

Water Quality Status of Kinta River Tributaries Based on Land Use Activities

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Abstract. Kinta River basin lies on latitude: 4.1° and longitude: 101.0166667° in this study. Twenty two sampling stations were selected along the Kinta River and water samplings were carried out at the incoming river, upstream and downstream of the seven confluences except for upper part of Kinta River known as Ulu Kinta. Six water quality parameters were measured and Malaysian Department of Environment Water Quality Index (DOE-WQI) was calculated and classified based on the Interim National Water Quality Standard, Malaysia (INWQS). The physical and chemical variables tested were dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS) and ammoniacal nitrogen (AN). Results showed that the range of WQI was between -56.04 to 81.9. With respect to the INWQS, we found that Serokai River tributary and Kinta River downstream were the most polluted rivers and classified under Class V. Significant relationships between land use and land cover (LULC) with water quality have been found in watersheds around the world. Correlation analysis revealed that developed area highly correlated with pH, SS and COD and AN. Forested and agricultural lands only strongly correlated with DO and BOD respectively. In contrast, mining and ex-mining areas only gave weak positive correlation with pH. While for water body area, it was highly negatively correlated with DO and BOD.

Keywords: water quality index, interim water quality standard, correlation

1. Introduction

Changes in river-water quality are strongly related to surrounding LULC [1] and the type of land-use usually determines the kinds and amounts of contaminants that flow into rivers, lakes and aquifers [2]. The type of water contamination is directly related to anthropogenic practices and non-point or point source, which can be quantified in terms of the population density and land use type in the watershed [3]. River water quality deteriorates due to diffused and concentrated pollutant loads from point sources and from non-point sources, such as forest, grassland, agricultural and residential area in the watershed [4]. In managing water quality, it is important to determine the aggregate of point and non point source pollution loads in order to set maximum allowable loads from each source that contribute to pollution of a river [5].

Kinta River is one of the rivers in Perak with latitude: 4.1°, longitude: 101.0166667° originating from Gunung Korbu at Ulu Kinta, Tanjung Rambutan into the main Kinta River. The length of this river is 100 km and the size of the river basin is 2,500 km². The main function of Sungai Kinta is mainly for water supply. Under the implementation of Lembaga Air Perak (LAP), Kinta River Dam is the only dam in Perak that is able to provide 639 million liters of water per day; expected to be able to meet water demand in the Kinta Valley until 2020. The aims of this study are: (i) to evaluate the Kinta River status; WQI and INWQS based on LULC and (ii) to investigate the relationship between water quality and LULC.

2. Methodology

Twenty two water quality sampling stations were selected based on the major tributaries and developed areas of Kinta River. Water samplings were carried out at the incoming river (tributary), upstream and

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downstream of the seven confluences except for upper part of Kinta River known as Ulu Kinta. All the parameters which comprised of DO, pH, BOD, COD, SS and AN were analyzed in accordance to the American Public Health and Association (APHA) standard methods for water and wastewater [6]. Arc View [7] was used to determine the composition of the land use within the watersheds. For each of the sub-watersheds, ArcView's buffer facility was used to extract landscape data for the area 200 m which allowed a comparison of the influence of landscape data on the water quality. The land use for seven main watersheds was subdivided into five categories: (1) developed area; (2) mining; (3) forested land; (4) agricultural land; and (5) water body land. A significant data were observed by using one-way ANOVA. Multiple regressions were used to determine whether landscape factors have positive or negative influence on separate water quality variables. WQI was calculated using the mean of these six parameters which then converted to sub indices (SIs) using the best-fit equation and aggregated to compute the WQI according to the following equation [8]:

$$WQI = 0.22 \times SI_{DO} + 0.19 \times SI_{BOD} + 0.16 \times SI_{COD} + 0.15 \times SI_{AN} + 0.16 \times SI_{SS} + 0.12 \times SI_{pH}$$

These parameters are in mg/L except for pH and DO and SI is the sub index of each parameter. The descriptions of the water quality status related to the WQI are stated in Table 1, which is according to the values referred by the Malaysian Department of Environment (DOE) [9].

Table 1: Water Quality Index Classes [9]

Parameter	Unit	Class				
		I	II	III	IV	V
AN	mg/L	< 0.1	0.1-0.3	0.3-0.9	0.9-2.7	> 2.7
BOD	mg/L	< 1	1-3	3-6	6-12	>12
COD	mg/L	< 10	10-25	25-50	50-100	> 100
DO	mg/L	> 7	5-7	3-5	1-3	< 1
pH		> 7.0	6.0-7.0	5.0-6.0	<5.0	>5.0
TSS	mg/L	< 25	25-50	50-150	150-300	>300
WQI		> 92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31
Pollution Degree		Very Clean	Clean	Moderate	Slightly Polluted	Severely Polluted

3. Results and Discussion

The total areas of main tributaries which were A2, B2, C2, D2, E2, F2 and G2 are 24780325 m², 12642337 m², 8420085 m², 1.38×10⁸ m², 2.57×10⁸ m², 54725092 m² and 1×10⁸ m² respectively. Fig. 1 shows the percentage of land use composition 200 m buffer zone area of all sampling points. C2 is the most polluted tributary of Kinta catchment since the area covered more that 97% of the developed area and only 1.3% of forested area. Most of the pollutants including the untreated effluent are discharged from the industrial areas to the nearest river or watershed.

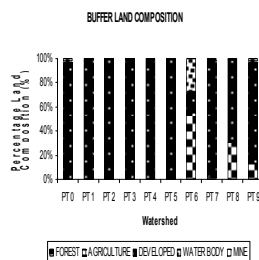


Fig. 1: The percentage of 200 m buffer zone landscape characteristics of 22 watersheds

pH as the most stable parameter recorded about 5.19-7.01. Only four points (UP, A1, A2 and A3) recorded the level of DO more than 5 mg/L which located at the upper part of Kinta River. The average of BOD values of nine sampling points ranged between 2-3 mg/L. The highest values of BOD (7±1 mg/L) indicated the presence of excess biodegradable organic matter at B2 and G1. E2 was recorded as having the highest level of SS concentrations of the range between 11-67 mg/L. D3 shows the highest level of AN and overall points indicate less than 1 mg/L. The highest values of COD and AN were 17600±529 mg/L and

1.28±0.0436 mg/L respectively that occurred at C2. Land use of recreational park and urban development along the riverbank will lead to the higher level of AN. All the water quality parameters except DO and BOD had a significant positive correlation with the developed area as shown in Table 2. pH recorded as the strongest positive correlation with the percentage of developed areas suggested that pH violation in the developed area might be caused by a factor or combination of factors related to the increase in urban land cover and residential area. Only DO gave the strongest positive correlation while the other parameters were recorded as the weak negative relationship. The strongest negative correlation was observed between pH and percentage of agriculture ($r = -0.8$). Multiple regression results showed that all the predictors except SS and BOD were significant ($p < 0.05$) which indicated that both parameters were not related with the value of WQI. However, the R^2 value shows that the predictors explained 98.2% of the variance in WQI value.

Table 2: Result of Pearson correlation analysis between 200 m buffer land use types and water quality characteristics

Variable	DO	pH	COD	SS	BOD	AN
Dev (%)	-0.2	0.75	0.11	0.41	-0.12	0.12
Mining (%)	-0.15	0.05	-0.13	0.31	-0.11	-0.2
Forest (%)	0.68	-0.05	-0.03	-0.4	-0.19	-0.13
Ag (%)	-0.21	-0.8	-0.11	-0.25	0.31	-0.03
WB (%)	-0.4	0.1	0.17	0.46	-0.21	0.05
WQI	0.38	-0.2	-0.97	-0.27	0	-0.85

Dev = Developed area, Mining = Mining area, Forest = Forested area, WB = Water body, Ag = Agricultural land

Advanced water quality or ecologically based standards that integrate physical, chemical, and biological numeric criteria offer the potential to better understand, manage, protect, and restore water bodies [10]. The Interim National Water Quality Standard, Malaysia (INWQS) categorizes surface water in Malaysia into six classes that are classes I, IIA, IIB, III, IV, and V. Class I means water is acceptable to use for conservation of natural environment water supply I: practically no treatment and fishery I: very sensitive aquatic species; class IIA for water supply II: conventional treatment required and fishery II: sensitive aquatic species; class IIB for recreational use with body contact; class III for water supply III: extensive treatment required and fishery III: common, of economic value, and tolerant species livestock drinking; class IV for irrigation; and class V: water not provided for any uses.

From this research, the variation of WQI indicates that the water quality at Serokai River (C2) is the most polluted river followed by downstream of Kinta River (C3) since they were classified under class V as shown in Table 3. Whilst for the other sampling sites, they were classified in the range of Class II to III. pH as the most stable parameter with overall average reading is 6.5 was classified under Class II. The variation in pH regulates most of the biochemical and chemical reactions which affect water composition [11]. While DO was classified under Class III since the average reading was 4.4 mg/L. B2 and G2 were recorded as the highest levels of BOD, hence are classified under Class IV. While the BOD of other sampling stations were classified under Class II. Pari River is the major tributary of the Kinta River from the northwest side and this major tributary becomes the downstream channel among other tributaries along Pari River. The area of Pari River subcatchment is about 7.1 km² and consists of more than 15% of non-strata housing area. The untreated discharged wastewaters from the residential areas along the river as well as the daily need to use the water for different purposes are the main reasons of the river pollution. These wastes usually contain huge amount of dangerous substances that are harmful to both human and animals.

C2 was recorded as the highest level of COD reading and according to INWQS Standard for COD value, 73% of the sampling points are under Class V. This site is exactly next to the industrial area, Kawasan Perindustrian Pengkalan that is a medium industry. Some industrial activities such as pulp and paper production, and sugar beet processing, may produce wastewater with COD exceeding 1000 mg/L. The SS fall within Class I to III. The sampling point for this tributary is closed to the urban developed area and recreational park. The possible sources of the contributing pollution to this high SS could be the soil erosion from the construction and earthworks activities within in this area [12]. AN reading of D3 (0.56 mg/L) was considered under Class V. Sullage or grey-water may cause high level of AN because it contains untreated

organic materials, household chemicals and pathogens. It is proved from previous studies [13] that sullage is very polluting in nature and must be treated properly before being allowed to enter the water body.

Table 3: Water quality stations with the coordinates and the values of WQI, class and pollution degree

Locations	River	Coordinates	WQI	Class	Pollution Degree
UP	Ulu Kinta	N4 40 20.8 E101 11 53.4	76.5	II	Clean
A1	Pari Upstream	N4 39 45.6 E101 05 45.7	69.1	III	Moderate
A2	Chepor (tributary of Pari)	N4 39 46.1 E101 05 44.6	77.3	II	Clean
A3	Pari Downstream	N4 39 42.3 E101 05 45.1	79.4	II	Clean
B1	Kinta Upstream	N4 34 54.8 E101 04 19.7	80	II	Clean
B2	Pari (tributary of Kinta)	N4 34 55.1 E101 04 17.7	67.5	III	Moderate
B3	Kinta Downstream	N4 34 39.4 E101 04 11.2	73	III	Moderate
C1	Kinta Upstream	N4 32 26.0 E101 03 39.7	62.6	III	Moderate
C2	Serokai (tributary of Kinta)	N4 32 14.0 E101 03 36.7	-56.04	V	Severely Polluted
C3	Kinta Downstream	N4 32 12.1 E101 03 37.1	11.9	V	Severely Polluted
D1	Kinta Upstream	N4 30 12.4 E101 03 24.3	68.9	III	Moderate
D2	Pinji (tributary of Kinta)	N4 30 07.7 E101 03 24.8	61.5	III	Moderate
D3	Kinta Downstream	N4 30 01.7 E101 03 23.0	56.6	III	Moderate
E1	Kinta Upstream	N4 28 30.8 E101 03 13.4	77.7	II	Clean
E2	Raia (tributary of Kinta)	N4 28 25.0 E101 03 16.7	81.9	II	Clean
E3	Kinta Downstream	N4 28 17.6 E101 03 08.3	66.8	III	Moderate
F1	Kinta Upstream	N4 22 33.6 E101 04 16.9	70.9	III	Moderate
F2	Teja (tributary of Kinta)	N4 22 31.8 E101 04 19.6	67.3	III	Moderate
F3	Kinta Downstream	N4 22 19.5 E101 04 24.8	68.2	III	Moderate
G1	Kinta Upstream	N4 07 42.3 E101 01 24.6	64.5	III	Moderate
G2	Keruh (tributary of Kinta)	N4 07 28.9 E101 01 36.1	60.1	III	Moderate
G3	Kinta Downstream	N4 07 11.5 E101 01 24.8	62.4	III	Moderate

BOD and AN were the parameters that were most related to agricultural lands. High level of BOD in the river might be caused by the manure and the organic matter while the component AN is caused by the non-biodegradable matter [14, 15]. The pig farms located near the sampling points were expected to be the cause of river water quality degradation. The estimated BOD loading contributed by pig farming is 197537.1 kg/day [13]. High level of AN also might be due to the leaching of fertilizer residue on agricultural land into the river system that is used to fertilize the crops. Human activities were found to be the cause of higher levels of several parameters like pH, SS and COD in the developed area. The causes of water pollution are diverse and vary both spatially and temporally [16]: they include the release of wastewater from scattered industrial operations [17] and urbanized areas [18], as well as sediment discharge from cultivated land affected by soil erosion [19]. Forest is mostly related to good water quality in various studies in different watersheds around the world [20] and has a minimal effect on water quality as shown by UP. The mining area including the ex-mining area and water body area including pond and canal are highly positively correlated with SS. However, these both predictors did not give any big effect to the water quality changes compared to the developed area.

4. Conclusion

The status of water quality expressed in terms of the WQI, which concluded that only two locations; C2 and C3, are in the worst situation which are classified under Class V. Other locations are still under control but the quality of water needs to improve. The main sources of pollution were defined as industries area, poultry, residential areas, recreational park, sewerage and urban areas. Urbanization and agriculture highly significantly influenced the water quality. Regarding to this output we found that COD parameter has become the main pollution point source for this study. Forested area gave the strong positive value with DO indicates the least pollution.

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