ASSESSMENT OF THE IMPACTS OF LAND USE ON WATER QUALITY OF BRANTAS UPSTREAM, BATU CITY, INDONESIA

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ABSTRACT

Unsuitability land uses have significant impact on conditions of many river basins along line from upstream to downstream through the cities in Indonesia. Water of Brantas upstream running along line through Batu City from Bumiaji Sub-District to Junrejo Sub-District may show varied concentrations of contaminants. The objective studies are (i) to evaluate the land use at existing-condition; (ii) to monitor the water quality parameters; (iii) to assess the water quality index and water pollution index of the Brantas upstream water. In this study, Pearson correlation of BOD and COD shown a very high positive correlations (r) of 0.8779. Meanwhile, high positive correlations were shown in TSS vs T-PO$_4$ and T-NO$_3$ vs T-PO$_4$, whereas DO vs TDS, DO vs T-NO$_3$, and DO vs T-PO$_4$ have high negative correlations. Based on the four river water quality classifications in Indonesia, all stations shown the status of water pollution index at moderate level (Class I and II). Meanwhile, the water pollution index status of Class III were dominated by moderate level. In contrast, the status of water pollution index in Class IV was dominated by good level. Water pollution index in Category IV was relatively similar result to NSF-WQI status rather than other categories.

Keywords: *Brantas upstream watershed, land use, water pollution index, water quality parameters*

1. INTRODUCTION

River water quality has become an environmental problem in recent years especially in developing countries. The problem occurs due to land use changes in river basin area. The water resources was potentially affected by land use changes (Stonestrom *et al*., 2009). Uncontrolled land use changes from forest to agriculture field and from agricultural to settlement uses have significant impact on conditions of many river basins along line from upstream to downstream through the cities in Indonesia. In our previous research on land suitability in Batu Municipality, the unsuitable land use on existing and spatial planning conditions were 25.7% and 32.1% of the total area, respectively (Rahadi et al., 2014). The increase numbers of the land use changes, that is not suitable with a land capability, throughout a river basin can decrease their water quality. Wastes from domestic dan agricultural activities can enter to the river and increase concentration and variation of contaminants.

Brantas Upstream is used as the source of water supply for industry, domestic and agricultural activity and mainly as the buffer area of avalaible-water for human living and activity in Brantas Downstream. However, intensive activity of agricultural sector at rural landscapes of Bumiaji District in Batu City affected the condition of a river basin of Brantas Upstream has gotten worse. A large amount of highly suitable land for forest in hillside of the Arjuno Mountain has been converted to agricultural and settlement uses. The agriculture activity in hillside is predominantly increase soil erosion and sedimentation along line the river. A frequently applied fertilizer and pesticide in high dose in the agriculture field affect high concentration of contaminants in watershed. Similarly, settlement use for living or recreation places increase domestic wastes that is put in river basin for years. Researcher from Live-Environmental Board of East Java (2011) had reported that condition of Brantas Downstream particularly Surabaya River and Porong river was highly polluted. Therefore, a quality of the Brantas Upstream waters should be maintained and managed in order to continuously keep water drinking supply.

Brantas upstream flows from Bumiaji district to Junrejo district in Batu Municipality may show varied concentrations of

contaminants. Also, a different amount of water quality parameters may describe different water pollution index. The distribution concentration of the parameters and water pollution index may help the local government to manage the quality of the river water to supply several purposes, particular supply for drinking water treatment. Therefore, it is important to assess the water quality in upstream area of the Brantas River. The aims of this study are to analyze concentration of contaminant in Brantas upstream river, and to identify their water quality and water pollution indexes.

2. MATERIALS AND METHODS

2.1. Study Site

Area study is Brantas Upstream water running through Batu City started from Bumiaji Sub-District to Junrejo Sub-District, where they geographically located between 127°17' - 120°56' East Longitude and 7°44' - 8°26' South Latitude. Batu City is composed of three sub districts namely: Bumiaji, Batu and Junrejo with an area of 12,798 Ha, 4,546 Ha and 2,565 Ha, respectively.

2.2. Land Evaluation

In our previous study, both land capability and land suitability of Batu Municipality has been observed. The land assessment was rely on the description of primary attributes for map units. These attributes are converted into land use. Land capability assessment is applied to land classification and land use maps (≥1:250 000 scale), whereas land suitability assessment is applied to detailed soil mapping (1:100 000 scale). This matches the detail of the land evaluation to the detail of the available land resource data.

2.3. Water Sampling Points and Procedures

Each place of sampling and discharge measurements was pointed with GPS. In this study, 12 points were observed, by sampling and analysis of some parameters to determine the quality of the water. Water samples from the specified locations were collected in May 2015 (rainy season). The water samples were taken according to standard method (APHA, 1992.). The water samples were collected from the number of distribution sites and selection of the sample was performed depending on stream

characteristics, study objectives and availability of equipments. The samples were taken from left, middle and right sides of the Brantas upstream at mid-depth throughout the study area.

At each sampling point, the river water was fully put to 1.5-L bottle and discharge measured at three different locations (two edge, one central) from the river. Discharge streams and rivers wide were measured. The collected samples were put in cool box during sampling and transported to the Laboratory and stored in freezer until the time a chemical analysis done. The samples were chemically analysed at the Water Analysis Laboratory of Jasa Tirta Co., in Malang, East Java, Indonesia. All chemical analyses were achieved according to standard methods (APHA, 1992).

Table 1. Selected parameters of water quality standard for river water in Indonesia according to Government Regulation no 82/2001.

	Class I	Class II	Class III	Class IV
pH	Dev 3	Dev 3	Dev 3	Dev 5
DO	6,0	4,0	3,0	0,0
BOD	2,0	3,0	6,0	6,0
COD	10,0	25,0	50,0	100,0
TSS	50,0	50,0	400,0	400,0
TDS	1000,0	1000,0	1000,0	2000,0
T-NO_3	10,0	10,0	20,0	20,0
T-PO_4	0,2	0,2	1,0	5,0
DET	0,2	0,2	0,2	None
FC	100,0	1000,0	2000,0	2000,0

Unit measurement of all parameters is mg/L, except for Fecal Coliform (FC) using MPN/100mL. Dev: deviation.; pH value in the range of 6.5 – 9.0, Class I is for drinking water or any other use with the similar requirements; Class II is for service water, recreational, aquaculture or any other use with the similar requirements; Class III is for fresh water agriculture, farming and any other use with the similar requirements; Class IV is for irrigation and any other use with the similar requirements

2.4. Water Sample Analysis

Collected samples were analyzed in the laboratory for determining concentration of the selected water quality parameters (Table 1). The water quality parameters such as pH, dissolved

oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solid (TSS), total dissolved solid (TDS), total of nitrate (T-NO$_3$), phosphate (T-PO$_4$), detergent (DET) and Faecal coliform (FC) were analyzed using appropriate methods.

The parameters of pH determined by pH meter, DO by Winkler method, BOD by oxygen consumed in five days by calculation of the first DO reading (it was taken just after collecting the samples) and the second one (it was taken after 5 days preservation in incubator at 20°C temperature), COD by Open Reflux method, TDS by Digital conductivity meter (LT-51), TSS using methods developed by APHA (1995), T-NO$_3$ by Spectrophotometric method, T-PO$_4$ by Ammonium molybdate ascorbic acid reduction method, Detergent by measurement of linear alkylbenzene sulfonate/LAS (Hanan, 2014), Fecal coliform by MPN method (Shafi, 2013).

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

*Minister of Environment Decree No. 115/2003

2.5. Water Quality Index

Water quality index (WQI) that was calculated based on the comparison of water quality parameters with their respective regulatory standards. WQI was calculated by sum values of multiplying Q-value and weighing factor for all parameters (Equation 1). Q-value (Qi) is indication of water quality relative to 100 of each parameter. Weight score is a value of each parameter relative importance to overall water quality parameters. Weight scores (Wi) of pH, DO, BOD, TSS, T-PO$_4$, T-NO$_3$ and FC of the Brantas upstream water in the study area were 0.13, 0.20, 0.13, 0.12, 0.11 and 0.19, respectively. WQI numerically summarizes the information from multiple water quality parameters into a single value (Table 2), can be used to compare data from several sites.

$$WQI = \sum_{i=1}^{n} Q_i \, x \, W_i \quad \text{………………………..} \quad (1)$$

2.6. Water Pollution Index

Water pollution index (WPI) is one of the method to assess water quality in a river ecosystem (Nemerow and Sumitomo, 1970). Later, it was implemented by the Indonesia Ministry of Environment in the Ministerial Decree No.115/2003. The WPI is a function of maximum and average ratios (C$_i$/L$_i$), where C$_i$ represents the concentration of parameter i and L$_i$ represents the concentration permissible value of parameter i. The WPI is intended to point out contamination level for each parameter as described in Equation 2. Determination of criteria is based on the score at Table 3.

Table 3. Classification of water quality status

Index range	Rating
90 ≤ WQI ≤ 100	Excellent
70 ≤ WQI ≤ 89	Good
50 ≤ WQI ≤ 69	Medium
25 ≤ WQI ≤ 49	Bad
WQI < 24	Very Bad

$$WPI = \sqrt{\frac{(C_i/L_i)^2_M + (C_i/L_i)^2_R}{2}} \quad \text{………………} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1. Land Evaluation

Based on classification results of land sub classes, Batu is categorized in classes I, II, III, IV, V, VI and VII (Figure 1). The largest area is at class VI by the area percentage of 7860.43 Ha or 40%. Result of the land use evaluations are consists of 14,852.8 Ha (74.33%) suitable landuse, and 5,128.1 Ha (25.67%) unsuitable landuse (Rahadi et al., 2014). Land of class I on unsuitability of land use exists on the meadow that based on direction of the land use class I, which is intended for crops. Unsuitable land use for class II is notified by dominant bushes and meadows grow in the land that actually productive for agriculture (crop). The same as class III, unsuitable land use for irrigation, paddy field dependent on rain, garden, and meadow, better for perennial/hardwoods. Land class IV is considered for irrigated field and garden, but it is not suitable for perennial or hardwoods, grassing, and non agriculture. Also,

class V, unsuitable land use for settlements, irrigated field, and garden, it should be used for non agriculture, grassing, and perennial. Land class VI is directed for perennial and animal husbandry, therefore this land is unsuitable for settlements and garden. Land class VII is directed for production forest and meadow, therefore such land is unsuitable for unirrigated field, irrigated field, bushes, and garden.
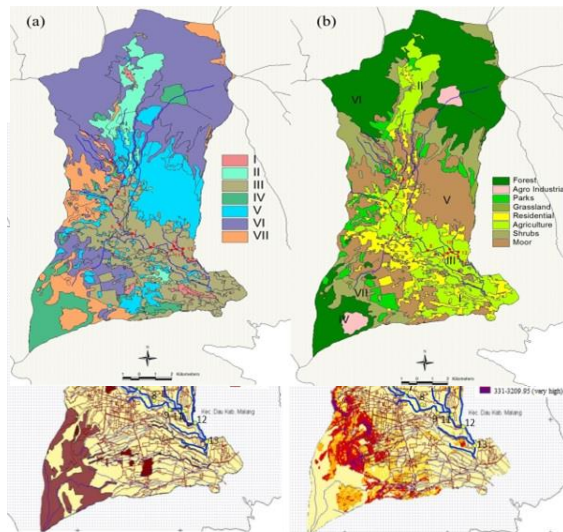

Figure 1. Land classification (a) and land use maps of Batu Municipality (b) (Rahadi *et al*., 2014).

Figure 2. Soil type (a) and Erosion (b) Maps of Batu City (Rahadi et al., 2014)

The land use within the watershed has great impacts on the water quality of rivers. The water quality of rivers may degrade due to the changes in the land cover patterns within the watershed as human activities increase (Ngoye and Michiwa, 2004). Changes in the land cover and land management practices have been regarded as the key influencing factors behind the alteration of the hydrological system, which lead to the change in runoff as well as the water quality (Yong and Chen, 2002). Figure 2 shown soil type and soil erosion in Batu City. Soil types in Batu City were consisted of Alfisols, Andosols, Entisols, Inceptisols and Mollisols. Andosols and Inceptisols are dominantly distributed in Batu City rather than other type of soils. Alfisol has higher clay fraction and hard soil texture, distributed in Junrejo and

Sumberejo at total area of 211,68 Ha. Alfisols form in semiarid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility. Because of their productivity and abundance, the Alfisols represent one of the more important soil orders for food and fiber production. They are widely used both in agriculture and forestry, and are generally easier to keep fertile than other humid-climate soils. Andisols are soils formed in volcanic ash and defined as soils containing high proportions of glass and amorphous colloidal materials, including allophane, imogolite and ferrihydrite. Because they are generally quite young, andisols typically are very fertile except in cases where phosphorus is easily fixed (this sometimes occurs in the tropics). They can usually support intensive cropping, with areas used for wet rice in Java supporting some of the densest populations. An entisol has no diagnostic horizons, and most are basically unaltered from their parent material, which can be unconsolidated sediment or rock. Entisols are the second most abundant soil order (after inceptisols). Meanwhile, inceptisols are formed quickly through alteration of parent material. They are more developed than entisols. They have no accumulation of clays, iron oxide, aluminium oxide or organic matter. They have an ochric or umbric horizon and a cambic subsurface horizon. Mollisols form in semi-arid to semi-humid areas, typically under a grassland cover. Each soil group does not only contain landuse types, such as forest, bush, grassland, shifting cultivation, upland, and wetland rice, but also types of vegetation. One mapping unit may contain more than one land use types.

Erosion rate catagories at the existing land use in Batu, which include five components, such as no erosion (e0), light erosion (e1), medium (e2), heavy (e3), very heavy (e4). The area of no erosion is about 4780,1 Ha, light erosion is about 815.9 Ha, medium erosion is about 6567,3 Ha, heavy erosion is about 2660,4 Ha, and very heavy erosion is about 4726,7 Ha.

Table 4. Water quality parameter of Brantas upstream watershed

Station	pH	DO	BOD	COD	TSS	TDS	T-NO$_3$	T-PO4	Fecal coliform
					(mg/L)				MPN/100mL)
1	7.8	7.4	9.2	22.7	13.5	151.6	0.2	0.4	22.7
	(0.1)	(0.2)	(1.5)	(5.7)	(3.1)	(5.1)	(0,0)	(0.1)	(4.6)
2	7.6	7.8	13.7	57,0	19.5	160.2	0.2	0.4	13.3
	(0.1)	(0.8)	(2.4)	(14,0)	(5.3)	(22.9)	(0,0)	(0.1)	(2.1)
3	6.9	7.2	2.6	6.4	5.9	161.3	0.2	0.3	29.3
	(0,0)	(0.4)	(0.7)	(1.5)	(0.4)	(50.4)	(0,0)	(0.1)	(9.5)
4	7.3	5.9	3.3	8.1	7.4	202.7	0.2	0.3	62.5
	(0.1)	(0.9)	(0.3)	(1.5)	(1.2)	(21.3)	(0,0)	(0.1)	(12.5)
5	7.6	3.1	18.8	46.3	19.9	204.1	0.3	0.7	84,0
	(0,0)	(0.1)	(1.9)	(3.3)	(3.3)	(49.1)	(0,0)	(0.2)	(9,0)
6	7.4	4,0	7.6	18.9	14.2	188.6	0.4	0.5	57,0
	(0.2)	(0.5)	(1.5)	(3.5)	(3.8)	(20.5)	(0,0)	(0.2)	(18,0)
7	7.8	3,0	15.5	61.3	23.9	218.3	0.3	0.7	23,0 (4.4)
	(0.2)	(0.6)	(3.6)	(11,0)	(13.9)	(18.4)	(0.1)	(0.1)	
8	7.7	4,0	3.2	7.7	8.3	236.6	0.2	0.7	25.3 (4.6)
	(0.5)	(0.5)	(0.3)	(1.1)	(1,0)	(8.5)	(0,0)	(0.2)	
9	7.8	4.3	7.8	13.1	133.1	234.8	0.1	0.6	16,0 (5,0)
	(0.1)	(1,0)	(1.4)	(3.2)	(24.4)	(13.8)	(0,0)	(0,0)	
10	7.6	2.4	14.3	57.5	165.6	219,0	0.6	1.3	13,0 (1,0)
	(0.1)	(0.5)	(2.3)	(1.4)	(41.2)	(9.5)	(0.1)	(0.1)	
11	8,0	3,0	9.2	35.1	78.3	192.7	0.4	0.5	21,0 (6.6)
	(0.6)	(0.6)	(2.5)	(9.3)	(17,0)	(21,0)	(0,0)	(0.1)	
12	8.5	4.9	8.2	24.2	97.2	217.1	0.3	0.3	25.3 (4.6)
	(0.1)	(1,0)	(0.8)	(2.8)	(22,0)	(47.6)	(0,0)	(0.1)	

Numbers are average, numbers in the bracket shown as standard deviations

3.2. Water Quality Parameters

Some parameters of river water qualities such as pH, DO, BOD, COD, TSS, TDS T-NO$_3$, T-PO$_4$ and total fecal coliform observed among 12 stations were analyzed by each parameter (Table 4). Water pH of Brantas upstream was vary in the range of 6.9 (at Station 3) to 8.5 (at Station 12) with an average of 7.7. Based on pH data, the water conditions of the river at any stations were slightly alkaline. Among 12 sampling stations, the varied pH were still in the range of water quality standard of pH 6 to 9. DO values for 12 sampling stations along Brantas upstream river were higher average DO in the range between 7.2 and 7.8 mg/L at Station 1, 2 and 3, whereas their DO levels were more than 6 mg/L as a minimum level for drinking purposes regarding to government policy. DO value at Station 4 was a medium level of 5.9 mg/L compared to the other stations that have

DO levels in the range of 2.4 – 4.9 mg/L, therefore their DO levels can apply for recreation, aquaculture, animal husbandry and agriculture purposes. Lower BOD levels were in the range of 2.6 mg/L to 3.3 mg/L suitable for aquaculture, animal husbandry and agriculture purposes that distributed at Station 3, 4 and 8. Meanwhile, the middle BOD levels from 7.6 mg/L to 9.2 mg/L were less than 12.0 mg/L suitable for agriculture irrigation purposes. However, four station such as Station 2, 5, 7 dan 10 have levels of BOD more than 12 mg/L indicated that the water was bad for agriculture purposes. COD values were lower than 10 mg/L as a minimum COD level for drinking purposes at Station 3, 4 and 8. The middle COD levels were between 10 and 50 mg/L was found at Station 1, 5, 6, 9, 11 and 12. The higher COD levels at Station 2, 5 and 7 were between 50 to 100 mg/L, but it could be used for agriculture irrigation. TSS levels were less than 50 mg/L

distributed at Station 1 – 8, but the other stations have TSS levels more than 50 mg/L and less than 170 mg/L, the water could be used for agriculture purposes accordint to government law less than 400 mg/L. TDS levels were varied in the range of 151.6 – 236.6 mg/L, but it less than 1000 mg/L as a maximum TDS level for drinking purposes. Total Kjeldahl Nitrogen levels were also lower between 1.0 and 6.0 mg/L, and less than 10 mg/L as a maximum level for drinking purposes. The levels of $T-PO_4$ were in the range of 0.3 – 0.7 mg/L, where the maximum level of 1.0 mg/L for freshwater aquaculture, animal husbandry and agriculture, but only Station 10 had $T-PO_4$ level at 1.3 mg/L or less than 5.0 mg/L as the maximum level for agriculture purposes. Fecal coliform was found in the range of 13.0 – 84.0 MPN /100 mL in all stations shown lower levels in comparison with the levels regarding to maximum levels of 100 MPN/100mL as a standard level for drinking purposes.

Table 5. Pearson Correlations between several parameters among 12 stations in Brantas upstream river

	pH	DO	BOD	COD	TSS	TDS	T-NO₃	T-P₂O₅	DET	FC
pH		-0,290**	0,261*	0,251**	0,391**	0,303**	0,035**	0,041**	0,322**	-0,267**
DO			-0,389**	-0,313**	-0,441**	-0,591**	-0,644**	-0,634**	-0,368**	-0,143**
BOD				0,878**	0,212**	-0,031**	0,431**	0,412**	-0,093**	0,099**
COD					0,220ᴺˢ	-0,040**	0,448**	0,429**	-0,116**	-0,166ᴺˢ
TSS						0,396**	0,435**	0,502**	0,272**	-0,428ᴺˢ
TDS							0,213**	0,333**	0,413**	0,080**
T-NO₃								0,622**	0,115**	0,118**
T-P₂O₅									0,133**	-0,078**
DET										-0,174**
TFC										

Fecal Coliform (FC); Detergent (DET); * and ** is notified for significant different (2-tailed) between parameters at p=0.01 and p=0.05, respectively. ns is not significant at p=0.05.

Pearson correlations between several parameters observed among 12 sampling stations shown a positive-negative and strength-weakness correlations (Table 4). Those correlations of between several parameters were significantly different at p<0.01, except for the correlation between pH and BOD was significantly different at p<0.05, and some correlations of COD vs TSS, COD vs Fecal Coliform, and TSS vs Fecal Coliform were found no significant different at p<0.05.

Table 6. Water quality of 12 observed-stations of Brantas upstream watershed

Sta.	Water Pollution Index of River Water Quality Classifications in Indonesia								Acceptability WQ	
	Class I		Class II		Class III		Class IV		NSF	
	WPI	Status	WPI	Status	WPI	Status	WPI	Status	WQI	Status
1	3.16	Moderate	2.53	Moderate	1.39	Moderate	0.56	Good	70.21	Good
2	3.76	Moderate	3.14	Moderate	2.01	Moderate	0.93	Good	71.16	Good
3	1.62	Moderate	1.59	Moderate	0.36	Good	0.31	Good	77.30	Good
4	1.63	Moderate	1.57	Moderate	0.44	Good	0.31	Good	71.34	Good
5	4.38	Moderate	3.72	Moderate	2.53	Moderate	1.44	Moderate	49.95	Bad
6	2.98	Moderate	2.38	Moderate	1.14	Moderate	0.58	Good	58.18	Medium
7	4.08	Moderate	3.42	Moderate	2.23	Moderate	1.14	Moderate	51.71	Medium
8	2.77	Moderate	2.70	Moderate	0.63	Good	0.40	Good	63.39	Medium
9	3.09	Moderate	2.56	Moderate	1.17	Moderate	0.51	Good	54.97	Medium
10	4.16	Moderate	3.88	Moderate	2.17	Moderate	1.06	Moderate	44.64	Bad
11	3.33	Moderate	2.68	Moderate	1.45	Moderate	0.61	Good	50.89	Medium
12	3.11	Moderate	2.46	Moderate	1.26	Moderate	0.55	Good	54.07	Medium

Class I is for drinking water or any other use with the similar requirements; Class II is for service water, recreational, aquaculture or any other use with the similar requirements; Class III is for fresh water agricultural, farming and any other use with the similar requirements; Class IV is for irrigation and any other use with the similar requirements

Gerstman (2016) classified correlation of two parameters became four classes such as *very high correlation* (r is equal or higher than 0.7), *high correlation* (r is equal or higher than 0.5 and less than 0.7), moderate correlation (r is equal or higher than 0.3 and less than 0.5), and low correlation (r is less than 0.3). In this study,

Pearson correlation of BOD and COD shown a very high positive correlations (r) of 0.8779. Meanwhile, high positive correlations were shown in TSS vs $T-PO_4$ and $T-NO_3$ vs $T-PO_4$, whereas DO vs TDS, DO vs $T-NO_3$, and DO vs $T-PO_4$ have high negative correlations. However, pH vs $T-NO_3$, pH vs $T-PO_4$, BOD vs

TDS, and COD vs TDS have no correlation. Fecal coliform has low correlation to other parameters, except for TSS was found in negative moderate correlation. It meant that a higher level of TSS was correlated to a lower level of fecal coliform, and a lower level of TSS was correlated to higher level of fecal coliform. Detergent shown low correlation with other parameters, except for pH, DO and TDS given moderate correlations. Correlations of Detergent vs pH and Detergent vs TDS shown a positive, but that of Detergen vs DO was a negative. $T-PO_4$ has a moderate positive correlation with parameters of BOD, COD and TDS. $T-NO_3$ shown moderate positive correlation with parameters of BOD, COD and TSS. Moderate correlations were also found in TDS vs pH, TDS vs TSS, TSS vs pH, TSS vs DO, DO vs BOD and DO vs COD.

3.3. Pollution and Quality Indexes of river water

The WPI is applied for evaluating water quality of 12 locations along line of river at different water level (Table 6). The results demonstrated that waters in the floodplain area in four classifications were good to moderate polluted water. In the Class I and II. all stations shown the status of water pollution index at moderate level. Meanwhile. water pollution index status of class III were dominated by moderate level. In contrast. the status of water pollution index in class IV was dominated by good level. Water pollution index in class IV was relatively similar result to NSF-WQI status rather than other classes.

4. REFFERENCES

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