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Assessment of water quality conditions in the Upper Johor River Basin

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Abstract. The water quality data from 2 sampling stations in the Upper Johor River Basin (Upper Johor River and Sayong River) were analysed to evaluate the water quality conditions. The variation in water quality parameters between base and storm flow events were compared to identify the pollutant sources. The results indicated that Biochemical Oxygen Demand (BOD) was the main cause for non-point source pollution of the study area. The overall water quality conditions were good in terms of dissolved oxygen and total nutrients (Nitrogen and Phosphorus). The dominant sources of BOD could be from the fertiliser timing and application. Different from BOD, the majority of the water quality samples were from baseflow events for dissolved oxygen, total nitrogen and total phosphorus. The major differences between four water quality parameters are failing septic system, oil palm mills, wastewater treatment plants and domestic waste. The results from this research would provide useful information for total maximum daily load calculation, establishment of watershed and nutrient model, and development of Best Management Practices for the Upper Johor River Basin and comparable study area.

1. Introduction

In recent years, there has been an increasing interest in the variation of rainfall amounts and air temperature that cause severe soil erosion and high nutrient loads in rivers [1]. This issue had become severe when agricultural lands expanded and together with ineffective management practices [2]. In tropical regions, most of the agricultural lands are planted by oil palms and have a high demand due to economic growth [3]. Around 410 to 570 hectare of forest lands are cleared for oil palm and thus affect the animal habitat [4]. Malaysia's palm oil area has risen dramatically to 2.4 million hectares and lost around 651,757 hectares of forestland in between 1988 and 2014 [5, 6]. The anthropogenic activities in the Johor river basin consist of agriculture, aquaculture, urban and oil palm mills [7]. Eugene et al. [8] showed that the contribution of pollutants from the eastern part (Johor River Estuary) is more significant than the western part due to more non-point sources in the east. Nutrients via fertilisation and least in urban activities are main water quality problems in the river [9]. Scott and Judith [10] suggested that nutrient concentrations must be controlled from land to reduce non-point source pollution in the river and groundwater.

Besides the non-point sources, Brett et al.[11] described the point source pollution based on the anthropogenic activities that primarily contributed to river water quality degradation. In the Johor river basin, POME from mill contains 200 mg/L of total nitrogen and 115 mg/L of ammonia [12]. Changes of non-point sources and unmonitored point source discharge at agricultural watershed can lead to algal blooms in the downstream areas [13]. Factors that influence this incident are mainly from phytoplankton, which are blue-green algae that induce toxins to fishes. Other reasons are an increment of water temperature and a low level of dissolved oxygen [14]. Exploiting these problems using a statistical analysis may provide an understanding of how to control nutrient contaminants in a tropical watershed scheme. The research objective is to assess the water quality condition in the Upper Johor River Basin and compare the differences in water quality between base and storm flow events.

2. Materials and method

2.1. Study area description

The upper Johor River Basin is situated in the south-eastern part of the Johor region in Malaysia and covers between latitudes (1° 35' to 2° 0' N) and longitudes (103° 30' to 104° 05' E) as indicated in Figure 1. It is an agricultural basin with a length of 122.7 km and a total area of 2612 km^2. The upper Johor River Basin consists of two main tributaries known as Sayong River and Linggiu River situated from the northern site. The upper Johor River basin is selected due to the availability of long-term historical data input on streamflow, water quality constituents, and land-use. It covers more than 60% of the oil palm plantations, with yellowish-brown sandy clay and medium on permeability. The highest point of the upper Johor River Basin is 977 m, and the lowest part is 3 m based on the DEM data. This basin has an average of 37.7 m^3/s on flow located at upper Johor station (Figure 2).

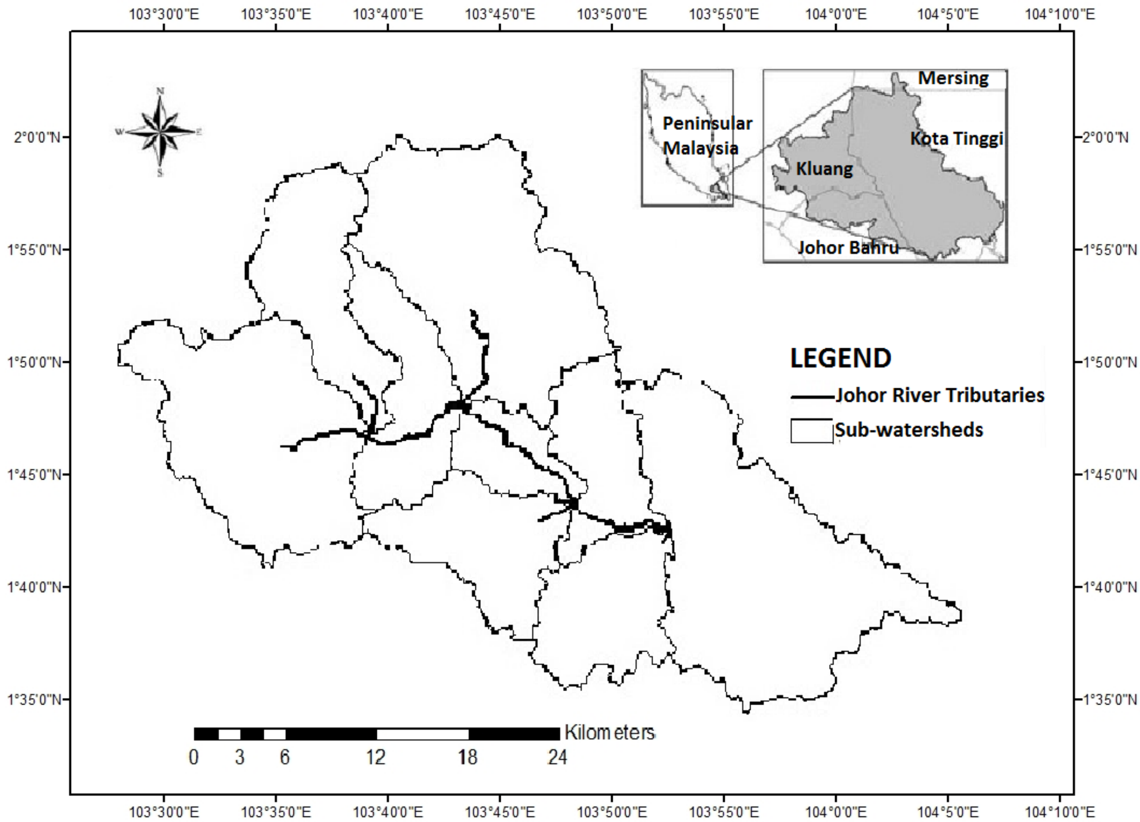

Figure 1. Location of upper Johor River Basin.

2.2. Sampling stations and monitored parameters

A total of 2 stations were selected to monitor the water quality parameters in the Johor River Basin. The locations of these sampling stations are shown in Figure 2 and the geographical area are given in Table 1. The water quality data from 55 base and 45 storm events were collected from these sampling stations during 2000 to 2017. The sampling wet weather events were distributed throughout the year to capture the seasonal variations in water quality. The sampling of storm events occurred following a dry inter-event period of at least 36 hours, whereas the sampling of base flow events was conducted at least 72 hours after the last storm events. The collected water quality parameters were dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total nitrogen (TN) and total phosphorus (TP). Following each sampling event, the samples were analysed according to the approved quality assurance project plan and defined quality control procedures and quality assurance requirements.

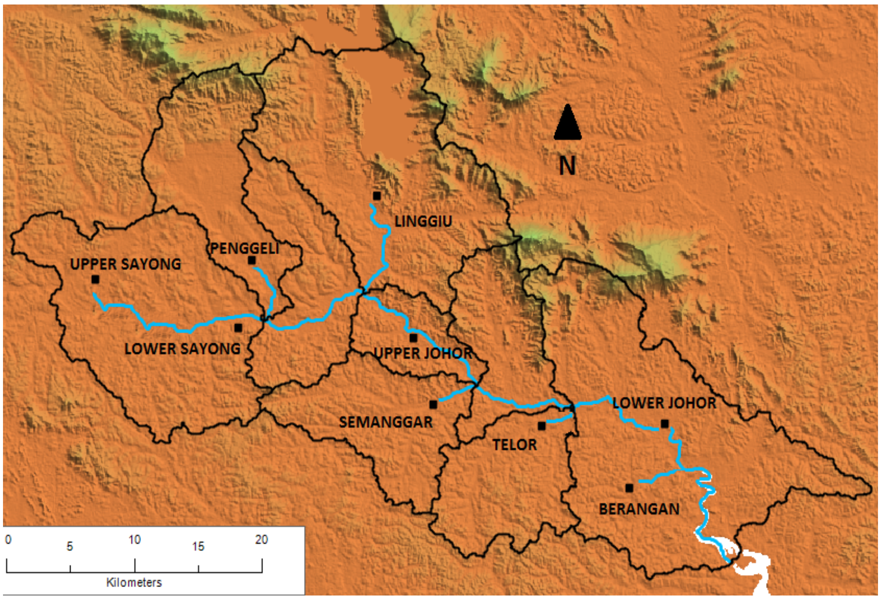

Figure 2. Locations of tributaries at upper Johor River Basin.

Table 1. Main rivers in upper Johor River watershed.

No.	Rivers	Area (km^2)	Length (km)
1	Johor	405.22	48.18
2	Sayong	109.88	26.42
3	Pengeli	152.83	17.23
4	Linggiu	60.59	16.22
5	Semanggar	142.72	13.04
6	Telor	57.61	13.09
7	Berangan	43.15	6.92

2.3. Data analysis

Water quality standards, established by the National Water Quality Standard (NWQS), Malaysian Department of Environment (DOE), are in general designed to protect water quality for the designated stream uses [15]. The DO water quality criteria to protect aquatic life requires that in-stream instantaneous DO level remains between 5.0 to 7.0 mg/L for Class IIA/IIB (Table 2). For BOD_5, TN and TP, the general requirement for water supply and fisheries remain at level 3, 7.3 (cummulative from ammoniacal nitrogen and nitrate) and 0.2 mg/L for Class IIA/IIB respectively. The standard deviation and minimum, maximum, median, and mean values were calculated for each water quality constituent. The observed data were compared with the water quality criteria and NWQS target values to assess the water quality conditions in the Johor River Basin. The differences in water quality between base and storm flow events were examined using boxplots.

Table 2. Extract of the National Water Quality Standards (NWQS) [15].

Parameters	Unit	Class				
		I	IIA/IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.9	2.7	>2.7
Nitrate	mg/l	-	7	-	5	>5
Phosphorus	mg/l	-	0.2	0.1	-	-
BOD_5	mg/l	1	3	6	12	>12
COD	mg/l	10	25	50	100	>100
DO	mg/l	7	5-7	3-5	<3	<1
pH		6.5-8.5	6.5-9.0	5-9	5-9	-
Total Suspended Solids	mg/l	25	50	150	300	300
Temperature	^{o}C	-	Normal+ $2^{o}C$	Normal+ $2^{o}C$	-	-
Water Quality Index (WQI)	mg/L	>92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31.0

3. Results and discussion

3.1. Assessment and comparison of water quality between base and storm flow events

The evaluated water quality constituents included DO, BOD, TN and TP. The calculated statistics of the water samples from all stations are given in Table 3. The water quality assessment and comparison of water quality between the base and storm flow events were conducted for each group.

Table 3. Calculated statistics of the observed DOE water quality data.

Name of Rivers	Water quality constituents	Minimum value	Maximum value	Median value	Mean value	Standard deviation
Upper Johor	DO (mg/L)	2.77	6.88	5.11	6.02	0.85
	BOD (mg/L)	1.2	34	3.1	2.13	1.93
	TN (mg/L)	0.01	3.65	0.55	0.83	0.69
	TP (mg/L)	0.01	1.26	0.01	0.13	0.11
Upper Sayong	DO (mg/L)	4.61	9.1	7.19	6.5	0.65
	BOD (mg/L)	0.77	13	2.2	2.43	1.29
	TN (mg/L)	0.21	9.04	1.32	1.43	2.8
	TP (mg/L)	0.01	2.03	0.01	0.05	0.19

3.1.1. Dissolved oxygen (DO). Compared with the Upper Sayong River, the observed DO data at the Upper Johor River had much lower variations (Table 3). The observed DO for both rivers ranged from 2.9 to 8.8 mg/L, respectively. Of the total 110 water samples, only 6% of water samples had DO values lower than the NWQS Standard for class II: 5.0 mg/L. Thus, the overall DO condition is good for both stations. The average between two stations shown that the minimum (3.6 mg/L), maximum (7.4 mg/L), and median values (6.1 mg/L) from baseflow was slightly higher than the corresponding values from storm flow events (4.6, 6.9, and 5.5 mg/L, respectively) (Figure 3). It was concluded that all the water samples with lower DO values were from the storm flow events. This denoted that non-point sources were the main pollutant sources controlling DO condition.

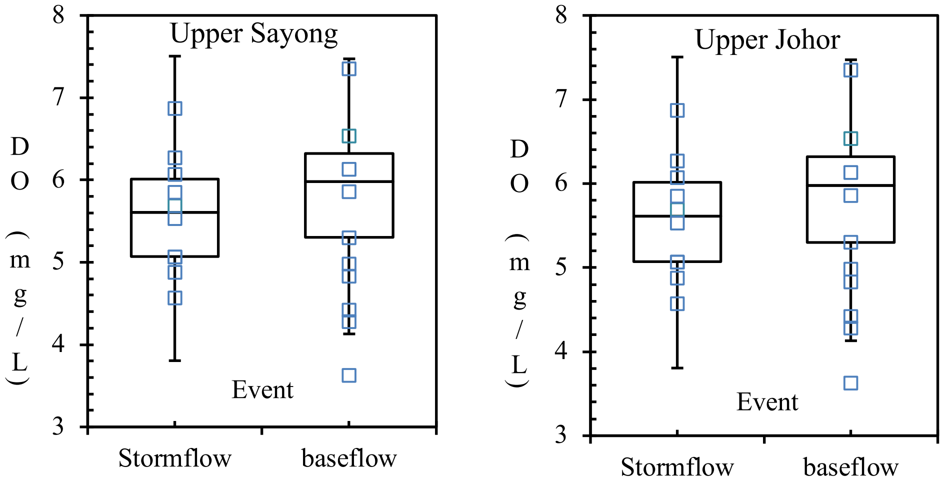

Figure 3. Comparison of dissolved oxygen (DO) between base and storm flow events.

3.1.2. Biochemical oxygen demand (BOD). For biochemical oxygen demand (BOD), of the total 32 samples exceeding the NWQS target value for class II: 3 mg/L, almost half from them were from storm flow events (Figure 4). The potential sources of BOD in the study area comprised allowable release from oil palm mills, wastewater treatment plant and fertiliser wash-off from oil palm land segments. In certain cases, the continual discharges of BOD from failing septic system into the groundwater resulted in the higher level of BOD [16]. During the storm events, the rainfall diluted the BOD concentration, and resulted in lower values of BOD compared with based flow events [16]. Among the above causes, fertiliser wash-off from oil palm plantations could change the water quality of rivers. Therefore, the foremost source of BOD in the storm flow events could be from the fertiliser timing and application.

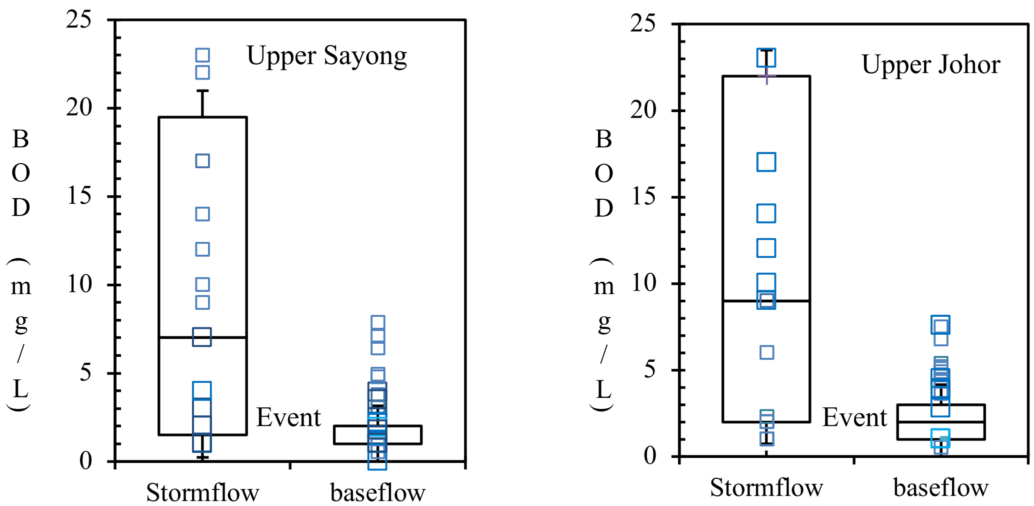

Figure 4. Comparison of biochemical oxygen demand (BOD) between the base and storm flow events.

3.1.3. Total nutrients (total nitrogen and total phosphorus). The calculated statistics for total nitrogen (TN) and total phosphorus (TP) are given in Table 3. Of the total 108 water samples, 13.5% water samples had TN and TP values exceeded the NWQS target value for class 2: 7.3 mg/L and 0.2 mg/L, respectively. The observed maximum value of TN at Sayong River was 10.5 mg/L much higher than the NWQS target value of 7.3 mg/L. However, for the Johor River, it is shown that the maximum value was 3.0 mg/L much lower than the NWQS target value. TP is an essential nutrient of the crop, human and animal, which exists largely as orthophosphate or in the organic composite. As shown in Figure 6, the observed maximum value of TP was 2 mg/L at Sayong River, 10-fold the NWQS target value (0.2 mg/L). The antecedent results implied that the overall water quality condition is worse in terms of eutrophication. The comparison of TN and TP between base and storm flow events are illustrated in Figure 5 and Figure 6, respectively. Of the total water samples exceeding the NWQS target values, base flow events are dominant for TN and TP. Since this river basin is dominated by the large number of oil palm cultivation areas, it is likely that the increase of high nutrient contents are accumulated by uncontrolled fertilizers usage although some studies had proved logging activities also contribute to the high content of TN and TP [17].

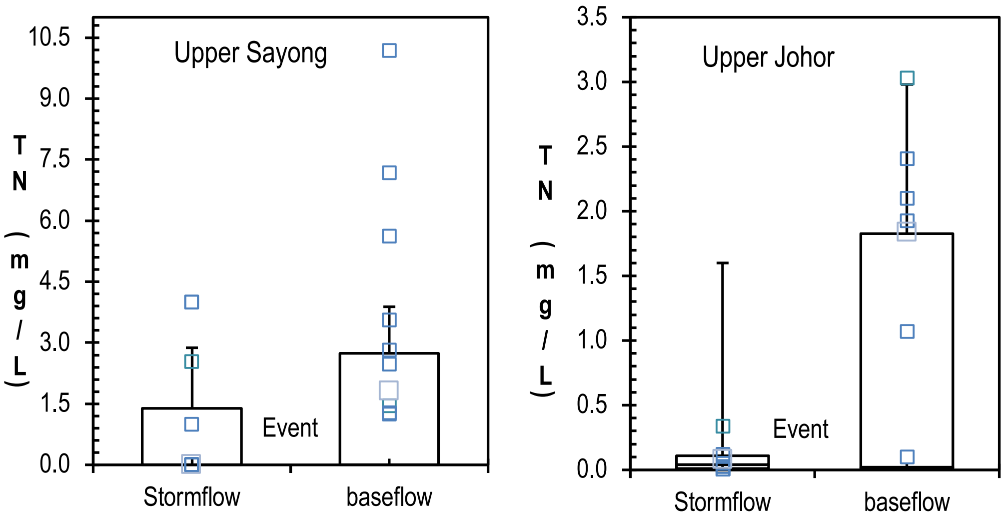

Figure 5. Comparison of total nitrogen (TN) between base and storm flow events.

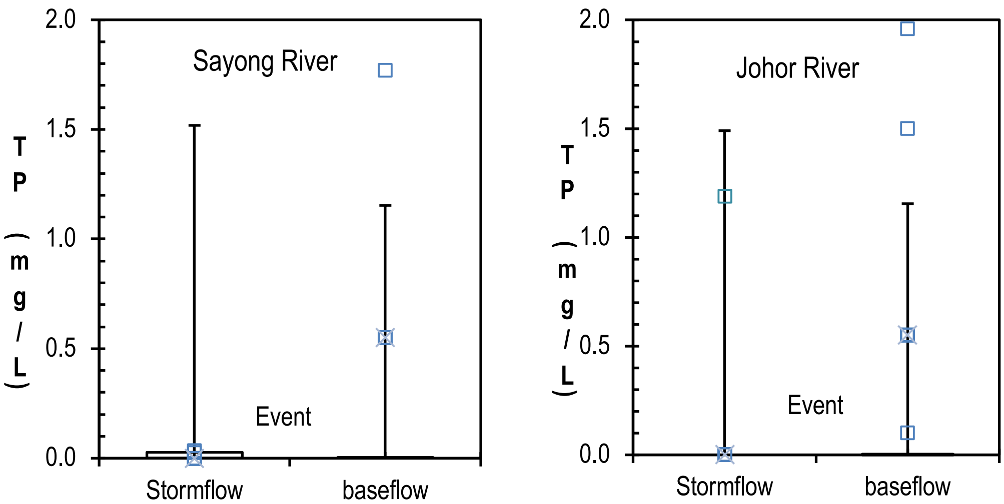

Figure 6. Comparison of total phosphorus (TP) between base and storm flow events.

4. Conclusion

The objectives of this research were to assess the water quality conditions and compare the water quality differences between base and storm flow events in Johor River Basin. The water quality data were collected by NWQS. The major conclusions were that point source is the major cause of nutrients impairment and high BOD, while low DO is triggered by rainy seasons (storm flow). The overall water quality conditions is good in terms of DO content but needs more emphasis on the eutrophication process due to high nutrients. As illustrated, the comparison of the difference in water quality parameters between base and storm flow events can provide useful information for identifying the pollutant sources and development of a computational watershed model, and TMDL studies for similar study areas.

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