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CASE STUDY: ANALYSIS OF WATER QUALITY IN SUNGAI BATU FERRINGHI

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Abstract

A patch of black water as the size of a football field has been spotted at Ferringhi beach. The black water stretching for about 100m from the Sungai Batu Ferringhi, is believed to be the source of the pollution. The aim of this study is to investigate the current water quality index of Sungai Batu Ferringhi and classify it in accordance to the Water Quality Index (WQI) Malaysia. WQI is a very useful tool to determine the water quality of the surface water by mean of water quality assessment from the determination of physico-chemical parameters. The chemical parameters tested include Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Dissolved Oxygen (DO) and Ammoniacal Nitrogen (NH_3-N), while physical parameters include pH, temperature and suspended solid (SS). An external biological parameter, Escherichia Coli (E-coli) has been tested to investigate the current concentration of bacteria from Sungai Batu Ferringhi. The concentration of E.coli has been reduced from 16,000 cfu/100ml to 900 cfu/100ml. Measuring procedures of all physic-chemical parameters are in accordance to American Public Health Association (APHA) and United States Environmental Protection Agency (USEPA) standards. Calculation of WQI is based on DOE-WQI using six parameters (pH, DO, SS, BOD, COD and NH_3-N). The calculated values of WQI at three location A and B are 84.12 and 85.00 classified as Class I considered clean, while WQI for location C is 79.73 classified as Class II considered slightly polluted based on DOE Water Quality Index Classification. The overall WQI obtained was 82.95 and Sungai Batu Ferringhi was classified as Class II.

Keywords: Water Quality Index (WQI), Sungai Batu Ferringhi, Surface Water Analysis, Physico-Chemical Parameters, Biological Oxygen Demand (BOD).

1. Introduction

The access to clean water is a basic essential requirement or needs of human life. More than 70 percent of the Earth's surface is covered by water, 97.5 percent out of 70 percent is saltwater, leaving only 2.5 percent as fresh water [1]. The remaining is saline and ocean-based. This means that the competition for a clean, copious supply of water for drinking, cooking, bathing, and sustaining life intensifies increasing dramatically every year. In Malaysia, the most tapped raw water sources are rivers [2]. There are total 180 rivers whereby 150 of them are the major river systems while 97 percent of Malaysia's water supply comes from those rivers and streams [3].

According to the Department of Environmental, in the Environment Quality Report 2009 showed that 46 percent out of the total rivers in Malaysia are polluted when compared to the previous years [4]. The accessibility to clean water will be more challenging if pollution continues to occur. Fresh water is not only vital for protecting public health, it also plays some important roles especially in providing ecosystem habitats. Therefore, it is important to determine the water quality for the classification of the current river. It is important to have a good water quality for a healthy river.

The water quality is judged or classified based on evaluating the water quality index (WQI). Water quality index serves as a mean indication of water quality assessment through the determination of physico-chemical parameters of surface water. Furthermore, WQI can be used as an indicator of water pollution by providing feedback on the quality of water to the policy makers and environmentalist. Water quality index is important to be measured in order to determine health of the river before consuming or safe to use in other purposes. In order to develop these water quality indexes, several parameters have to be considered. The parameters are physical, chemical, biological and radioactive. Each of the parameters has significant impact on the water quality [5]. The physical parameters include temperature, pH, turbidity, total dissolved solids and total suspended solids. In terms of chemical, the parameters involve Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrates and total phosphate. Fecal coliform such as Escherichia Coli (E-coli) and groups of microorganism are classified under biological parameters. Measurements of these indicators can be used to indicate and determine the classification of the river by comparing with the national water quality standards of Malaysia from Water Environment Partnership in Asia (WEPA) and Interim National Water Quality Standards for Malaysia (INWQS). When these conditions are not met, species population in the water becomes stress and eventually dies. Therefore, a good water quality is important for maintaining a healthy river and ecosystem.

Although a massive cleanup was carried out by the Department of Environmental on February 2014, this research focused on analysis of the latest characteristics of water quality at Sungai Batu Ferringhi by scoping at determining the current Water Quality Index (WQI) and concentration of E. Coli. It is aimed first to investigate the current water quality indexes through several biological and physio-chemical parameters and secondly to classify the Sungai Batu Ferringhi in accordance to the Water Quality Index (WQI) Malaysia.

2.1. Study area

According to New Straits Times, February 2014, a patch of black water the size of a football field has been spotted at Ferringhi beach [6]. The black water stretching for about 100m from the Sungai Batu Ferringhi is believed to be the source of the pollution. A loosen control valve from a nearby sewage treatment plant is the cause of the black effluence that being released to the river then flow out to the sea. The possibility of black effluence is the bacteria called Escherichia Coli (E-coli) [6]. Both faecal coliform and E.coli reading's in the river were at a staggering 16,000 cfu per 100ml [6].

2. Research Methodology

2.1. Overall methodology process flowchart

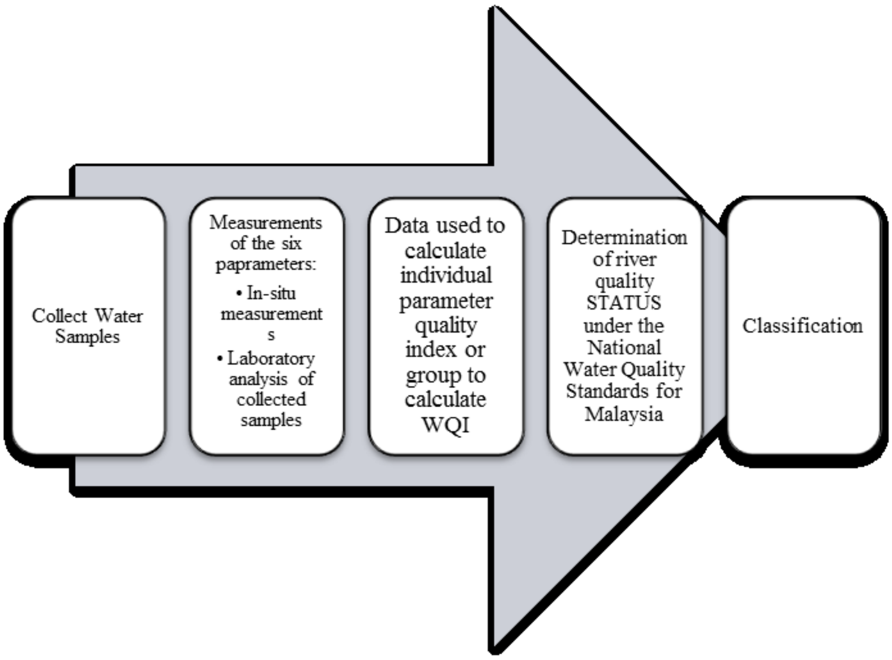


Fig. 1. Procedure for calculating Water Quality Index (WQI) [7].

2.2. Sampling surface waters

The sample is taken 10 cm below the surface away from the edge using telescopic sampling system or polyethylene dipper (TW-06282-90) at predetermined locations. The samples were collected from three different predetermined locations including upstream (location A), mid-stream (location B) and downstream (location C) of Sungai Batu Ferringhi. All the sample containers were labeled before site collection. The samples were collected by directly filling the container from the surface body and by decanting the water from a collection device [8]. During transferring the samples using a collective device, the device was avoided from contacting with the sample containers. Preservations have been done on the site immediately at the time of sample collection. Collected samples were placed into the icebox with temperature approximately 4°C during transportation to lower or retard the metabolism of the organism on the sample. All the samples were stored in the refrigerator at the temperature less than 6°C with covered layer to maintain dark condition. The overall laboratory analysis was completed within 14 days from the date of sample collection.

Fig. 2. Sampling Stations include Upstream (Top Tight), Midstream (Bottom Left) and Downstream (Bottom Right).

2.3. In-situ measurements

The in-situ parameters include pH, temperature and dissolved oxygen (DO) were conducted on site. Temperature and pH were measured using portable probe meter (Microcomputer pH Meter, TI9000) by WalkLAB that provided by the university laboratory. For DO, a portable Dissolved Oxygen Tester (Extech DO600) was used at the site.

2.4. Ex-situ measurements

All the sample preparation and preservations conducted were following on the standard procedures provided by American Public Health Association (APHA) and United States Environmental Protection Agency (USEPA) Methods.

Table 1. Standard Methods Used in Chemical Analysis for Liquid Samples [8].

Parameters	Analytical Methods
Biological Oxygen Demand	APHA 5210B: 5-Day BOD Test
Chemical Oxygen Demand (COD)	APHA 5220C: Closed Reflux, Titrimetric Method
Ammonia Nitrogen (NH_3 – N)	APHA 4500 - NH_3C
Dissolved Oxygen (DO)	APHA 4500 O-C or Portable Meter
E.coli	USEPA 1603

2.5. Laboratory analysis

The laboratory analysis results were recorded and Water Quality Index (WQI) equation was applied to determine the water quality index of the samples. Refer to Eq. (1) below:

$$WQI = 0.22SIDO+0.19SIBOD+0.161SICOD+0.15SIAN+0.16SISS+0.12SIpH \quad (1)$$

where;

SIDO = Sublndex DO (% saturation)
SIBOD = Sublndex BOD
SICOD = Sublndex COD
SIAN = Sublndex NH3-N
SISS = Sublndex SS
SipH = Sublndex pH
$0 \leq WQI \leq 100$

Subindex, SI was calculated using the equation as shown on Table 2. Different parameter has different subindex with different ranges.

Table 2. Best-fit equations for the estimation of various subindex values [9].

Subindex, SI	Equation	Ranges
Dissolved Oxygen, SIDO	= 0	For $x \leq 8$ %
	=100	For $x \geq 92$ %
	$= -0.395 + 0.030\ x^2 - 0.00020\ x^3$	For 8 % < x < 92%
Biochemical Oxygen Demand, SIBOD	$= 100.4 - 4.23\ x$	For $x \leq 5$
	$= 108e^{-0.055x} - 0.1$	For x> 5
Chemical Oxygen Demand, SICOD	$= -1.33x + 99.1$	For $x \leq 20$
	$= 103e^{-0.0157x} - 0.04x$	For x > 20
Ammoniacal Nitrogen, SIAN	$= 100.5 - 105x$	For $x \leq 0.3$
	$= 94e^{-0.537x} - 5\ abs(x -2)$	For 0.3 < x < 4
Suspended Solids, SISS	$= 97.5e^{-0.00676x} = 0.05x$	For $x \leq 100$
	$=71e^{-0.0016x} - 0.015x$	For 100 < x < 1000
	= 0	For $x \geq 1000$
pH, SIPH	$= 17.2 - 17.2x + 5.02x^2$	For x <5.5
	$= -242 + 95.5x - 6.67\ x^2$	For $5.5 \leq x < 7$
	$= -181 + 82.4x - 6.05\ x^2$	For $7 \leq x \leq 8.75$
	$= 536 - 77.0x + 2.76\ x^2$	For $x \geq 8.75$

The x in Table 2 represents the concentration of each parameter in mg/L except for pH. After each subindex for each parameter has been calculated, the values will be substituted into Equation 1 to calculate Water Quality Index, WQI. The classification of river will be conducted once the value of WQI is confirmed. The classification of river water is based on Table 3 below.

2.5.1. Total suspended solids

APHA 2540D: Total suspended solids dried at 103-105°C is the analysis standard for determining the total suspended solids in water. In this final year project, the analytical procedures from the APHA Standards were followed but not the equipment set-up. For the experiment set-up, the operating principle remained unchanged but a different type of apparatus was used.

Table 3. Classification of Water Quality Index [9].

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Biological Oxygen Demand	mg/l	< 1	1 - 3	3 - 6	6 - 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 - 25	25 - 50	50 - 100	> 100
Dissolved Oxygen	mg/l	> 7	5 - 7	3 - 5	1 - 3	< 1
pH	-	> 7	6 - 7	5 - 6	< 5	> 5
Total Suspended Solid	mg/l	< 25	25 – 50	50 - 150	150 - 300	> 300
Water Quality Index (WQI)	-	< 92.7	76.5–92.7	51.9–76.5	31.0–51.9	> 31.0

3. Results and Discussion

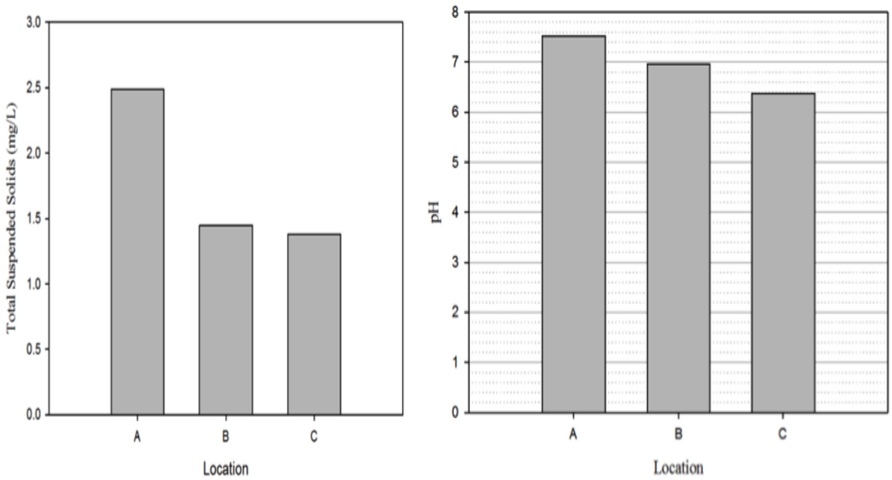
3.1. Physical parameters

3.1.1. Total suspended solids

Total Suspended Solids (TSS) represents the amount of the particles presence in the water. It consists of inorganic and organic particles. High concentration of TSS is one of the many reasons why the water quality deterioration leads to aesthetic issue [10]. The increase of TSS not only increase the cost of water treatment, it is also caused some impacts of ecological degradation on aquatic environments. The water sample from Sungai Batu Ferringhi only contains organic particles based on the assumption that no other industrial (Heavy or Light) area is built along the river. There is an existence of a small-scale Tilapia fish farm being built at the side of location A. The concentration of TSS is the highest at location A (Up-Stream) of the river with the mean value of 2.49 mg/L. The high mean value of TSS found at location A is believed to result from the discharge of waste water from the fish warm, thus the water of the feedstock is being changed. All the water that contains organic matters is directly discharged into the river. Despite the concentration is at the highest on Location A, the concentration decreases along the river. Location B has the mean value of 1.47 mg/L while location C has the lowest mean value of 1.38 mg/L. The concentration trend of TSS is decreased from 2.49 to 1.38 mg/L which indicate that the organic matter is being consumed along the river by the microorganism. Regarding the TSS level, location A, B and C are classified as Class I under the Department of Environmental Water Quality Index Classifications since the concentration of TSS is less than 25 mg/L.

3.1.2. pH

Location A has the value of 7.52, B with the value of 6.97 and lastly location C with the value of 6.38. The pH value started to decline from 7.52 to 6.38 as it reaches location C. Location A is more approachable to alkaline region while B and C are started to approach to acidic region. In other words, the pH from A to C is declined from alkaline region to acidic region. This indicates that activity of hydrogen ion started to increase right after the water flow out from location A. Despite the activity of hydrogen ion increases, the status of location A and B are close to neutral while the pH value at location C is considered slightly acidic. In general, the pH values recorded at Location A, B and C are almost at neutral level. Based on the DOE Water Quality Index Classification, location A is classified as Class I whereas for locations B and C are classified under Class II. The pH values for all locations fall within the acceptable limit of 6 to 8 [11].



(a) Total suspended solids (ml/L) **(b) pH**

Fig. 3. Concentration of physical parameters from sampling locations.

3.2. Chemical parameters

3.2.1. Dissolved Oxygen

The average concentration of DO obtained from locations A to C is 8.97 mg/L, 8.15 mg/L and 8.01 mg/L as shown in Fig. 4. The concentration of DO has been depleted from 8.97 mg/l to 8.01 mg/L along the river. Location A has the highest concentration of DO since the concentrations of COD and BOD are the lowest. This confirmed the sentence saying that the concentration of DO is lower due to high concentration of COD and BOD. This is proven by referring to the concentration of DO, COD and BOD at location C. The concentration of COD and BOD at location C is the highest but lowest concentration of DO. The low concentration of DO is due to high COD and BOD concentration which rapidly consumed the oxygen content of the river during the decomposition of organic matters, suspended solids and etc. According to DOE Water Quality Index Classification (refer to table 3), DO concentrations at three locations A, B and C are greater than 7 mg/L. Hence classification of water at this river under dissolved oxygen category is under Class 1.

3.2.2. Biochemical oxygen demand

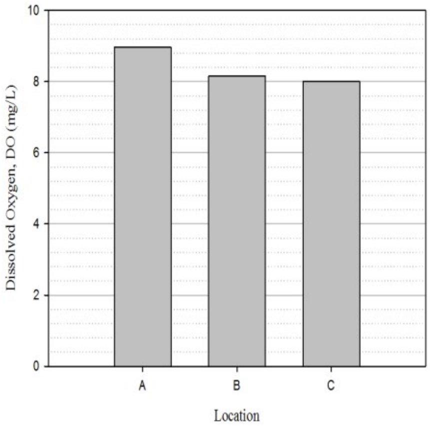
Location A has the value of 5 mg/L, location B with 8 mg/L and lastly location C with the concentration of 10 mg/L. The concentration of BOD at location A increased from 5 mg/L to 8 mg/L at B and eventually reached to 10 mg/L at location C. This increasing trend of BOD level along the river from A to B implies the higher demand of oxygen required by microorganism when consuming the organic matters contained in water flowing from location A to B. Therefore, the concentration of BOD is raised from 5 mg/L to 8 mg/L. The consumption of organic matter by microorganism continues to increase as can be seen in the rise of BOD up to 10 mg/L at the location C (downstream), where residential area, restaurants and a sewage treatment plant are surrounded or beside the downstream of the river. Thus, the waste discharged from these surrounding places are determined to be the source of pollution, i.e., some of the discharge from the residential areas or restaurants might escape and flew into the river. Hence, the oxygen demand of microorganism required to break down the organic matters at location C is the highest. As stated by the Department of Environmental (DOE) Water Quality Index Classifications Malaysia, location A is classified as Class III whereas location B and C are classifies as Class IV. According to Interim National Water Quality Standards (INWQS) for Malaysia, extensive treatment is required at location A where locations B and C can be only used for irrigation purposes according to INWQS as the concentration falls between 6 to 12 mg/L.

3.2.3. Chemical oxygen demand

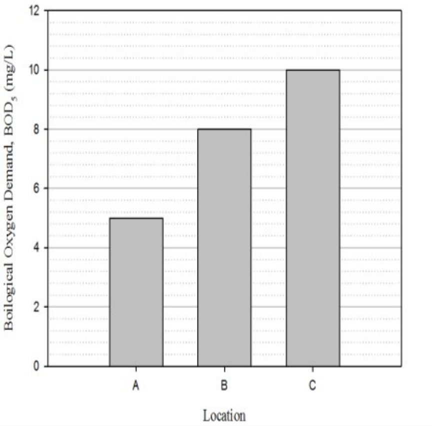
Location A has the lowest value of 32 mg/L, location B with the concentration of 48 mg/L and maximum value of 64 mg/L at location C. According to Fig. 4.3, the concentration of COD has been increased from locations A to C. For location A, 30 mg of oxygen is being consumed per litre of solution. The concentration above 25 mg/L is classified as Class III according to DOE Water Quality Index Classification [9]. Both locations A and C are classified as Class III and location D is classified as Class IV with the concentration of 64 mg/L. Location C having the higher concentration of COD value compared to others is due to high decomposition of organic matters and suspended solids that produced from the activities nearby. Extensive requirement is needed at locations A and C needed extensive treatment if the water is used as water supply according to NWQS for Malaysia while the water at location C is only for irrigation purposes and not consumable. Location C has the highest concentration of COD compared to other locations due to higher decomposition demand of organic and inorganic contaminants from the surrounding activities as mentioned in section 3.2.2.

3.2.4. Ammoniacal nitrogen

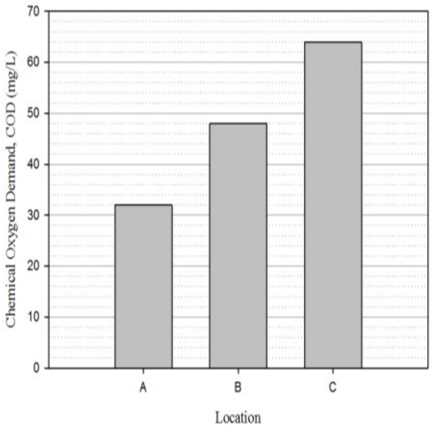
Location A has the value of 0.3 mg/L and location C with the concentration of 0.1 mg/L. For location B, the concentration for NH_3-N cannot be detected, as the value is not more than 0.1 mg/L. 0.3 mg/L of NH_3-N was detected at location A is believed to result from the fish farming activity beside the stream. The discharged wastewater from the farm which contains high concentration of excreta is from the fish and is directly being discharged into the river. Hence, high level of ammonia was detected at location A. Excreta contains organic and inorganic substances including nutrients which pose a potential threat to human health and the environment [12]. According to DOE Water Quality Index Classification, Locations A and C are classified under Class II and location B as Class I. Conventional treatment is required location A and C.



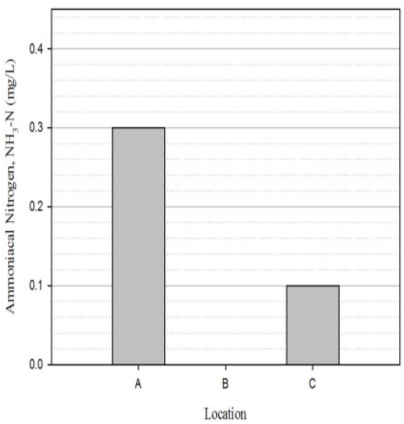
(a) Dissolved Oxygen (mg/L).



(a) Biological Oxygen demand (mg/L).



(c) Chemical Oxygen demand (mg/L).



(d) Ammoniacal Nitrogen (mg/L).

Fig. 4. Concentration of chemical parameters from sampling locations.

3.3. Biological parameter

3.3.1. Escherichia Coli

The concentrations of Escherichia Coli obtained from locations A, B and C were 800 cfu/100ml, 640 cfu/100ml and 920 cfu/100ml. 800 cfu/100ml of E.coli was found at location A. This is due to the source of pollution from the fish farm located at the side of the stream. The wastewater from the farm which contains animal fecal materials are directly being discharged to the river without any treatments. Thus, high colony-forming unit per 100 ml water of E.coli was found at location A. At location B, moderate amount of E.coli was obtained as the bacteria can remain in streambed sediments for long periods of time [13]. For location C, 920 cfu/100ml of E.coli was found and this amount is considered as high. As mentioned before, location C is surrounded by hotels, restaurants and a sewage treatment plant. This could be a possible reason causing the high concentration of E.coli at the particular area is due to human sources. Human sources include failing septic tanks, leaking sewer lines, combined sewer flows and wastewater treatment plants [13].

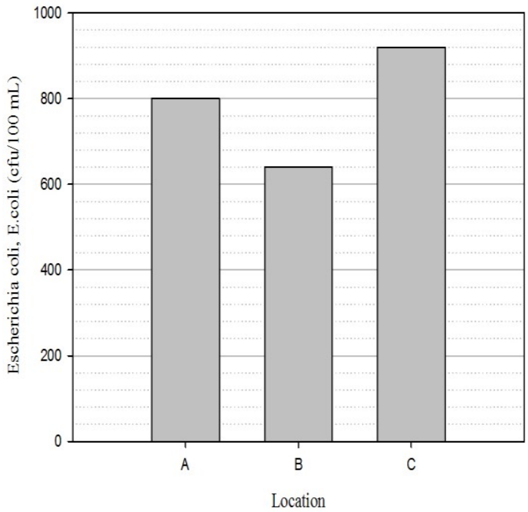


Fig. 5. Concentration of biological parameter from sampling locations.

3.4. Water quality index

Based on the WQI calculated from Table 4, all the locations are classified under Class II according to DOE Water Quality Index Classification. The calculation shows that locations A to C have the WQI of 84.12, 85 and 79.73 respectively. Location C is considered slightly polluted while locations A and B are considered to be clean. The overall WQI obtained by averaging the WQI from all the locations obtained is 82.95. The overall WQI also indicates that Sungai Batu Ferringhi is categorized as Class II. According to DOE Water Quality Index Classification, the overall WQI of Sungai Batu Ferringhi is considered clean. Although the overall WQI falls with the range of 81-100, where it is considered clean, 82.95 falls on the lower region of the clean classification. In other words, the water quality of Sungai Batu Ferringhi is close to the region of slightly pollution with the range of 60 – 80.

Table 4. Water Quality Index of Sungai Batu Ferringhi using WQI Equation.

Location	Subindex, SI						WQI
	SIDO	SIBOD	SICOD	SIAN	SISS	SIPH	
A	100	79.25	61.04	69	96.00	96.51	84.12
B	100	68.76	46.56	100.5	96.62	99.60	85.00
C	100	61.31	35.15	90	96.66	95.79	79.73
Overall WQI							**82.95**

4. Conclusion

As can be seen from the findings, the water quality at three tested locations (A, B and C) along Sungai Batu Ferringhi river is degraded and it indicates that the level of pollution increases considerably despite the fact that the overall WQI of the river is considered as clean according to DOE Water Quality Index Classification based on water quality index. The overall WQI determined is 82.95, hence Sungai Batu Ferringhi is classified as Class II. In term of biological parameter, the concentration of E.coli has been reduced from 16,000 cfu/100ml to 900 cfu/100ml. A conventional treatment for the recreational purpose (only body contact) could be a suitable solution for this river.

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