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Recent assessment of physico-chemical water quality in Malacca River using water quality index and statistical analysis

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Abstract. River are one of vital water resources for human and ecosystem, and it is important to monitored and controlled the river water quality. Malacca watershed is located at the centred of Malacca state, and one of the important attraction places for tourism and urbanization activity. The tremendous activity at Malacca river has led to water pollution issues and of river water quality. There are several cases of fish kills incident reported at the estuarine Malacca River. The objectives of present work are to assess water quality status of the Malacca river based on Water Quality Index (WQI) analysis and to investigate the sources of pollution at Malacca River using correlation analysis. The statistical analysis was done by using Pearson Correlation Coefficient Analysis based on water quality data collected from August 2014 until October 2014 at Malacca River. As a result, from the WQI analysis at four different times of sampling, Malacca River was classified into Class III, which is polluted river. The correlation analysis shows the strong correlation between PO_4^{3-} and TP; PO_4^{3-} and NH_3-N; TN and NH_3-N; COD and TSS; and COD and DO; at probability value, p equals to 0.01. As a conclusion, present work is crucial for water quality assessment to develop the suitable watershed management in order to sustain the river water quality. This study can be used for future study in developing water quality modelling and total maximum daily load (TMDL) approach.

Keywords: Water Quality Assessment, Pearson Correlation Coefficient, Water Quality Index, Malacca River

Abbreviation. Ammoniacal Nitrogen (NH_3-N), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Department of Environment (DOE), Dissolved Oxygen (DO), Global Positioning System (GPS), Phosphate (PO_4^{3-}), Total Nitrogen (TN), Total Maximum Daily Load (TMDL), Total Phosphorus (TP), Water Quality Index (WQI)

1. Introduction

River is a natural watercourse, usually freshwater, moving towards the ocean, lake, or another river. It is an important water source to the ecosystems, especially for human usages either for daily usage, industrial or recreational purpose [33]. Besides that, it is also a source of water, food, transportation, and power supply such as hydropower. However, river water quality has been affected by a wide range of natural and human pollution. The increasing usage of river has increased the numbers of pollution occurs in Malaysia. The higher sources of pollution that flow into the river may come from the various activities that have been carried out near to the river areas, which has disrupted the river water quality. The sources of pollution may contribute by anthropogenic sources such as sewage discharge, agricultural runoff, industrial disposal and a human waste [17]. The polluted river water also gives several impacts to human health by drinking or exposure to it [18].

The water pollution issues in Malaysia are becoming more serious. Malacca River is one of important water sources in Malacca State of Malaysia, which is one of tourist centre and attractions listed by UNESCO in July 2008 as historical and heritage place [10]. The water quality of Malacca River has been deteriorated with increasing of pollution sources. Recently, Malacca River is often associated with environmental pollution problems resulting outstanding issues such as the fish kill incident [10]. Several cases of hundreds of wild marine and freshwater fishes were reported floating and dead in Malacca River due to the low dissolved oxygen in the river [21]. Rapid development and increase of population, without the presence of a specific monitoring system and planning strategies for the preservation of the river, led to the decline in water quality. The main sources of pollution are identified from sewage, domestic waste from commercial and residential areas, waste from wet markets and industries. In addition, the sources of nonpoint pollution are from the agricultural, construction and municipal areas. Based on the water quality monitoring data conducted by the Department of Environment (DOE) on the years of 2011 to 2013, the water quality status of the Malacca River is a Class III, particularly near the river downstream of Malacca City [22]. This has encouraged the government to take efforts to restore water quality in the Malacca River. To restore water quality, the study of water quality analysis by using few methods such as Water Quality Index (WQI) and statistical analysis can be done.

This research emphasis on a study of the water quality of Malacca River which due to degradation of river water quality because of environmental factor. The objectives of present work are to study the influence of water quality parameter such as Dissolved Oxygen (DO), chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), ammoniacal nitrogen (NH_3-N), phosphate (PO_4^{3-}), Total Nitrogen (TN), and Total Phosphorus (TP) to the river health based on the DOE-WQI analysis and also its correlation between parameters using statistical analysis. In the present work, the application of statistical analysis was done by using SPSS version 20, which offers the detection of presence the change in anthropogenic activities [1]. The Pearson Correlation analysis was done to analyse the correlation between concentrations of water quality parameter at the specific sites. Taking Malacca River as the study area for this research, there are difficulties to detect the change of anthropogenic activities since there was effect from external factors such as water flow, seasonality, water temperature and precipitation that might cause an argument to the result unless the statistical analysis can eliminate all the possible environmental effect.

2. Material and methods

2.1. Study area

The study area involves Malacca watershed includes the area of Alor Gajah, Central Malacca and east of Jasin. In general, the topography of the study area consists of coastal plains and inland. The Malacca River flow from Alor Gajah at the upstream and across the Central Malacca at the downstream [10]. The study area consists of uniform climate with high moisture and heavy rain, with their main monsoon is southeast and northeast monsoons [9]. During the southwest monsoon season, the study area receives little rainfall as protected by Sumatra. Twenty sampling stations of the river were selected (M1-M20). M1-M9 are located at the downstream of the river, where M1 to M5 are used for tourism activities such as river cruise along this site. M7, M8 and M9 do not involve with the river cruise activities, but there are construction activities occur to build river bed. M10-M16 is located at the middle of the river, which a lot of activities occur near the river, while M17-M20 is located at the upstream, where the plantation activities usually are. The latitude and longitude of sampling location were recorded by using Global Positioning System (GPS) model Garmin. The latitude and longitude of sampling location are shown in Table 1.

Table 1. Description of sampling site location

Location	Latitude (N)	Longitude (E)	Explanation
M1	2°11'18.48"	102°14'37.72"	Malacca River mouth (downstream)
M2	2°11'46.04"	102°15'10.98"	Chan Koon Cheng Bridge
M3	2°12'30.30"	102°14'53.35"	Hang Tuah Bridge
M4	2°12'10.71"	102°15'60.16"	Morten Village Bridge
M5	2°12'29.26"	102°15'50.53"	Hang Jebat Bridge
M6	2°12'32.01"	102°14'49.57"	Panglima Awang Bridge
M7	2°13'22.92"	102°14'34.22"	Bridge at Jalan Nangka 2, near windmills
M8	2°13'33.00"	102^{0}15'16.90"	Housing estate at Taman Bachang Utama, on the old bridge, new bridge in construction
M9	2°13'35.94"	102°15'39.54"	Jalan Dahlia 1, near water gate
M10	2°14'38.84"	102°14'55.40"	Near Jamek Mosque, Malacca, have discharge outlet
M11	2°15'22.42"	102°14'11.56"	Jalan TTC, near a bridge, Taman Teknologi Cheng industrial area
M12	2°15'52.00"	102°14'17.74"	Jalan Jasa Merdeka 5, have discharge outlet
M13	2°17'45.95"	102°15'38.21"	Krubong industrial area, have discharge outlet
M14	2°19'07.40"	102 15'16.00"	Near Taman Belatuk Emas
M15	2°20'90.91"	102°15'23.58"	Rural area, near paddy field. Next to Taman Krubong Permai.
M16	2°20'23.40"	102°15'15.28"	Near Belimbing Dalam village
M17	2°21'04.90"	102 13'55.90"	Near Beringin village
M18	2°22'24.85"	102°13'18.21"	Palm oil estate at Melaka Pindah 2
M19	2°23'55.05"	102°14'41.17"	Near Rumah Awan Seri Pangkalan.
M20	2°23'55.50"	102°14'41.17"	At Buloh Cina village, upstream of Melaka River (upstream)

*M refer to sampling points along Malacca River.

2.2 *Samples Collection and analysis*

The locations of 20 sampling sites were selected to be sampled four times from August 2014 until November 2014, which based on monthly basis. Sampling schedule was set at alternate weeks, thus to enable the trend for wider sampling data can be observed. Furthermore, there is variation on time sampling to detect the sources of pollutant load released into the river. Each river surface water sampling was varied during morning and evening. First and third samplings were done during the morning, second and fourth sampling during the evening. An in-situ parameter such as water temperature, salinity, pH, DO and conductivity was analysing using EUTECH Instrument PCD650, which calibrated prior sampling. The one litter of surface water samples were taken using water sampler, and transfer into acid washed plastic bottles. The samples were preserved at 4°C and in the dark. The samples need to be in dark and cool temperature to ensure the biological activities are reduced and stopped to avoid loss of nutrients.

There are parameters tested in the laboratory, which is BOD, COD, TP, phosphate (PO_4^{3-}), TN, and ammoniacal nitrogen (NH_3-N). The BOD_5 analysis was done, where the initial DO analysis was taken as soon as reach to the laboratory and the water samples were kept in an incubator for 5 days. Phosphate analysis was done within 48 hours of samples collection to avoid interference of another parameter. All laboratory analysis was done within 7 days of samples collection. The laboratory analysis of ex-situ parameter was conducted accordance with the standard method [2].

2.3 Data analysis
WQI was basically used to measure the water quality level that can be categorized into five classes which are Class I, Class II, Class III, Class IV and Class V. The calculation of WQI were done for Malacca River to study the classes of water quality and level of river health. The WQI calculation was based on DOE-WQI, adopted from DOE. The DOE-WQI was calculated based on six water quality parameter which is DO, pH, BOD, COD, SS, and NH_3-N. Besides that, WQI also can be used to make a comparison between different sampling points of a river or between different watersheds. WQI can be calculated by using the formula [28] as refer in Eq. (1):

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

The water quality index was calculated using equation 1 to determine the river health by setting the benchmark of water quality for protection and management purpose [8]. In Malaysia, there is six parameters (BOD, COD, DO, pH, SS, and NH_3-N) were used to calculate the WQI and classified into different water classes. However, some other country used different water quality parameter to determine their WQI based on their intended interest such as by using DO, fecal coliform, BOD, nitrate, phosphate, water temperature, turbidity and total solid as their weighting parameter [18]. The WQI has calculated the weighted average of all interest parameter and shows the level of natural water quality has been affected by anthropogenic activities [27]. The result is present in single numerical values which become most effective tools for analysing the water quality level either by professional or public. By calculating WQI values, the classes and intended purpose of river water can be determined and classify [7, 13, 20]. WQI becomes simple tools to help the stakeholders and decisions maker in the water quality assessment [5].

2.4 Statistical analysis
The water quality data in this study were analysed based on statistical analysis method using SPSS version 20.0. Statistical tests were conducted to support and strengthen the data analysis. The Pearson Correlation Coefficient analysis was done to study the significant correlation between the water quality parameter. The significant level (p-value) used in this study were 0.01 % and 0.05 %. While the statistical analysis was one of the crucial element in water quality determination by providing the important data sets for planners and decision makers in determining the task for management strategies for river health [14]. Meanwhile, the multivariate statistical analysis is another degree of interpretation of complex data set for better understanding the water quality and impact of anthropogenic sources, which widely used by other researcher [1, 3, 4, 6, 23, 30, 32].

3. Results and discussion
3.1 Water quality analysis
Water quality analysis of physico-chemical analysis including DO, BOD, PO_4^{-3}, TP, NH_3-N, TN and COD. The result trend of water quality parameter along the Malacca River according the different samplings stations (M1-M20) is showed in Figure 1. DO is among the most important water quality parameter in determining the water quality status of the river. According to DOE water quality standard, the good water quality condition of river should be higher than 7 mg/L. However, the sufficient value of DO for water aquatic life is 5 mg/L, while less than 3mg/L, the aquatic life is suffered. The highest average value of DO was recorded at M13 (8.04 mg/L) and the lowest value of DO was recorded at M10 (2.59 mg/L). The lower DO value at M10 may due to the contribution of anthropogenic sources, from the shop lot discharge into the river. Uqab et al., (2017) reported lower value of DO indicates the process of bioaccumulation, and bacterial decomposition of organic matter activity, while the higher DO value shows the good aeration condition at the location.

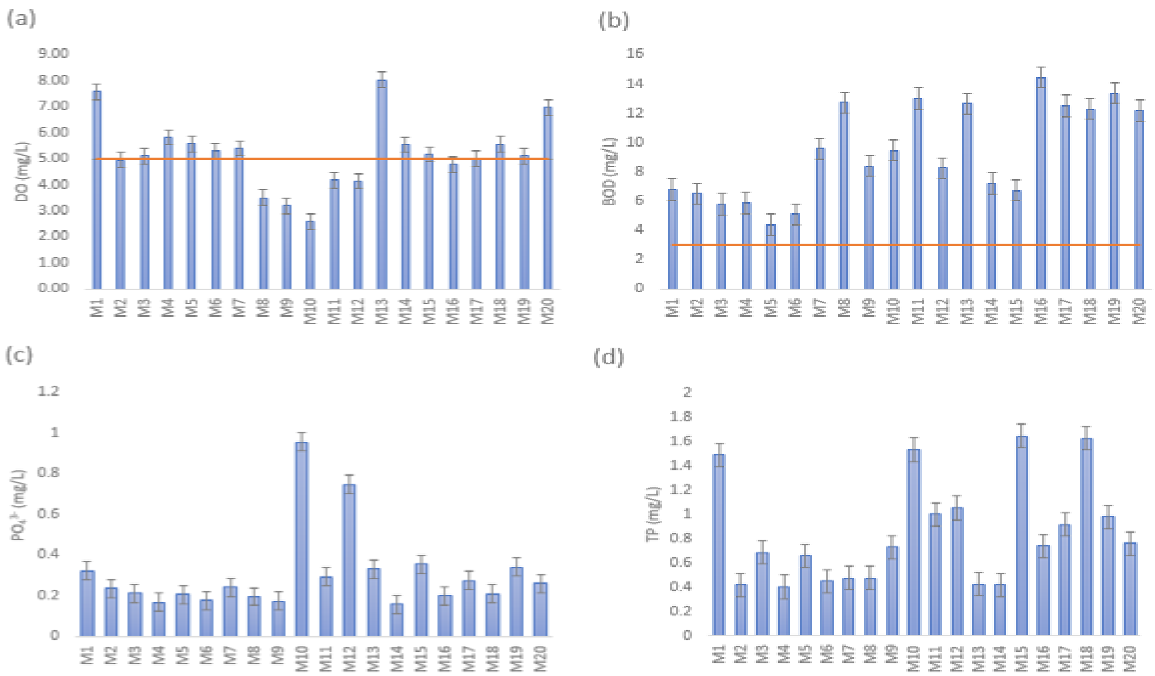
BOD is a measure of the amount of oxygen used by aerobic microbes in water to perform the degradable of organic material process [29. The BOD value of Malacca River is higher than the acceptable range for Class II (1-3 mg/L) according to the DOE water quality standard. The BOD is range from 4.40 mg/L to 14.45 mg/L, with the highest value recorded at M16. The sources of pollution at M16 may come from the decomposition of organic matter from agricultural runoff, since there are agricultural activities occurs at M16.

COD determine the amount of total oxygen used by organic and inorganic matter to oxidized by strong chemical oxidizing agent in an acidic medium. The spatial variation of COD among the sampling location indicate the COD range from 10.16 mg/L at M14 to 365.54 mg/L at M1. The range of COD value is widely separate between the sampling locations. The value of COD at five sampling locations are less than 25.00 mg/L which is at M9 (22.30 mg/L), M11 (24.34 mg/L), M14 (10.16 mg/L), M17 (12.10 mg/L), and M20 (15.28 mg/L). To achieve Class II water quality standard, the value of COD must below than 25.00 mg/L. Higher level of COD has been recorded at downstream of Malacca river, shows the intrusion of anthropogenic sources into the water bodies. The downstream area of Malacca River is found as highly polluted area from the previous study [22] with many residential and commercial activities occurs there [11].

NH_3-N is part of inorganic nitrogen and able to be absorbed by plant. It is range from 0.14 mg/L to12.87 mg/L, where the highest value at M5, and the lowest value at M13. The sources pollution of NH_3-N coming from wastewater and organic matter decomposition [24]. M5 located at downstream area with high industrial and tourism activities occurs.

PO_4^{3-} is a form of phosphorus and absorbable by plants. It occurs very less than any other element, with natural concentration in surface water is 0.005-0.02 mg/L. In Figure 1, the value of PO_4^{3-} higher at M10 and M12 (0.96 mg/L), while the lowest value at M14 (0.16mg/L). The variation of NH_3-N and PO_4^{-3} may significant to the impact of raining and sunny day [24]. This has also been found by Samsudin et al. (2017), the nitrogenous fertilizer from the agricultural runoff can increase the concentration of NH_3-N and PO_4^{3-}. Besides that, the anthropogenic sources from industrial and domestic waste are also contribute to the NH_3-N and PO_4^{3-} pollution.

The average value of TN along the Malacca River ranges from 0.15 mg/L to 0.66 mg/L. The highest concentration of TN recorded at M15, while the lowest concentration of TN found at M13. The figure shows the variation of TN, where the downstream show the lower value of TN excepts at M1, compare to the upstream shows the higher value of TN. The variation of sampling time plays significant roles in determine the level of TN concentration. The value of TN varied during the raining and sunny day, which the runoff from agricultural activities might affect the amount of TN enters the river. The TP value ranges from 0.40 mg/L to 1.65 mg/L according to the sampling location. The higher value of TP found at M15 and the lowest value of TP has been observed at M4. The value of TP was widely separate and range among the sampling location based on the pollution sources enter the water bodies near the sampling location.



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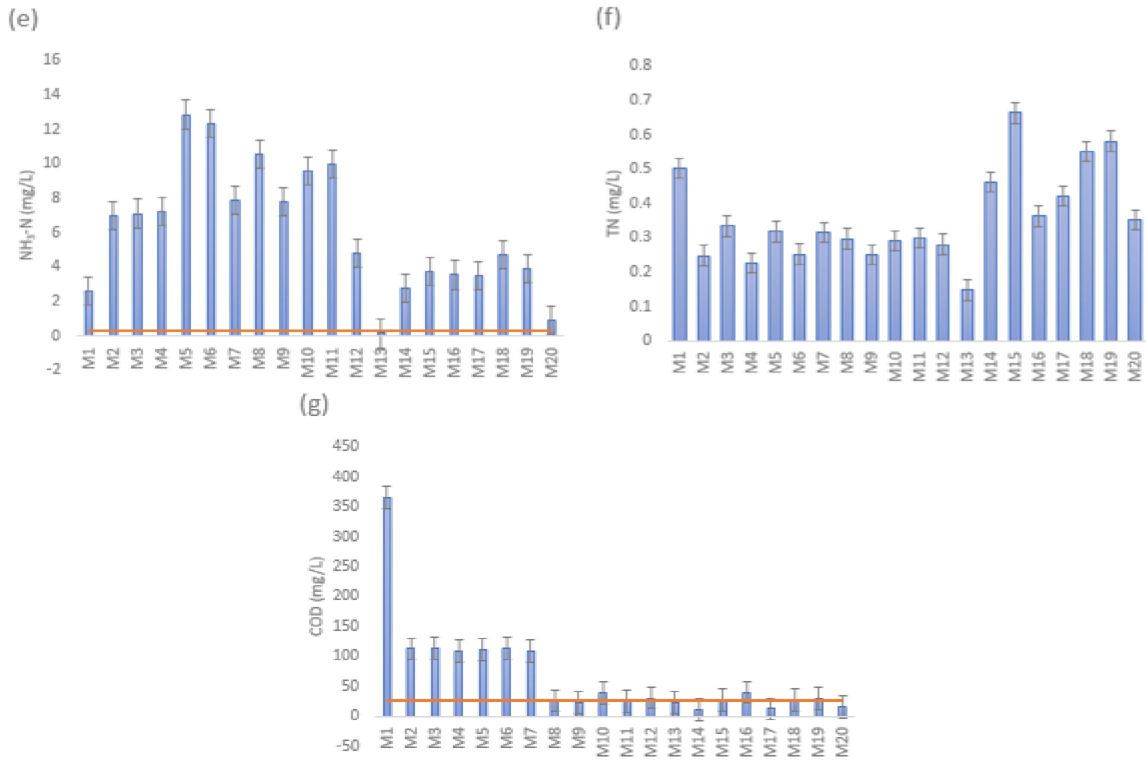

Figure 1. Trend concentration of (a) DO, (b) BOD, (c) PO_4^{3-}, (d) TP, (e) NH_3-N, (f) TN and (g) COD parameter at different samplings location (M1-M20) along the Malacca River

3.2 Water Quality Index (WQI)

The WQI for Malacca River were calculated based on DOE-WQI classification. Figure 2 shows the average WQI value for Malacca River during Sampling 1 (S1), Sampling 2 (S2), Sampling 3 (S3) and Sampling 4 (S4). The water quality sampling was done from August 2014 until October 2014, which S1 in 21st August 2014, S2 on 4th September 2014, S3 on 19th September 2014, and S4 on 1st October 2014. During S1 and S2, Malacca River was classified as slightly polluted with WQI value 68 and 69, accordingly. While in S3 and S4, Malacca River are falls into polluted river categories with WQI value 59. The Malacca River was classified into Class III based on the overall result of water quality index analysis which suitable for water supply with extensive treatment needed, and fisheries activity by using common and tolerant species that benefits to economic values. It is also suitable for livestock drinking. The DOE-WQI classified the river into three categories which is polluted river (0-59), slightly polluted river (60-80), and clean river (81-100).

According to the overview of average WQI for S1 until S4, there is no significant changes of the overall water quality in Malacca River. However, there was no improvement on the WQI value from Sampling 1 until Sampling 4. The WQI of Malacca River decreasing from slightly polluted into the polluted river within the three months' time gaps of sampling. This shows it is crucial to conduct the monitoring programmed along the Malacca River, to ensure the water quality over polluted. There are few factors that affected the water quality of the river such as the activities occurs at the location of samplings, which contributes to the anthropogenic sources, time of sampling which cause to the variation of environmental condition of the rivers, and the flow rate of the river water which give significant impact to the water velocities [3]. The activities occur on the sites also the introduction of anthropogenic sources to the water body [16].

Malacca River basically can be divided into three main part which is downstream, middle stream and upstream of the river and differentiates based on activities occurs at there. According to study done by Hua, 2017 and Rosli et al., 2015, the downstream area is categorised as highly polluted sites (HPS), the middle stream falls into moderately polluted sites (MPS) and upstream are describe as low polluted sites (LPS). The downstream of Malacca River were used for tourism attraction by having river cruise activities and sightseeing of the river, which contribute to high input of point sources pollution into the river. However, to be used for recreational activities involves the contact with the body, the downstream of Malacca River need to achieve class IIB. Hence, in this situation the monitoring process is quite challenging to control the water quality in downstream area. However, in the middle stream and upstream of the river which are near to the village and housing area, and agriculture activities there is high contribution of pollutants from point and nonpoint sources into the river. By having a high number of activities, the health of human may have defected.

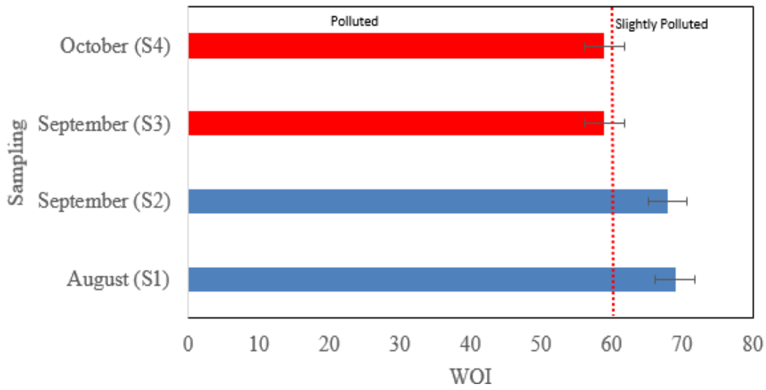

Figure 2. Trend of WQI during sampling 1 to 4 (S1-S4) at Malacca River within the time variation from August to October in 2014

3.3 Pearson Correlation Coefficient Analysis

Pearson correlation coefficient analysis was done to determine the correlation among physicochemical parameter which help to identify the sources of pollution that enter the water bodies. The data shows the physicochemical parameter properties that either correlated positively or negatively significant. The positive correlation indicates the similar sources of origin and similar contamination trend, while negative correlation indicates opposite nature of sources. The strong significant correlation occurs at p value 0.01 and 0.05.

According to the correlation matrix that has been calculated by using SPPS software, based on four samplings carried out, there was a significant correlation between each parameter. During S1and S2, there was a strong positive significant correlation between PO_4^{3-} and TP, with r value 0.703 and 0.940, respectively. The same situation also predicted in the study of water quality monitoring done by Kim et al. (2009). In S1, there is a strong significant correlation between PO_4^{3-} and NH_3-N (r value: 0.641), and TSS and TN (r value: 0.621). The COD parameter shows the negative correlation between pH (r value: -0.208), TP (r value: -0.27), TSS (r value: -0.31), and NH_3-N (r value: -0.121). The negative correlation shows that the value of one parameter decrease and another value of parameter are increase. There was strong positive significant correlation relationship between TP and PO_4^{3-} (r value: 0.940), TN and NH_3-N (r value: 0.697), and COD and TSS (r value: 0.740) occurs during S2. Negative relationship between pH and PO_4^{3-} (r value: -0.451), pH and TP (r value: -0.530), DO and TP (r value: -0.508) and COD and BOD (r value: -0.545). The negative relationship between COD and BOD indicates the properties of BOD as the extent of biodegradable organic matters and needed of oxygen for this process [12], while COD has its own properties which are indicator of organic wastes [19].

The strong significant correlations also appear between COD and DO (r value: 0.699), TSS and DO (r value: 0.657), COD and TP (r value: 0.606), TP and TN (r value: 0.696), TP and TSS (r value: 0.622), and COD and TSS (r value: 0.975) during S3. However, only three strong significant correlation occurs during S4, which is between DO and BOD (r value: 0.886), TP and TN (r value: 0.827), and COD and TSS (r value: 0.608). The strong significant correlation occurs with the p-value is 0.01, where the linearly significant correlation between two variables, and H_0 hypothesis (There no correlation occurs between two variables) are rejected. The smaller the p values the better. The r value indicates the strength and direction (+/-) relationship of the correlation, and the bigger the value is better. Based on the correlation analysis done for S1, S2, S3 and S4, there is variation occurs between the relationship among types of variables. The variation of different two variables may occur because of flow water because of rainfall [3]. There are high numbers of correlation occurs during S1 and S2, compared to numbers of correlation occurs during S3 and S4, where there is heavy raining especially during Sampling 4, while no rainfall events happen during S1 and S2. The correlation becomes weaker during raining season compared to dry season [15]. The high flow due to rainfall events can be shown in the relationship between TSS and COD, TSS and DO, and DO and COD.

Besides that, the correlation between COD and nutrients, such as TP and TN, indicates the presence of the high load of organic pollution from the industrial and domestic wastewater [12], where it gives the significant concentration of COD to be increased. COD is one of the indicator in determining the contamination with organic waste [19]. Furthermore, the occurrence of relationship TN, TP, PO_4^{3-} and NH_3-N with DO, indicates the high nutrient content in the river, increase the level of DO, cause by the photosynthesis process to occur [12]. The correlation between TP and PO_4^{3-}, and NH_3-N and TN describe the cycles of nitrogen and phosphorus.

The correlation between PO_4^{3-} and TSS related to the properties of non-soluble and adsorptive phosphorus where it behaves with soil particles [15]. It is proved with increasing the amount of TSS, concentration of PO_4^{3-} linearly increased. A study done by Kim et al. (2009), shows that TSS and PO_4^{3-} belong to the same group in cluster analysis. Furthermore, the correlation between TN and TSS shows the relationship between TSS as the carrier of nitrogenous pollutants [33], as the value of TSS higher, the concentration of TN increase. The correlation occurs between the water quality parameter shows the relationship of the sources of pollutant. The relationship between NH_3-N and DO are associated with extensive pesticide usage for agricultural activities such as oil palm and rubber plantations, and animal husbandry carried out within the Malacca River basin. The correlation between pH, DO, COD, and BOD are explained based on the various sources from the anthropogenic activities such as industrial effluents, domestic waste water, commercial activities and wastewater treatment plants at the middle stream and downstream of Malacca River. The relationship between BOD and COD are related to source of the pollutant which possibly from sewage treatment plants and industrial effluents. The high pollution from the anthropogenic sources has given significant impact to human and aquatic life. This has proven with fish kill incident occurs along the Malacca River. High contribution of chemical pollutant into the river also affect the human health if they contact or consume with the water from river.

4. Conclusion

This study has demonstrated the water quality status of Malacca River by using two approaches which are WQI and statistical analysis. By using these two tools, the water quality status of Malacca River was obtained and the impact of man-made pollution to the river pollution was analysed. By using effective tools for analysis, the significant result can be provided for future study. The study has proved the usefulness of statistical analysis to study the correlation and similarities between two parameters. With the further long-term observation, the improvement of water quality will be achieved and realize. The sufficient information will help the government, private agencies and scientist to build suitable watershed management program for Malacca River. The further action can be taken to improve the water quality of the river such as the development of Total Maximum Daily Load (TMDL) program and watershed management.

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