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Development of Total Maximum Daily Load by Using Water Quality Modellling as an Approach to Investigate the Quality of Water in Sungai Batu Pahat

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Abstract: Nowadays, one of the most critical uses of river water is for human consumption and environmental purposes. However, the rapid development and urbanization, has led to decreasing of river water quality due to overloading of pollutant concentration that flow into the river. Therefore, there were several approaches have been implemented to overcome water pollution issues such as Integrated River Basin Management (IRBM) and Total Maximum Daily Load (TMDL). This study attempts to quantify six selected water quality parameters (pH, DO, BOD, COD, NH3-N, TSS) and to develop the TMDL implementation plan with the application of water quality modelling tools. On the other hand, the water flow velocity of the river was also being measured, and the water flow and water quality modelling were simulated by using Qual2K water quality modelling software. Based on the analysis, it shows that the commercial sector pose the most contributor towards the pollution loading (kg/day) in Batu Pahat River, which mainly come from CP1 Fisheries, CP3 Workshops, CP4 Wet Market, CP5 Restaurant, CP6 Workshop, and CP7 Workshop. In addition, high tide flow produced higher pollution load (kg/day) compared to low tide flow due to larger amount of discharge during high tide flow. The simulation for both low tide and high tide flow demonstrates that when DO concentration input is higher, there will be decrease in the concentration of COD, BOD, TSS, and NH3-N. As a conclusion, the development TMDL plan could improve water quality at the Batu Pahat River by analysing pollution loading reduction and for future management of watersheds.

Keywords: Total Maximum Daily Load (TMDL), Water Quality Modelling, Qual2k

1. Introduction

TMDL implementation have been developed by the Environmental Protection Agency (EPA) with implemented in United States [1]. This TMDL implementation has been widely used in all over the

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world including United States, Korea, China, Taiwan, and Thailand. TMDL can be described as the maximum amount of a pollutant can be accepted by a river on a daily basis, but at the same time still maintaining the water quality standards [2]. TMDL is the sum of individual waste load allocations (WLA) for point sources and load allocation (LA) for non-point sources, so that assimilative capacity of water body is not exceeded [2]. By using the TMDL plan, it gives a better and more efficient approach in river management. The implementation of TMDL will help the stakeholders and regulators to control and improve the water quality of the river [1]. The river pollution happened that we see today is due to the rapid development of urbanization and others human activities which all those activities had led to the degraded of river water quality. Literally, there are two main categories that contributed to the river pollutions, which are Point Sources (PO) and Non-Point Sources (NPS). Both point and non-point sources have caused the river quality to deteriorated significantly. The increasing amount of waste discharged into river and the level of assimilative capacity has greater impact to the river water quality [3]. Batu Pahat River was reported badly polluted back in 2010. The factory waste which dumped directly to drain, flowed to the river and caused river pollution. The aim of this study is to implement the Total Maximum Daily Load (TMDL) as one of the management tools for the Sungai Batu Pahat Watershed. The main objectives of this study are to to quantify six selected water quality parameters for water quality monitoring to develop the TMDL implementation plan with the application of water quality modelling tools.

2. Materials and Methods

The National Water Quality Index (WQI) proposed by the Department of the Environment (DOE) was applied to assess the river water quality status and classes. There are 6 parameters used to determine the WQI, which are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia Nitrogen (NH3), Acidic and Alkaline (pH), Dissolved Oxygen (DO), Total Suspended Solids (TSS). On the other hand, the water flow velocity of the river also being measured on site. Finally, the water quality modelling was simulated by using Qual2K water quality modelling software.

2.1 Study area

The study location located at Batu Pahat River. Batu Pahat River, originating from Sungai Simpang Kiri and Sungai Simpang Kanan, which the river split as Sungai Bekok and Sungai Sembrong in Tanjung Sembrong near Tongkang Pechah, and it flows through Batu Pahat (Bandar Penggaram) and until the mouthh of the river in Pantai Minyak Beku. The total length of the river is 12 km. The river has a mean annual rainfall of 2057 mm which is taken from Department of Irrigation and Drainage (DID) Johor [4]. In this study, the river has been divided into three main types of landuses (commercial, residential, and agriculture) with 6 kind of activities

2.2 Data Collection and Testing

Site visits were conducted at the Batu Pahat River in order to identify the suitable locations for carrying out the data collections and water sampling.

2.2.1 Water Quality sampling

There are 11 checkpoints selected for the water sampling locations along the Batu Pahat River (11 sampling checkpoints; CP1-CP11) (Figure 1). The latitude and longitude of sampling locations are located by using the Global Positioning System (GPS) through the google maps.

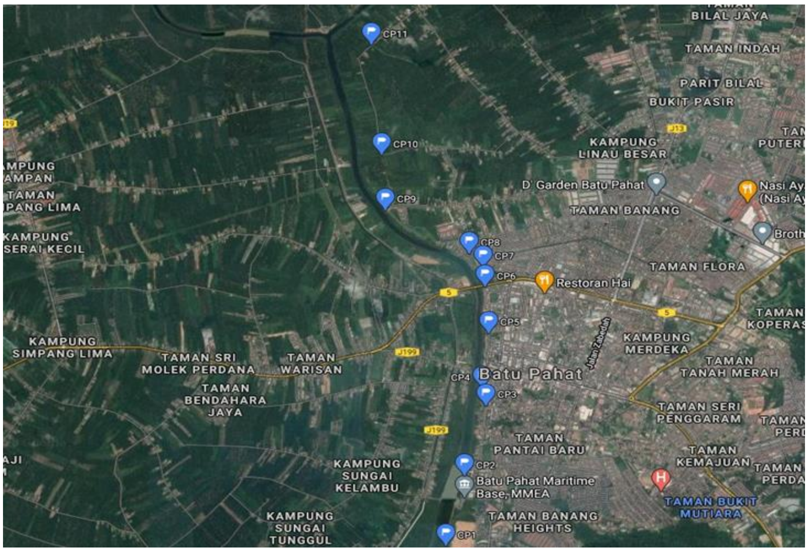

Figure 1: Checkpoints marked on Batu Pahat River map

2.2.2 Water quality analysis

Water samples were collected by using water sampler, preserved in acid washed plastic bottles as prescribed in APHA method, and kept in the cool box until transportation to the laboratory for the tests by using the APHA method illustrated by [5].

2.2.3 Water quality index (WQI)

In Malaysia, the water quality status can be determined based on the six parameters as suggested by DOE [6]. These parameters will be served as a basis for WQI calculation. The river quality can be classified whether it is in category of clean, slightly polluted or polluted based on the DOE water classification [6]. The summation of the weight ages for all the sub-indices must have a value of unity.

2.3 Water Quality Modelling

The aims of using water quality modelling tool is to simulate and calibrate the water quality parameters. In this project, the QUAL2K software is used to simulate and calibrate the water quality model. There are three major data that are required in this software, which are hydraulic data, location data, and water quality data. For hydraulic, the data include velocity, width and depth of the river at every checkpoints. The latitude and longitude for every checkpoints are required to determine its location.

The simulations of Batu Pahat River water via QUAL2K on Low tide and high tide flow are capable to demonstrate the magnitude of impact. The water quality of Batu Pahat River based on the low tide flow and high tide flow simulation were assessed and the impact of land use activities observed along the river were evaluated.

2.3.1 Modelling

The water quality input parameter included in the model are flow, pH, DO, BOD, COD, ammonium nitrogen (NH3-N), and total suspended solid (TSS). The river geometries, its depth and water velocities were used to determine the hydraulic characteristics at each sampling locations. Microsoft Excel is employed as the graphical user interface.

The Qual2k model was calibrated using site measurements data and hydraulic calibration was applied. Stream velocity, cross-sectional area, and depth are computed from stream flow. The flow simulation output are presented on pH, DO, BOD, TSS, NH3-N, and COD graphs for loq and high tide flow.

2.3.2 Calibration

The model is considered well calibrated if the prediction fits the estimated adequately. This process was carried out in order to allow the model to reproduce the observed water quality patterns in the river, which compared the simulated water quality to the observed data, and the key kinetic parameters were adjusted until a reasonable match was reached between the model results and the data [1].

2.4 TMDL Development

From the value of point sources and non-point sources obtained, it then can be used to calculate the TMDL. Equation (1) is used to calculate the TMDL [1]. The Margin of Safety (MOS) is often ranging from 7% to 15% of the total TMDL, to provide a safety buffer between the estimated TMDL and the actual load that will allow the water body to satisfy its beneficial use. The MOS used in this study, it is considered as 15% by referring from the previous study in Sungai Semenyih [7].

$$TMDL = Point\ Sources\ (WLA) + Non + point\ Sources\ + MOS \quad (1)$$

Where,

WLA : Waste load allocation from point sources (kg/day)

LA : Load allocation from non-point sources (kg/day)

MOS : Margin of safety (%)

Pollution loading (Point Sources) formula is stated as below [1]:

Loading (kg/day) = Flowrate (m3/day) X Concentration (kg/m3) (2)

Non-point sources are identified through several methods include categorization of landues, factors to be considered during non-point sources sampling, non-point sources sampling method. Non-point sources loading can be calculated by using the formula below [1]:

L=(R x EMC x A x Cv)/100 (3)

Where,

L : Annual pollutant load (kg/year)

R : Mean annual rainfall (mm/year) → rainfall data (DID)

EMC : Event mean concentration (mg/L)

A : Catchment area (ha)

Cv : Area-weighted volumetric runoff coefficient for the whole catchment

The mean annual rainfall (mm/year) value is taken from the Department of Irrigation and Drainage (DID) Johor which has a value of 2057 mm [4].

3. Result And Data Analysis

The data is then being analysed and implemented into the TMDL development and water quality modelling by using the Qual2K software in this project in order to determine and estimate the allowed pollutant loads and then allocate them to existing and future pollution sources in a watershed.

The data was then being used to analysed and served as input data to calculate the Total Maximum Daily Load (TMDL). Finally, the water quality model was carried out to determine and estimate the pollutant loading as well as the simulation of pollution loading allocation were carried out to existing and future pollution sources in a watershed.

3.1 Water Quality Status

By referring to Table 3, the highest values of DO was recorded at CP6 while the lowest value was recorded at CP4. This value is well correlate with the activity and condition at the site, where CP6 is located at workshop area with slow flowing of water, while CP4 located at the wet market area and the water is stagnant which lead to decreasing value of DO.

CP4 also has recorded the highest value of COD, BOD, TSS, and NH_3-N due the all activities at the wet market. The highest value of BOD at CP4 is well correlated with the wet market activity as low DO concentration is recorded. In contrast, the lowest concentration value of BOD, NH_3-N, TSS and COD were recorded at CP1. These values are well correlated with the condition of the river, where CP1 has the largest amount of discharge and causes the DO concentration value to be high.

Table 1: Water quality measurements of Batu Pahat River and tributaries

CHECKPOINT	pH	DO	BOD (mg/L)	NH_3-N (mg/L)	TSS (mg/L)	COD (mg/L)	WQI
CP1 (High)	4.10	7.18	1.82	0.21	3	4	85.40
CP1 (Low)	3.42	7.67	2.11	0.37	7	5	83.76
CP2 (High)	3.64	5.38	3.11	0.51	6	4	66.23
CP2 (Low)	3.38	4.82	3.21	0.88	9	7	62.53
CP3 (High)	3.07	5.36	2.51	2.06	12	15	66.91
CP3 (Low)	2.46	4.44	2.71	2.53	19	22	59.23
CP4 (High)	7.32	3.81	15.80	19.41	325	94	36.31
CP4 (Low)	7.29	3.36	16.95	22.6	414	210	29.52
CP5 (High)	3.49	4.86	3.33	1.08	42	39	62.76
CP5 (Low)	4.18	3.77	4.87	2.06	51	50	52.32
CP6 (High)	3.62	7.95	1.84	1.10	23	28	73.91
CP6 (Low)	3.97	5.16	3.59	2.22	53	39	59.66
CP7 (High)	7.33	5.55	2.06	3.09	9	11	76.00
CP7 (Low)	7.27	3.77	3.41	3.50	19	23	64.68
CP8 (High)	7.10	6.12	3.48	1.01	16	18	82.48
CP8 (Low)	7.30	5.71	4.02	1.91	37	41	71.50
CP9 (High)	4.15	5.42	3.94	0.81	25	10	74.83
CP9 (Low)	6.83	4.60	5.65	1.92	61	37	65.50
CP10 (High)	2.98	9.05	1.54	0.33	4	4	84.22
CP10 (Low)	3.90	8.33	2.88	0.79	5	9	80.78
CP11 (High)	3.28	8.02	3.66	0.28	17	9	78.54
CP11 (Low)	3.70	7.98	4.11	0.59	21	25	76.21

3.1.1 Point Sources and Non-Point Sources Pollution Loading

All the 6 parameters which are pH, DO, BOD, COD, NH_3-N, and TSS, and also the hydraulic data, are used to determine the pollutant loading in kg/day. Table 4 and Table 5 shows the total pollution loading for COD, BOD, NH_3-N, and TSS in Sungai Batu Pahat catchment for low tide and high tide flow condition repectively.

In this study, there are only two non-point sources of pollution were identified, which are CP1 Fisheries and CP2 Residential. Generally, based on the landuse in the catchment, CP1 Fiheries is the major contributor of non-point sources of pollution load compared to CP2 Residential. CP1 Fisheries contribute greater pollutant load compared to CP2 Residential, which producing 714 kg/day of BOD, 5184 kg/day of COD, 37.026 kg/day of NH_3-N, and 6146.316 kg/day of TSS.

Table 2: Total load for COD, BOD, NH3-N, and TSS in Sungai Batu Pahat catchment during low tide flow.

Sg. Batu Pahat Sub-catchment	Loading (kg/day)			
Point Type	**BOD**	**COD**	**NH_3-N**	**TSS**
CP1 Fisheries	714	5183	37.026	6146.316
CP2 Residential	471.3	2553.971	19.22	3370.189
CP3 Workshop	94.44	766.66	88.17	662
CP4 Wet market	10.495	130.03	14	256.35
CP5 Restaurant	281.915	2894.4	119.249	2952.288
CP6 Workshop	19.64	213.41	12.147	290.016
CP7 Workshop	63.8352	430.56	65.52	355.68
CP8 Residential	202.608	2066.4	96.624	1864.8
CP9 Residential	102.514	671.328	34.836	1106.784
CP10 Agriculture	17.1072	53.46	4.6926	29.7
CP11 Agriculture	8.178	49.5	1.1682	41.58

Table 3: Total load for COD, BOD, NH3-N, and TSS in Sungai Batu Pahat catchment during high tide flow.

Sg. Batu Pahat catchment	Loading (kg/day)			
Point Type	**BOD**	**COD**	**NH_3-N**	**TSS**
CP1 Fisheries	714	5183	37.026	6146.316
CP2 Residential	471.3	2553.971	19.22	3370.189
CP3 Workshop	161.925	967.68	132.895	774.144
CP4 Wet market	21.614	128.592	26.553	444.6
CP5 Restaurant	248.39	2909.088	80.56	3132.864
CP6 Workshop	22.257	338.688	13.3056	278.208
CP7 Workshop	68.2272	364.32	102.34	298.08
CP8 Residential	298.668	1544.832	86.682	1373.184
CP9 Residential	129.358	328.32	26.594	820.8
CP10 Agriculture	15.246	39.6	3.267	39.6
CP11 Agriculture	8.138	17.82	0.5544	33.66

CP5 Restaurant resulted to be the largest contributor of pollution load of BOD, COD, NH_3-N, TSS among all of the point sources observed in this study. Both low tide and high tide flow condition shows CP5 Restaurant have the highest point sources pollution loading (kg/day) in Sungai Batu Pahat, which during low tide, the load produced for BOD is 281.915 kg/day, COD is 2894.4 kg/day, NH_3-N is 119.249 kg/day, and TSS is 2952.288 kg/day. While, during high tide, CP5 Restaurant contribute 248.39 kg/day of BOD, 2909.088 kg/day of COD, 80.56 kg/day of NH_3-N, and 3132.864 kg/day of TSS. It is also proved that the total load contributor from CP5 Restaurant greatly exceeds all the other observed point sources basically due to the large volume discharged by the CP5 Restaurant.

In contrast, CP11 Agriculture during low tide condition are to be found have the lowest load for BOD (8.178kg/day), COD (49.5kg/day), NH_3-N (1.1682kg/day), and TSS (41.58kg/day). While during high tide condition, the load for BOD (8.138kh/day), COD (17.82kg/day), NH_3-N (0.5544kg/day), and TSS (33.66kg/day. The lowest value NH_3-N found in Sungai Batu Pahat comes from CP11 Agriculture, which are only 1.1682 kg/day for low tide flow and 0.5544 kg/day for high tide flow.

From the result tabulated in table 4 and Table 5, we can conclude that high tide flow will result higher pollution loading compared to low tide flow. It shows that high tide flow has a greater discharge compared to low tide flow with lower discharge that will result larger pollution loading from high tide flow. The lower discharge flow of the river which will subsequently abating the capacity of the river to receive pollutant load [8].

3.1.2 Implementation of TMDL

The waste load allocation (WLA) and load allocation (LA) were derived from the water quality model developed in this study. The landuses are divided into three major landuses, which are Commerical, Residential and Agriculture. Table 6, Table 7, Table 8 and Table 9 show the landuses for both during low tide and high tide and the allocation pollutant loading within the Batu Pahat River catchment for all COD, BOD, NH_3-N, and TSS.

Commercial landuses include CP1 Fisheries, CP3 Workshop, CP4 Wet Market, CP5 Restaurant, CP6 Workshop and CP7 Workshop. Residential landuses include CP8 Residential and CP9 Residential. Agriculture landuses include CP10 Agriculture and CP11 Agriculture.

Table 4: BOD allocation pollutant loading within the Batu Pahat River catchment

Land Use	**Low Tide**		**High Tide**	
	Current Load (kg/day)	**Load with 15% MOS (kg/day)**	**Current Load (kg/day)**	**Load with 15% MOS (kg/day)**
Commercial	1185.448	1363.265	1236.413	1813.9
Residential	780	897	899.326	1034.225
Agriculture	25.285	29.08	23.384	26.89

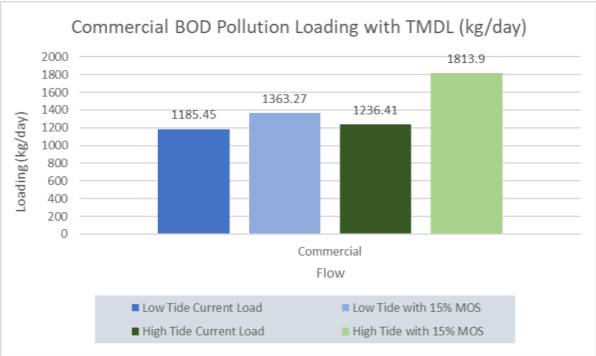

Figure 1: Commercial BOD Pollution Loading with TMDL (kg/day)

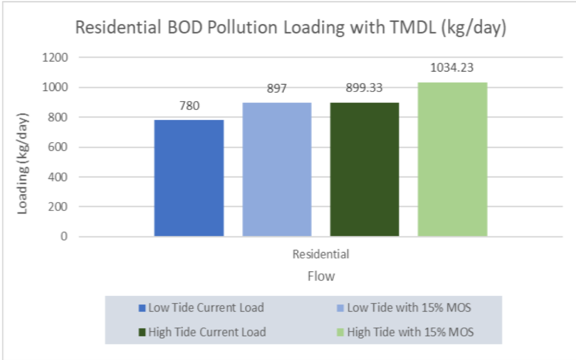

Figure 2: Residential BOD Pollution Loading with TMDL (kg/day)

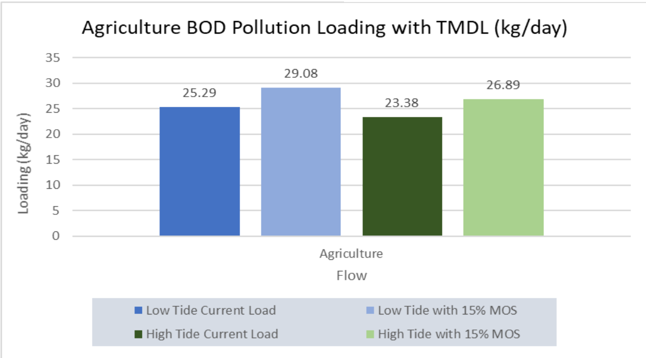

Figure 3: Agriculture BOD Pollution Loading with TMDL (kg/day)

For BOD, high tide flow contribute more pollution load compared to low tide flow for all landuses types (commercial, residential, and agriculture). It seems that the most critical period of water pollution occurs during high tide flow period due to the large amount of discharge. Table 6 shows that the commercial landuses has become the main contributor to the BOD pollution loading, which come from the activity of CP1 Fisheries, CP3 Workshop, CP4 Wet Market, CP5 Restaurant, CP6 Workshop and CP7 Workshop . The total current BOD pollution loading produced by commercial landuse are 1185.448 kg/day during low tide and 1236.413 kg/day during high tide flow.

The Margin of Safety (MOS) used in this study is considered as 15% by referring from the previous TMDL study in Sungai Semenyih[7]. With 15% of Margin of Safety (MOS), the total maximum daily load (TMDL) of BOD from commercial landuses will be 1363.27 kg/day during low tide flow and 1813.9 kg/day during high tide flow.

Table 5: COD allocation pollutant loading within the Batu Pahat River catchment

Land Use	Low Tide		High Tide	
	Current Load (kg/day)	Load with 15% MOS (kg/day)	Current Load (kg/day)	Load with 15% MOS (kg/day)
Commercial	8311.55	9558.278	9618.06	11060.77
Residential	4427.123	5091.19	5291.7	6085.46
Agriculture	57.82	66.49	102.96	118.404

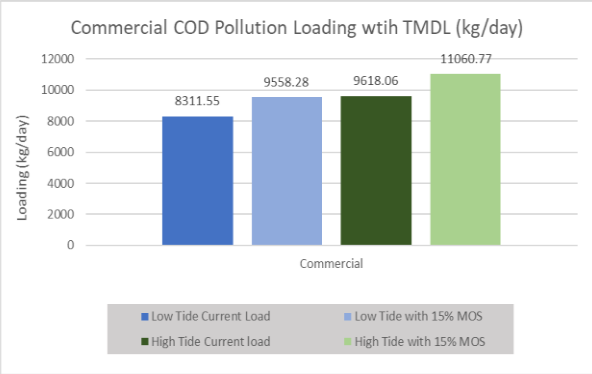

Figure 4: Commercial COD Pollution Loading with TMDL (kg/day)

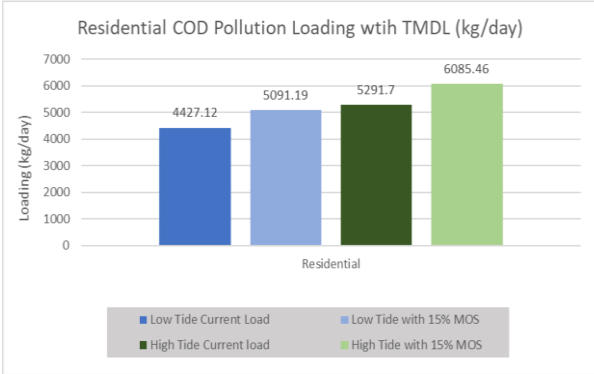

Figure 5: Residential COD Pollution Loading with TMDL (kg/day)

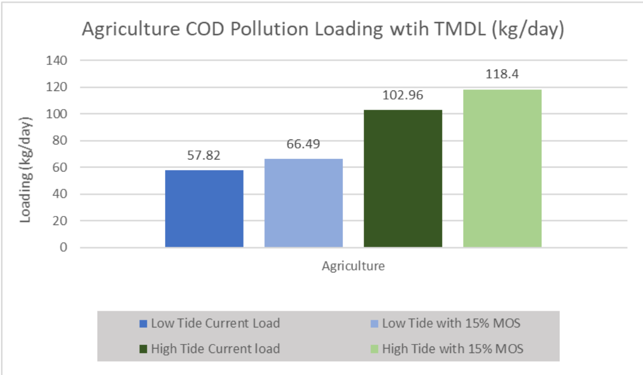

Figure 6: Agriculture COD Pollution Loading with TMDL (kg/day)

For COD, high tide flow contribute more pollution load compared to low tide flow for all landuses types. It seems that the most critical period of water pollution occurs during high tide flow period due to the large amount of discharge. Table 7 shows that the commercial landuses has become the main contributor to the COD pollution loading, which comes from the activity of CP1 Fisheries, CP3 Workshop, CP4 Wet Market, CP5 Restaurant, CP6 Workshop and CP7 Workshop. The total current COD pollution loading produced by commercial landuse are 8311.55 kg/day during low tide and 9618.06 kg/day during high tide flow. With 15% of Margin of Safety (MOS), the TMDL of COD from commercial landuses will be 9558.278 kg/day during low tide flow and 11060.77 kg/day during high tide flow.

Table 8: TSS allocation pollutant loading within the Batu Pahat River catchment

Land Use	Low Tide		High Tide	
	Current Load (kg/day)	Load with 15% MOS (kg/day)	Current Load (kg/day)	Load with 15% MOS (kg/day)
Commercial	9629.532	11073.96	7710.362	8866.92
Residential	5564	6398.6	6039.373	6945.28
Agriculture	73.26	84.25	71.58	82.32

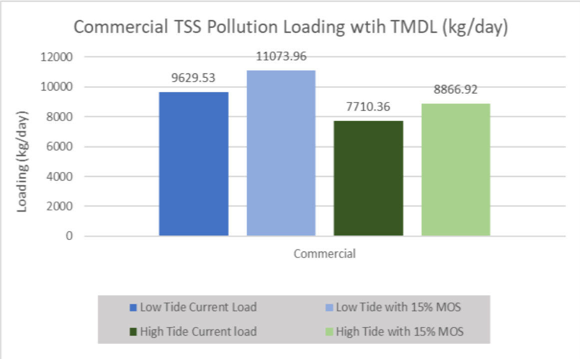

Figure 7: Commercial TSS Pollution Loading with TMDL (kg/day)

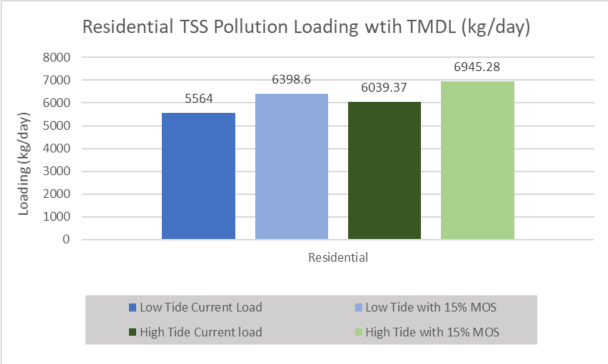

Figure 8: Residential TSS Pollution Loading with TMDL (kg/day)

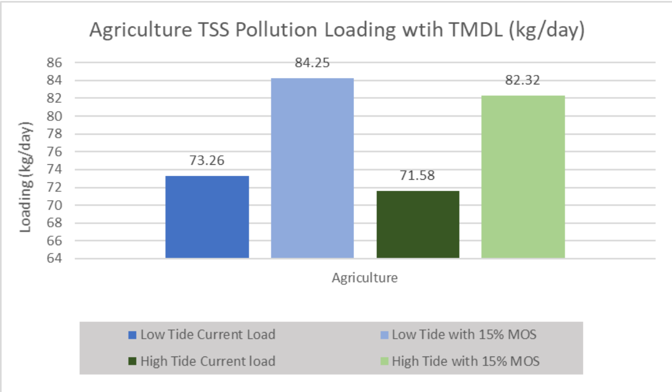

Figure 9: Agriculture TSS Pollution Loading with TMDL (kg/day)

For TSS, low tide flow contribute more pollution load compared to high tide flow for all landuses types (commercial, residential, and agriculture). It seems that the most critical period of water pollution occurs during low tide flow period. Table 8 shows that the commercial landuses has become the main contributor to the TSS pollution loading, which comes from the activity of CP1 Fisheries, CP3 Workshop, CP4 Wet Market, CP5 Restaurant, CP6 Workshop and CP7 Workshop. The total current TSS pollution loading produced by commercial landuse are 9629.532 kg/day during low tide and 7710.362 kg/day during high tide flow. With 15% of Margin of Safety (MOS), the total maximum daily load (TMDL) of TSS from commercial landuses will be 11073.96 kg/day during low tide flow and 8866.92 kg/day during high tide flow.

3.2 Water Quality Modelling

The model was calibrated by using Qual2k software with all the 6 water quality parameters (COD, BOD, NH3-N, pH, DO and TSS) in order to fulfil the need of the study All the results are in figure below. It is important to ensure the simulated data of all parameters are well-fitted with the observation data. Based on the calibration analysis done, it shows that the model was calibrated successfully.

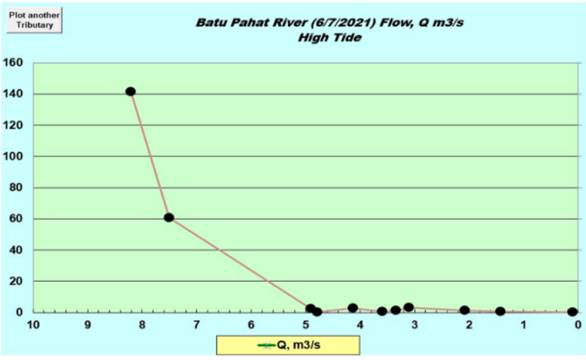

Figure 10: Flow, Q (m3/s) of Batu Pahat river during high tide flow

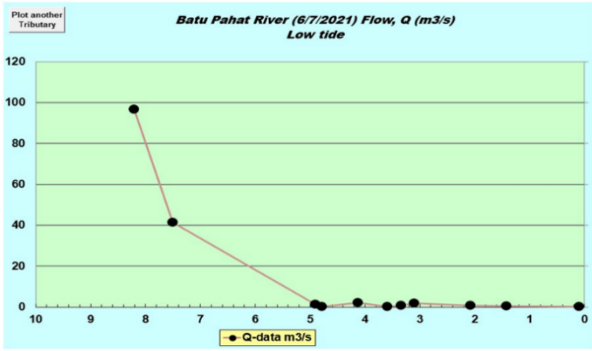

Figure 11: Flow, Q (m3/s) of Batu Pahat river during low tide flow

According to the hydro geometric data from the Qual2K simulatioan as shown in Figure 10 and Figure 11, the discharge pattern decrease as it starts to flow to mid-stream of Batu Pahat River before it slightly increases in the downstream and then slightly decrease to the downstream for both during low tide and high tide flow. The velocity is accurately represented because the gradient in the upper stream is fairly steep and gradually decreases as it reaches the mid-stream

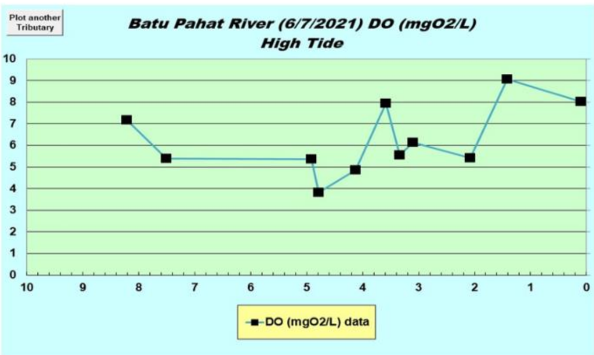

Figure 12: DO (mgO2/L) of Batu Pahat River during high tide.

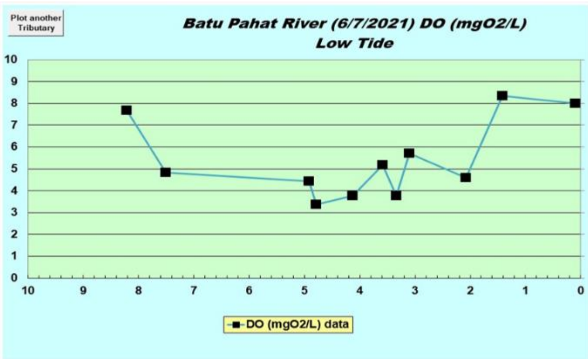

Figure 13: DO (mgO2/L) of Batu Pahat River during low tide.

From the simulation of Qual2k, it shows that the concentration of DO concentration during high tide flow is higher than during low tide flow. The DO concentration starts to decrease gradually as it flows through until km 4.79 as it was consumed by high concentration of BOD at CP4 Wet Market. A decrease in the DO value usually denotes an increase in the BOD value [9]. However, the DO concentration managed to recover at km 4.13 onwards after confluence with CP5 Restaurants where a larger volumetric input was introduced (2.59 m3/s) during high tide and (2.01 m3/s) during low tide flow and dilution occurred causes the BOD to decrease.

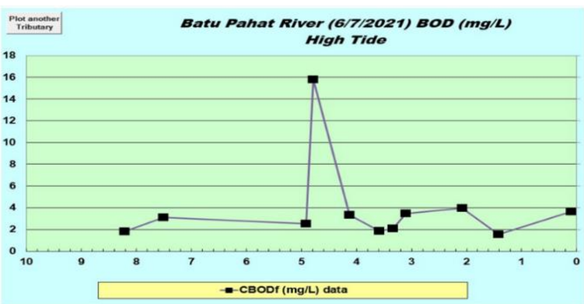

Figure 14: BOD (mg/L) of Batu Pahat River during high tide.

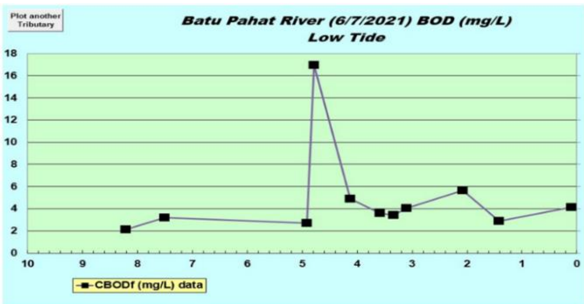

Figure 16: BOD (mg/L) of Batu Pahat River during low tide.

From the Figure 14 (high tide) and Figure 16 (low tide), both show that the BOD concentration gradually increase through km 7.51 at CP2 Residential and slightly decrease downstream to km 4.91 CP3 Workshop. However, the BOD concentration bounce back upstream steeply at km 4.79 CP4 Wet Market with concentration of 15.80 mg/L (high tide) and 16.95 mg/L (high tide) and causes the DO concentration to decrease. BOD start to decrease steeply through km 4.13 until km 3.34 due to denitrification as high NH3-N was recorded at km 4.13.

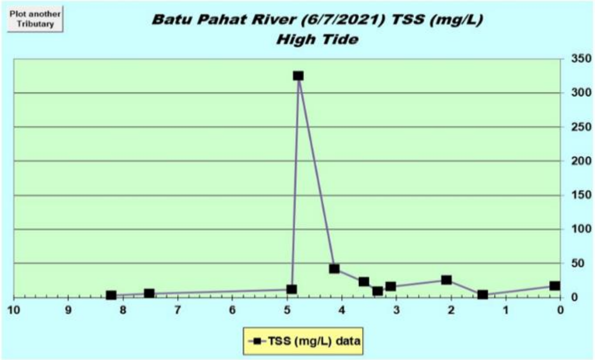

Figure 17: TSS (mg/L) of Batu Pahat River during high tide.

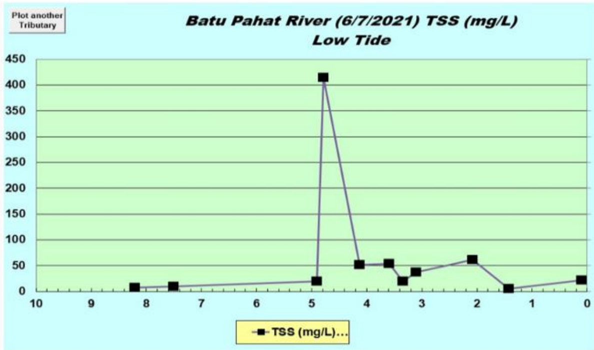

Figure 18: TSS (mg/L) of Batu Pahat River during low tide.

From the Figure 17 (high tide) and Figure 18 (low tide), both show that the TSS concentration gradually increase through km 7.51 at CP2 Residential until km 4.91 CP3 Workshop. The value of TSS concentration rose significantly at km 4.79 CP4 with 325 mg/L (high tide) and 414 mg/L (low tide). The spike of TSS concentration is due to the contribution of CP4 Wet Market and activities from along the river. However, the TSS concentration start to decrease steeply through km 4.13 During high tide flow, TSS concentration continue to decrease slightly through km 3.59 to km 3.34 until it rose back slightly at km 2.08.

3.3 Discussion

The hydro geometric data shows that discharge pattern decrease as it flows downstream the river for every reaches. The simulation for both low tide and high tide flow demonstrates that when DO concentration input is higher, there will be decrease in the concentration of COD, BOD, TSS, and NH3-N in Batu pahat River. A decrease in the DO value usually denotes an increase in the BOD value [9]. It also proved that, besides high amount of DO concentration, when the amount of discharge is huge, the concentration of COD, COD, TSS, and NH3-N will be decreased in the Batu Pahat river. The most critical period of water pollution occurs during low flow periods, where the river's ability for dilution is reduced [7]. It also shows that CP4 Wet Market has become the most contributor of pollution load for both during low tide and high tide flow. The simulation of Qual2k helps to identify the trend of water quality of Batu Pahat River and to identify the most contributor of pollution load. All the data obtained from simulation of Qual2k will be used to monitor in further development of TMDL program.

From the data observed, it shows that the commercial sector of landuses have become the most contributor towards the pollution loading (kg/day) in Batu Pahat River, which are come from CP1 Fisheries, CP3 Workshops, CP4 Wet Market, CP5 Restaurant, CP6 Workshop, and CP7 Workshop. The observed data also shows that high tide flow produced higher pollution load (kg/day) compared to low tide flow due to larger amount of discharge during high tide flow. The lower discharge flow of the river which will subsequently abating the capacity of the river to receive pollutant load [8].

4. Conclusion

This study developed a hydrodynamic and water quality model for Batu Pahat River, Malaysia by using Qual2k water quality modelling. The model is well calibrated using all the 6 water quality parameters. From the the modelling, it shows that the flow in Batu Pahat River has a reduction trend in velocity and discharge when it flows from upstream to the downstream of the river. Most of the water quality parameters (COD, BOD, NH3-N, TSS) has a high concentration value at CP4 Wet Market due to low concentration value of DO with low amount of discharge.

From the data and result analysis observed, commercial sector of landuses have become the most contributor towards the pollution loading (kg/day) in Batu Pahat River compared to residential and agriculture types of landuses for both low tide and high tide flow. It also shows that, larger pollution loading (kg/day) will be produced during hide flow compared to low tide flow due to a large amount of discharge. For example, the current BOD pollution loading produced during high tide are 1236.41 kg/day from commercial landuses, 899.33 kg/day from residential landuses, and 23.384 kg/day from agriculture. With 15% of MOS, the TMDL of BOD during high tide are 1813.9 kg/day from commercial landuses, 1034.23 kg/day from residential landuses, and 26.89 kg/day from agriculture landuses. During low tide flow, the current BOD pollution loading produced are 1185.45 kg/day from commercial landuses, 780 kg/day from residential landuses, and 25.29 kg/day from agriculture. With 15% of MOS, the TMDL of BOD are 1363.27 kg/day from commercial landuses, 897 kg/day from residential landuses, and 29.08 kg/day from agriculture landuses.

The more comprehensive study for watershed management can be done. Although the efforts to implement TMDL in Batu Pahat River would require substantial cost and time, the long-term benefits are immense.

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