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Assessment of Water Quality Status in Rainy and Dry Seasons along the Brantas Upstream Watershed, Batu City

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ABSTRACT

The Brantas Upstream Watershed located in Batu City is one of the water resources that supporting for many purposes. However, the water quality of the upstream is deteriorating due to the human activities throughout land-use change and the effluents. The aims of the study were to determine characteristics of water, to assess the water quality and pollution indexes along the Brantas Stream. The pH values of the Year of 2015 was higher than that of 2017. Moreover, the BOD and COD in the Year 2015 (rainy season) were fluctuative and higher than that of 2017 (dry season), while the Nitrate levels in the Year 2015 was lower significantly than that of Year 2017. According to Class I, status of water quality became deterioriate from the Year 2015 to 2017, where the water pollution indexes in Year 2017 were dominantly extremely polluted, meanwhile the water quality indexes in the Year 2017 were bad status.
KEYWORDS: Brantas Stream, land use, water pollution index, water quality index

INTRODUCTION

The Brantas river is one of the longest river (320 km) and the strategic watershed with catchment area of 12,000 km^2 in East Java, Indonesia [1]. The Brantas watershed is on the high land with dominant land use as forest, so it is suitable area for water conservation [2]. Moreover, the arable soils that is supported by tropical climate is favorable lands for agriculture. The beautiful green lands is attractive places for tourisms. The human populations including permanently stay, work or visit increase every year in Batu City. Many peoples who live at surrounding sides of the watershed depend on the river water to support daily human activities for drinking, household, agriculture, industry and other purposes [3][4] [5]. Therefore, there was decreased in a number of ground water resources in 2005. Impact on the increase of human populations and their daily activities to use water together with a number of organic and harmfull substances, then discharge into water body cause the water quality deteriorating year by year [6][7].

Deterioration of the water quality in the Brantas Stream due to the landuse change has been reported by several researchers [8] [6] [7]. In 1999, the water quality of the Brantas downstream was classified as bad [9]. Meanwhile, the quality of river water was deteriorated by higher inorganic nitrogen (NO_3-N and NH_4-N) and sedimentation with high phosphours content in the upstream site due to the agroforestry activity increased [10].

According to Regulation of the Indonesia Republic Number 82 Year 2001, there are four classes in determining the status of water classes that reviewed based on water quality parameters namely Class I for drinking water, Class II for water recreation facilities, freshwater fish farming, farming, water to irrigate crops, Class III for freshwater fisheries, livestock, water to irrigate crops and Class IV to irrigate crops. Assessment methods to determine the river water quality have been carried out by previous researchers. Two common methods to assess water quality are water quality index [11] [12] and water pollution index [13] [14][15] [16]. The aims of the study were to determine physical, chemical and biological characteristics of water, and to assess their water quality and pollution index along the Brantas Stream.

MATERIALS AND METHODS

Study Area

This research was conducted in the upstream area of Brantas Watershed in East Java, Indonesia which flows in three districts of Batu City, covering Bumiaji District (12,798 Ha), Batu District (4,546 Ha) and Junrejo district (2,565 Ha). Geographically, the study area lies in Batu City which has a latitude of 7°52' S and a longitude of 112°32' E.

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Water Sampling Location and Procedure

Water sampling was conducted in May 2015 (Wet Season) and in July 2017 (Dry Season). Establishment of water observation points was using GPS which was taken in 12 Points. After taking Points, the researcher conducted water quality testing using various parameters. Samples were taken from the left side, middle and right side of Brantas Stream from the half of river's depth in all sampling area. The samples taken from each Points were retained in 1.5 L bottles measured in three different locations (two riverbanks and one midstream) of the river. The samples taken were put in a cooler box and analyzed in a laboratory [17].

Water Samples Analysis

Water quality parameters tested include pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), total dissolved solid (TDS), total of nitrate (T-NO_3), phosphate (T-PO_4) and faecal coliform (FC). Based on East Java Governor Regulation No. 61/2010, it is explained that upstream water from Bumiaji District to Junrejo District according to water quality classification is classified as Class I. Water quality in Class I must be obtained interval value of pH 6.5-9.0, DO ≥ 6 mg/L, BOD ≤ 2 mg/L, COD ≤ 10 mg/L, TSS ≤ 50 mg/L, TDS ≤ 1000 mg/L, T-NO3 ≤ 10 mg/L, T-NO4 ≤ 0.2 mg/L and FC ≤100 MPN/100mL.

The pH was measured using pH meter, DO using Winkler titration method, BOD was determined by knowing the amount of oxygen consumed for 5 days by the DO way of reading on the first day and DO on the fifth day with the temperature of incubator 20^{o}C. COD was measured by using the Digital Conductivity Meter (LT-51), TSS was determined by measuring the sediment weight difference before and after heating with temperature of 105^{o}C for 1 hour [18]. The T-NO3 was measured by Spectrophotometric method, T-PO4 was determined by ammonium molybdate ascorbic acid reduction method, and Fecal coliform using MPN method [19].

Water Quality Index

Water Quality Index (WQI) is an index that can define water quality value from the considerably high value into a value which can be explained in simple way [12]. Water Pollution Index has been used by developing countries based on National Sanitation Foundation (NSF) of USA. WQI is utilized to determine water quality of a river [20]. WQI was determined by summing up the multiplication result of Q_i and W_i values ,where Q_i value is water quality parameter value, W_i value is a weight score of each parameter. W_i value in pH, DO, BOD, TSS, T-PO4, T-NO3 and FC parameters are 0.13, 0.20, 0.13, 0.1, 012, 0.11 and 0.19, respectively. Status qualification of water quality index can be seen in Table 1.

$$\mathrm{WQI} = \sum_{i=1}^{n} Q_i \, x \, W_i$$

Table 1. Classification of water quality status

Range	Status
90 ≤ WQI ≤ 100	Excellent
70 ≤ WQI ≤ 89	Good
50 ≤ WQI ≤ 69	Medium
25 ≤ WQI ≤ 49	Bad
WQI < 24	Very Bad

Water Pollution Index

The Water Pollution Index is a method for determining water quality simply [15]. Water Pollution Index in Indonesia has been implemented based on Ministerial Decree Number 115 Year 2013. The equation used to determine water pollution index, where Ci is the parameter concentration i, Li is the parameter concentration i permitted according to the water quality standard, the M value is the maximum value and the value of R is the average value. The determination of water pollution index criteria based on WPI values can be seen in Table 2.

$$WPI \quad = \sqrt{\frac{(\mathrm{C_i}/\mathrm{L_i})^2{}_{\mathrm{M}} + (\mathrm{C_i}/\mathrm{L_i})^2{}_{\mathrm{R}}}{2}}$$

Table 2. Classification of water pollution index

Score	Criteria
WPI > 10.0	Extremely polluted
5.0 ≤ WPI ≤ 10.0	Polluted
1.0 ≤ WPI ≤ 5.0	Moderately polluted
0.0 ≤ WPI ≤ 1.0	Good

RESULTS AND DISCUSSION

Sampling Site Description

Batu City is divided into 8 areas i.e., moor, forest, agro industrial, parks, grassland, residential, agricultural and shrubs. According to Agricultural and Forestry Office of Batu City (2014), agricultural area in Batu City is 2,480 Ha, area for agro industrialarea is 860.99 Ha, moor area is 3323.57 Ha, forest is 11,071.2 Ha, and the rests are 2,172.96 in sum. Even though the area for forest is more dominant compared to other land area in Batu City, however, Batu City earns astronomical increase in tourism field, so that it affects to how high land functional shift nowadays which causes degradation of river's water quality.

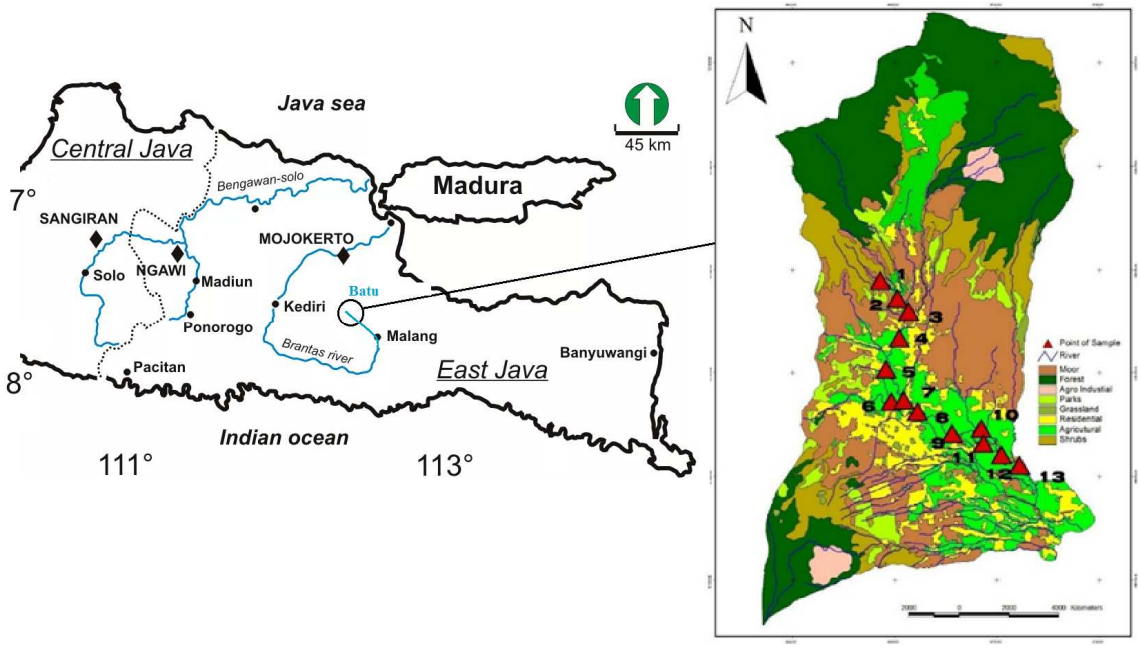

Figure 1. Sampling points along the Brantas Upstream river, in East Java, Indonesia

Determination of observation station used to determine water pollution value at Brantas Stream are taken from 12 points (Table 3). Such point determination is taken from the impact of land change due to land use for residential area, agricultural purpose, cemetery area, dam establishment, farming and due to stone quarry on the water quality of the river. In detail, positioning of observation station location can be seen in Figure 1.

Table 3. Observation Station Brantas's Upstream

River	Coordinate		Wide River	Description	Vegetation
	X	Y	(m)		
1	0667912	9134758	8.0	Agriculture Land	Bamboo, Vegetables, Pine Tree and Fern
2	0667890	9134719	4.7	Agriculture Land	Bush, Bananas and Vegetables
3	0668164	9133756	7.2	Settlement andGround Water Sources	Ornamental Plants and Elephant Grass
4	0668224	9133756	4.0	Settlement, Stone Mining and Goat Farm	Bamboo, Mango Tree and Bush
5	0667973	9133239	9.0	Settlement, Goat Farm and Funeral	Bamboo and Bush
6	0667539	9131941	7.8	Stone Mining andDam	Bamboo
7	0667464	9131914	8.7	Stone Mining and Funeral	Bamboo and Bush
8	0667614	9131659	8.1	Dam and Agricultural Land	Bamboo, Ornamental plants and Vegetables
9	0667971	9130328	7.1	Agricultural Land	Rice, Corn Bamboo, Banana tree and Cassava
10	0668693	9130313	6.4	Agricultural Land	Rice, Corn Bamboo, Banana tree and Cassava
11	0668746	9130265	8.3	Stone Mining	Bamboo and Bush
12	0668693	9130313	4.0	Stone Mining	Bamboo and Bush

Physical-Chemical-Biological Characteristics of the River Water

In this study, the water sampling was conducted on 12 observation points for testing of several parameters of the river water quality as pH, TSS, TDS, DO, BOD, T-NO3, T-PO4 and FC. In 2015 (Rainy Season), the pH values of the river water were in the range of 6.9 to 8.5, higher than that of pH in 2017 (Dry Season) shown fluctuative from 6.3 to 7.8. In the rainy season, pH of the water tended to be higher due to the materials from upper area was 6.30 and the largest value 7.83 with an average pH of 6.95. Compared to the Year of 2015, the pH value of 2017 was tends to be more acidic. When compared to the first class water quality standard, the pH is still categorized according to the standard.

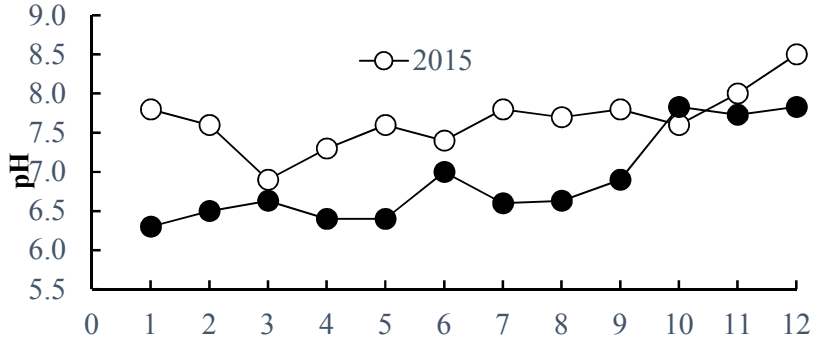

Figure 2. pH of the river water on 12 Locations in 2015 (Rainy Season) and 2017 (Dry Season)

Figure 3 shown that the lowest DO in 2017 was 5.47 mg / L and the largest value was 6.43 mg / L with an average of 6.03 mg / L. The average DO score of research in 2015 was 4.75 mg / L, so in this study it had a DO increase of 27%. The largest BOD value in 2017 was 9.97 mg/L and the lowest was 5, 63 mg/L, with an average grade of 7.28 mg/L. When compared with research in 2015, then there was a decrease of 23%. The largest COD value was 26.32 mg / L and the lowest was 17.52 mg / L with an average value of 20.59 mg / L. When compared to the research in 2015 then there is a decrease of 31%. The COD value graph on 2015 tends to be unstable, this is inversely proportional to 2015.

With the BOD / COD chart shows that water quality condition in dry season (year 2017) is better than rainy season (year 2015). This may be due to the non-mixing of pollutants carried by the rainwater, thus decreasing the value of BOD and COD.

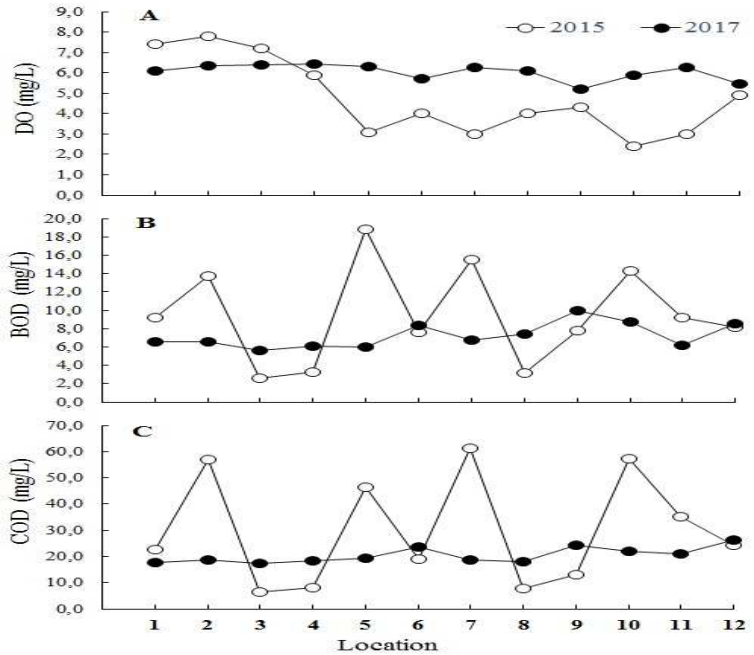

Figure 3. DO (A), BOD (B) and COD (C) of the water along the Brantas River

Figure 4 shown, the highest TSS value was 140.9 mg/L and the lowest value was 7.57 mg/L with an average 50.12 mg/L. In case it was compared to research conducted in 2015, there was an increase by 2%. The highest TDS value was 316.20 mg/L and the lowest value was 134.60 mg/L with anaverage 234.30 mg/L. In case it is compared to research conducted in 2015, there was an increase by 18%.

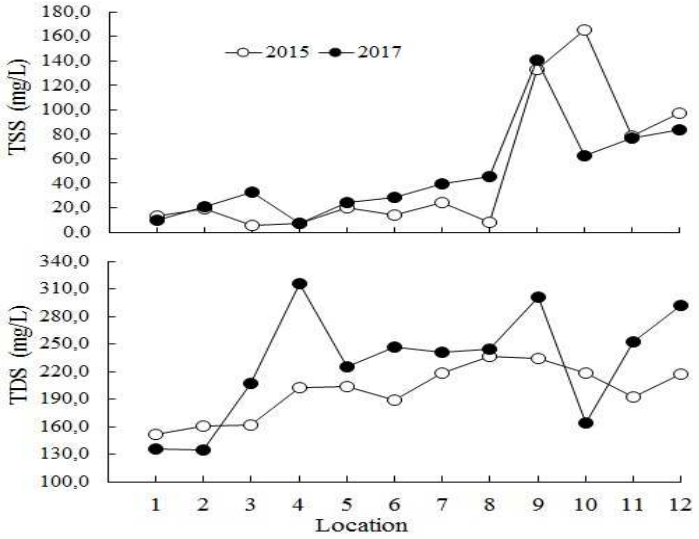

Figure 4. TSS (A) and TDS (B) of the water along the Brantas River

Figure 5 shown, the highest T-NO3 value in 2017 was 24.26 mg/L and the lowest value was 2.89 mg/L with an average 11.38 mg/L. In case it was compared to research conducted in 2015, there was a significant increase by 3.916%. The highest T-PO4 value was 0.79 mg/L and the lowest value was 0.12 mg/L with an average 0.12 mg/L. In case it was compared to research conducted in 2015, there was decrease by 26%. If we take a look at the chart, T-NO3 value in 2015 and 2017 has significant difference, which in 2017, the T-NO3 was far higher. The average value of FC was 2.00 MPN/100 mL. In case it is compared to research conducted in 2015, there was a decrease by 94%, thus, such value is classified into class I category where the water functions as drinking water.

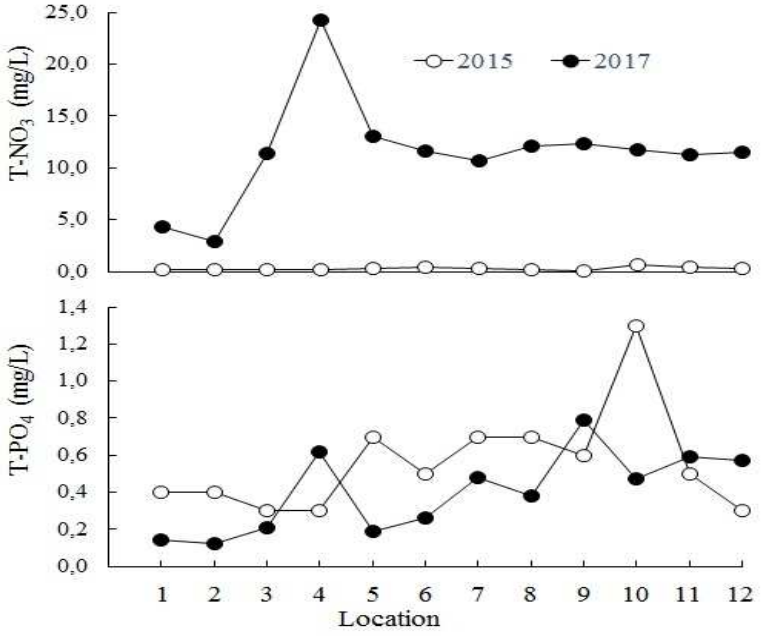

Figure 5. T-NO_3-N (A) and T-PO_4 (B) of the water along the Brantas River

The correlation of Pearson connecting the water quality parameters from the 12 sampling points has a positive and negative correlation (Table 4). Correlation between parameters with significant difference p <0.01 can be seen in the relationship between BOD and DO, COD and BOD, TSS and DO, TSS and BOD, TSS and COD, T-NO3 and TDS, T-PO4 and TSS, T-NO4 and TDS. When compared to the 2015 study, almost all parameters showed a markedly significant difference of p <0.01 except BOD and pH. Correlation between parameters with significant difference value p <0.05 can be seen in the relationship between TSS and pH, whereas in the 2015 study the correlation was success different p <0.05 seen in the BOD relationship and pH. This may result in uneven distribution of pollutants in various sampling locations, resulting in lower correlation values.

Table 4. Pearson Correlationfrom 12 Observation Points in Brantas Stream

		pH	DO	BOD	COD	TSS	TDS	T-NO3	T-PO4
pH	**2015**		-0.290	0.261	0.251	0.391	0.303	0.035	0.041
	2017		-0.492	0.505	0.737	0.612	0.245	0.011	0.511
DO	**2015**			-0.389	-0.313	-0.441	-0.591	-0.644	-0.634
	2017			-0.945	-0.860	-0.777	-0.369	0.052	-0.518
BOD	**2015**				0.878	0.212	0.031	0.431	0.412
	2017				0.794	0.741	0.297	-0.029	0.530
COD	**2015**					0.220	-0.040	0.448	0.429
	2017					0.710	0.462	0.060	0.536
TSS	**2015**						0.396	0.435	0.502
	2017						0.470	0.007	0.750
TDS	**2015**							0.213	0.622
	2017							0.735	0.780
T-NO3	**2015**								0.543
	2017								
T-PO4	**2015**								
	2017								

The highest correlation value lies in the relationship between BOD and DO parameters of 0.945 with a real difference value p <0.01. This is different in the research in BOD and COD of 0.878. This is due to the consistency of each observation station between the two parameters. While the lowest correlation value lies in the relation of T-NO3 and TSS parameters that is 0.007. In the 2015 study, the lowest correlation value lies in the relationship of TDS and BOD of 0.031. In the parameter with the same concept value, it will show a positive correlation. If there is a negative correlation relationship because the value in each relationship of the parameters is inconsistent or does not indicate the stability [21, 22].

Upstream Water Pollution and Quality Indices

Water Pollution Index (WPI) in 12 water quality observation points, it is obtained the data of water quality as presented in Table 5. Result of WPI shows the highest WPI value of 34.61 (Point 4), while the lowest WPI shows a number of 4.19 (Point 2), which are 16.36 in average. Should it be compared to research conducted in 2015, the average WPI of 3.17, then the WPI shall increase by 413.88%. As reviewed based on WPI status in 12 class I Points, it shows that status water quality of Brantas' upstream in location 1 is polluted, however, in point II, there is decrease in WPI by 47%. From location no.3 up to 12, there are increases in WPI, so that in class I, such WPI value shall be categorized as extremely polluted. In the research conducted in 2015, the rating of all observation points on WPI shows that the water is moderately polluted, so that it can be concluded that there is degradation of water quality within the last 2 years. It can be seen on the significant increase of T-NO3 compared to the research conducted in 2015, so that it affects water quality degradation. In Water Quality Index (WQI), it can also be seen that averagely, the statuses of water quality are classified in bad category under WQI value of 39.11, where in the research conducted in 2015, the value of water quality were still in 'medium' category.

Table 5. Water quality from 12 Observation Stations in Brantas's Upstream

Observation Station	WPI on the Quality of River Water in Indonesia in the Class I Classification				Acceptability WQ in NSF			
	2015		2017		2015		2017	
	WPI	Status	WPI	Status	WQI	Status	WQI	Status
1	3.16	Moderately polluted	6.16	Polluted	70.21	Good	57.61	Medium
2	3.76	Moderately polluted	4.19	Moderately polluted	71.16	Good	46.13	Bad
3	1.62	Moderately polluted	1.22	Extremely polluted	77.30	Good	40.85	Bad
4	1.63	Moderately polluted	34.61	Extremely polluted	71.34	Good	38.98	Bad
5	4.38	Moderately polluted	18.63	Extremely polluted	49.95	Bad	41.16	Bad
6	2.98	Moderately polluted	16.71	Extremely polluted	58.18	Medium	38.89	Bad
7	4.08	Moderately polluted	15.34	Extremely polluted	51.71	Medium	37.39	Bad
8	2.77	Moderately polluted	17.33	Extremely polluted	63.39	Medium	37.00	Bad
9	3.09	Moderately polluted	17.68	Extremely polluted	54.97	Medium	29.04	Bad
10	4.16	Moderately polluted	16.76	Extremely polluted	44.64	Bad	34.65	Bad
11	3.33	Moderately polluted	16.07	Extremely polluted	50.89	Medium	34.65	Bad
12	3.11	Moderately polluted	16.59	Extremely polluted	54.07	Medium	33.17	Bad

CONCLUSIONS

In this study was taken in 12 points in upstream of Brantas river which will be reviewed from 2 seasons namely wet season (2015) and dry season (2017). Sampling is taken based on changes in land use due to agricultural land, settlements, stone mining, goat farms, cemeteries and dams. Water quality parameters tested pH, DO, BOD, COD, TSS, TDS, T-NO3, T-PO4 and FC. The results show that pH in 2017 (dry season) is lower than in 2015 (rainy season) with a range of 6.3-7.8. The DO value in 2017 (dry season) was higher with an average of 27%, while the BOD, FC, COD values decreased by 23%, 31% and 94%. In contrast, TSS and TDS values increased 2% and 18%. At the value of T-NO3 in 2017 (dry season)increased by 3.9%, but T-PO4 decreased by 26%. According to the class I air class for drinking water, by 2017 (dry season) the status of WPI status increase from 'moderately polluted' becomes 'extremely polluted'. In WQI status spelled out the status of the 'medium' to 'bad'.

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