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[Abstract] Full Text: (PDF) [References]

Sustainable Development Concept Implementation in Environmental Education

Alla A. Marchenko, Alla A. Korzhanova, Galina A. Kamalieva, Ivan A. Sharonov, Marina G. Lichutina, Sergey S. Sharov, Olga V. Vashechkina, Petr K. Varenik

Issue: 107, **Pages:** 219-227, **Article No:** e107076, **Year:** 2019

[Abstract] Full Text: (PDF) [References]

The Environmental Study on Evaluation of Water Quality at Prafi River, Manokwari, West Papua Using Macrozoobenthos Biotics Index and Physicochemical of Water Parameters

Sabarita Sinuraya, Endang Arisoesilaningsih, Suharjono, Catur Retnaningdyah

Issue: 107, **Pages:** 229-236, **Article No:** e107015, **Year:** 2019

[Abstract] Full Text: (PDF) [References]

Effects of Organizational Justice on Organizational Climate and Organizational Performance in Ecology Industry

Ling-Chuan Huang, Ming Gao, Ping-Fu Hsu

Issue: 107, **Pages:** 237-241, **Article No:** e107077, **Year:** 2019

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The Environmental Study on Evaluation of Water Quality at Prafi River, Manokwari, West Papua Using Macrozoobenthos Biotics Index and Physicochemical of Water Parameters

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Abstract

Globally, pollution of rivers and streams has become one of the most crucial environmental problems of the 20th century. This study aimed to determine the water quality along the Prafi River at Manokwari, West Papua, using some macrozoobenthic biotic index and chemical physics of water parameters. The location grouping was done using cluster and biplot analysis based on a macrozoobenthic biotic index and water chemical physics. Sampling was done based on the Purposive Random Sampling method in different part of river, such as upper (no human activities), plantation, dam, irrigation and fisheries, oil palm plantation, domestic, agriculture and livestock, and fishing area. In all locations, the results showed that the pH ranged from 7.80—8.36 and biochemical oxygen demand (BOD) from 0.53—5.51 mg/L. Prafi river was dominated by high activities of human and had an impact on poor water quality based on macrozoobenthos biotic index (Family and Hilsenhoff, respectively) but taxa score (ASPT) showed lightly polluted. Based on cluster and biplot analysis, half more of Prafi River was also dominated by polluted water in downstream site. Biologically, the polluted water could be identified by high percentage of Chironomidae around the river.

Keywords: biotic index, macrozoobenthos, Prafi River, water quality, environmental conditions

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INTRODUCTION

The Prafi River in Manokwari, Papua is utilized by communities along the river to meet the needs of life such as bathing, washing, latrines, agriculture/plantation, fisheries, tourist attractions, reservoirs for hydropower, irrigation reservoirs, livestock and oil palm plantations. All the human activity along the Prafi River ultimately discharges its waste into aquatic bodies. This can negatively affect the river ecosystem, i.e., causing changes in the water quality and the structure of the aquatic biota community (Singh et al. 2013).

Changes in the structure of the Prafi River community indicates in the downstream areas due to the use of teodan and electric socker in free fishing. The use of theodans resulted in a very disturbed ecosystem balance, decreased fish catch, which had an impact on the economic decline of the community (Fadli 2015). Based Dwiranti et al. (2014), it is noted that high cases of diarrhea and skin diseases in the community happen because the source of water used does not meet health standards. A preliminary study of the area found out a fact that the existence of oil palm and dam plantation activities has resulted on silting and decreasing the quality of water which gives a severe impact on river water that can not be utilized for bathing activities.

Changes in the structure of the diatom community in several locations of Prafi River indicate that there has been a decrease in water quality. In the context of proper management, a more thorough evaluation of water quality is required. Water quality monitoring can be done in physics, chemical, and biological analysis. One of the best water biota used as bioindicator is benthic macroinvertebrate (Hakwes 1979). Some of the benefits of monitoring using macrozoobenthos as bioindicators are easy to do, fast and relatively low cost and can provide a clear picture of water because the nature of

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Table 1. Sampling location or observation sites on Pravi river

No.	Observation site	Label
1.	Upper (no human activities)	1
2.	Plantation area	2
3.	Dam	3
4.	Irrigation reservoir	4
5.	Oil palm plantation	5
6.	Domestic area	6
7.	Agricultural and livestock area	7
8.	Fishing area	8

these macrozoobenthic organisms can rapidly respond to pollutants and environmental changes (Singh et al. 2013, Kahveci et al. 2018).

The determination of the water quality category through the macrozoobenthos as a bioindicator can be based on biotic indexes. Some macrozoobenthic indexes are used as bioindicators to determine the organic material contamination called FBI (Family Biotic Index) and HBI (Hilsenhoff Biotic Index). Moreover, the ASPT (Average Score Per Taxa) index is used to identify the level of contamination with toxic substances (Retnaningdyah and Arisoesilaningsih 2014). Also, the presence of several species of insects of the Ephemeroptera, Plecoptera and Trichoptera orders can be indications of water quality which is still good (Rini 2007). Thus, this research was aimed to evaluate the water quality along Prafi River at Manokwari, West Papua, using a macrozoobenthic biotic index and the chemical physics of the water parameters.

MATERIALS AND METHODS

Study Area

This research was conducted on Pravi River, Manokwari. The sampling locations were determined using purposive random sampling and divided into eight observation sites (**Table 1**).

Measurement of Physicochemical and Macrozoobenthos Biotic Index

The measurement of physicochemical analysis was peformed based on pH, turbidity, biochemical oxygen demand (BOD) with three replications in each area. Macrozoobenthos biotic index was measured by collecting macrozoobenthos around the observation sites. Macrozoobenthos was collected by surber and hand net until at least 100 individual organism were obtained in each location and repeated in three times. Sample was preserved in 70 % ethanol identified using a stereo microscope in an Environmental and Animal Diversity Laboratory, Brawijaya University. The identification was carried out using the Jutting and Benthem identification key (1956), Edmonson (1963), and Quigley (1977). Average score per taxa (ASPT), Family and Hilsenhoff biotic index (FBI and HBI, respectively), and percentage of EPT (Ephemeroptera, Plecoptera, Trichoptera) and Chironomidae were used for macrozoobenthos biotic index.

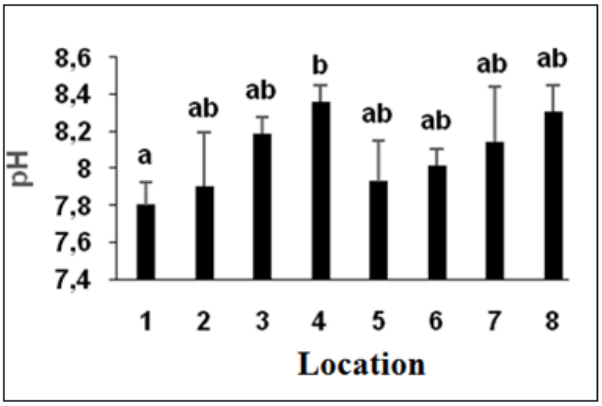

Fig. 1. The pH level from eight locations in Pravi river. **Note:** Graph followed by different letter showed significantly different at 5 %

Data Analysis

Different values of each chemical physics parameter using the analysis of variance (ANOVA) and Brown–Forsythe test at 5 %. The location groupings were based on the macrozoobenthic biotic index, and the chemical physics parameters were analyzed by cluster and biplot analysis. Data analysis test performed used PAST version 3.19.

RESULT AND DISCUSSION

Physicochemical Water Quality of Pravi River

The pH level

The degree of acidity or pH at the eight sites ranged from 7.80 to 8.36. This value was categorized as class I (very good) water quality based on Indonesian Goverment Regulation no. 82/2001 which set a pH value ranging from 6 to 9. Locations 2, 3, 5, 6, 7 and 8 have relatively similar pH values, indicated by the same notation (**Fig. 1**). The increase of pH may be caused by various activities that take place at this location, such as bathing, washing, extracting stone or sand, or as a place of recreation for people either from Prafi or from outside Prafi. Increased levels of detergent in aquatic bodies can increase the pH value to the alkaline range from pH 10 to 11 (Sastrawijaya 2000). The low water pH might be caused by high degree of ionized acidic substance inside. Effendi (2003) stated that ionized ammonium content released by human sewage can cause the pH in the water to be lower.

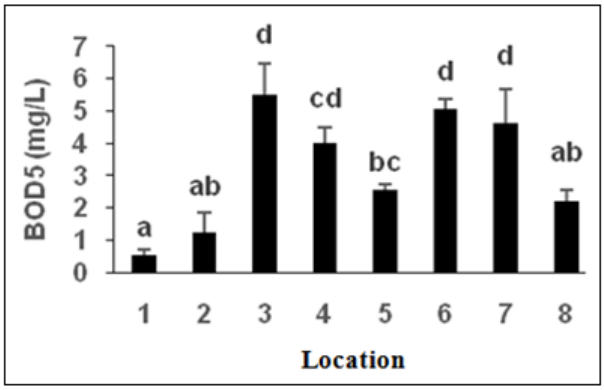

Fig. 2. The biochemical oxygen demand (BOD) level from eight locations in Pravi river. **Note:** Graph followed by different letter showed significantly different at 5 %

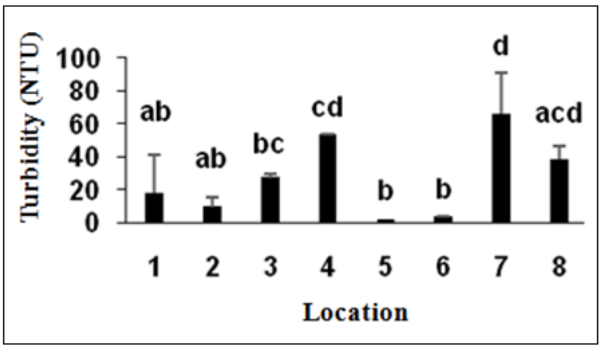

Fig. 3. The turbidity level from eight locations in Pravi river. **Note:** Graph followed by different letter showed significantly different at 5 %

Biochemical oxygen demand (BOD) level

The Biochemical Oxygen Demand (BOD) value in all location ranged from 0.53 to 5.51 mg/L. That value complied with the class III (normal) water quality standard which set below 6 mg/L. Locations 3, 6, and 7 have a relatively high degree of similarity, indicated by the same notation (**Fig. 2**). The BOD value of the research results was farther from the upstream so the higher the BOD value. This may be due to the existence of a variety of higher level of activities along the waters of the Prafi such as dam construction, toilets, recreation, sand and stone retrieval, agriculture, and animal husbandry. Aerobic microorganisms need more oxygen to decompose the organic compounds resulting from these activities (Effendi 2003).

Turbidity level

Turbidity values in all location ranged from 1.93—66.36 NTU. Turbidity values at location 5 and 6 were qualified in maximum turbidity (< 5 NTU) based on WHO in Wakman et al (2015) for drinking water and 1, 2, 3, 5 and 6 were categorized into fish farming activities with turbidity value requirements between 2 to 30 NTU (**Fig. 2**) except the turbidity values at location 4,7, and 8 consecutive values of 53.23 NTU; 66.36 NTU and 38.72 NTU. Location 5 and 6 had similar relative similarity, indicated by the same notation. Meanwhile, location 1, 2 and 3 also had similarity levels, but they are significantly different from those of locations 4, 7 and 7 (**Fig. 3**). This indicated a difference in activity at location 1, 2, 3, 5, and 6 with those happened at locations 4,7 and 8. Thus, it affected different turbidity values. Activities of sand and stone taking, agriculture, livestock, using electric socker and various river systems can lead to high turbidity (Meutter 2005). Water turbidity is caused by suspended particle particles such as dust, clay, mud, dissolved organic materials, bacteria, plankton and other organisms in water (Koswara et al. 2015).

Macrozoobenthos Biotic Index of Pravi River

Average score per taxa (ASPT)

The calculated ASPT values of the eight locations ranged from 5.857—7.417 (**Table 1**). Locations 1, 2, 5, 6 and 8 had clean water quality (above 6) based on Mandaville (2002) categorizing. This might be because Plecoptera was found, which was not present at locations 3, 4 and 7. Plecoptera can be used as a bioindicator of good quality water with a high oxygen content and low nutrient concentration (nitrogen and phosphorus) (Tyufekchieva et al. 2013). On the other hand, locations 3, 4 and 7 are classified as having slightly contaminated water quality. This may be caused by the activities of people using fertilizer for gardens on the bank of the river, and there is also the activity of rock and sand dumping. Furthermore, there was much garbage scattered by the river from recreational activities, and other activities of the people around these locations.

Family biotic index (FBI)

The FBI value of the macrozoobenthos is an index that can show the level of pollution of water due to organic matter. The FBI values across all locations ranged from 3.852 to 4.978 (**Table 1**). Locations 1 and 2 have excellent water quality, while locations 3, 4, 5, 6 and 8 are considered to have good water quality based on Mandaville (2002) cetagorizing. Locations 1 and 2 are in the area of the mountains with an altitude of 293–1435 mdpl, so there are still many trees along the water's edge. The population was therefore still sparse, although the community carried out gardening activities. At downstream locations, the altitude ranged from 14–296 mdpl. Thus, there were more and varied activities taking place along the water with a denser

Table 2. Macrozoobenthos index value in Pravi river

Location	Average Score Force (ASPT)	Family Biotic Index (FBI)	Hilsenhoff Biotic Index (HBI)	Ephemeroptera, Plecoptera, Trichoptera (EPT) (%)	Chironomidae (%)
1	7.4/E	3.852/VG	5.726/F	62.845	31.277
2	7.417/E	4.121/VG	5.901/F	41.864	50.441
3	6/F	4.949/G	6.613/FP	60.632	33.768
4	6/F	4.674/G	6.173/F	70.361	23.375
5	6.875/E	4.705/G	6.04/F	77.539	14.760
6	7/E	4.264/G	4.765/G	59.350	14.064
7	5.857/F	4.974/G	5.648/F	89.140	10.169
8	6.25/E	4.978/G	6.6/FP	63.594	14.289

Note: Water quality category: Excellent (E); Very Good (VG); Good (G); Fair (F); Fairly Poor (FP)

population. Hence, it can be said that the condition had decreased from very good to excellent.

Hilsenhoff biotic index (HBI)

The calculation of HBI values from the eight locations ranged from 4.765 to 6.60 (**Table 1**). Locations 1, 2, 4, 5 and 7 (**Table 2**) are classified as having fair water quality which indicates significant and organic significant pollution based Mandaville (2002) categorizing. Location 6 (**Table 1**) is classified as good water quality showing little organic pollution. Locations 3 and 8 (**Table 2**) are relatively weak, indicating significant organic pollution. The quality of water that is classified as moderate and severe is caused by the various activities being carried out along the river that affect it, such as community gardening activities, dam-making, bathing and fishing using thiodan and electric shockers by both the local community and people from beyond Prafi River. The location is easy to reach for recreation purposes and is not yet managed by local government or private companies. Furthermore, there is still much garbage scattered on the riverside by recreational users, as well as sand and stone collecting activity, agricultural activity and farming.

Ephemeroptera, Plecoptera, Tricoptera (EPT) and Chironomidae percentage

The EPT value of macrozoobenthos based on calculations from all locations was more than 50%, except for location 2 with 41.864% (**Table 2**). EPT taxa can be considered to have good water quality (NRCS 2001). However, Chironomidae was found to be more than location 2. Therefore, this location can be categorized in medium quality. Chironomidae is a tolerant pollution-tolerant taxa, the presence of these taxa may indicate the quality of moderately to severe polluted water. The high value of EPT could be caused along the river which there was still abundant riparian vegetation. More nutrients are needed to be able to support the viability of macrozoobenthos, and this can be supplied from riparian vegetation along the water (Lestari and Trihardiningrum 2011).

Water Quality based on Cluster and Biplot Analysis

The water quality at all the observation locations, based on the chemical physics and biotic indices of the macrozoobenthos as bio-indicators of water quality, can be grouped into five groups based on cluster and biplot analysis, as can be seen in **Figs. 3** and **4**. Based on cluster analysis (**Fig. 4**) at a 73% equivalence level, Group I consists of locations 4, 7 and 8, forming one group at an 87% equality level. Group II is a different location to another one and has a similarity within the group of about 78.449%. Group III consists of location 3, and group IV consists of location 1, which has a similarity rate of about 93%. Groups III and IV have a similarity with group II for about 73%. Group V consists of locations 5 and 6, which have a similarity rate of about 89% and similarity with the other groups of about 80%. This grouping is also supported by a biplot analysis that obtains similar results (**Fig. 5**). Based on the cluster and biplot analysis of **Figs. 3** and **4**, it can be seen that locations 4, 7 and 8 are one group characterized by EPT, BOD, HBI, FBI, turbidity and high pH, and moderate Chironomidae, but low ASPT. The EPT value indicates clean water quality, the high HBI and FBI values characterize the water quality in terms of organic material contamination, the low ASPT values indicate pollution from toxic compounds, BOD is still below 5.1, indicating unfrewed waters, high turbidity indicates suspended particles such as dust, clay, mud, and dissolved organic materials from agricultural activities, bacteria, plankton and other organisms in the water, while a high pH is a sign of increased detergent or household waste. The two sites based on biplot analysis (**Fig. 5**) were characterized by high Chironomidae and ASPT, moderate HBI and FBI, while they are slightly wet and have high turbidity and pH values, and these result in low EPT and BOD values. The high percentage of Chironomidae indicates contaminated water. However, the high ASPT showed there was no contamination by toxic or inorganic substances. The HBI values, moderate FBI and low EPT indicate the

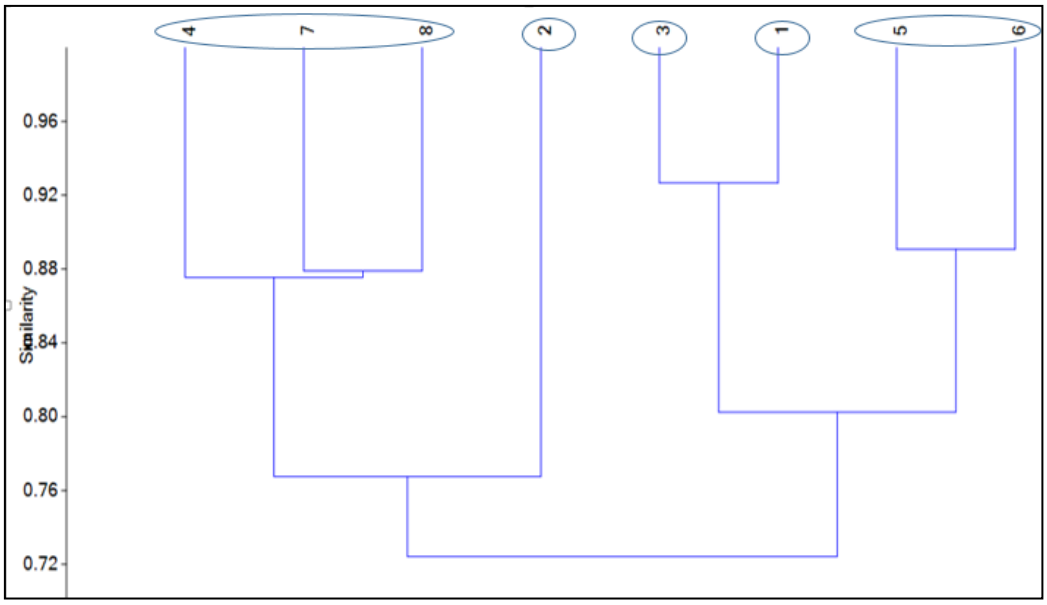

Fig. 4. Cluster Analysis based on physics and chemistry parameters and Macrozoobenthos Biotics Index at Prafi river

presence of organic material contamination, while the slightly alkaline pH indicates an increase in detergent or household effluent, whereas high turbidity indicates suspended particles of organic compounds. Next, the low BOD values show that few organic compounds are described. Thus, it can be said that this location has water that is contaminated with organic matter at a reasonable or light level. This may be due to a small amount of plantation activity around the river and bathing and washing activities done by the community. Thus, this location can be said to have water quality contaminated with organic and inorganic materials at a moderate level. This can be due to sand, rock, washing, bathing, recreation, fishing with explosives activities and agricultural activities with chemical fertilizers and pesticides applications. At this location found% EPT in the high category, but also found% Chironomidae being. Chironomidae found at this location of its existence comes from adjustments to environmental conditions (Noortiningsih et al. 2008). Chironomidae is a pollution tolerant taxa, and the presence of these taxa may indicate moderate to severe water quality (Mandaville 2002).

The three sites based on biplot analysis (**Fig. 5**) are characterized by HBI, FBI,% EPT, pH, BOD and high turbidity, together with moderate Chironomidae and ASPT. The high HBI and FBI values indicate slight contamination with organic matter to slightly worse. Next, the high EPT values indicate moderate water quality, with chironomid and ASPT values indicating mild contamination with inorganic compounds. Then, the pH, BOD, and high turbidity indicate the presence of medium-level pollution from human activities consisting of both organic and inorganic compounds. Thus, it can be said that this location has water contaminated with organic and inorganic materials at a moderate level. This can be due to plantation activities, river widening, dam-making activities, and bathing and washing activities. At this location there found high percentage of EPT and Chironomidae was also found at the same time. Chironomidae found at this location of its existence comes from adjustments to environmental conditions (Noortiningsih et al. 2008). Chironomidae is a pollution tolerant taxa, and the presence of these taxa may indicate moderate to severe water quality (Mandaville 2002).

The one location based on biplot analysis (**Fig. 5**) is characterized by high ASPT values, while the Chironomidae, HBI, FBI, turbidity, and pH are moderate, with low EPT and BOD levels. The high ASPT value shows that there is no contamination with toxic or inorganic materials, given the value of the Chironomidae percentage of the HBI. Then, the FBI shows the presence of pollution from organic compounds, while the EPT percentage shows clean water quality, and the turbidity shows that there were fewer suspended particles of organic compounds. In this case, the pH is seen to be not too far from normal pH, while the BOD value indicates that there is little or a low level of organic compounds. Thus, it can be said that this location has clean water quality. This may be due to the location, where there is a lack of human

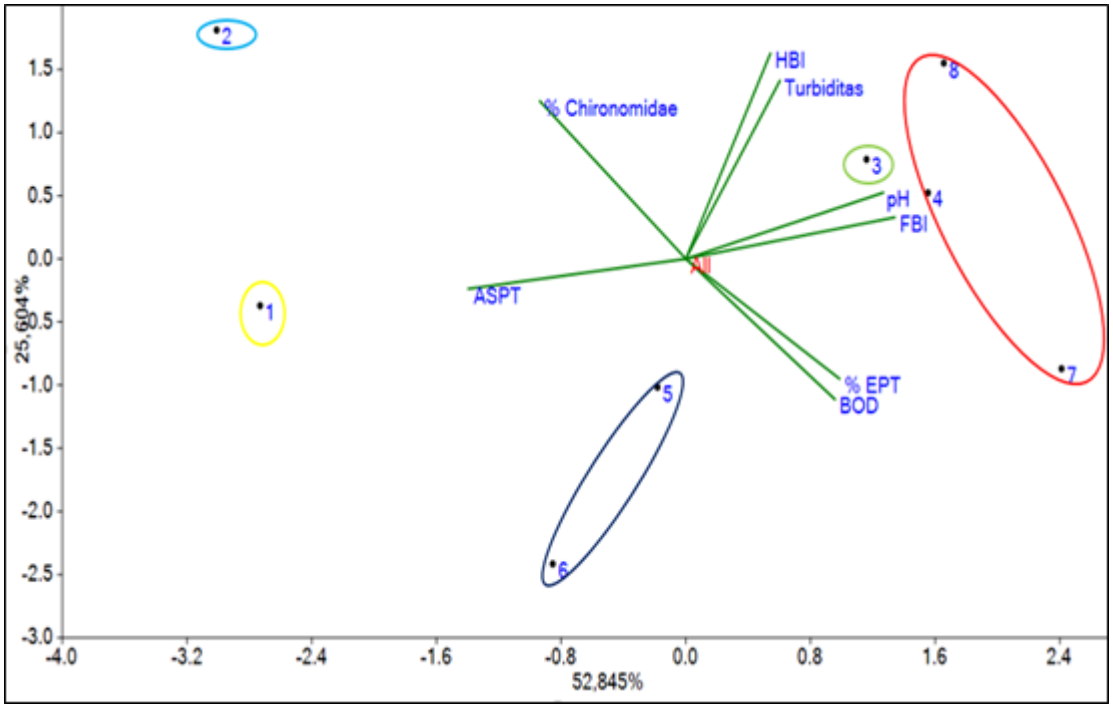

Fig. 5. Biplot analysis based on physical and chemical parameters using Macrozoobenthos biotic index at Prafi river

activity and still many trees along the river so that BOD is low. The primary source of DO comes from the atmosphere and oxygen from the air that is absorbed by direct diffusion on the water surface due to the wind and current movement (Firdaus et al. 2013).The percentage of EPT values indicate clean water quality, so this is related to EPT organisms in a group of benthic sensitive benthic macroinvertebrates (Badawy et al. 2013).

Locations 5 and 6 become one group based on cluster analysis and the biplot **Figs. 3** and **4**, characterized by high EPT and ASPT values. For moderate FBI and HBI values, it was found that there are low chironomid values followed by high BOD, and this will result in slightly wet pH and low turbidity. The high values of EPT and ASPT show that there was no pollution. Next, the FBI and HBI values show a slight and reasonable organic matter contamination, while the BOD values are still below 5.1 mg/L, showing that they are not in a medium contaminated state. On the other hand, the pH and turbidity values reflected a lack of pollution. The turbidity values still meet the maximum water turbidity standard for water based on the WHO standard for drinking water (<5 NTU), and the pH value still meets the quality standard of class I water quality based on PP 82/2001, which sets the pH value range from 6 to 9. Thus, it can be said that this location has a clean water quality. This may be due to the small amount of community plantation activities.

CONCLUSION

In Manokwari, in contrast to many other environmental marine, phosphate rather than nitrate is the limiting nutrient. The quality of the physicochemical of the Prafi River based on the pH values at eight sites still meets the quality standards of first-class water quality (raw materials of drinking water, fishery, recreation, livestock, and irrigation) based on PP 82/2001, which specifies pH values ranging from 6 to 9. Of the turbidity values at the eight sites, locations 5 and 6 still meet the maximum water turbidity standard of water based on the WHO standard for drinking water (<5 NTU). Locations 1, 2, 3, 5 and 6 can also be classified as having fish cultivation activity with the requirement for turbidity values between 2 and 30 NTU. However, locations 4, 7 and 8 have already exceeded the standard according to WHO and the requirements for aquaculture. The BOD5 values at the eight locations still fulfill the class III water quality standard (for fishery, livestock and irrigation) based on PP 82/2001, which sets the value of BOD5 <6 mg/L. Based on the ASPT values, the water quality in all locations is classified into two categories: the water at locations 1, 2, 5, 6 and 8 is assessed as clean, while the water at locations 3, 4 and 7 is classified as light water quality. Based on the FBI values, the water quality in all locations is classified into two groups: locations 1 and 2 have an excellent standard while the remaining locations 3, 4, 5, 6, 7 and 8 are considered as good. Based on the HBI values, the water quality in all locations is

classified into three groups: location 6 is classed as good, followed by locations 1, 2, 4, 5 and 7 which are considered as having medium water quality, and lastly locations 3 and 8, which are slightly worse. Based on the water quality category using cluster and biplot analysis, the locations are grouped in three categories: locations 1, 5 and 6 show clean water conditions; locations 5 and 6 are categorized as uncontaminated water, and location 2 is categorized as mildly polluted water, while locations 3, 4, 7 and 8 are considered to have medium levels of polluted water.

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