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RESEARCH ARTICLE

Identification of The Main Water Quality Parameters for Monitoring and Evaluating Watershed Health

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Abstract Water quality is one of the crucial parameters in monitoring and evaluating watersheds. A large number of parameters causes the monitoring and evaluation of watershed performance to be less efficient and costly. This study aims to determine the main parameters as a method of simplifying water quality observation parameters by producing equations that can be used to predict the level of pollution of a non-point source pollutant (watershed). A sampling of surface water was carried out by purposive sampling at several outlets located in the Brantas and Upper Solo watersheds. The research parameters analysed were: TSS, TDS, BOD, COD, Phenol, Free Chlorineine, Sulfide, Arsenic, Fe, Pb, Phosphate, Nitrate, Nitrite, Detergent, Turbidity and E. Coli. The results of the analysis of water quality are used to calculate the value of the Pollution Index (PI) according to the Decree of the Minister of Environment No. 115 of 2003 and to determine the class of water quality standards that refer to Class III water quality standards, in Government Regulation No.82 of 2001. The analysis showed that all samples were at mild to moderate pollution levels, and did not meet class III water quality standards. Multiple regression analysis produced two equations, namely: Model 1: PI = 3.952 + 91.668 Phenol and Model 2: PI = 3.086 + 80.167 Phenol + 0.152 BOD, with R squared values of 53% and 69.9% with a confidence level of 0.005. Thus the prediction of pollution levels of similar watershed can be made only by using the two most influential parameters namely phenol and/or BOD alone.

1. Introduction

A watershed is an area that is an integral part of a river and its tributaries, which functions naturally to accommodate, store and flow water that comes from rainfall to lakes or the sea, the boundary on land is the topographic separator and the boundary at the sea until the area where waters still affected by land activities (Pemerintah Republik Indonesia, 2012). Watershed management is inseparable from land use and land management. Land use that is not suitable for its designation and capabilities, and does not pay attention to the principles of soil and water conservation, will cause damage to the watershed ecosystem. Damage to watershed ecosystems in Indonesia can be seen from the many occurrences of various disasters such as floods, erosion, sedimentation, and landslides (Paimin, Sukresno, & Purwanto, 2010). Damage to the ecosystem must be prevented by proper watershed management.

Related to water quality, some types of cover/land use can affect water quality (Effendi, Muslimah, & Permatasari, 2018; Permatasari, Setiawan, & Effendi, 2017; Shukla et al., 2018; Singh et al., 2017). The water quality of the river can be polluted not only in rural but also in urban areas (Shukla et al., 2018). Fertilisers are the main pollutant in agriculture area while domestics and industrial wastes mostly contribute in the urban area. Organic manure spreading in agriculture activities has negative and positive effects as well. Beside improving organic matter content of the soil, this nutrient may be carried away by runoff to the stream (Singh et al., 2017).

Based on Government Regulation of the Republic of Indonesia No. 37 of 2012 concerning Management of Watersheds, it is stated that watershed management is "Human efforts in regulating the reciprocal relationship between natural resources and humans in a watershed with all its activities, to realize the sustainability and harmony of ecosystems and increase the usefulness of natural resources for humans sustainably" (Pemerintah Republik Indonesia, 2012). Appropriate watershed management requires the support of monitoring and evaluation activities. Watershed Monitoring and evaluation is an activity to obtain a description of the entire watershed area covering various aspects such as land use, institutional socio-economic, and water management (Dirjen RLPS, 2009). Water management, especially water quality, is very crucial because it is very influential for life (Kurnaz, Mutlu, & Uncumusaoğlu, 2016; Mutlu & Uncumusaoğlu, 2017; Nazir et al., 2015). Observation of water quality can be conducted by analysing water samples. In the Regulation of the Director General of RLPS No. P.04 / V-SET / 2009 (P.04/2009), it has 17 parameters for monitoring water quality. The parameters are divided into 3 groups, namely physical parameters (colour, Total Dissolved Solid (TDS) and turbidity); chemical parameters (pH, Electrical Conductivity (EC), Nitrate, Sulphate, Phosphate, Potassium, Chlorineide, Sodium, Magnesium and Calcium); and biological parameters

(Organic Matter (OM), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)). Based on this regulation, the number of parameters that must be observed is very large. This parameter analysis will be very costly. Therefore, it is necessary to select parameters that are simpler while reflecting the conditions of water quality and polluting compounds. The statement is in following Basuki's finding (2015) that the number of parameters is difficult to be explained.

Apart from each element's parameter, the condition of water quality in a water body can also be seen from the Pollution Index (PI) values. PI can be used as input to assess the quality of water bodies, and also can be used as a reference in carrying out several actions to improve its quality based on its pollutants limitation. PI includes water quality parameters independently but still has meaning (Keputusan Menteri Lingkungan Hidup No. 115 Tahun 2003). This study aims to find out the main parameters that most influence water PI, which can reflect water quality in a watershed.

2. The Methods

Location and Time

This research was conducted in 2 watershed areas, namely Upper Solo Watershed and Brantas Watershed. The study was conducted for three years in 2015-2017. The Upper Solo and Brantas Watershed were chosen because they represent watersheds with high population densities and high rainfall intensity dominated by mineral soils such as alfisol, inceptisol, entisol, vertisol, ultisol (Jariyah, 2019; Jariyah & Pramono, 2018; Wahyuningrum & Basuki 2019; Wahyuningrum & Putra 2019), thus the resulting regression equation will represent regions with similar conditions. Non-Point-Source (NPS) sampling locations were at the outlets of sub-watershed. The sample locations chosen represent all types of land use based on land use activities near the flow; besides this location also represents the whole activities in the whole catchment area. The results thus illustrate the impact of activities in the catchment area. This sampling method was practiced by Ding et al. (2015). Also, according to Medium Term Development Plan (Rencana Pembangunan Jangka Menengah), these two watersheds were classified as the Priority Watershed to be restored (Bappenas, 2015) and also were potentially polluted due to various types of pollutants produced by community activities, for example domestic, agricultural, industrial and other activities as stated by Roosmini et al. (2018); Darmawan, Sulardiono, & Haeruddin (2018). The outlets of Solo and Brantas Watersheds are located 7°20’48,84”S; 111°07’25,56”E and 7°26’50,40”S; 112°27’15,04”E, respectively. The study areas can be seen in Figure 1.

Data collection

Land use/land cover was collected from the secondary data from BPKH (Balai Pemantapan Kawasan Hutan), which is resulted from image interpretation. DEM (Digital Elevation Model) map was used to determine the sub-watershed boundary based on the selected outlet position. Road and river network maps were obtained from the RBI (Rupa Bumi Indonesia) map. All of these spatial data were processed using ArcGIS 9.2.

The data was collected by taking surface water samples by purposive sampling at each selected sub-watershed outlet. The number of sub-watershed outlets in this study was 28, which consisted of 13 in the Upper Solo watershed and 15 in the Brantas watershed. Sampling is carried out in the wet and dry seasons. These samples were considered Non-Point Source (NPS) data. The number of samples observed was higher than the number used by Effendi & Wardiatno (2015); Effendi (2016); Effendi, Muslimah et al. (2018); Effendi, Sabila, & Setiawan (2018) in determining the water quality index and the correlation of land use changes on water index in Ciambulawung and Ciliwung River Basins. The number of samples used for correlation-regression analysis differed in several studies; there was no exact amount to be collected (Table 1). The number of samples in this study is considered to be sufficient, although the model obtained still requires

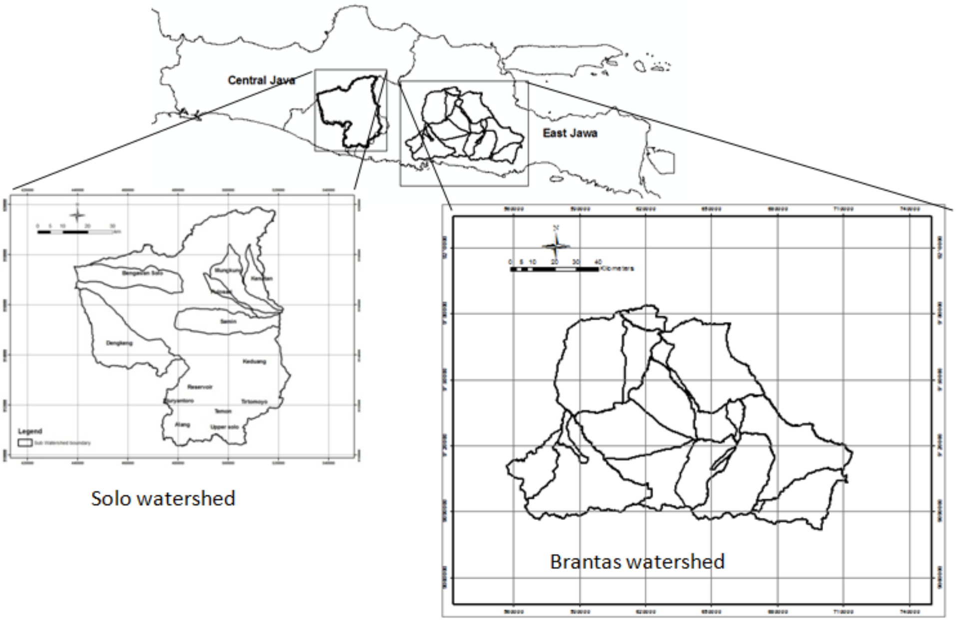

Figure 1. Study area map

Table 1. The number of samples used in several studies related to water quality

Watersheds	Countries	Total Area (ha)	Number of Samples Used	References
Choaku Lake	China	1,335,000	81	Huang, Zhan, Yan, Wu, & Deng (2013)
Jacaré–Pepira River and Jacaré–Guaçu River	Brazil	Not Available	15	Souza, Fonseca, Libório, & Tanaka (2013)
Ciambulawung	Indonesia	Not Available	9	Effendi & Wardiatno (2015)
Upper Solo	Indonesia	Not Available	27-32	Basuki (2015)
Dong Jiang	China	3,534,000	83	Ding et al. (2015)
Grojokan Sewu	Indonesia	1,130	4	Wahyuningrum & Pramono (2013)

validation using other data.

The research parameters observed were water quality both, physical, chemical, and biological, namely: Total Suspended Solid (TSS), TDS, BOD, COD, Phenol, Free Chlorineine (Cl), Fe, Phosphate, Nitrate, Nitrite, Detergent, Turbidity and E. coli. Water quality analyses was carried out by the Laboratorium of Balai Besar Teknik Kesehatan Lingkungan dan Pengendalian Penyakit in Yogyakarta

Data Analysis

The average value of the water quality of each sample was used to calculate the PI value and class of water pollution. The guideline used is the Decree of the Minister of Environment No. 115 of 2003 concerning Guidelines for Determining the Status of Water Quality, while the water quality standard used is Government Regulation No.82 of 2001 (PP 82/2001) concerning Management of Water Quality and Water Pollution Control in Class III. This Class III, is a class with the designation of freshwater fisheries, livestock, irrigation, or other designation that requires the same quality. The use of class III is the same as the method used by (Effendi, 2016). A descriptive analysis was performed to determine the diversity of data, followed by correlation analysis of each water quality parameter with PI. The regression analysis was then performed using water quality parameters as an independent variable and PI as the dependent variable. Variables with high correlation values (> 0.5) were used in regression analysis. Multiple linear regression was used for the analysis, using the following equation:

$$Y = a + b_1X_1 + b_2X_2 + \ldots.. + b_nX_n + \varepsilon \qquad (1)$$

Where:

Y = PI

X_1 , $X_{2\ldots}$Xn = Water quality parameters

A = Constant

ε = Error

3. Result and Discussion

Land use/land cover types

Some community activities such as agriculture, domestic and industries have the potential to cause pollution which results in a decrease in water quality. The results of a study conducted by Shukla et al. (2018) showed that population growth and agricultural activity were directly related to a decrease in water quality, especially BOD, DO, and E. coli. Moreover, Huang, Zhan, Yan, Wu, & Deng (2013) found that there was a positive correlation between agricultural land with DO and NH_3-N concentrations; this is due to the opening of the soil surface due to tillage and also because of the application of chemical fertilisers. Vegetation covers may also influence water quality, as stated by (Wahyuningrum & Pramono, 2013). They stated that the forest area has a correlation with sodium, nitrite, TDS, sulphate and organic matter in quadratic form Wahyuningrum & Pramono (2013). This indicates that the forest can reduce water pollution because it can function as a filter to hold nutrient-containing sediments so that it does not enter the river flow. Besides, Urban areas consisting of settlements, industrial complexes, offices, and trade areas can contribute many pollutants which have implications for the reduction of water quality because compared to other land cover types this urban area produces more wastewater (Permatasari, Setiawan, Khairiah, & Effendi, 2017).

Information about the condition of land use/land cover is crucial, to provide an overview of the sources of pollution in a watershed. Human activities are described in the distribution of land use/land cover. Locations that have the potential pollution can be easily identified if land use/land cover distribution map is available. The water quality observed at the outlet represents the community activities based on the distribution of land cover types. Each sub-watershed has a different type of land use/land cover composition. This composition will have an impact on water quality. The types and extent of land use/land cover of each sub-watershed can be seen in Figure 4 and 5. The type of land use/land cover that has the potential pollution is seasonal crops such as rice fields and dry fields, and settlements (buildings area) (Shukla et al., 2018; Singh et al., 2017). Samples distribution and land use / land cover of the study areas can be seen in Figure 2 and Figure 3.

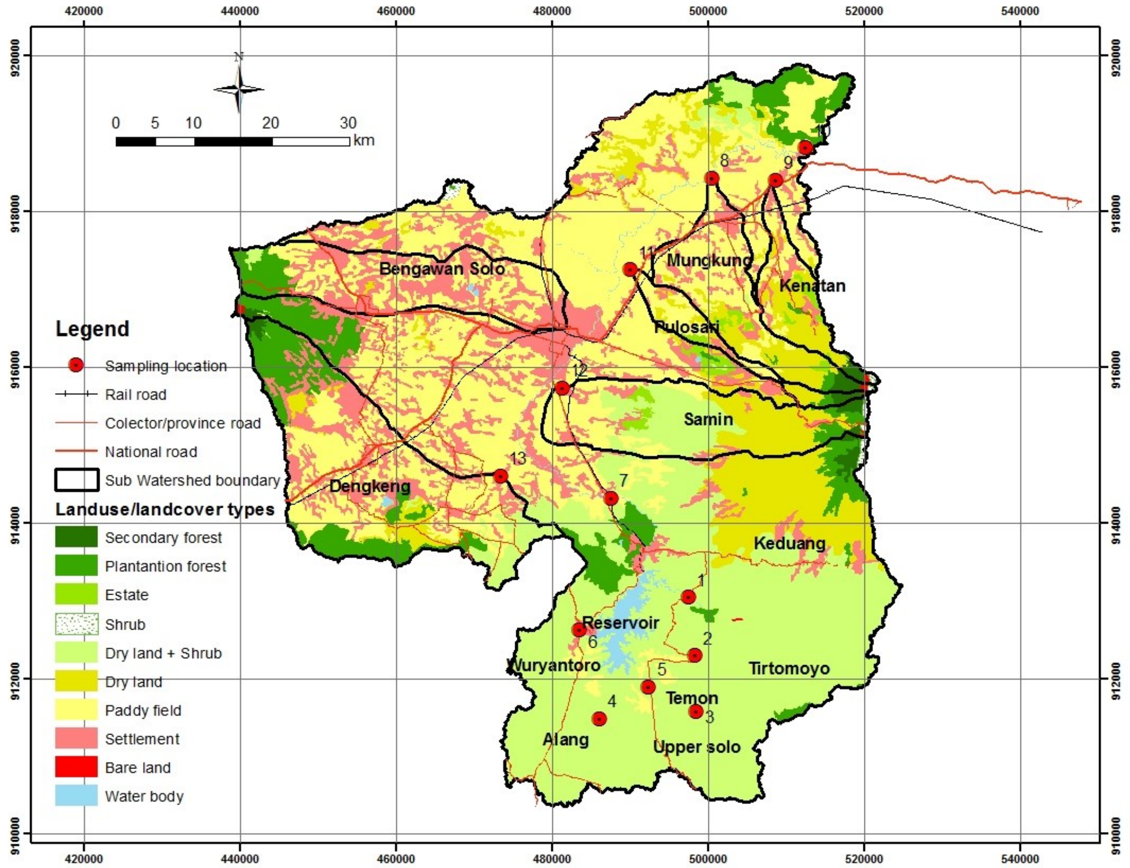

Figure 2. Distribution of Non-Point Source samples and land use/land cover of Upper Solo watershed

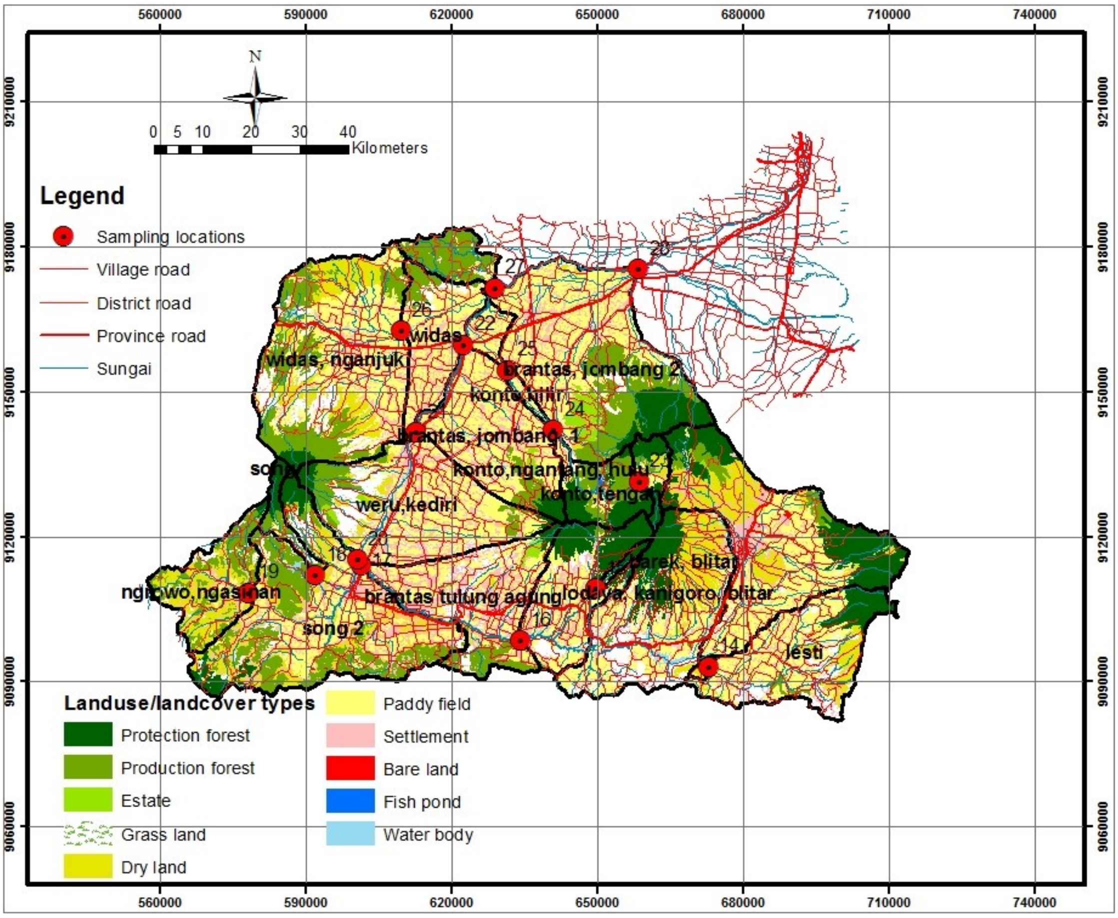

Figure 3. Distribution of Non-Point Source samples and land use/land cover of Brantas watershed

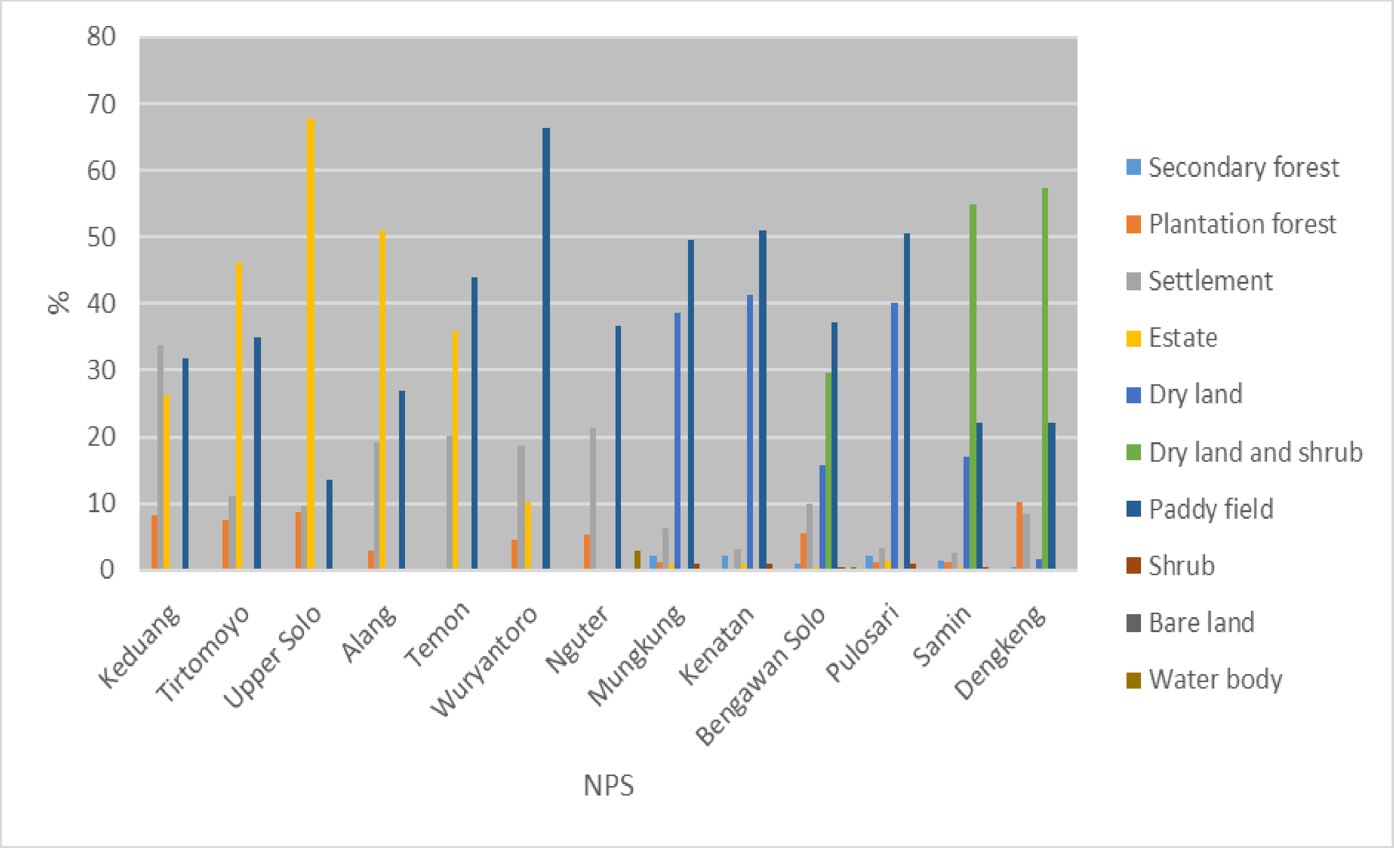

Figure 4. Percentage of land use/land cover area of each Non-Point Source in Solo watershed

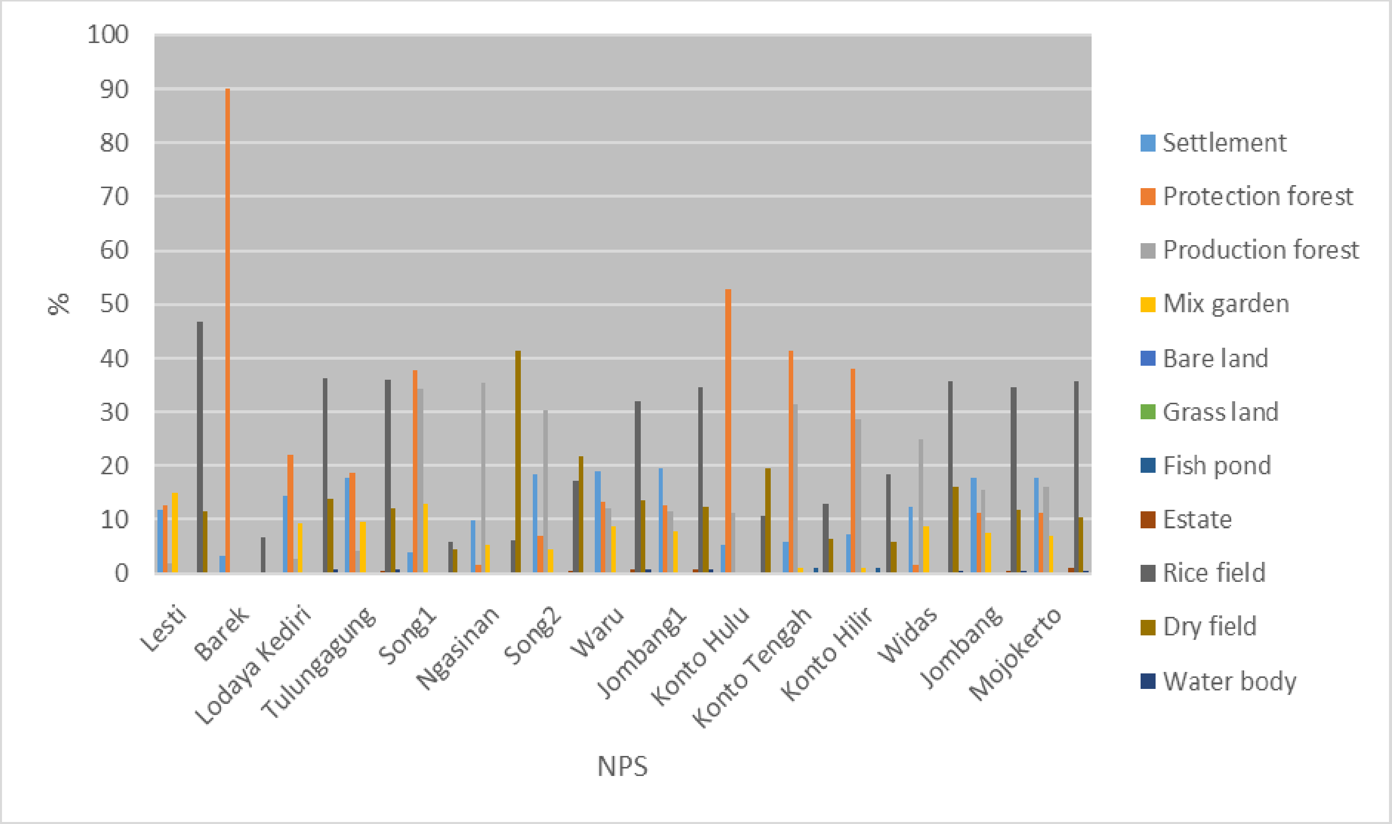

Figure 5. Percentage of Land use/land cover area of each Non-Point Source in Brantas watershed

Water Quality and Pollution Index (PI)

The results of laboratory analysis of water quality parameters, calculation of pollution indices, and water quality crtiteria are presented in the Table 2 (organic and inorganic chemistry) and Table 3 (physical and biological), while the results of the descriptive analysis of each parameter are presented in Table 4.

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Table 2. Average value of organic and inorganic chemistry parameters of each Non-Point Source

NPS	OD mg/L	B ODm g/L	C Phenol mg/L	Free chlorine mg/L	Fe mg/L	Phosphate mg/L	Nitrate mg/L	Nitrite mg/L	Deter-gen mg/L
PP 82/2001, Class III	6	50	0.001	0.03	-	1	20	0,06	0,2
Keduang	5.1	30.35	<0.0215	0	0.17465	0.431	1.475	0.09305	0.0013
Tirtomoyo	3.8	25.7	<0.0215	0	0.2357	0.9669	2.055	0.03445	0.1319
Upper solo	3.8	27.05	<0.0215	0	0.35405	0.2462	2.37	0.12565	0
Alang	3.8	27.6	<0.0215	0	0.131	0.48705	2.81	0.0654	0
Temon	4.6	33.7	<0.0215	0	0.20425	1.47805	2.455	0.24145	0.0289
Wuryantoro	3.8	18.9	<0.0215	0	0.5864	0.34145	1.47	0.04825	0.0066
Nguter	3.3	22.4	<0.0215	0	0.38895	0.33695	1.63	0.05975	0.1053
Mungkung	13	43	0.01325	0	1.55625	1.3905	6.73	0.3753	0.0547
Kenatan	9.5	24.1	<0.0215	0.15	0.73735	1.3611	4.14	0.19105	0.00125
Bengawan Solo	11.25	48.55	<0.0215	0.05	1.20295	5.8205	4.94	0.0365	0.03025
Pulosari	9.3	36.7	0.0221	0.1	0.20935	1.1138	4.855	0.2584	0.0289
Samin	15.25	36.65	0.0211	0.05	1.51825	0.89885	1.24	0.32375	0.02705
Dengkeng	10.8	34.35	<0.0215	0.2	0.12	3.0502	4.135	0.2451	<0.0002
Lesti, Malang	2.95	25.75	0	0.25	1.4239	0.8272	16.005	0.08375	0.01085
Barek Blitar	2.75	18.75	0	0.2	0.7442	0.29965	487	0.19025	0.01205
Lodoyo	2.55	17.45	0	0.2	2.90725	0.8057	12.055	0.01955	0.0081
Brantas Tulungagung	3.85	16.7	0	0.25	3.51335	0.47725	5.615	0.02835	0.06415
Song 1 Tulungagung	7.65	23.2	0	0.25	7.9125	3.8	1.86	0.1003	0.06325
Ngasinan, Trenggalek	8	32.25	0	0.2	3.46335	2.6083	4.435	0.04785	0.0065
Song 2 Tulungagung	8.95	32.65	0	0.35	2.95745	0.2685	6.095	0.3584	0.07425
Bendung Waru Kediri	3.75	19.85	0.01915	0.55	0.0806	0.9362	11.105	0.02535	0.0286
Brantas Jombang I	3.35	15.4	0.02995	0.45	0.5815	1.4029	12.545	0.0485	0.04695
Konto, Ngantan, Malang	4.4	37.85	0.0116	0.15	3.18575	1.3027	20.415	1.6892	0.01895
Konto Tengah	16.3	31.3	0.02505	0.4	1.7141	2.4625	6.475	0.0577	0.08245
Konto Hilir	4.8	22.8	0.03585	0.45	0.3199	0.8068	15.855	0.09445	0.02655
Widas Nganjuk	3.7	21.9	0,0216	0.45	0.3118	0.92045	5.705	0.06545	0.025
Brantas Jombang II	3.8	19.35	0,0221	0.6	0.1227	1.663	11.12	0.09665	0.13595
Mojokerto 1	1.85	17.1	0	0.05	1.76215	0.67511	11.055	0.10485	0.0158

Table 3. The average value of physical and biological parameters of each Non-Point Source

NPS	TSS mg/L	TDS mg/L	Turbidity NTU	Total E. coli / 100mL
PP 82/2001, Class III	1000	400	25	10000
Keduang	78	149	103.5	270
Tirtomoyo	171.5	189,5	211.5	800
Upper solo	76	192,5	107	800
Alang	209.5	211	278.5	0
Temon	14.075	215	483.5	11.55
Wuryantoro	42.5	200	43.5	0
Nguter	103	486,5	121	0
Mungkung	55.5	118	341	1,700
Kenatan	29.5	105	70.5	230,000
Bengawan Solo	124	120,5	227.5	24,000
Pulosari	60	99	130	16,000
Samin	77	104	153	540,000
Dengkeng	76	151	105	230,000
Lesti, Malang	77.5	152	92.5	1,600
Barek Blitar	11.5	76	24	16,000
Lodoyo	55	101	72	23
Brantas Tulungagung	85.5	158	103.5	260
Song 1 Tulungagung	483	39	169.45	1,600
Ngasinan, Trenggalek	456.5	112	74.6	260
Song 2 Tulungagung	76	70	135	920
Bendung Waru Kediri	97	106	72.5	94
Brantas Jombang I	149	129	153.5	110
Konto, Ngantan, Malang	42	118	77	16,000
Konto Tengah	84	992	2891.5	16,000
Konto Hilir	94.5	353.5	584.5	79
Widas Nganjuk	115	114.5	77.5	12
Brantas Jombang II	117	169.5	160.5	46
Mojokerto 1	72.5	170	80.5	94

Table 4. Statistical description of water quality data

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance
TSS (mg/l)	11.50	483.00	1.1188E2	110.11839	1.213E4
TDS (mg/l)	39.00	992.00	1.8577E2	180.92246	3.73E4
BOD (mg/l)	1.85	16.30	6.2839	4.02221	16.178
COD (mg/l)	15.40	48.55	27.1911	8.55674	73.218
Phenol (mg/l)	0.00	0.04	0.0079	0.01158	0.000
Chlorine (mg/l)	0.00	0.60	0.1911	0.18661	0.035
Fe (mg/l)	0.08	7.91	1.3721	1.70296	2.900
Phosphat (mg/l)	0.25	5.82	1.3087	1.20841	1.460
Nitrate (mg/l)	1.24	20.42	6.6255	5.15271	26.550
Nitrite (mg/l)	0.02	1.69	0.1825	0.31333	0.098
Detergent (mg/l)	0.00	0.14	0.0370	0.03887	0.002
Turbidity (NTU)	24.00	2891.50	2.5514E2	532.26544	2.833E5
E.coli (/100 ml)	0.00	5.40E5	3.9167E4	1.14836E5	1.319E10

Source: Data analyses (2019)

the descriptive analysis of each parameter are presented in Table 4.

Table 4 shows that the smallest variance is for the Phenol parameter while the biggest is for E. coli. Large variance values indicate that the parameter data varies significantly from one location to another and vice versa. The maximum value of some parameters exceeds the Class III standard of water quality such as TDS, BOD, Phenol, Chlorine, Phosphate, Nitrite, Nitrate, Detergent, Turbidity, and E. Coli. This causes the water quality at that location to be classified into class IV. Table 5 and 6 show that all NPS water samples have water quality, which is included in Class IV because it is not following Class III and above (Class I and II). The results of PI analysis of each NPS can be seen in Table 3. It shows that, even though they have the same class, however, each has a different PI value with different limiting parameters. The following

Table 5. Pollution levels and its limiting factors at each observation location

Lokasi	PI Value	Pollution Level	Limiting parameters
Solo Watershed			
Keduang	2.92	lightly polluted	turbidity, nitrite
Tirtomoyo	4.01	lightly polluted	turbidity
Upper Solo	2.98	lightly polluted	turbidity, nitrite
Alang	4.44	lightly polluted	turbidity, nitrite
Temon	5.31	lightly polluted	turbidity, nitrite, phosphate
Wuryantoro	1.58	lightly polluted	turbidity
Nguter	3.16	lightly polluted	TDS, turbidity
Mungkung	4.88	lightly polluted	phenol, phosphate, nitrite, turbidity
Kenatan	5.65	lightly polluted	BOD, chlorine, phosphate, nitrite, turbidity, E. coli
Bengawan Solo	4.22	lightly polluted	BOD, chlorine, phosphate, nitrite, E. coli
Pulosari	5.62	lightly polluted	BOD, phenol, chlorineine, phosphate, nitrite, turbidity, E. coli
Samin	7.04	lightly polluted	BOD, phenol, chlorineine, nitrite, turbidity, E. coli
Dengkeng	5.07	lightly polluted	BOD, phosphate, nitrite, turbidity, E. coli
Brantas watershed			
Lesti, Malang	4.03	lightly polluted	chlorine, nitrite, turbidity
Barek Blitar	3.68	lightly polluted	chlorine, nitrite, E. coli
Lodoyo	3.66	lightly polluted	chlorine, turbidity
Brantas Tulungagung	4.01	lightly polluted	chlorine, turbidity
Song 1 Tulungagung	4.09	lightly polluted	BOD, chlorine, nitrite, turbidity
Ngasinan, Trenggalek	3.71	lightly polluted	BOD, chlorine, phosphorus, turbidity
Song 2 Tulungagung	4.58	lightly polluted	BOD, chlorine, nitrite, turbidity
Bendung Waru Kediri	5.35	lightly polluted	phenol, chlorine, turbidity
Brantas Jombang I	6.06	lightly polluted	phenol, chlorine, phosphate, turbidity
Konto, Ngantan, Malang	6.01	lightly polluted	phenol, chlorine, phosphate, nitrite, nitrate, turbidity, E. coli
Konto Tengah	8.22	lightly polluted	TDS, BOD, phenol, chlorine, phosphate, turbidity, E. coli
Konto Hilir	6.37	lightly polluted	phenol, chlorine, nitrite, turbidity
Widas Nganjuk	5.54	lightly polluted	phenol, chlorine, nitrite, turbidity
Brantas Jombang II	5.62	lightly polluted	phenol, chlorine, phosphate, nitrite, turbidity
Mojokerto 1	2.55	lightly polluted	chlorine, nitrite, turbidity

Source: Primary data, 2019

Table 6. Correlation between PI values with each parameter

		Correlations												
		PI_III	TSS	TDS	BOD	COD	Phenol	Chlorine	Fe	Phosphat	Nitrate	Nitrite	Detergent	Turbidity	E.coli
Pearson Correlation	PI_III	1.000	-0.111	0.347	0.559	0.281	0.728	0.497	-0.088	0.241	0.281	0.259	0.182	0,538	0.397
	TSS	-0.111	1.000	-0.119	0.050	-0.024	-0109	0.105	0.605	0.398	-0.197	-0.218	0.130	-0,050	-0.144
	TDS	0.347	-0.119	1.000	0.287	-0.002	0.279	0.104	-0.164	0.035	-0.023	-0.148	0.319	0,894	-0.114
	BOD	0.559	0.050	0.287	1.000	0.693	0.218	-0.070	0.142	0.497	-0.288	0.088	0.057	0,504	0.551
	COD	0.281	-0.024	-0.002	0.693	1.000	-0.035	-0.392	0.001	0.521	-0.160	0.401	-0.101	0,158	0.257
	Phenol	0.728	-0.109	0.279	0.218	-0.035	1.000	0.613	-0.239	-0.017	0.421	0.071	0.203	0,358	0.103
	Chlorine	0.497	0.105	0.104	-0.070	-0.392	0.613	1.000	0.063	0.061	0.516	-0.112	0.267	0,204	-0.148
	Fe	-0.088	0.605	-0.164	0.142	0.001	-0.239	0.063	1.000	0.276	0.057	0.188	0.078	0,001	-0.065
	Phosphate	0.241	0.398	0.035	0.497	0.521	-0.017	0.061	0.276	1.000	-0.058	-0,032	0.046	0,209	0.080
	Nitrate	0.281	-0.197	-0.023	-0.288	-0.160	0.421	0.516	0.057	-0.058	1.000	0.433	-0.050	0,008	-0.246
	Nitrite	0.259	-0.218	-0.148	0.088	0.401	0.071	-0.112	0.188	-0.032	0.433	1.000	-0.108	-0,088	0.116
	Detergent	0.182	0.130	0.319	0.057	-0.101	0.203	0.267	0.078	0.046	-0.050	-0.108	1.000	0,257	-0.185
	Turbidity	0.538	-0.050	0.894	0.504	0.158	0.358	0.204	0.001	0.209	0.008	-0.088	0.257	1.000	-0.01
	E. coli	0.397	-0.144	-0.114	0.551	0.257	0.103	-0.148	-0.065	0.80	-0.246	0.116	-0.185	-0.061	1.000
Sig, (1-tailed)	PI_III	,	0.287	0.035	0.001	0.074	0.000	0.004	0.328	0.109	0.073	0.091	0.177	0.002	0.018
	TSS	0.287	,	0.274	0.400	0.452	0.290	0.298	0.000	0.018	0.158	0.133	0.255	0.400	0.232
	TDS	0.035	0.274	,	0.069	0.495	0.076	0.300	0.202	0.430	0.454	0.226	0.049	0.000	0.281
	BOD	0.001	0.400	0.069	,	0.000	0.133	0.361	0.235	0.004	0.069	0.329	0.386	0.003	0.001
	COD	0.074	0.452	0.495	0.000	,	0.430	0.020	0.498	0.002	0.207	0.017	0.305	0.211	0.093
	Phenol	0.000	0.290	0.076	0.133	0.430	,	0.000	0.110	0.466	0.013	0.359	0.150	0.031	0.302
	Chlorine	0.004	0.298	0.300	0.361	0.020	0.000	,	0.376	0.379	0.002	0.285	0.085	0.149	0.226
	Fe	0.328	0.000	0.202	0.235	0.498	0.110	0.376	,	0.078	0.386	0.169	0.347	0.498	0.372
	Phosphate	0.109	0.018	0.430	0.004	0.002	0.466	0.379	0.078	,	0.384	0.436	0.409	0.143	0.343
	Nitrate	0.073	0.158	0.454	0.069	0.207	0.013	0.002	0.386	0.384	,	0.011	0.399	0.483	0.103
	Nitrite	0.091	0.133	0.226	0.329	0.017	0.359	0.285	0.169	0.436	0.011	,	0,293	0.329	0.279
	Detergent	0.177	0.255	0.049	0.386	0.305	0.150	0.085	0.347	0.409	0.399	0.293	,	0.093	0.174
	Turbidity	0.002	0.400	0.000	0.003	0.211	0.031	0.149	0.498	0.143	0.483	0.329	0.093	,	0.380
	E. Coli	0.018	0.232	0.281	0.001	0.093	0.302	0.226	0.372	0.343	0.103	0.279	0.174	0.380	,

Source: Primary data, 2019

are the results of PI calculations and the limiting factors in each of the observed locations (Table 5).

Based on Table 5 it can be seen that there are various PI values and limiting parameters. Upper Solo watershed has a range of PI values between 1.58 (Wuryantoro) to 7.04 (Samin) with mild and moderate polluted categories, and also the Brantas watershed has the lowest PI value of 2.55 (Mojokerto), and the highest is 8.22 (Konto Tengah) with the mild and moderate contaminated categories. This value indicates that the water quality of Class III does not meet the quality standards, according to PP 82/2001. All sample points are in a polluted condition, both lightly and moderately polluted.

This is due to the many limiting factors in each observation location exceeding the quality standard. Some of the limiting factors include turbidity, nitrite, nitrate, phosphate, TDS, BOD, chlorine, phenol, and E. coli. This result is slightly different from the results of Basuki (2015), the values that exceed the standard values were BOD, COD, NTU, nitrite, detergent and chlorine, while TDS and nitrate were still below the Class III threshold value. The limiting factor at each sampling location cannot be separated from the influence of land use and land cover of its catchments. Various community activities will produce pollutant sources which will ultimately affect water quality (Rezagama et al., 2016). At the sampling location that has many mixed gardens and paddy fields, it is known that there are parameters that exceed the quality standards such as phenol, TDS, chlorine, and turbidity. This may be caused by fertilising activities, the use of pesticides and insecticides. Mariyono & Irham (2001) stated that chemical pesticides commonly used in agricultural activities could cause environmental damage and pollution.

Based on data on land use/land cover, it is known that in areas with the dominant use of paddy field and dry field, land experience intensive management that may cause erosion and will ultimately increase water turbidity. Intensive land management can cause erosion and sedimentation, which accumulates in both the upper and lower slopes (Arianti, Suratman, Martono, & Suprayogi, 2012). Meanwhile, areas dominated by settlements will have limiting factors such as turbidity, BOD, chlorine, phosphate, Fe, and nitrite. This is due to a large amount of waste entering the water body due to various domestic activities. Hamakonda, Suharto, & Susanawati (2017) said that domestic activities could cause pollution by BOD and nitrite.

The main parameters of water quality

Correlation analysis results show that several parameters have a large enough correlation (>0.50) (Table 9) such as, COD-BOD, BOD-Turbidity, COD-Phosphat, Turbidity-TDS. These findings are similar to those stated by Basuki (2015). Basuki (2015) found that the strong correlation between COD-BODand BOD-Turbidity.

Multistage regression analysis using the value of PI as a dependent variable and limiting factor as independent variables give results about some of the most influential limiting factors. Table 5 shows the correlation between PI values with each parameter measured.

Based on the Table 3 it can be seen that there is a positive correlation between the value of PI with Phenol and BOD. This is indicated by the high correlation value of 0,728 (Phenol) and 0,559 (BOD). The two parameters also show the percentage value that describes the PI content at the sampling location (Table 4).

Table 9 shows that the value of R when using phenol alone illustrates the PI value of 72.8%, with a value of R Square of 53% (Model 1). If a BOD factor is added, the percentage will increase to 83.6% with an R square value of 69.9% (Model 2). The error value of these two parameters can also be seen in the ANOVA in Table 5. It means that the phenol variable can significantly explain 72.8 % of the Model 1 at a confidence level of 0.05 and so as Model 2, BOD and phenol can significantly explain 83.6 %.

The regression coefficient is used to determine the model to be used. Coefficient regression analysis can be seen in Table 6.

The equations formed from the analysis are: Model 1: PI = 3.952 + 91.688 phenol and Model 2: PI = 3.086 + 80.167 Phenol + 0.152 BOD. Both models can be used to predict PI based on phenol and BOD values. Model 1 only requires phenol as a parameter, while Model 2 requires phenol and BOD. Model 2 has a higher R square value based on R square analysis (Table 4). By knowing the phenol and BOD value, the water quality of a watershed can be predicted.

The use of phenol and BOD as PI estimator variables are in line with some researches finding. Phenol is a dangerous pollutant when found in water bodies (Kahn, Li, & Zhao, 2015). Effendi (2003) stated that phenol in water bodies would cause changes like water that can be toxic to aquatic biota. Jauhari & Thamrin (2012) added that phenol is one of the pollutant sources that have an impact on the environment and is toxic to the human body. Apart from industrial activities, the phenol content in water bodies is also caused by the natural decomposition of organic matter and agricultural activities (Zhong, Wang, & Wang, 2017). Yogafanny (2015) stated that phenol could come from the decay of organic materials such as wood, twigs, or other organic waste, as well as the remaining animal feed and the rest of the or-

Table 7. R square value of PI contents

Model	R	R Square	Adjusted R Square	Std, Error of the Estimate
1	0.728[a]	0.530	0.512	1.01819
2	0.836[b]	0.699	0.675	0.83156

Remarks: a. Predictors: (Constant), Phenol; b. Predictors: (Constant), Phenol, BOD

Table 8. Analysis of Variance (ANOVA)

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	30.424	1	30.424	29.347	0.000[a]
	Residual	26.954	26	1.037		
	Total	57.378	27			
2	Regression	40.091	2	20.046	28.989	0.000[b]
	Residual	17.287	25	0.691		
	Total	57.378	27			

Remark: a. Predictors: (Constant), Phenol; b. Predictors: (Constant), Phenol, BOD

Table 9. Coefficients regression

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.952	0.235		16.853	0.000
	Phenol	91.688	16.925	0.728	5.417	0.000
2	(Constant)	3.086	0.301		10.263	0.000
	Phenol	80.167	14.162	0.637	5.661	0.000
	BOD	0.152	0.041	0.421	3.739	0.001

Remark: Dependent Variable: PI_III

ganic fertiliser which dissolves and enters the water body. The number of activities that have the potential to produce phenol will cause an increase in PI values. This shows that phenol can be a parameter for monitoring and evaluating the health of a watershed. Also, Aufa (2017) and Ontañon, González, & Agostini (2015) stated that phenol becomes the primary concern Environmental Protection Agency (EPA) and Canada's National Pollutant Release Inventory (NPRI). Moreover, Villegas et al. (2016) stated that phenol is a priority pollutant in water because it is hazardous even in low amounts.

BOD is an important parameter used in water quality analysis (Jouanneau et al. 2014; Gomolka, Twarog, Zeslawska, Lewicki, & Kwater, 2017) and the value of Water Quality Index (Kumar, Gupta, Kumar, & Sharma, 2014). BOD analysis is used to determine the dissolved oxygen content needed by organisms to decompose organic matter in water and is a potential pollutant in observing water quality (Ahmed & Shah, 2015; Kurnaz et al., 2016; Lee & Nikraz, 2015). Basuki (2015) revealed parameters BOD can represent COD, $KMnO_4$, turbidity, nitrite, chlorineide, colour, and sulphate parameters.

4. Conclusion

The water pollution index shows the level of pollution in a water body. Water quality analysis is essential to find out the pollution index in the water body. A large number of parameters needed for water quality analysis is an obstacle in assessing water quality in a watershed. The equations that can be used to predict the pollution index are Model 1: PI = 3.952 + 91.688 Phenol and Model 2 : PI = 3.086 + 80.167 Phenol + 0.152 BOD. To selects the most appropriate model, model validation is necessary. Model validation uses other water quality data from the deferent area which has similar characters. For the present, phenol and/or BOD can be used to predict the pollution index in the watersheds which have similar characters with the study area. It is hoped that the simplification of these parameters can facilitate the observation of the health of water bodies in a watershed.

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