

Total coliform/100 ml in all sampling sites was recorded below the ambient standard (> 1.000 – 5.000/ml), except in Sampling Site 2. The total coliform in Site 2 was counted 4.600/100 ml and included in the status of Class 2. This result was reasonable since Sampling Site 2 located near the people settlement.

Total coliform that was even counted low in Sampling Site 6 is very potential to increase, because the site is also located near people settlement and crop plantation. Thus wastes from domestic activities and agricultural residues will discharge into the river which frequently flows in low debit. According to Badiamurti and Muntalif (2013) the presence of bacterial pathogen in river water can be identified through the presence of bacterial coliform.

B. Water Quality Status

The analysis of STORET method to determine the quality status of water showed that the water quality in all sampling sites did not comply with water quality standard Class 1 with total score ranged from -44 to -71 (Table 4). The water was categorized as heavily polluted, since the score was > - 31. The water in all sampling sites is recommended not to be utilized as source for drinking water or for any other purposes with the same requirements.

Water quality in sampling site 1, 2, 5, and 6 did not comply with the water quality standard Class 2 and it was included as heavily polluted with score ranging from -32 to -41. Some water quality parameters having values exceeding the values of water quality standard Class 2 with worse condition were TSS, TDS, pH, Colour, DO, BOD_5, COD, NO_2-N, and PO_4-ortho. Water quality in Site 3 and 4 did not meet the water quality standard Class 2 with scores ranging from -17 to -28 and it was categorized as moderately polluted. Some parameters having values exceeding the values of water quality standard Class 2 at moderate level of pollution were TSS, colour, pH, DO, BOD_5, COD, NO_2-N, and PO_4-ortho. The water in these sites is suggested not to be used for recreation related activities, aquaculture, animal husbandry, crop irrigation, and other purposes with similar requirements.

Table 4 Analysis of Storet used in determining the quality status of water in Separi River

No	Site	Class Category and Total Score			
		Class 1	Class 2	Class 3	Class 4
1	Site 1	-62 (D)	-32 (D)	-13 (C)	-1 (B)
2	Site 2	-71 (D)	-41 (D)	-26 (C)	-11 (C)
3	Site 3	-44 (D)	-17 (C)	-3 (B)	0 (A)
4	Site 4	-46 (D)	-28 (C)	-12 (C)	0 (A)
5	Site 5	-57 (D)	-40 (D)	-16 (C)	-2 (B)
6	Site 6	-56 (D)	-39 (D)	-21 (C)	-5 (B)

Note: D= worse, C = moderate, B = good, A= very good

The water quality in Sampling Sites 1,2,3,5 and 6 did not fulfil the water quality standard Class 3 with scores ranging from -12 to -26, and it was moderately polluted. Water quality parameters having scores exceeding the values of water quality standard Class 3 at moderate condition, were TSS, TDS, pH, colour, BOD_5, COD, NO_2-N, and PO_4-ortho. Water quality in Site 3 did not meet the water quality standard Class 3 with scores -3 and included as slightly polluted. Water quality parameters having scores exceeding the values of water quality standard Class 3 at slightly polluted were colour and NO_2-N. The water in all sample sites except in Site 3, is not recommended to be utilized for fish culture, animal husbandry, crop irrigation and for other uses with similar requirements.

Water quality in Sampling Site 2 did not comply with water quality standard Class 4 with total scores -11, and included as moderately polluted. Water quality parameters having scores exceeding the values of water quality standard Class 4 with moderate condition were TSS, colour, and COD. The water quality from sampling sites 1, 5 and 6 complied with the water quality standard Class 4 with scores ranging from -1 to -5 and categorized slightly polluted. Water quality parameter having scores exceeding the values of water quality standard Class 4 at slightly polluted condition was TSS and colour. Water quality in Sampling Site 3 and 4 was in very good condition and not polluted. The water in all sampling sites except in Sampling Site 2 was in good condition and can be used to irrigate crops and for other uses with similar requirements.

C. Aquatic Biota

1. Fish Community

Fish has an ability to respond the changes of water quality and may become an indicator for water pollution. From 149 total individuals of fish caught in all sampling sites, 23 species of fish from 9 families was successfully identified. Almost half of all species or as many as 11 species came from the class of Cyprinidae as a specific character of river fish in Indonesia. The most abundant species caught in Sampling Site 3 were *Labiobarbus festivus* and *Parachela oxygastroides* (class Cyprinidae), and *Ompok bimaculatus* (class Siluridae). The abundant species caught in Sampling Site 1 and 5 was *Cyclocheilichtys apogon from* class Cyprinidae (Table 5).

Cyprinids include as fast swimming fish and have an ability to adapt with flowing stream. The species is able to move fast avoiding extreme condition in water and looking for safer environment. The fish caught from Sampling Site 3 where aquatic weeds densely growing were specifically more diverse.

This study found that the number of individual and species of fish was distributed almost evenly in all sampling sites, except in Sampling Site 3. The riparian area in Sampling Site 3 was covered by dense vegetation and received less pollution, so it provided good habitat for various species of to grow.

The characteristic of aquatic biota in all sampling sites based on their diversity (H'), homogeneity (E), and dominance (D) was similar, except at Sampling Site 2. At all sample sites except at Sample Site 2, the diversity of fish was moderate, and the homogeneity (E) was distributed or stable, and no dominant species was found. Although at some sampling sites there was a difference in total individual and species of fish, but the diversity was averagely moderate and the homogeneity was evenly distributed. The diversity and homogeneity of fish species at Sampling Site 2 was low and unstable and dominated by certain species. Fish catch in this site was the lowest, due probably to the worse water quality condition caused by high turbidity, shallow water, and low flow debit. Coal mining wastes flowing into this site worsened the condition of water quality for the welfare of aquatic organisms.

Table 5. Structure of fish population at six sampling sites in Separi River

No	Family/Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Total
A	**Cyprinidae**							
1	*Barbodes gonionotus*			7				7
2	*Cyclocheilichthys apogon*	6				8	1	15
3	*Hampala macrolepidota*			2	1			3
4	*Labiobarbus festivus*			22				22
5	*Leptobarbus hoeveni*	1				1	1	3
6	*Osteochilus enneaporos*	1						1
7	*Osteochilus hasselti*			6	2			8
8	*Parachela oxygastroides*			21		1	1	23
9	*Puntioplites waandersi*	2			2	3	1	8
10	*Rasbora caudimaculata*			10				10
11	*Thynnichthys thynnoides*			8				8
B	**Channidae**							
12	*Channa striata*	2		2			1	5
C	**Clariidae**							
13	*Clarias batrachus*			1				1
14	*Clarias* [illegible]			1				1
D	**Siluridae**							
15	*Kryptopterus lais*		1		1			2
16	*Ompok bimaculatus*	1		17		1	2	21
17	*Ompok* [illegible]					1	1	2
E	**Bagridae**							
18	*Mystus micracanthus*		2					2
19	*Mystus planiceps*				1			1
F	**Synbranchidae**							
20	*Monopterus albus*			1				1
G	**Eleotrididae**							
21	*Oxyeleotris marmorata*				1			1
H	**Pristolepididae**							
22	*Pristolepis fasciata*			3				3
I	**Soleidae**							
23	*Synaptura panoides*	1						1
	Total individu	14	3	102	8	14	8	149
	Total species	7	2	17	6	6	7	23
	H' - diversity	1.67	0.56	2.24	2.26	1.75	1.73	
	E - homogeneity	0.86	0.53	0.82	0.82	0.89	0.79	
	D - dominance	0.24	0.7	0.13	0.13	0.21	0.26	
	1-D - reciprocal diversity	0.76	0.3	0.87	0.87	0.79	0.74	

Fish species capable to adapt with relatively extreme environment because they have arborescence organ (an additional respiratory organ) are species from the class of Channidae, Clariidae, and Siluridae. Fish adaptable to inhabit the dark and turbid habitat are species from the class of Bagridae, Synbranchidae, and Eleotrididae species. Relationship between the number of fish species (Y) and temperature (X_1), TSS (X_2), TDS (X_3), colour (X_4), and turbidity (X_5) is shown by the following equation $Y = 8{,}657 – 0{,}101\ X_1 - 0{,}002\ X_2 – 0{,}013\ X_3 - 0{,}008\ X_4 + 0{,}021 X_5$. ($r = 0{,}792$; $R = 0{,}628$). And the relationship with pH (X_1), DO (X_2), COD (X_3), and BOD_5 (X_4) is indicated by equation $Y = - 8{,}503 – 1{,}105\ X_1 + 2{,}054\ X_2 + 0{,}043\ X_3 + 3{,}501\ X_4$. ($r = 0{,}648$; $R = 0{,}419$). The relationship between number of fish species and the mentioned water quality parameters is positively and fairly strong.

As indicated by the reciprocal index of Simpson diversity, the water in Sampling Site 2 was categorized as heavily polluted with diversity index of 0.3. The diversity index of water in Sampling Site 1, 5, and 6 ranged from 0.74 to 0.79 indicating that the water was moderately polluted. The water in Sampling Site 3 and 4 was slightly polluted with average diversity index of 0.87.

2. Plankton Community

Plankton in water affects the life of other organisms since plankton are source of food for others like fish. Phytoplankton species from the class of Cyanophyceae and Crysophyceae were identified almost in all sampling sites (Table 6) and zooplankton species was mostly identified from the Class Mastigophora (Table 7).

Table 6. Structure of phytoplankton population at all sampling sites in Separi River

	Phytoplankton	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Total
	Chlorophyceae							
1	*Closterium* [illegible]	189						189
2	*Closterium moniliferum*	126			63			189
3	*Closterium* [illegible]	126						126
4	*Cosmarium* [illegible]						126	126
5	*Spirogyra varia*	126						126
6	*Staurastrum longiradiatum*				189		126	315
7	*Ulothrix aequalis*	315	315	315				945
8	*Cosmarium* [illegible]	63						63
9	*Pediastrum boryi*	126			63		189	378
10	*Pleurotaenium sp*	63						63
11	*Xanthidium* [illegible]	252			126			378
	Cyanophyceae							
12	*Oscillatoria sp*	189	315	126	126	252	378	1386
13	*Spirulina major*		63					63
	Crysophyceae							
14	*Melosira* [illegible]	126						126
15	*Navicula sp*		126			63	126	315
16	*Nitzschia sp*	189	315	126	252	126	378	1386
17	[illegible]	315	189	189	315	126	504	1638
18	*Surirella robusta*	63		315	126			504
19	*Synedra ulna*	126	126		189	315	315	1071
	Sub Total	2394	1449	1071	1449	882	2142	9387

Relationship between the number of plankton species (Y) and some water quality parameters as temperature (X_1), TSS (X_2), TDS (X_3), colour(X_4), and turbidity (X_5) is

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shown by equation $Y = 2551{,}355 - 69{,}582\ X_1 - 0{,}101\ X_2 + 0{,}256\ X_3 + 0{,}128\ X_4 - 0{,}362\ X_5$ with weak relationship ($r = 0{,}372$). The weak relationship in this case is reasonable since plankton is microorganism greatly affected by water flow. The water quality in all sampling sites was also very changeable from time to time and hardly related to the presence of certain species of plankton. The high turbidity of water flow was not favourable either for the growth of plankton, especially phytoplankton.

If the diversity index of Shannon-Wiener (H') is used to predict water pollution, the water quality at all sampling sites was found moderately polluted with index values ranging from 2.06 to 2.93. And if the Simpson diversity index is used, the level of water pollution at all sampling sites was slightly polluted with index values ranging from 0.86 to 0.93.

Saprobic index can be used also to know the level of dependency of certain species on its source of nutrition, and thus to relate the abundance of plankton to the level of water pollution. In this study, the species *Closterium spp* includes α-mesosaprobic (high level pollution) plankton and *Pediastrum biwae* dan *Spirogyra sp.* are β-mesosaprobic (moderate level pollution) plankton. *Staurastrum longiradiatum* and *Ulothrix aequalis* includes as oligosaprobik (low level pollution) plankton. Saprobic systems currently are applied in European countries but there are no concrete activities (according to the knowledge of the authors) [25].

Table 7. Structure of zooplankton population at all sampling sites in Separi River

	Zooplankton	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Total
	Mastigophora							
20	*Euglena acus*		315				126	441
21	*Euglena oblonga*	756	315	126	504		189	1890
22	*Euglena viridis*	504	378	189	504	126		1701
23	*Phacus undulatus*	315	567	126	315	63	189	1575
24	*Strombomonas fluviatilis*	126	126		63			315
25	*Trachelomonas sp*	126	252	126				504
26	*Trachelomonas schauinslandii*			63				63
27	*Trachelomonas oblonga*	126	126	252				504
28	*Trachelomonas volvocina*	63			63	126	126	378
29	*Peridinium bipes*			119				119
	Sarcodina							
30	*Arcella vulgaris*	504	378	378	630	252	252	2394
31	*Difflugia globulosa*			126				126
	Rotatoria							
32	*Brachionus calyciflorus*				63			63
33	*Trichocerca longiseta*	126			252		126	504
34	*Keratella cochlearis*						189	189
	Crustacea							
35	*Cyclops sp*		126	63			63	252
Sub Total		2646	2583	1764	2394	567	1260	11.114
Total Individual		5.040	3.072	2.835	3.743	1.638	3.402	20.[illegible]
Number of species		24	16	15	17	9	16	
Diversity (H')		2.93	2.64	2.58	2.58	2.06	2.43	
Homogeneity (E)		0.93	0.95	0.95	0.91	0.94	0.95	
Dominance (D)		0.07	0.08	0.08	0.09	0.14	0.08	
Simpson's Diversity (1-D)		0.93	0.92	0.92	0.91	0.86	0.92	

Oscillatoria sp. from class Cyanophyta and *Nitzschia* sp. from class Crysophyceae was plankton species identified at all sample sites. Species of plankton that produces mucous, changes water colour, and excretes corrosive substance in water is *Oscillatoria* sp. *Nitzschia* sp (Crysophyceae) is an indicator for water pollution [26].

Plankton *Melosira sp* (Crysophyceae) was only found at Sampling Site 1. *Melosira* is one species of phytoplankton that can be found in clean water [26]. Sampling Site 1 is located at the mouth of Separi River where the water flow from Separi River meets the water flow of Mahakam River. The water flow from Separi River was generally more turbid than the water flowing from Mahakam River. Thus the water quality at this site was very changeable between bad to good condition influenced greatly by the movement of tide. *Nitzschia sp* (Crysophyceae) identified at Sampling Site 1 was an indicator to show that the water in this site was polluted too. Plankton *Navicula sp* (Crysophyceae) was only identified at Sampling Site 2, 5 and 6 and *Oscillatoria sp* (Cyanophyta), *Spirogyra* (Chlorophyceae), *Navicula sp* and *Nitzschia sp* (Crysophyceae) are bio-indicators to predict water pollution [26].

4. Benthos Community

There were only 3 families of benthos identified in Separi River bottom i.e. Gastropoda, Pelecypoda, dan Oligochaeta (Table 8). *Pleurocera acula* from class Gastropoda was found at all sample sites, but *Lumbricus sp* from class Oligochaeta was only identified at Sampling Site 3. Diversity Index (H') of benthos at Sampling Site 1, 2, 3, and 5 ranged from 0 to 0.89 indicating that almost all sample sites in this study had low benthos diversity, low distribution of individual species per m², and low stability of benthos community. Sample Site 4 and 6 had moderate diversity, moderate distribution of individual species per m², and moderate stability of benthos community. At Sampling Site 5 was found very few benthos species, because at the time of sampling there was an activity of river normalization in the form of river bottom dredging and river widening by land cutting and sliding.

Table 8. Structure of benthos population at all sampling sites in Separi River

No.	Benthos Species	Sampling Site						
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Total
A.	**Gastropoda**							
	Brotia sp	39	-		65		-	104
	Bellamya sp	-	221		-		26	247
	Pleurocera acula	143	429	598	143	117	208	1638
	Pomacea lamellata	-	-		26		26	52
B.	**Pelecypoda**							
	Anodonta cygnea	39	-		-		26	65
	Corbicula sp	-	65		65		52	182
C.	**Oligochaeta**							
	Lumbricus sp	-	-	13	-		-	13
Total individual benthos/m²		221	715	611	299	117	338	2301
Number of Species		3	3	2	4	1	5	
H' diversity		0.89	0.89	0.1	1.25	0.0	1.18	
E homogeneity		0.81	0.81	0.1	0.90	0.0	0.73	
D' dominance		0.48	0.46	0.9	0.33	1.0	0.42	
1-D reciprocal diversity index		0.52	0.54	0.1	0.67	0	0.58	

Homogeneity Index (E') of benthos in Sampling Site 3 and 5 was ranging from 0,00 to 0,15 indicating that species were not spread evenly and not dominated by certain species, and it was assumed that the community was in stress condition. The benthos at Sampling Site 6 with the score of 0.73 showed that the benthos community was in unstable condition, and at Sampling Site 1, 2, and 4 with the scores ranging from 0.81 to 0.89, the benthos community was stable and evenly distributed. The score for index of dominance ranging from 0.33 to 0.48 at Sampling Sites 1, 2, 4, and 6, and ranging from 0.96 to 1.00 at Sampling Site 3 and 5 showed that was no dominant species of benthos in the community.

Linear equation showing relationship between the number of benthos species (Y) and temperature (X_1), TSS (X_2), TDS (X_3), colour (X_4), and turbidity (X_5) was $Y = 1356{,}461 - 21{,}310\ X_1 - 0{,}816\ X_2 + 0{,}153\ X_3 + 0{,}012\ X_4 - 0{,}248\ X_5$ (r = 0,444 and R = 19,7 %). Habeeba et al. (2012) found that some benthos families had negative relationship with temperature and TDS as for example for Oligochaeta, and had positive relationship with transparency, TDS, and water depth as for Cladocera.

Based on reciprocal diversity index for benthos, it was found that the level of water pollution at all sampling sites was categorized as moderately to heavily polluted water with average score of 0.67. The water was heavily polluted if the index < 2 [6]. The water is moderately and heavily polluted if the diversity index is < 1 and in between 1-3 [4; 5].

IV. CONCLUSION

Based on this study the condition of biophysical environment of Separi River in the District Kutai Kartanegara may be concluded as follows:

1. The diversity of aquatic biota (fish, plankton, and benthos) at all sample sites was in low to moderate category, their homogeneity was in low to evenly distributed category, and both dominant and not dominant category of species were found.
2. Fish from class Siluridae and Bagridae can still be found in the water with category of moderately polluted Class 4.
3. Phytoplankton from class Chlorophyceae (*Spyrogira* sp), Cyanophyceae (*Oscilatoria* sp), Chrysophyceae (*Nitzschia* sp and *Navicula* sp) can be used as bio-indicators to predict water pollution
4. Based on reciprocal index of plankton diversity, the water at all sampling sites was included as slightly polluted, but based on benthos diversity the water at all sampling sites was categorized as moderately to heavily polluted.
5. The quality status of water at all sampling sites based on physical, chemical, and biology parameters was included in the category of Class 4, indicating that the water can be utilized only to irrigate agricultural crops or for other uses with similar requirements.
6. Coal mining operations in the watershed area of Separi River and the activities of river normalization by dredging, land cutting and sliding, and land clearing gave negative impacts to forest stands and aquatic biota.
7. The pollution of water environment caused by wastes released from soil erosion and coal mining activities brought about disadvantages for local people as water users living in the riparian area.

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