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Surface water quality assessment of the Gebeng industrial area using water quality standard and index

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Abstract: Surface water is a quick impact of pollution because of their easy accessibility for disposal of wastewater. Natural processes and industrial activities determine the quality of surface water in a region. The study was done to evaluate the surface water quality of Gebeng industrial estate, Pahang, Malaysia. Ten stations were established along the Tunggak and Balok River to collect water samples. The data were calculated according to Water Quality Index which obtained by Department of Environment (WQI-DOE) and categorized to compare with National Water Quality Standard Malaysia (NWQS). Water quality of Gebeng was classified based on WQI Malaysia as class III (51.9 – 76.5), and IV (< 51.9) which are slightly polluted and polluted due to low levels of DO and pH, and high levels of AN, BOD, COD, and TSS. It is clear that stations IZ2, IZ3, HA1, HA2, DS are received the largest pollutants discharged from the industrial sector. Generally, the results of this study will be very useful for policy maker and future studies to control and management of pollution in the study area.

Key words: *DO, Electrical conductivity, Watersheds.*

INTRODUCTION

Substantial deterioration of water quality can be caused by intensive land use in river watersheds and rapid response of organic pollutants from different sources, which pose a direct or indirect threat to the quality of life of local people and health of aquatic ecosystem [1[,[2],[3]. Water is very important for the survival of all existing organisms. The quality of water is necessary for mankind since it is connected with human health. The anthropogenic input from mining, national and industrial activities such as discharge from wastewater from electroplating smelting, corrosion of copper tubing and metal engraving industries are considered a significant source of surface water pollution. Nowadays, large quantities of untreated industrial wastewater have been discharged into surface water bodies for disposal [4].

Malaysia is enjoyed with abundant of water resources which contribute to the economic and industrial development of the country. However, according to the Environmental Quality Report 2010, approximately 50% river water is polluted in Malaysia which is higher than the last couple of years. Conventional and non-conventional pollutants in the industrial area which is directly discharged in the river systems and that cause the deterioration of water quality [5].

The growing industrial area in Malaysia is Gebeng, Kuantan, Pahang. The contamination level in surrounding Gebeng watershed has increased due to industrialization, and most of the wastewater released from the industries contains pollutants and dumped into the surface water [6], especially in the space of the Balok and Tunggak River [7]. Nowadays, continuous and regular monitoring programs have been used to understand the spatial and temporal variations in physio-chemical properties of water and to give the reliable information about surface water quality properties [8]. Pearson regression and correlation have widely used for interpretation and assessment of large and complex water quality data sites [9],[10],[11],[12].

Few limited studies have been found about Gebeng industrial area that has been given a few information about the water quality. The results of Hossain et al. [13] indicated that the DO concentration was very low in all parts of the Tunggak River. In addition, BOD and COD were very high compared to the standard level of Malaysia. Whereas, the study of Sobahan et al. [14] indicated that the water river having

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lower DO, higher contamination level of BOD, COD, NH3-N, and phosphate.

MATERIALS AND METHODS

Study Area

Gebeng industrial estate which is one of the potential industrial areas of Malaysia. The industrial park is situated between the coordinates of 03 ° 54 ′ 00″North and 103 ° 21 ′ 00″ East (Figure 1). Gebeng town is about 20 km far from Kuantan city and near Kuantan port. The two rivers namely the Bhalok and Tungguk are flowing through the industrial area which ended into the South China Sea [6]. The industries such as steel industries, polymer, chemicals, petrochemicals, metal works factories, pipe coating, palm oil mills, oil and gas industries, energy, chicken food, cool mining, detergent and air product, concrete ducting and concrete ducting discharge their pollutants in these two rivers which led to polluted the area [15].

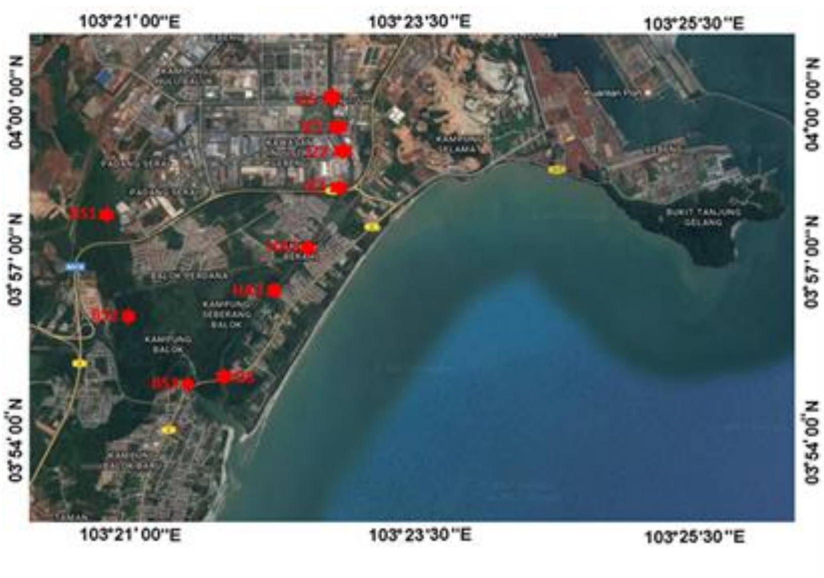


Figure 1. Map of the study area and sampling stations

Samples collection

Samples were collected from 10 sampling stations (Table 1) during October 2016 to February 2017 from about 10-15 cm below the surface by using 1000 ml HDPE bottles. Sampling for BOD analysis was collected by using dark BOD bottles (300 ml), according to Bartram and Ballance. [16] and APHA [17]. Collected samples were kept immediately in the cool box during sampling and before transported to the laboratory.

Table 1. The sampling stations with their geographical coordinates at Gebeng area.

Station	Name	Geographical coordinates	Source of pollution
US	Upstream Station	N 03°59`13.8" E 103°23`17.9"	Forest Area
IZ1	Industrial Zone 1	N 03°58`32.9" E 103°23`18.2"	Industrial Area
IZ2	Industrial Zone 2	N 03°58`12.0" E 103°23`22.2"	Industrial Activities
IZ3	Industrial Zone 3	N 03°57`54.1" E 103°23`21.4"	Industrial Activities
HA1	Housing Area 1	N 03°57`41.3" E 103°23`13.7"	Urban Area
HA2	Housing Area 2	N 03°57`28.6" E 103°23`06.7"	Urban Area
DS	Downstream Station	N 03°56`34.7" E 103°22`30.5"	South China Sea
BS1	Balok Station1	N 03°59`34.8" E 103°21`27.5"	Industrial Activities Surrounding the Study Area
BS2	Balok Station2	N 03°57`33.3" E 103°21`47.9"	Forest Area
BS3	Balok Station3	N 03°56`30.9" E 103°22`19.3"	South China Sea

Analysis Methods

Six parameters (Temperature, pH, Turbidity, DO, EC and salinity) were measured in-situ by using a portable YSI multisensory (model 6600-M). Analysis of AN, Phosphate, Sulphate, Nitrate and COD were measured by using Spectrophotometer (HACH DR5000 model) [18]. BOD was analyzed by DO meter whereas TSS and TDS were measured in the laboratory by using the Gravimetric method.

The assessment of water quality of the Tunggak and Balok River was done by using Water Quality Index (WQI). Six parameters were obtained to calculate WQI (DO, BOD, COD, AN, SS, and pH) [19]. The following equation (1) used to calculate DOE-WQI:

$$WQI=0.22\times SIDO+0.19\times SIBOD+0.16\times SICOD+0.15\times SIAN+0.16\times SISS+0.12\times SIPH \quad (1)$$

Where the SI indicates the sub-index function and the coefficients are the weightages for the corresponding parameters with a total value of unity.

Statistical Analysis

IBM SPSS software (version 21) was used to calculate Pearson regression and correlation to identify the significant differences among the physicochemical water quality parameters.

RESULTS AND DISCUSSION

Physical-chemical water quality parameters were analyzed by descriptive statistics from 10 sampling stations which were presented in table 2. The relationship among the water quality parameters was measured by using Pearson correlation (two-taildel) analysis (table 3).

Table 2. Mean and standard deviation of physical-chemical parameters at 10 sampling statistic

St. No.		Temp	pH	EC	DO	TDS	Turbidity	Salinity	BOD	COD	NO_3-N	AN	PO_4	TSS	SO_4
	Standards	25±2	6.5-8.5	1000	7	500	5	0.5	1	10	-	0.10	0.20	25	250
US	Mean	28.73	6.65	304.11	4.59	0.77	53.22	0.01	10.16	17.11	0.10	1.50	0.20	12.11	35.78
	SD	0.62	0.88	79.09	0.44	0.03	6.69	0.007	1.26	5.53	0.083	0.15	0.05	9.20	6.48
IZ1	Mean	27.73	6.43	467.77	4.60	2.56	41.56	0.02	11.96	21.67	0.19	1.33	0.23	41.78	33.11
	SD	1.24	1.02	290.25	0.18	0.32	2.79	0.012	7.05	8.31	0.023	0.13	0.08	44.27	9.99
IZ2	Mean	28.05	6.66	554.78	5.01	1.42	108.11	0.01	28.36	40.56	0.13	4.62	0.34	55.33	30.44
	SD	1.08	0.52	164.29	0.25	0.61	99.95	0.005	8.76	17.90	0.050	1.05	0.09	63.82	11.51
IZ3	Mean	29.28	5.09	310.22	3.55	1.21	107.22	0.01	28.07	41.67	0.04	4.54	0.34	57.78	25.67
	SD	1.30	1.64	17.51	1.43	0.09	110.59	0.007	12.03	23.43	0.009	1.05	0.04	42.04	16.01
HA1	Mean	29.73	5.98	480.89	3.90	2.55	181.00	0.04	27.08	46.89	0.08	5.15	0.32	19.56	21.78
	SD	1.60	1.38	239.14	0.44	0.89	213.51	0.022	6.34	19.41	0.078	0.99	0.05	8.97	11.48
HA2	Mean	28.83	5.72	420.66	4.48	2.58	63.44	0.04	20.83	27.78	0.19	1.77	0.18	21.00	24.33
	SD	0.58	1.37	277.83	0.47	0.56	15.68	0.011	0.90	4.32	0.022	0.031	0.07	3.24	16.76
DS	Mean	28.95	6.28	495.56	3.40	26.18	91.00	0.52	13.24	27.44	0.22	2.18	0.28	106.00	76.56
	SD	0.64	0.14	275.98	0.81	15.58	31.01	0.26	4.45	5.98	0.061	0.12	0.03	15.27	34.44
BS1	Mean	27.93	7.44	393.56	5.03	17.24	52.22	0.03	10.67	19.56	0.02	5.27	0.26	33.78	67.67
	SD	0.17	0.20	203.16	0.81	5.94	20.92	0.012	1.47	4.80	0.015	0.76	0.01	12.75	7.14
BS2	Mean	28.35	6.59	220.89	4.36	2.88	38.00	0.08	11.42	31.00	0.03	1.58	0.21	23.22	34.11
	SD	0.28	0.95	79.57	0.36	3.21	10.01	0.042	0.78	11.21	0.008	0.05	0.04	6.20	5.79
BS3	Mean	28.31	6.43	646.67	4.11	24.04	54.77	0.36	7.70	26.56	0.02	1.44	0.14	25.22	132.88
	SD	0.29	1.02	44.36	0.59	18.10	21.07	0.006	4.32	11.80	0.007	0.09	0.02	8.51	11.44

Table 3. Pearson correlation coefficient (r) among the water quality parameters

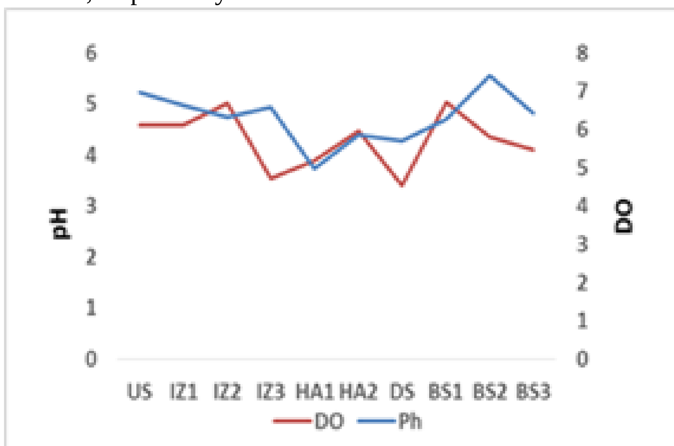
	Temp	PH	EC	DO	Turbidity	salinity	BOD	COD	Nitrate	PO_4	AN	SO_4	TDS	TSS
Temp	1													
PH	0.163	1												
EC	0.526**	0.307**	1											
DO	0.094	0.434**	0.181	1										
Turbidity	-0.315**	-0.399**	-0.230*	-0.132	1									
salinity	-0.022	-0.264*	0.069	-0.419**	0.035	1								
BOD	-0.256*	-0.433**	-0.208*	-0.192	0.604**	-0.243*	1							
COD	-0.338**	-0.185	-0.092	-0.166	0.755**	-0.071	0.722**	1						
Nitrate	0.423**	-0.012	0.236*	-0.028	-0.125	0.248*	0.004	-0.160	1					
PO_4	-0.562**	-0.294**	-0.511**	-0.048	0.574**	0.133	0.549**	0.584**	-0.083	1				
AN	-0.149	-0.320**	-0.084	0.060	0.515**	-0.304**	0.633**	0.528**	-0.354**	0.397**	1			
SO_4	-0.227*	-0.128	0.081	-0.128	0.029	0.740**	-0.323**	-0.053	-0.195	0.212*	-0.179	1		
TDS	0.062	-0.098	0.121	-0.124	0.019	0.772**	-0.323**	-0.063	.059	0.047	-0.103	0.749**	1	
TSS	-0.317**	-0.203	-0.229*	-0.121	0.398**	0.402**	0.369**	0.354**	0.167	0.609**	0.233*	0.241*	0.295**	1

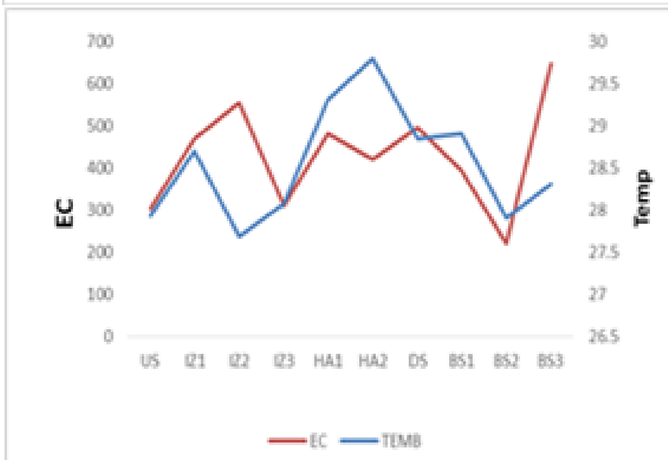
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

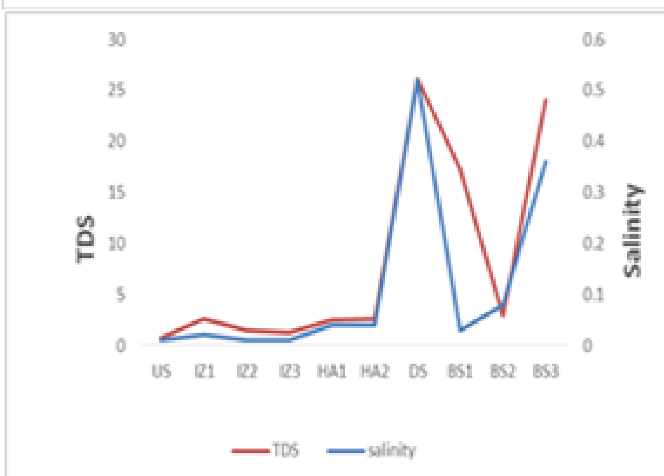
Water temperature recorded between 27.73°C and 29.73°C while the mean temperature was 28.55±0.68°C, which was within the normal standard of the department of environment Malaysia [20]. The temperature had a strong positive relation with EC at (r=0.526). The pH was in acidity range throughout the stations (5.09-7.44) and mean pH was 6.32±0.68 and it had significant positive correlation with EC and DO at (r=0.307, r=0.434), respectively.

Conductivity was within the permissible ranges of NWQS for all the sites (Figur. 2) and recorded from 220.99 to 646.67 µS cm^{-1} while the mean conductivity was 429.51±127.44 µS cm^{-1}. Oxygen is necessary for aquatic life and the DO in a water body is considered an important water quality parameter owing to low DO has identified as a major water quality problem [21]. In the study area, mean DO was 4.30±0.56 mg L^{-1} was under class III [20] and it had strong positive significance at (r=0.434) with pH.

The TDS, TSS, turbidity, and salinity mean values were 8.14±3.21 g L^{-1}, 39.58±8.82 mg L^{-1}, 79.06±44.08 NTU and 0.11±0.18 %, respectively. Correlation showed that there was a significant positive correlation between TDS and salinity at (r=0.772). One the other hand, salinity had a strong positive correlation at (r=0.740) with sulfate (SO_4).







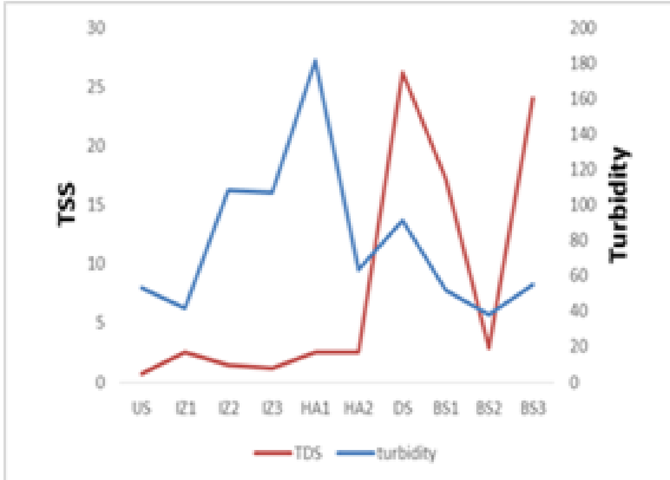
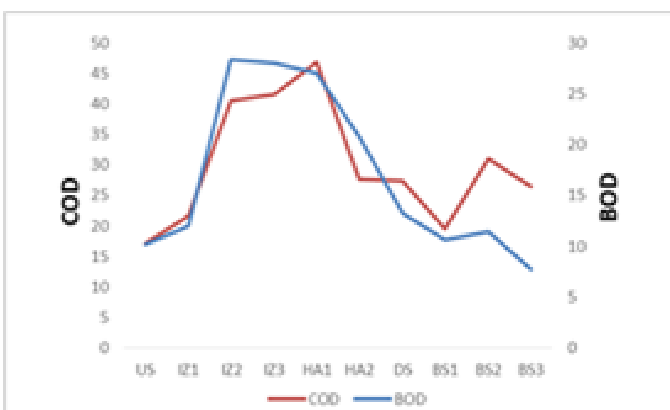
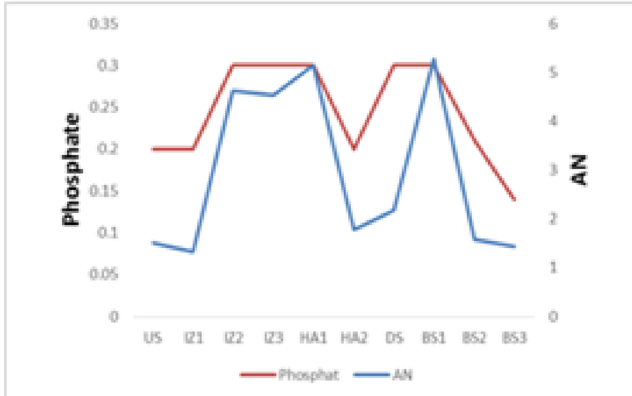


Figure 2. Physicochemical parameters at different sampling stations

The higher BOD was recorded at site IZ2 while the lower at site BS3. COD was ranged from 17.11 to 46.89 mg L^{-1} and the mean value was 30.02±10.01 mg L^{-1}, which higher than the standard that recommended by DOE Malaysia. [20]. Hossain et al. [13] have found a similar result and they indicated that because of industrial wastewater pollution. There was a significant positive correlation at (r=0.722) between COD and BOD.

In the study area, nitrate (NO_3-N) ranged from 0.02 to 0.22 mg L^{-1} with mean 0.10±0.02 mg L^{-1}. The higher AN (NH3-N) was recorded in station BS1 whereas the lower in station IZ1 at 5.27 and 1.33 mg L^{-1}, respectively. According to (Table 1), the surface water of the study area is significantly polluted by AN (NH_3-N) and this match with the results of Sujaul et al. [23]. AN (NH_3-N) had a strong positive correlation with Turbidity, BOD, COD, and Phosphate (PO_4) at (r=0.515, r=0.633, r=0.528 and r=0.397), respectively. Phosphate and sulfate are the mineral nutrient. However, the excessive presence of phosphate and sulfate in water bodies, which is mainly considered as a result of the untreated sewage effluent and agricultural run-off causes eutrophication problem in lakes, rivers, and seas. Eutrophication induces overgrowth of phytoplankton, thus deteriorating water quality, depopulating aquatic species and accelerating water scarcity [22]. COD, BOD and the distribution of nutrients over different sampling stations are showed in figure 3.





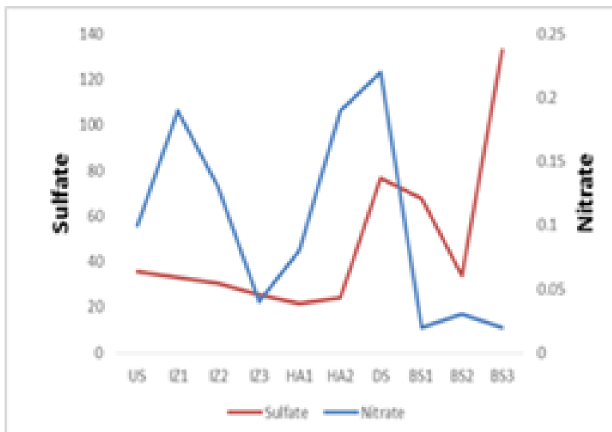


Figure 3. COD, BOD and the distribution of nutrients over different sampling stations

WATER QUALITY INDEX (WQI)

Water quality has been categorized by WQI into 6 classes according to the department of Environment Malaysia. In this study, the water quality of the study area was classified into Slightly polluted to highly polluted (class III and IV).According to (Table 5) the lowest WQI was in station 5 (HA1) at (43) followed by station 4 (IZ3) (44) and station 3 (IZ2) (50) which Classified under class IV (high polluted) and all these three stations were located in the middle of the Tunggak river. While the highest WQI was in station 1 (US) followed by station 2 (IZ1) And 10 (BS3) at (69, 66, and 66), respectively. The deterioration sequence of water quality was found to be HA1>IZ3>IZ2>DS>HA2>BS1>BS2> IZ1= BS3> US. It is clear that the last part of the Tunggak River IZ2 station until DS station more polluted than others (US and IZ1) due to higher anthropogenic activities at all those parts. In addition, most of the industries such as metal, wooden, gas and energy, chemical, petrochemical, mining and food industries were established there and discharged their wastes in the mid- stream of the river which takes its way then to the south china sea [5]. The last three stations BS1, BS2, and BS3 which situated on the Balok River were less polluted because this river located outside the industrial area and also the industrial activities were less there. Generally, the water quality of both rivers was polluted and cannot be used for water supply only after extensive treatment [19].

Table 5. Water quality classification of the study area

Stations	DOE-WQI (Score)	WQ Class	WQI Status
US	69	III	SP
IZ1	66	III	SP
IZ2	50	IV	P
IZ3	44	IV	P
HA1	43	IV	P
HA2	60	III	P
DS	53	III	P
BS1	63	III	SP
BS2	64	III	SP
BS3	66	III	SP

*SP = Slightly Polluted and P = Polluted. *Class I = >92.7, Class II = 76.5 – 92.7, Class III = 51.9 – 76.5, Class IV = < 51.9

CONCLUSION

Gebeng surface water quality has exposed to anthropogenic activities from the industries which established theirs. In Gebeng area different parameters such as temperature, pH, EC, turbidity, salinity, DO, TDS, TSS, BOD, COD, AN, nitrate, phosphate, and sulfate were used to analysis the water quality. Based on WQI, the water quality of the Tunggak and Balok River was found to be slightly polluted class III to polluted class IV all over the sites. WQI revealed that the sites IZ2, IZ3, HA1, HA2, DS which are located in the Tunggak River more polluted than others and the water of the study area unsuitable for human consumption. For this reason, sustainable management approaches should be applied on Gebeng industrial area for protection of surface water from industrial pollutants.

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