Water Quality Index of Perlis River, Malaysia

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Abstract— Water pollution was viewed as crucial issue nowadays and if not properly managed and improved can threat human health, aquatic life as well as the environment. Aware of the importance of water quality, this study conducted to characterize the quality of Perlis River specifically Kangar, base on the Water Quality Index (WQI) calculation method. Water samples from three sampling stations sampled from January until March 2012. The three stations marked as Kangar City (Station 1), Department of Irrigation and Drainage (DID) monitoring station (Station 2) and Kangar wet market (Station 3). WQI was calculated based on the six parameters which were dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, total suspended solid (TSS) and ammoniacal nitrogen (NH3-N). The finding from the study shows that Station 3 was the lowest in quality compared to others due to wastewater produced from nearby activity, namely wet market. It was classified from Class IV to V meanwhile Class II to IV for Station 1 and 2. Based on Department of Environment (DOE), Station 3 was identified as polluted range whereas Station 1 and Station 2 classified as slightly polluted.

Index Term— River water quality, water quality index, water quality parameters.

I. INTRODUCTION

Rivers are vital resource for life. Globally, demand for water is increasing, however, fresh water is a restricted resource. There are many factors that contribute to the difficulty of assuring the quality and quantity of water present.

Perlis, Malaysia’s smallest state, located at the north-western tip of the Malay Peninsula bounded by Thailand in the north, and by Kadah to the east and south. Its western coastline borders the Straits of Melaka. It measures approximately 810 km² and has a population of 217,480. From January to April the weather is generally warm and dry. Days are hot and windy but nights can become cold towards dawn. September to December is wet. The average annual rainfall is within the range of 2000 mL to 2500 mL and humidity is high throughout the year. Temperature varies little the year round, ranging from 21 to 32°C [1]. The river reach lies in a high altitude region with a relatively larger temperature range. Perlis River located at the north of Peninsular of Malaysia with latitude 6.40° and longitude 100.13°. Perlis River has more than 10 tributaries and size of river basin approximately 350 km². Length of river is 9.6 km through Kangar City to Kuala Perlis.

In Malaysia, the classification of rivers by the Department of Environment (DOE) is based on a water quality index (WQI) [2]. WQI relates a group of water quality determinants to common scale and combines them into a single number in accordance with a chosen method or model of computation. WQI calculation involves six basic parameters, namely dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH3-N), pH and total suspended solid (TSS) [2]. The developed WQI could be applied to measure water quality which being categorized into five categories namely, very good, good, moderate, polluted and very polluted [3]. In addition, it could be used for analyzing and comparing water quality among different reaches of rivers or between different watersheds. WQI was used as a basis for assessment of a watercourse in relation to pollution load categorization and designation of classes of beneficial uses as stipulated in the National Water Quality Standards for Malaysia (NWQS) [2].

In Malaysia, a total of 1,055 water quality monitoring stations located at 570 rivers were monitored in 2010. Out of these 1,055 monitoring stations, 527 (50%) were found to be clean, 417 (40%) slightly polluted and 111 (10%) polluted The decrease in the number of clean rivers were attributed to an increase in the number of polluting sources such as sewage treatment plants and agro-based industries which contributed to a high pollution loading [2].

The main causes of river pollution are rapid urbanization, arising from the development of residential, commercial, and industrial sites, infrastructural facilities and others. Apart from that, the destruction of rainforests and water catchments, and the subsequent erosion of soils together with the heavily silted run-offs may as well pollutes the rivers. The main factors influenced the water quality in Malaysia are sediment run-off, industrial waste, domestic waste, agricultural, livestock and heavy metal [4].

II. MATERIALS AND METHODS

A. Study Area and Sampling Points

Sampling stations are selected based on criteria of utilization of water and significant nearby activities. Three stations along a main stream were marked. The locations are central points of Perlis at Kangar City, DID monitoring station at Esplanade Pengkalan Asam and Kangar wet market and marked as Station 1, Station 2 and Station 3. The locations of these stations describe in Fig. 1 as below and land use for each sampling point is varies as summarized in Table I.
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Parameters involved are BOD, COD, NH$_3$-N, TSS and

a laboratory refrigerator at a temperature below 4°C to stop all

further analyses in laboratory. The water samples were kept in
polyethylene bottles. The water s
samples from each station were stored in one liter
sample was collected about 10 cm below water. Water

TABLE I

<table>
<thead>
<tr>
<th>Sampling station</th>
<th>Location name</th>
<th>Landuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kangar City</td>
<td>Residential area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial area</td>
</tr>
<tr>
<td>2</td>
<td>DID monitoring station</td>
<td>Residential area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recreational area</td>
</tr>
<tr>
<td>3</td>
<td>Kangar wet market</td>
<td>Residential area</td>
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<tr>
<td></td>
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<td>Wet market</td>
</tr>
</tbody>
</table>

B. Sample Collection

Water samples were collected from three stations located at
stations marked on January to March 2011. The surface water
sample was collected about 10 cm below water. Water
samples from each station were stored in one liter
polyethylene bottles. The water samples were kept in ice for
further analyses in laboratory. The water samples were kept in a
laboratory refrigerator at a temperature below 4°C to stop all the activities and metabolism of the organisms in the water [5][6].

C. Data Analysis

All six water quality parameters needed in calculating WQI will be tested in laboratory using appropriate procedures. Parameters involved are BOD, COD, NH$_3$-N, TSS and turbidity while pH and DO will measure directly at the station by using in-situ method due to process of obtaining the sample might change the measurement. Result obtained from the laboratory is compared with NWQS for Malaysia and DOE Water Quality Index Classification. All the result from the laboratory analysis records on the appropriate table. WQI calculates for each point using following WQI equation:

\[
WQI = 0.22SIODO + 0.19SIBOD + 0.16SI COD + 0.15SIAN + 0.16SISS + 0.12SlpH
\]

III. RESULTS AND DISCUSSIONS

All parameters of the samples have been successfully tested in three months starting from January until March 2012 for four times sampling for each station in order to obtain the accurate data. Theoretically, samples not suitable taken when raining, but only at least 72 hours after the rain had stopped, so that the river had returned to its usual flow conditions. Rain events contribute substantially to bacterial loading and nutrient contamination by surface runoff contributions [7]. For Station 1 and 3, sampling has done at 50 to 100m from the discharge source due to accessibility of sampling.

A. Chemical Oxygen Demand (COD) Analysis

COD test predicts oxygen requirement during the decomposition of organic matter and the oxidation of inorganic chemicals. Normally, the value of COD is higher than that of the BOD. Theoretically, if COD concentration is higher, then the water considered polluted.

Fig. 2 shows the result obtained for the concentration of COD for all three stations. COD values recorded from Station 1 to Station 3 are 26 mg/L, 18.75 mg/L and 68.5 mg/L respectively. By comparing to NWQS for Malaysia, Station 1 was classified as Class III and Station 2 as Class II whereas Station 3 was classified as Class IV. An increasing and decreasing COD concentration values for every sampling may contribute by weather condition, distance from discharge sources, accessibility, runoff factors and safety factor during sampling time.

The concentration of COD at Station 3 is higher than the other stations due to higher decomposition of organic and inorganic contaminants, dissolved or suspended in water that came from the wet market. The concentration of BOD is expected to be higher if sampling done at the exact point source.

Apart from that, the wastewater discharged from wet market also contained sullage. Hence, a pre-treatment need to propose to treat the wastewater before being discharged as to reduce the concentration of COD. Sullage quantity and quality also vary with time and day. Although the quantity and quality of sullage vary from source to source, the pollutant concentration could be high and should not be allowed to enter into the river system without any pre-treatment [8]. In Malaysia, there are guidelines to treat sewage, industrial effluents and runoff [9] but none have been established for the treatment of sullage. Consequently, sullage remains one of the main pollution sources. Sullage from wet markets would contain more pollutants, which suggest it is not suitable for any use [10]. Pollution at all three stations can be contributed by non-point source and point source. Non- point source pollution refers to diffuse contamination that does not originate from a single discrete source. Non- point source pollution is often accumulative effect of -small amounts of contaminants gathered from a large area. A varies reading is occurred for every sampling maybe contribute by accessibility and runoff factors.
B. Biochemical Oxygen Demand (BOD) Analysis

BOD is the amount of oxygen required by bacteria to stabilize organic matter under aerobic conditions. The BOD test involves the determination of oxygen uptake by bacteria under standard conditions which is five days incubation at 20 ºC. The concentration of BOD in water sample can determine the degree of pollution caused by microorganisms through biodegradation. If the BOD concentration is higher, then the water is considered polluted.

Fig. 3 shows the concentrations of BOD in river water at three stations involved for every sampling. The average values of BOD from Station 1 to Station 3 are 5.68 mg/L, 3.05 mg/L and 9.08 mg/L respectively. Concentration of BOD for station 3 is higher than the others station. BOD is also related to DO and they are inversely proportional to each other [11].

According to the parameter limits of NWQS for Malaysia, Station 1 and Station 2 were classified as Class III where an extensive treatment needed for water supply whereas Station 3 was classified as Class IV. The high concentration of BOD implies that biodegradation process caused by microorganisms was occurred in river water especially at Station 3 that generate higher sullage production whereas BOD concentration at Station 1 may contribute by nearest activities such as restaurants, residential, commercial building and others related activities. While for Station 2, the BOD value is lesser compared to others due to not many activities that can contribute to microorganism activities due to function as a Perlis River recreational park.

Prevention is an especially important strategy for controlling the pollutant. Prevention step and education program should be implemented to citizen. Business activities which contribute pollutants to the river should work with those businesses to control the release of those pollutants. Proper waste management should be applied [12].

C. Ammoniacal Nitrogen (NH$_3$-N) Analysis

NH$_3$-N indicates nutrient status, organic enrichment and health of water body. It commonly forms as organic, ammonia, nitrate, nitrite and gaseous nitrogen [13]. If higher value of NH$_3$-N recorded, then the river water considered as polluted.

The results of NH$_3$-N concentrations for Perlis River for three months were shown in Fig. 4. Result of NH$_3$-N in Station 1 and Station 2 which are 1.02 mg/L and 1 mg/L respectively. Both classified as Class III. While for Station 3 it is recorded slightly high which is 2.8 mg/L and classified as Class V. Kangar wet market recorded the highest mean values because the sullage production contained of fresh composing materials. The threshold level should be less than 5 mg/L for NH$_3$-N and wet market result have complied with threshold level if sampling done at the discharge point and done at peak hour of activity.

A high concentration of nutrients in sullage is critical issue which causes algal problems in the water bodies. Although the concentration of NH$_3$-N in the sullage is less than that in the typical sewage, if excessively high, it can degrade the aquatic status of the urban stream where the assimilative capacity of the streams is low. Discharge of untreated sullage adds oxygen demanding substances, nutrients and toxic elements such as NH$_3$-N into the water, which in turn make the streams unsuitable for aquatic flora and fauna [14]. As such, like any other pollution source, sullage should also be treated effectively before discharged into the streams.

D. Total Suspended Solid (TSS) Analysis

Suspended solid (SS) in water consist of inorganic and
organic particles. Inorganic particles such as clay, silt and other soil constituent and organic material such as plant fibers and biological solids like algae, bacteria, plankton are found in water. Higher inorganic and organic particles in river contribute higher of TSS in river as well can effect turbidity in river water. Increasing the TSS value then increased the river to pollute.

Fig. 5 shows the result obtained for the TSS concentration in river water samples. The TSS value recorded as 50.25 mg/L, 30 mg/L and 68.75 mg/L respectively from Station 1 to Station 3. According to the parameter limits of NWQS for Malaysia, Station 2 is categorized as Class II and Station 1 as Class III. Station 3 categorized as Class III which is within range 50 mg/L to 150 mg/L. The Station 3 is recorded the higher result of TSS followed by Station 1 and Station 2. This was probably caused by the wet market discharged from the market located at this site. The result of TSS loading in river water varies depended on the level of runoff on the sampling day. Increasing the runoff level which is the rainfall rate, will decrease the TSS result in river water due dilution of river water. In addition, as these particles could be organic in content, they also require oxygen demand [15].

![Average TSS reading for each station](image)

**Fig. 5.** Average TSS reading for each station

E. Dissolved Oxygen (DO) Analysis

DO is an essential parameter for the survival of all aquatic organisms. Oxygen is the most well established indicator of water quality. DO test present the amount of oxygen is available in river water. Hence, low DO, high BOD and COD rapidly decrease the oxygen content of the river making it difficult for the fish and other valuable aquatic fauna to survive. Oxygen concentrations vary with the volume and velocity of water flowing in a stream. The colder the water, the more oxygen it can hold [16].

As can be seen in Fig. 6, the average DO obtained from Station 1 to Station 3 is 2.92 mg/L, 3.38 mg/L and 1.98 mg/L. In all the four periods of sampling, Station 3 recorded a lower value of DO. The main factor contributing to changes in dissolved oxygen levels is the build-up of organic wastes in wet market discharge. This is due to the reason that the concentration of DO is affected by factors such as flow of the river, present of sources of organic pollution, temperature of the water and assimilative capacity of the river.

The low concentration of DO recorded for station 3 indicate that the input of organic pollutants upstream of the sampling station affects the DO concentration at the sampling station downstream due to the utilization of the DO by microorganism to breakdown the organic matter. The DO value of a water body directly reflects the growth situation for aquatic organisms and pollution conditions [17]. Depletions in dissolved oxygen can cause major shifts in the kinds of aquatic organisms found in water bodies and directly affect the river water quality.

According to NWQS, Station 1 and Station 3 is categorized as Class IV while Station 2 is categorized as Class III. Based on these classes of water quality, Station 3 is identifying as polluted range according to classification of river water, NWQS for Malaysia and DOE Water Quality Index Classification [2].

![Average DO reading for each station](image)

**Fig. 6.** Average DO reading for each station

F. pH Analysis

pH indicates contamination and acidification. Low pH allows toxic elements and compounds to become mobile. The lower the pH, the higher the hydrogen ion (H+) activity and the more acidic is the water [18]. The neutral pH is considered as 7.0. Theoretically, unpolluted streams normally show a near neutral or slightly alkaline pH. As can be seen in Fig. 7, the average value is recorded for pH from Station 1 to Station 3 is 7.38, 6.94 and 6.46 respectively. In general, the pH values recorded are almost at the neutral level, indicating that the wastes discharge did not affect the pH water.

pH values for all station fall within the acceptable limit of 6 to 8. pH for Station 2 is classifying into Class I whereas for Station 1 and Station 3 is classifying into Class II. The pH results for all stations are acceptable and suitable for conservation of natural environment water supply.

![Average pH reading for each station](image)

**Fig. 7.** Average pH reading for each station
G. Turbidity Analysis

The clarity of a natural water is a major determinant of the condition and productivity of that system. Turbidity in water caused by suspended matters such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds and plankton and other microscopic organism. Generally, turbidity not only affected by TSS, but also by the shape of particles, size distribution, refractive index, color and absorption spectra. However turbidity was not measured within this research and TSS was considered instead of it, since both parameters are highly correlated.

Fig. 8 shows the turbidity for three stations recorded as 65.85 NTU, 42.85 NTU and 78.25 NTU respectively. According to the parameter limits of NWQS for Malaysia, the values obtained from Station 2 is classified as Class II whereas Stations 1 and Station 3 are classified as Class III. Class III represents that an extensive treatment is required.

Turbidity is the measurement of the effect that suspended solids has on the transmission of light through the water. It was considered previously by [19] in order to develop a WQI in their study using the minimum water quality parameters. In this case, a higher turbidity maybe because of the soil erosion, river flow, presents of sources of organic pollution and run off factors. Other factors are distance sampling from discharge sources and accessibility.

H. Water Quality Index (WQI) Calculation

Based on the result finding, WQI calculation was carried out to determine the Perlis River WQI. Overall WQI for river basin is calculated by averaging WQI from all sampling stations in each river basin [2]. The calculations show that Station 1 to Station 3 of WQI as 58.30, 61.87 and 41.64 respectively. According to DOE Water Quality Index Classification [2], Station 2 is categorized as slightly polluted where it class of classification in range of 60 to 80 whereas Station 1 and Station 3 are categorized into polluted range as in range of 0 to 59. Table II shows the summary for all laboratory test, WQI class and activities related with stations involved.

IV. CONCLUSION

As a conclusion, it can be clearly concluded that it is important to understand the relationship between water quality and quantity and their effect. Water quality monitoring is importance due to threat such activities are harmful to aquatic organisms and public health. From the result finding show, the objective one there is determination of WQI parameter value for Perlis have been achieved. It found that, Station 1 to Station 3 of WQI as 58.30, 61.87 and 41.64 respectively. Basically, decreasing the WQI value, show a higher level of water pollution in river.

According to DOE Water Quality Index Classification [2], Station 2 is categorized as slightly polluted where it class of classification in range of 60 to 80 whereas Station 1 and Station 3 are categorized into polluted range as in range of 0 to 59. From the finding the second objective that refers to classify and characterize Perlis River base on WQI calculation method is achieved.

By generally comparing research data with DOE and DID data show, the result obtained basically influenced by several factors. Research data station 2 show the parallel result with the recorded data from DID. The overall WQI for three months recorded as slightly polluted which has class range

![Turbidity Analysis](image)

![WQI Calculation](image)

**Table II**

<table>
<thead>
<tr>
<th>Station</th>
<th>WQI class</th>
<th>Sources/ Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58.30</td>
<td>Residential area</td>
</tr>
<tr>
<td></td>
<td>(polluted)</td>
<td>Commercial building</td>
</tr>
<tr>
<td>2</td>
<td>61.87</td>
<td>Residential area</td>
</tr>
<tr>
<td></td>
<td>(slightly polluted)</td>
<td>Recreation park</td>
</tr>
<tr>
<td>3</td>
<td>41.64</td>
<td>Residential area</td>
</tr>
<tr>
<td></td>
<td>(polluted)</td>
<td>Wet market</td>
</tr>
</tbody>
</table>
from 60 to 80. DID data recorded of average WQI as 65.2 whereas research data obtained as 61.87. Hence, the study objective to generally compare WQI value obtained with previous data is achieved.

In order to obtain better research outcome in future, further work can be done. More sampling stations should be selected as to represent the whole Perlis. Apart from that, distances for sampling from discharge point, accessibility of sampling point and monitoring duration should be took into consideration as to determine accurate water quality index.

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REFERENCES