Study of water quality for Sungai Perlis, Perlis during high and low tides

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Abstract. The aims of the study are to establish the pollutant profile along Sungai Perlis during high and low tides based on physical and chemical parameters and relate the water quality with the land used along the river. Sungai Perlis is the main river in Perlis, Malaysia with size of river basin approximately 310 km². Three station points were selected along Sungai Perlis which are one station at the upstream, one station at the middle stream and one at the downstream. Six parameters were selected which are DO, BOD, COD, TSS, AN and pH. From the findings, the water quality index during high tide for upstream and downstream of Sungai Perlis are in Class II, whereas during low tide, it classified in Class III. However, no changes in water quality index during high and low tides for middle stream of Sungai Perlis, which is in Class III. The pollutant profiles also showed that the river were less polluted during high tide compared to low tide. The land use activities along Sungai Perlis include residential areas, recreational, agricultural, commercial, construction and fisheries located at Kuala Perlis which are directly and indirectly also contributes to the water quality of Sungai Perlis.

1. Introduction

Rivers are sources for industrial, domestic and aquaculture. Sungai Perlis is one of the examples as the economic resources for human. Sungai Perlis also has been used for tourism and recreational purpose. It has the length about 9.8 km from Kangar city to Kuala Perlis with the basin size of approximately 310 km² [1]. Sungai Perlis has more than 10 sub tributaries such as Sungai Batu Pahat and Sungai Kechor [2].

River pollution are cause by various factors and it can affect both human and aquatic animal if it is not controlled. According to the Department of Environmental (DOE), the water quality of Sungai Perlis in 2017 is in Class II which is moderate based on the Interim National Water Quality Standards for Malaysia (INWQS). This indicated that the human activities near the Sungai Perlis has affected the water quality of the river. For example, the development of the new residential area and the human activities near the Sungai Perlis has disturb the soil surface which cause the pollution to the river. The rapid urbanization such as commercial area around this area also has caused the increasing in the population which can lead to the pollution on the river when it is discharge the wastewater into the river. Besides that, the highly development area and other activities also can cause erosion, greater runoff and mass movements of sediments into the river [3]. River water quality can be affected by the natural processes and anthropogenic activity [4].
Tidal of the river is one of the natural phenomena that can affect the water quality of the river. The current and flow rate during high tide and low tide can cause the difference in the water quality of the river [5]. During the high tide of the river, the flow rate and volume of the river is higher compared to the low tide which cause the water to has less concentration of the pollutant [2]. The increasing in the volume of the river can dilute the concentration of the pollutant and reduce the pollutants in the river. Furthermore, the velocity of the water also increases during high tide of the river to cause the mixing in the river and enhance the absorption of the chemical in the water which can reduce the pollutants to the river.

The aim of this research is to establish the pollutant profile along Sungai Perlis during high tide and low tide based on physical and chemical parameter and relate it to the land used along the river.

2. Materials and methods

2.1. Study area and sampling points

Water samples were taken at three different points along Sungai Perlis during high tide and low tide. The sampling points were selected at the upstream of Sungai Perlis, at the middle stream of Sungai Perlis near to the Kangar City and lastly, at the downstream of Sungai Perlis which is located at Kuala Perlis. Google Map and Global Positioning System (GPS) were used to determine the location and the coordinates of each point. The coordinate of the sampling points and location of each point are stated in Table 1 and Figure 1.

| Station | Location   | Coordinate               |
|---------|------------|--------------------------|
| P1      | Upstream   | 6°26'47.87"N, 100°13'0.16"E |
| P2      | Middle stream | 6°26'13.74"N, 100°11'27.61"E |
| P3      | Downstream | 6°24'30.20"N, 100°8'27.76"E |

Figure 1. Sampling point location.
2.2. Sample collection
Two liters of water samples were collected for sample analysis. Water sample has been tested for six times for every point which is three samples from high tide and another three samples from low tide. The water samples were kept in the ice box at temperature under 4°C when transporting the sample to the laboratory in order to stop the metabolism and activities of the organisms.

2.3. Data analysis
The Water Quality Index (WQI) is used to determine the classification of the river under Interim National Water Quality Standards for Malaysia (INWQS). The classification of the river is used to show the status of the water quality of waterway. The river can be classified into five class which is very clean, clean, moderate, polluted and very polluted. There are six parameters were recorded to determine the water quality of the river and these included Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammoniacal Nitrogen (AN) and pH. The calculation for the WQI of the river is shown in Equation 1 and the best fit equations for the estimation of various sub index values are shown in Table 2. Table 3 shows the classification of river based on WQI value.

\[
\text{WQI} = 0.22(\text{SIDO}) + 0.19(\text{SIBOD}) + 0.16(\text{SICOD}) + 0.15(\text{SIAN}) + 0.16(\text{SISS}) + 0.12(\text{SIpH})
\]

| Parameter | Sub index |
|-----------|------------|
| DO        | X ≤ 8      | SIDO = 0 |
|           | X ≥ 92     | SIDO = 100 |
|           | 8 < X < 92 | SIDO = - 0.395 + 0.03 X² – 0.0002 X³ |
| BOD       | X ≤ 5      | SIBOD = 100.4 – 4.23 X |
|           | X > 5      | SIBOD = 108 e - 0.055 X - 0.1 X |
| COD       | X ≤ 20     | SICOD = 99.1 – 1.33 X |
|           | X > 20     | SICOD = 103 e - 0.0157 X - 0.04 X |
| SS        | X ≤ 100    | SISS = 97.5 e - 0.00676 X + 0.05 X |
|           | 100 < X < 1000 | SISS = 71 e - 0.0016 X - 0.015 X |
|           | X ≥ 1000   | SISS = 0 |
| AN        | X ≤ 0.3    | SIAN = 100.5 – 105 X |
|           | 0.3 < X < 4| SIAN = 94 e - 0.573 X - 5 (X – 2) |
| pH        | X ≤ 5.5    | SIpH = 17.2 – 17.2 X + 5.02 X² |
|           | 5.5 ≤ X < 7| SIpH = - 242 + 95.5 X – 6.67 X² |
|           | 7 ≤ X < 8.75 | SIpH = - 181 + 82.4 X – 6.05 X² |
|           | X ≥ 8.75   | SIpH = 536 – 77 X + 2.76 X² |

| Parameter | Unit | I  | II | III | IV  | V  |
|-----------|------|----|----|-----|-----|----|
| DO        | mg/L | > 7 | 5 - 7 | 3 - 5 | 1 - 3 | < 1 |
| BOD       | mg/L | < 1 | 1 - 3 | 3 - 6 | 6 - 12 | > 12 |
| COD       | mg/L | < 10 | 10 - 25 | 25 - 50 | 50 - 100 | > 100 |
| TSS       | mg/L | < 25 | 25 - 50 | 50 - 150 | 150 - 300 | > 300 |
| AN        | mg/L | < 0.1 | 0.1 - 0.3 | 0.3 - 0.9 | 0.9 - 2.7 | > 2.7 |
| pH        | -    | > 7.0 | 6.0 - 7.0 | 5.0 - 6.0 | < 5.0 | > 5.0 |
| WQI       |      | > 92.7 | 76.5 - 92.7 | 51.9 - 76.5 | 31.0 - 51.9 | < 31.0 |
3. Results and discussion

3.1. Dissolved oxygen (DO)
DO concentration along Sungai Perlis during high tide and low tide were established in Figure 2. During low tide, the higher concentration of DO is at the upstream of the river which is 7.05 mg/L followed by middle stream 5.98 mg/L and downstream 5.47 mg/L. The DO value during high tide from upstream to downstream are 7.19 mg/L, 6.28 mg/L and 5.6 mg/L, respectively. DO concentration showed the higher value during high tide compared to low tide. The upward movement of the river water during high tide may have entrap the oxygen from the air into the river water.

![Figure 2. DO pollutant profile along Sungai Perlis during high tide and low tide.](image)

This finding was consistent with the research by Kaniz et al [4] which found that the highest DO occurred during high tide of the river and the lowest DO occurred during low tide of the river. This research also stated that the DO concentration may be influence by generated wave action at high tide which increase rate of oxygen saturation. The DO reading gradually decrease from upstream to downstream during high tide and low tide of the river. Awang et al [7] stated that the concentration of oxygen varies with the volume and velocity of water flowing in stream. The low concentration of DO at downstream of the river showed that the input organic pollutants at upstream can affect the DO concentration at downstream cause by the usage of DO by microorganism to breakdown the organic matters [1].

3.2. Biochemical Oxygen Demand (BOD)
Figure 3 shows the concentration of BOD along Sungai Perlis during high tide and low tide. The BOD concentration during high tide are 8.15 mg/L, 9.46 mg/L and 6.82 mg/L for upstream, middle stream and downstream of the river, respectively. The highest BOD value during high tide was observed at the middle of the river due to the discharge of organic materials from the commercial and residential area located at the Kangar City. The effluent discharge has increased the biodegradable process by the microorganism in the river especially at the middle of the river [1]. The BOD concentration during low tide are 8.55 mg/L, 10.4 mg/L and 11.3 mg/L, for upstream, middle stream and downstream of the river, respectively. The concentration of BOD during low tide is gradually increased from upstream to downstream of the river. The movement of water flow during the high tide to low tide has carry the organic pollutant from the upstream to downstream of the river. This was consistent with the research by Mitra et al [8] which found that the BOD concentration during low tide is more higher compared to high tide.
3.3. Chemical oxygen demand (COD)
Figure 4 shows the COD concentration during high tide and low tide. The COD concentration during low tide are 21.4 mg/L at upstream, 30.67 mg/L at middle stream and 26.67 mg/L at downstream of the river. During high tide, the COD concentration for upstream, middle stream and downstream are 17.17 mg/L, 29.0 mg/L and 21.23 mg/L, respectively. The middle stream shows the maximum value of COD during high and low tide. The effluent discharges from the restaurant, residential and commercial areas have increased the COD concentration at the middle stream during both tides. Ahmad et al [9] stated that the increasing of COD value might be caused by human activities and residential area along the river. The concentration of COD is decrease at downstream of the river but slightly higher compared to upstream because there is wet market near the downstream of the river. The wet market contributes to the pollution as the sullage discharge from the chicken slathering and other activities at the market carried more organic materials into the river [1].

3.4. Total suspended solid (TSS)
Figure 5 shows the profile of TSS along Sungai Perlis during high tide and low tide. During high tide, the TSS value are 16.67 mg/L, 30.25 mg/L and 26.6 mg/L for upstream, middle stream and...
downstream of the river, respectively. Whereas, during low tide, the TSS values were increased to 42.67 mg/L, 60.65 mg/L and 57.34 mg/L for upstream, middle stream and downstream of the river, respectively. The results showed that the highest TSS values were recorded in the middle stream for both tides due to the location of sampling point near to the town and recreational area. There also construction activities that ongoing along Sungai Perlis which has caused soil erosion into the river and thus increase the suspended solids in the river. The land erosion caused the excess amount of TSS as it will carry the soil into the river [10]. The TSS values along Sungai Perlis showed a higher value during low tide of the river compared to high tide. The river flow during the tidal event may affect the increasing and decreasing the concentration of organic and inorganic materials in the river as the volume of the river is increase and decrease during the high and low tides respectively. This result was consistent with the finding by Kamarudzaman et al [2] that found the TSS values during high tide was lower compared to the low tide. This was due to the river flow from the sea to upstream of the river during high tide and back to the sea as the tide decrease.

![Figure 5. TSS Pollutant profile of Sungai Perlis during high tide and low tide.](image)

3.5. Ammoniacal nitrogen (AN)

Figure 6 shows the AN pollutant profile of Sungai Perlis during high tide and low tide of the river. During high tide, the AN concentration are 1.27 mg/L, 2.29 mg/L and 1.14 mg/L for upstream, middle stream and downstream of the river, respectively. Whereas, during low tide, the AN concentration are 3.35 mg/L, 3.50 mg/L and 1.50 mg/L for upstream, middle stream and downstream of the river, respectively. The AN concentration were higher at the upstream and the middle stream of the river due to the agriculture activities along the river. The paddy field activities may contributes to the higher concentration of AN as the fertilizer was used for the growth of paddy. The fertilizer consists of gaseous ammonia and nitrogen which was used to increase the efficiency for plants [11]. The discharge of drainage into the river may contribute to the increase of the AN concentration especially during low tide. The higher AN concentration could be due to the presence of fertilizers and industrial effluent in the river water [10]. A high AN concentration in the river can affect the aquatic animal as the higher organic waste or nitrogen-based fertilizer in the river can cause eutrophication problems [12]. The downstream of the river showed the lowest concentration of AN for both tides. This indicated that there are minimal human activities that can lead to the increasing of AN and the river water can self-purified the AN when the water level was increased.
3.6. pH

The pollutant profile for pH are demonstrate in Figure 7. The pH value at upstream of the river during high tide fall in a neutral condition with pH 7.1 and in acidic condition during low tide with pH 6.68. The washing activities from the residential areas and restaurant that contain detergent may has increased the alkalinity of the river during the high tide of the river. The increase in pH was related to the increasing use of alkaline detergent and alkaline material from wastewater in industry.

The middle stream of the river falls under acidic condition with pH 6.7 during high tide and 6.4 during low tide. The discharge of effluent from the agriculture and commercial areas may has affect the amount of hydrogen ion in river. This result was consistent with the research by Dattamudi et al [11] which state that the uses of nitrogen based urea can increase the concentration of hydrogen ion that led to acidic condition. The downstream of the river was in slightly alkaline condition which is 7.36 during high tide and 7.18 during low tide. The downstream of the river is located near to the sea water which is slightly alkaline due to less concentration of hydrogen ion. Kaniz et al [4] stated that pH was higher in the downstream due to sea water is slightly alkaline in nature.

3.7. Water Quality Index of Sungai Perlis

Table 4 shows the WQI along Sungai Perlis during the tidal event of the river. The value of WQI during high tide is 77.08, 66.76 and 78.48 from upstream, middle stream and downstream of the river,
respectively. For upstream and downstream of the river is in Class II, whereas for middle stream is in Class III. This shows that middle stream of the river is slightly polluted compared to the upstream and downstream stream due to it was located near to the commercial, residential and recreational areas. During low tide, the WQI from upstream to downstream of the river are 72.66, 65.35 and 71.26, respectively. This shows that the upstream to downstream of Sungai Perlis is in Class III during low tide of the river. This indicated that the water flow and volume of river water can affect the water quality of the river. It is the same finding as the research by Ozaki et al [13] which state that the water quality of the river was more degraded at low tidal levels compared to the high tide. During high tide, the large volume of the river can dilute the concentration of pollutants in the river and high flow velocity of the river can increase the mixing of pollutants and reduce the gradient of pollutants concentration [14].

**Table 4.** Water Quality Index along Sungai Perlis during high tide and low tide.

| Parameter Sub-Index | High Tide | Low Tide |
|---------------------|-----------|----------|
|                     | Upstream  | Middle stream | Downstream | Upstream | Middle stream | Downstream |
| (0.22*SIDO)         | 19.71     | 15.44     | 19.63     | 21.45    | 18.60        | 19.63      |
| (0.19*SIBOD)        | 12.95     | 12.02     | 13.97     | 12.66    | 11.38        | 11.79      |
| (0.16*SICOD)        | 14.07     | 12.02     | 11.67     | 11.65    | 10.00        | 10.67      |
| (0.16*SISS)         | 14.07     | 13.20     | 13.24     | 11.55    | 10.84        | 11.05      |
| (0.15*SIAN)         | 6.26      | 4.01      | 6.70      | 3.08     | 3.02         | 6.60       |
| (0.12*SIpH)         | 11.89     | 11.81     | 11.73     | 11.80    | 11.52        | 11.55      |
| WQI                 | 77.08     | 66.76     | 78.48     | 72.66    | 65.35        | 71.26      |
| Class of the river  | Class II  | Class III | Class II  | Class III| Class III    | Class III  |

4. **Conclusion**

The study of water quality of Sungai Perlis during high tide and low tide has achieved its objectives. It was concluded that the water quality of the river can be affected by the tidal event during high tide and low tide of the river. The water quality of the river during high tide for upstream and downstream of the river are in Class II, while during low tide, it was classified in Class III. This indicated that the river was less polluted during the high tide compared to low tide of the river. The volume and flow of water can affect the water quality of the river. However, there was no changes in WQI during high tide and low tide at the middle stream of the river which is in Class III. The low concentration of DO was contributed to higher BOD and COD due to rapidly decreasing of oxygen content caused by the organic and inorganic materials in the river. Moreover, the land use along Sungai Perlis also can affect the pollution of the river. From upstream to downstream of the river, the discharge of effluents from the agricultural, residential and commercial areas are not well treated before released into the river and has contributed to the pollution of the river. The construction activities along the river also increase the erosion and cause the increasing of inorganic substance into the river. The littering habit from the residence also contributes to the pollution of the river. Therefore, an improvement for water quality index of the river should be conducted by increasing awareness of the local community about river pollution, sources and how to prevent river pollution. The local authorities also need to take action to reduce the pollution of the river. It is recommended for the local people to cooperate with local authorities in cleaning the river at least once a month to reduce the pollution of the river.
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