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Study on the Water Quality Index (WQI) of Parit Besar River in Batu Pahat

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Abstract: Water resources play an important role in supplying water for domestic, industrial and agricultural. More than 70% of the Earth's surface was covered with water sources were found in rivers, lakes, rainwater, groundwater, and others. However, over time, water quality deteriorates due to exposure to weather changes and urbanisation, and effects from point and non-point sources of pollution. The objectives of this study were to measure the Water Quality Index (WQI) parameters and identify the Parit Besar River latest status based on the WQI and National Water Quality Standards (NWQS) for Malaysia. Water samples were collected from three locations along the Parit Besar River and was analysed using six WQI parameters: the Ammonia Nitrogen (AN), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), pH, and Total Suspended Solids (TSS). In all upstream, middle and downstream sampling locations and WQI analyses, results show that the status of the Parit Besar river falls in Class IV. Meanwhile, the average NQWS Class of each parameter for AN, BOD, COD, DO, pH and TSS are 2.25 mg/L (Class IV), 6.18 mg/L (Class IV), 66.50 mg/L (Class IV), 6.15 mg/L (Class IIA), 6.86 (Class I) and 343.33 mg/L (Class V), respectively. It can be concluded that with the high population and high development of housing areas surrounding Parit Besar river have been leading this river to be highly contaminated, and this river is not appropriate for water supply or fisheries, hence it can only be used for irrigation purposes.

Keywords: Water quality, water quality index (WQI), river water quality, Batu Pahat river

1. Introduction

About 97% of the earths water is stored in the oceans, and a small portion of the remaining 3% was freshwater [1]. Freshwater on this surface consists of rivers, lakes, streams, and more. Water is required by all living creatures on this planet, from microorganisms to the noblest of beings, humans. There would be no life on this planet if there is no water because water is the most basic requirement for all living things. Water is, in essence, one of the most important elements of life [2]. Therefore, water quality is important to ensure that water bodies are safe to be uses for specific purposes and inhabited by aquatic life.

However, rivers are often polluted because of human activities that exceed sustainability limits. Where river water pollution occurs when pollutants entered the body of water indirectly or directly without treatment. In Malaysia, urbanization and development contribute a lot to the declining in water quality and worsening every year. This is due to changes in the earth's surface, and it affects the hydrological cycle in the area [3]. Rapid development in urban areas and inadequate drainage management systems to accommodate the amount of rainwater that falls in the area during the wet season resulted in floods. Rainwater precipitation that falls cannot infiltrate into the subsoil because the soil surface has been heavily covered and causes surface runoff to carry pollutants such as garbage, mud, other hazardous chemicals into the drainage system or nearby water bodies. This caused an increase in dirt and pollution on water bodies like river

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in the urban area. Therefore, these conditions will greatly affect the world's ecosystems and its living organisms and therefore pose a threat to the survival of flora, fauna and alteration of the hydrological cycle [4]. A river water quality monitoring program was administered in 2016 by the Department of the Environment (DOE) was conducted and river water quality was evaluated, and it was discovered that of the 477 rivers tested, 224 (47%) was found to be clean, 207 (43%) moderately polluted, and 46 (10%) was found to be contaminated [6].

Parit Besar river is one of the rivers in Batu Pahat that is close to urban areas and developing areas. The development that took place around the Parit Besar river has changed the characteristics of soil surfaces that normally permeable to infiltrate rainwater into the soil. Therefore, rainwater flows directly into a nearby river while carrying all the garbage, sediment, and all foreign matter into the river. In addition, waste discharges from residential and industrial areas are also discharged into nearby rivers. The effects of all these discharges will affect the characteristics of the waterbody. Therefore, the water pollution that occurs has reduced the quality of river water and it will disrupt human activities in daily life and threaten aquatic life in the river area.

The purpose of this study is to determine the water quality status in the Parit Besar river, Batu Pahat. Water quality studies are important for the environment to protect all living things. When the quality of water resources is disturbed due to pollution, the entire use will bear the risk of health and environmental impacts. This makes the quality of water resources as one of the most important factors in ensuring that the area was inhabited by living things. Therefore, this study was conducted to measure the water quality index (WQI) of Parit Besar river to classify and categorize a body of water due to relevant water quality parameters. The water quality index is an important way to assess the suitability of river water for a particular use to protect the health and life of all living things around it.

2. Materials and Methods

2.1 Study area

Sungai Parit Besar is connected to the main river of Simpang Kanan and is located in a residential area and small town in Batu Pahat District, Johor, Malaysia. The river is near to urban areas which have densely populated as well as industrial areas such as textile and food industries.

2.2 Sample collection and laboratory analysis

Three sampling locations were established along the river flow to give an overview of the quality of the river, it was monitored in November 2021 by collected water samples twice. The coordinates of Location 1, Location 2 and Location 3 were 1° 53' 18.1" N 102° 58' 05.1" E, 1° 52' 51.9" N 102° 57' 51.7" E and 1° 52' 13.1" N 102° 57' 30.9" E, respectively. River water flows from Location 3 (upstream) to Location 1 (downstream) and enters the Simpang Kanan River as shown in Figure 1. Water samples collection from rivers should have clear safety risks because water is a carrier of many disease-producing organisms. Safety precautions taken were to wear a face mask and gloves during sampling. In addition, three containers of polyethylene type were prepared and cleaned. Each container must be labeled and then filled with a sample of river water [7]. Water samples were collected at a certain depth using a clean bucket that had weights and tied with a rope. The first trial sampling activity was conducted on 16 November 2021 and the second trial was on 30 November 2021 between 8 am and 10 am where the river water recedes at low tide and in sunny weather conditions.

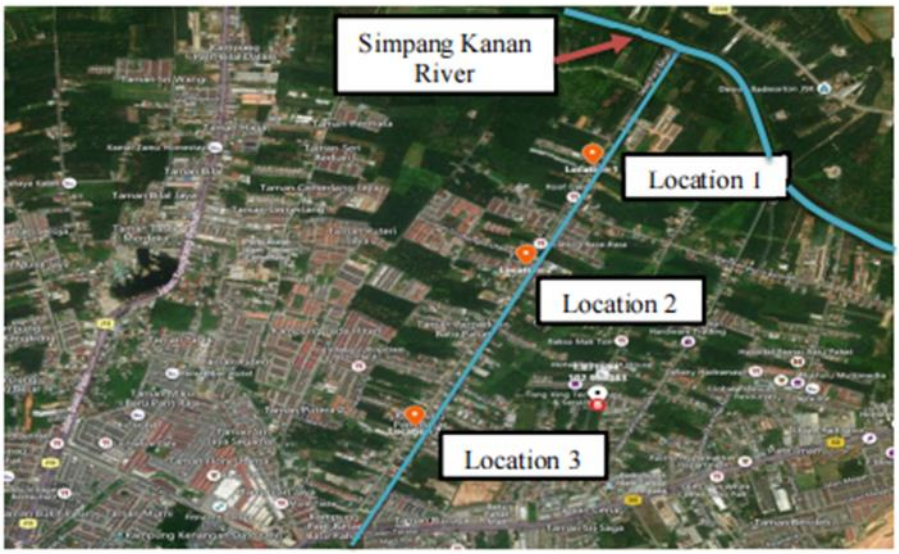

Fig. 1 - Map of the area with sampling locations (1-3) in Sungai Parit Besar.

The collected samples were used within 24 hours to ensure that the data are not affected. The WQI parameters testing were conducted in the Environmental Engineering Laboratory (EEL), UTHM. Each parameter uses a different testing method as shown in Table 1.

Table 1 - Analysis methods for all parameters

No.	Parameters	Location for test	No method	Method
1	pH	EEL	Method 10360	Direct Measurement
2	Dissolved Oxygen	EEL	Method 10360	Direct Measurement
3	Biochemical Oxygen Demand	EEL	Method 8043	Dilution
4	Chemical Oxygen Demand	EEL	Method 8000	Reactor Digestion
5	Total Suspended Solid	EEL	APHA 2540 D	Dried At 103-105 C°
6	Ammonia Nitrate	EEL	Method 8038	Nessler

2.3 WQI calculation

The Water Quality Index (WQI) is the formula used to measure the level of pollution and the suitability of a water use types as outlined by the National Water Quality Standards (NWQS). WQI is obtained based on the 6 parameters. Furthermore, WQI values will indicate the level of water contamination by providing policy makers and environmentalists with input on water quality [8]. The water quality index for a particular sample is calculated using the WQI equation shown in equation 1 after the results of the laboratory analysis were recorded.

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

The equations in Table 2 are used to measure all the subindices specified in Equation 1. The subindices for different parameters have different ranges.

Table 2 - The equations for the estimation of various subindex values [13]

$Subindex\ for\ DO\ (in\ \%\ saturation)$	
$SIDO = 0$	$for\ x \leq 8$
$SIDO = 100$	$for\ x \geq 92$
$SIDO = -0.395 + 0.030x2 - 0.00020x3$	$for\ 8 < x < 92$
$Subindex\ for\ BOD$	
$SIBOD = 100.4 - 4.23x$	$for\ x \leq 5$
$SIBOD = 108 * exp(-0.055x) - 0.1x$	$for\ x > 5$
$Subindex\ for\ COD$	
$SICOD = -1.33x + 99.1$	$for\ x \leq 20$
$SICOD = 103 * exp(-0.0157x) - 0.04x$	$for\ x > 20$
$Subindex\ for\ NH3-N$	
$SIAN = 100.5 - 105x$	$for\ x \leq 0.3$
$SIAN = 94 * \exp(-0.573x) - 5 * I\,x - 2\,I$	$for\ 0.3 < x < 4$
$SIAN = 0$	$for\ x \geq 4$
$Subindex\ for\ SS$	
$SISS = 97.5 * \exp(-0.00676x) + 0.05x$	$for\ x \leq 100$
$SISS = 71 * \exp(-0.0061x) - 0.015x$	$for\ 100 < x < 1000$
$SISS = 0$	$for\ x \geq 1000$
$Subindex\ for\ pH$	
$SIpH = 17.2 - 17.2x + 5.02x2$	$for\ x < 5.5$
$SIpH = -242 + 95.5x - 6.67x2$	$for\ 5.5 \leq x < 7$
$SIpH = -181 + 82.4x - 6.05x2$	$for\ 7 \leq x < 8.75$
$SIpH = 536 - 77.0x + 2.76x2$	$for\ x \geq 8.75$

3. Results and Discussion

The average pH reading value based on three locations of Location 1, Location 2 and Location 3 are 6.78, 6.83 and 6.89, respectively. This indicates that the readings of the pH value were similar at all locations. The average pH value of the Parit Besar river was found to be mildly acidic but closely to the neutral at pH 7 at all three locations. The mild

acidic value was mainly due to rain and runoff from local roads and surrounding areas that carry organic matter into the Parit Besar river. High pH readings were often associated with the presence of high organic matter. Based on the National Water Quality Standards for Malaysia, the average pH reading value is in the range of 6.5 to 8.5 indicating to be in Class I. While based on the DOE Water Quality Index Classification, the average value of the pH reading is in the range of 6 to 7 indicating to be in Class II.

The average value of Dissolved Oxygen for the Location 1 was 6.55 mg/L, however the average value for the Location 2 was 6.13 mg/L. Finally, the average value of the Location 3 was noticeably smaller than the others at 5.76 mg/L. According to Malaysia's National Water Quality Standards, the best DO read for quality water was more than or equal to 7 mg/L. This implies that the reading value for the DO reading at Location 1 was nearer to the best reading value. High rate of oxygen diffusion into a water body was influenced by several factors including a drop in temperature, the decreasing distance of water sampling depth from the surface, increased the movement of water flow, and the presence of air in the form of currents, waves, and tides. Based on the observation, the Location 1 is in the downstream area of the Parit Besar river, which was connected to the Simpang Kanan river, but the river level was higher than the Location 3. The average result for the three DO readings was between 5-7, which is in Class IIA and IIB, as according to Malaysia's National Water Quality Standards. While according with DOE Water Quality Index Classification, the average value of the DO reading was in the range of 5 to 7, suggesting that it is in Class II.

The average value of Biochemical Oxygen Demand for the Location 1 was 4.91 mg/L and the average value for the Location 2 was 6.54 mg/L. Finally, the average value of the Location 3 was 7.09 mg/L. The amount of BOD generated was determined by the type and quantity of organic compounds present, as well as temperature, pH, and the presence of nutrients and trace elements essential for growth. The amount of oxygen utilised by microorganisms in aerobic oxidation, or the breakdown of organic matter in water bodies, was measured using an empirical test. The higher the BOD reading, there are more organic matter in the water. The readings of all three locations were relatively high, potentially due to the presence of organic waste releases into relatively high-water bodies in the surrounding area. According to the National Water Quality Standards for Malaysia and the DOE Water Quality Index Classification shows the best BOD reading value that was in Class I was 1 mg/L or less. But the lowest average reading value was 4.91 mg/L in Location 1 indicating a reading that does not reach the specifications set by Class I. The average BOD reading value of the Location 1 in the range of 3 mg/L to 6 mg/L indicates to be in class III while the Location 2 and 3 are in the range of 6 mg/L to 12 mg/L indicates to be in Class IV.

The average value of Chemical Oxygen Demand for the Location 1 was 56.50 mg/L and the average value for the Location 2 is 69.00 mg/L. Finally, the average value of the Location 3 was 74.00 mg/L. According to the National Water Quality Standards for Malaysia and the DOE Water Quality Index Classification, the best COD value in class I was 10 mg/L or less. However, when comparing the best COD reading at Class I to the average reading of the lowest COD value at Location 1 from other places, there is a great disparity. This means that the COD reading value is quite high in all three places. The presence of aquatic organisms in the water body will be lowered because of the high COD content. The high COD value was related to the decomposition of organic and inorganic substances in the waste produced, according to [12]. The average COD reading value of each location was in the range of 50 mg/L to 100 mg/L indicating to be in Class IV.

The Total Suspended Solid reading value recorded based on three location of water sampling area. The Location 1 average value was 335.00 mg/L, meanwhile the Location 2 average value was 352.50 mg/L. Lastly, the Location 3 average value was 342.50 mg/L. According to the National Water Quality Standards for Malaysia and the DOE Water Quality Index Classification, the best TSS value in Class I was 25 mg/L or less. This indicates that the average reading of TSS values at all point locations was very high compared to the readings at Class I. High TSS readings can be caused by various types of wastes, such as silt, decomposing plant and animal species, industrial waste, and sewage entering the river from local sources. High suspended solids concentrations can cause many implications for the health of streams and aquatic life. The average TSS reading value for each location point was above 300.00 mg/L which indicates to be in Class V.

The average value of Ammoniacal Nitrogen for the Location 1 was 1.78 mg/L and the average value for the Location 2 was 2.45 mg/L. Finally, the average value of the Location 3 was 2.53 mg/L. According to the National Water Quality Standards for Malaysia and the DOE Water Quality Index Classification, the best value NH_3-N in Class I was 0.1 mg/L or less than 0.1mg/L. The average value of NH_3-N for each location was between the range of 0.90 mg/L to 2.70 mg/L which indicates to be in Class IV.

Table 3 shows the results of WQI values and classification of water bodies based on the sub-index of six parameters which is SIPH, SIDO, SIBOD, SICOD, SIAN, SISS and the water quality index for the three locations in the Parit Besar river. Water quality data obtained from the sub-index used to determine the water quality status whether clean, slightly polluted or contaminated in DOE Water Quality Classification based on Water Quality. The sub-index values for the three points for the BOD parameter was in the index range 0 to 79 and for the NH_3-N parameter was in the index range 0 to 70. While for the third parameter, the TSS was in the index range 0 to 59. According to DOE Water Quality Classification Based on water quality index these three sub-index values are in the range of polluted water quality index. WQI values for the three points were obtained by substituting sub-index values for each parameter involved in the Equation 1.

The WQI value at Location 1 was 39.34 and at the Location 2 was 34.83. Meanwhile, the Location 3 was 33.86. According to the DOE Water Quality Classification, these three WQI values are in the index range of 31.0 to 51.9 which shows that the water quality of this river was in Class IV. The appropriate use of river water for Class IV was irrigation. In addition, WQI values that were in the index range of 0 to 59 indicate the quality of polluted river water. Clear results show that most water quality parameters are contaminated during sampling.

Table 3 - The results of WQI values and classification of water bodies

Sub-index	Location	Sub-index value	Water Quality Index	Class (WQI)
SIPH		98.88		
SIDO		00.00		
SIBOD	1	79.63	39.34	IV
SICOD		40.16		(31.0 – 51.9)
SIAN		35.00		
SISS		4.17		
SIPH		99.12		
SIDO		00.00		
SIBOD	2	74.72	34.83	IV
SICOD		32.10		(31.0 – 51.9)
SIAN		20.84		
SISS		2.98		
SIPH		99.36		
SIDO		00.00		
SIBOD	3	72.42	33.86	IV
SICOD		29.27		(31.0 – 51.9)
SIAN		19.41		
SISS		3.65		

Through observation, it was found that the caused of river water pollution is from non-point source. This was because based on the study area, Location 1 was located next to the road, village housing area, mosque and close to oil palm plantations. While in Location 2 there was a vehicle workshop, a row of shops, restaurants, next to the road and a housing estate. Finally, Location 3, there was a hardware store, garbage dump, residential area, and roadside. The pollution that occurs may be from wastewater discharges, industrial dischargers, drainage, spills, and others. In the surrounding areas that carries physical, chemical, and biological pollution waste into the nearby river [10].

Wanting to further reinforce the fact of having spot pollution, it was found that there were pipes and drains that drain chemical and physical wastewater from economic, social, and developmental activities directly into the river without proper treatment. In addition, rainwater that could not seep into the soil because of many constructions covering the soil structure would carry waste flowing into the river.

Figure 2 shows the WQI values in graph form for the three locations in the Parit Besar river. Location 1 was the highest value while the value at the Location 3 was the lowest value. Nevertheless, all three sampling locations had indicated similar contaminated water quality at Class IV.

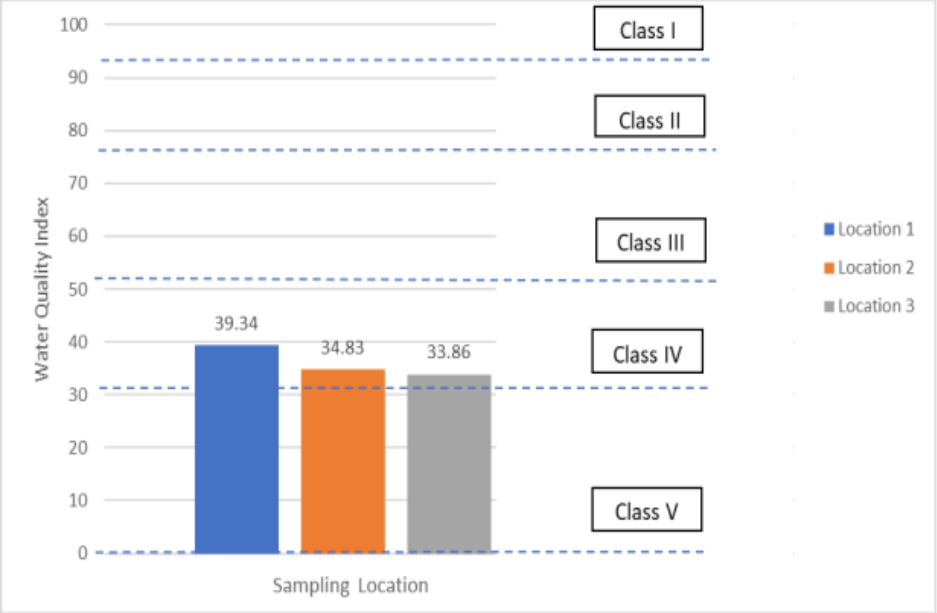

Fig. 2 - The WQI values in graph form

4. Conclusion

Based on this study, it can be concluded that water quality in Parit Besar in three locations are in bad state which was classified in Class IV and the appropriate use was only for water irrigation. This was due to the activities carried out in the vicinity and its location near the city of Batu Pahat which had a high population and high development activities. Because of this, ongoing planning and study were required to maintain and improve the quality of the country's river water in the future. Local authorities must also play a part, ensuring that any development activities consider the impact on the environment and the area's original ecosystem first. Furthermore, the local community must play a vital role in establishing an attitude of environmental stewardship and refraining from polluting the water bodies. The problem of pollution can be minimized and eliminated if all parties perform their respective duties. So that future generations can use clean and quality river water resources.

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