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Water Pollution and Water Quality Assessment on Sungai Batang Melaka River

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Abstract

The Gadek Water Treatment Plant in Melaka with a production capacity of 55 million liters per day (Mld) supplies treated water to consumers in the district of Alor Gajah Melaka. The raw water source for the plant is obtained from Sungai Batang Melaka. On 15th April 2016, a report was received on the pollution of the river which impacted the operation of the Gadek Water Treatment Plant. An investigation was immediately launched by the Department of Environment (JAS) with the cooperation of the Badan Kawalselia Air Melaka (BKSAM) and Syarikat Air Melaka Berhad (SAMB) and it was ascertained that water abstracted at the plant intake point was murky with a strong odour emanating from it. Preliminary surveys found that this was due to many activities carried out such as aquaculture effluent discharge by commercial catfish farm operators as well as effluent from sand mining activities that enter Sungai Batang Melaka and continue to flow into the inlet of Gadek Water Treatment Plant. In conjunction with that, this study aims to identify the economic activities that are operating along a stretch of Sungai Batang Melaka which has a direct impact on river water quality. This study will be focusing on point source and non-point source pollution, followed by a study on the river water quality parameters based on the Water Quality Index (WQI) and eventually identify the river classification of Sungai Batang Melaka. A total of twelve (12) stations were selected to obtain the water samples needed for a distance of 24 kilometres stretch of the river, while the laboratory analysis was based on HACH and APHA methods. The study shows that the raw water quality of Sungai Batang Melaka is influenced by point source and non-point source pollution, the main contributing factor being commercial fish breeding. Result obtained in this study shows the physical-chemical parameters of Sungai Batang Melaka are pH (5.97-7.68), TSS (19-426), DO (0.38-5.12), BOD (2-64.5), COD (9.2-120) and AN (0.58-17.16). Overall, the WQI for Sungai Batang Melaka was classified as a Class IV river in 2016, with an upgrade to Class III in 2017. Hopefully, the study's findings will provide the essential knowledge to ensure that this progress continues in the future.

Keywords: Physical-chemical parameter; Water Quality Index (WQI); Water Quality; Sungai Batang Melaka

1. Introduction

Pollution can occur either naturally or through man-made activities when a significant amount of unwanted foreign particles enters the drainage system resulting in the water being classified as polluted [1]. In the aquaculture industry, fish breeding has been identified as a sector that has the potential to expand on a big scale even the Malaysian government has embarked on it under the New Key Economic Area (NKEA) [2]. As one of the economy contributing activities, the volume of freshwater fish produced is expected to increase by 35.7% from 122.2 thousand metric tonnes in 2011 to 165.8 metric tonnes in 2015 [2]. These economic activities are obviously related to river water quality. According to a report by the Department of Environment, a total of 276 (58%) out of a total of 477 rivers being monitored have a clean water quality index and 168 (35%) are slightly polluted and 33 (7%) is polluted [3, 4]. Water pollution is defined as any change in water quality that has a negative impact on living organisms and those who need to use the water supply [5, 6]. Source of pollution either point source, pollution that comes out through pipes or any water outlet where the location is known or non-point source, from scattering source whose location is difficult to identify [7].

In Malaysia, the treated water supplied through the public supply system must comply with the standards set by the Ministry of Health (KKM) which is the

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National Water Quality Standard guideline. For river water, the determination of river classification is through the Interim National Water Quality Index (INWQI) and Water Quality Index (WQI) as set by the Ministry of Environment [8]. Malaysia relies primarily on surface water such as river water as the main source for the water treatment plants supplied to consumers. Consequently, the raw water quality especially the river water must also be monitored because polluted river water will result in increased costs of water treatment [9, 10]. In Malaysia, the treated water supplied through the public supply system must comply with the standards set by the Ministry of Health (KKM) which is the National Water Quality Standard guideline. For river water, the determination of river classification is through the Interim National Water Quality Index (INWQI) and Water Quality Index (WQI) as set by the Ministry of Environment [11].

In the incident of pollution on 15th April 2016 reported at Gadek WTP in Melaka total of 30,348 accounts registered with Syarikat Air, Melaka Berhad had been affected [12]. An investigation by the JAS with the help of BKSAM and SAMB indicated that this incident occurred due to numerous activities upstream such as effluent discharge from aquaculture activities involving commercial catfish farm breeding and sand mining activities which discharged directly into Sungai Batang Melaka and subsequently flowed into the intake point of Gadek WTP. Further investigation on 20th April 2016 revealed that water stored in temporary ponds at one of the fish breeding premises had overflowed resulting in the pollution of the Sungai Batang Melaka [13]. This is due to the absence of a systematic arrangement of the ponds before the water is discharged into the river. It was found that when this aquaculture effluent was discharged all the various chemical substances were simultaneously drained before flowing into the river. The polluted water will also impact aquatic and plant life inherent in the river and subsequently affects the river ecosystem itself. Being one of the major water treatment plants in Melaka, the continuous operation of the Gadek WTP which abstracts raw water from Sungai Batang Melaka is of utmost importance.

This study aims to ensure that the water treatment process is working optimally and that the treated water delivered conforms with the National Drinking Water Standard. Pollution in the Sungai Batang Melaka will have an impact not just on the river's water quality, but also on the Sungai Melaka, as it is one of the river's major tributaries. A significant level of pollution in the Sungai Batang Melaka river system will prevent the treatment plant from operating according to its standard design method. This raises concerns about the traditional treatment process's capacity to handle coloured and low-quality water in accordance with the National Drinking Water Quality standard.

2. Methodology

2.1. Sampling Area

A total of 12 sampling stations were chosen for the study in the Sungai Batang Melaka basin (Figure 1). Of these numbers, five sampling stations are point source pollution (station 1 3, 4, 6, 8 and 9) while the other seven stations are non-point sources (station 2, 5, 7, 10, 11 and 12). All sampling stations are tagged with the GPS. The selected sampling stations were determined by their hydrogeographical factors and their surrounding anthropogenic activities that may affect the river quality.

Fig. 1.Location of Sungai Batang Melaka

2.2. Location Information

The summary for 12 sampling stations is shown in Table 1 below.

Table 1
Location of sampling station

Status	Stations	Locations	Coordinates	Location Information	Surrounding Areas
Point Source	1	Gadek Intake	2°24'27.46"N 102°15'15.43"E	Streams from Kru River, Tebong River and Menggong River	Gadek Water Treatment Plant, Village Area and Gadek Town
	3	Gadek Hot Water	2°24'26.72"N 102°14'18.82"E	Flow from Tampin River	Gadek Hot Spring and Village Area
	4	Ganun Catfish	2°24'1.34"N 102°14'24.01"E	The flow leads to the Batang Melaka River	Catfish Pond and Village Area
	6	Pengkalan Series	2°22'24.91"N 102°13'17.58"E	Wastewater from the municipality into the Batang Melaka River towards the Melaka River	Municipalities such as Housing Parks, Schools and Towns
	8	Melaka Sand Move	2°22‘07.27"N 102°13‘09.66"E	Melaka River Flow	Villages and sand mining
	9	Melana Ditch Catfish	2°20‘46.15"N 102°16’33.20" E	The flow of the Catfish Pond enters the Melaka River	Catfish Pond
Non-Point Source	2	Batang Melaka River	2°24'31.86"N 102°15'9.29" E	Flow from Tampin River	Villages and Pekan Gadek
	5	Ganun River	2°23‘25.70"N 102°14‘24.60" E	The flow leads to the Batang Melaka River	Ganun Catfish and Gadek Hot Spring
	7	Pengkalan Series Bridge	2°24'26.72"N 102°14'18.82"E	Melaka River Flow	Municipalities such as Housing Parks, Schools and Towns
	10	Melana Ditch River	2°20‘46.15"N 102°16’08.05" E	The flow of the Catfish Pond enters the Melaka River	Catfish Pond and Village Area
	11	LA Park Bridge 21	2°18'49.60"N 102°16'56.22"E	The flow of the Catfish Pond enters the Melaka River	Housing parks and food courts
	12	Melaka River Intake	2°17'55.39"N 102°15'43.71" E	Melaka River Flow and Durian Tunggal Dam	Village Areas, Bunded Storage Durian Tunggal, Kolam (Local Plan Flood Alor Gajah and Central Melaka)

2.3. Study Parameters

The parameters under study involve the measurement of pH, Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Ammoniacal Nitrogen (AN). The tools and methods used in this study as shown in Table 2. The results obtained will determine the classification of the river by water quality parameters based on Table 3 as well as the use of the river as in Table 4.

Table 2: Tools and methods

Parameter	Tools	Standard Methods
Total Suspended Solids (TSS)	HACH Spectrophotometer DR 5000. Code Program: 630 Suspended Solids	Apha 2540
pH	HACH SensION+ PH1 Portable pH Meter	Apha 4500-H
Dissolved Oxygen (DO)	sensION6 Portable Dissolved Oxygen Meter	Apha 4500-O
Biological Oxygen Demand (BOD)	Standard Methods for the Examination of Water and Wastewater	Apha 5210b
Chemical Oxygen Demand (COD)	HACH Spectrophotometer DR 5000. Code Program: 430 COD LR	Apha 5220d
Ammoniacal Nitrogen (AN)	HACH Spectrophotometer DR 5000. Code Program: 380, N,Ammonia, Ness	Apha 4500b &c

Table 3: River classification based on water quality parameters [14]

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen (AN)	mg/l	<0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
Biological Oxygen Demand (BOD)	mg/l	<1	1-3	3-6	6-12	>12
Chemical Oxygen Demand (COD)	mg/l	<10	10-25	25-50	50-100	>100
Dissolved Oxygen (DO)	mg/l	>7	5-7	3-5	1-3	<1
pH	-	>7.0	6.0-7.0	5.0-6.0	<5.0	<5.0
Total Suspended Solids (TSS)	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	<3.1

Table 4: Classification of water classes and their uses [15]

Class	Uses
I	Conservation of natural environment
	Water Supply- Practically no treatment necessary
	Fishery- Very sensitive aquatic species
II A	Water Supply- Conventional treatment required
	Fishery- Sensitive aquatic species
II B	Recreational use with body contact
III	Water Supply- Extensive treatment required
	Fishery- Common, of economic value and tolerant species; livestock drinking
IV	Irrigation
V	None of the above

2.4. Classification Based on Water Quality Index

Classification based on the Water Quality Index is done to find out the pollution status of the river and the level of pollution. All experimental results for BOD, DO, COD, pH, AN and total suspended solids were evaluated using the WQI method based on the formula below [16]:

where;
SIDO = Subindex DO (% *saturation*)
SIBOD = Subindex BOD
SICOD = Subindex COD
SIAN = Subindex NH3-N
SISS = Subindex SS
SIpH = Subindex pH
$0 \leq WQI \leq 100$

Table 5: Best Fit Equations for the estimation of Various Subindex Value

Parameter	Value	Subindex Equation (SI)
COD	For X = < 20 For X > 20	SICOD = 99.1 – 1.33X SICOD = 103* [16]
BOD	For X = < 5 For X > 5	SIBOD = 100.4 – 4.32X SICOD = 108* [16]
AN	For X = < 0.3 For 0.3 < X < 4 For X = > 4	SIAN = 100.4 – 4.32X - SIAN = 94* (E)-0.573x-5(x-2) SISS = 0
SS	For X = < 100 For 100 < X < 1000 For X = > 1000	SISS = 97.5*[16]-0.00676x+ 0.1X SISS = 71*[16]-0.0016x+ 0.015X SISS = 0
pH	For X < 5.5 For 5.5 = < X < 7 For 7 = < X < 8.75 For X = > 8.75	SIpH = 17.2 – 17.2X + 5.02X^2 SIpH = -242 + 95.5X – 6.67X^2 SIpH = -181 + 82.4X – 6.05X^2 SIpH = 536 – 77X + 2.76X2
DO	For X = DO (mg\L) * 12.6577 For X = < 8 For 8 > X	SIDO = 0 SIDO=0.395+0.030$X^2$0.000198X^3

Note: X has multiplied the concentration of the parameter in mg/L except in pH and DO. * means multiply with.

Based on a calculation using the WQI formula referring to Table 5, best-fit equations for each subindex value, rating of water quality is determined according to Table 6.

Table 6: Rating of Water Quality According to WQI

Class	WQI Value	Rating of Water Quality
I	90 – 100	Excellent water quality
II	75 – 90	Good water quality
III	45 – 75	Medium water quality
IV	20 – 45	Poor water quality
V	0 - 20	Very poor water quality

3. Results and Discussion

3.1. Physical-Chemical Parameters

3.1.1 pH

The analysis of water samples obtained from rivers shows that the pH of raw waterfalls is within the set standards. Figure 2 shows the pH profile result. The lowest pH reading is recorded at Station 1 which is the location of the Gadek WTP intake with a reading of 5.97. For the location where catfish breeding is carried out which is station 9 at Parit Melana, the pH reading was recorded as 7.68. The high pH value at this point also shows an increase in the concentration of ammonia at this location, in line with the problem statement discussed in the first chapter of this study. Meanwhile, the pH profile for the point source shows the lowest pH reading was recorded at station 2 located at Sungai Batang Melaka with a reading of 6.12 while the highest reading was recorded at station 5 which is the site of catfish breeding at Ganun with a pH reading of 7.48. Altowayti, Algaifi, Bakar and Shahir [17] and Haris, Altowayti, Ibrahim and Shahir [18] state that there was a negative correlation between the activity of heavy metals in the water and pH. These results indicate that pH may be an important factor in water quality assessments [19].

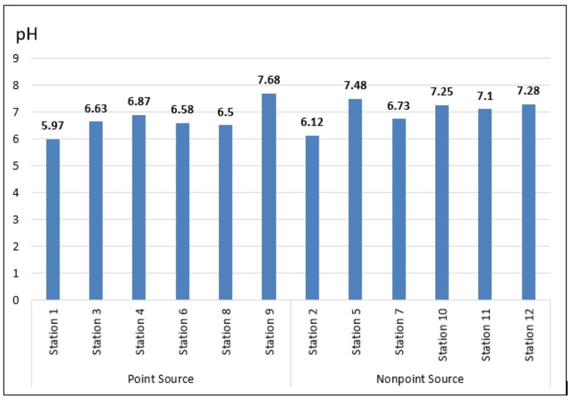

Fig. 2. pH profile

3.1.2 *Total Suspended Solid (TSS)*

Suspended solids have a big impact on the water treatment process. The suspended solids will cause the water to become murky rendering the water to be unsuitable as drinking water. Water containing a high suspended solid content is difficult to treat to produce clean water. In fact, the cost of treatment will increase due to the higher volume of chemicals involved. The suspended solid content will be higher if samples are taken after it rains as the river will be murky. Figure 3 shows the parameter value of suspended solid in this research.

Iloms, Ololade, Ogola and Selvarajan [20] state that municipal and industrial wastewater effluents are point source pollution. For point source location, under Class V, station 9 and station 3 show the highest value of 426 mg/l and 356 mg/l respectively. This is closely related to the activities being carried out at both stations in which effluent from catfish breeding at Parit Melana is released at station 9 and effluent from a chicken coop cleaning is discharged at station 3. Two (2) stations that are closely allied to urban and rural activities fall under river classification Class IV which is station 1 and station 6 with readings of 163 mg/l and 188 mg/l respectively. Station 8 is under Class III with a reading of 60 mg/l and the last station 4 is under Class II with a TSS value of 46 mg/l.

While for the parameter values of suspended solids for non-point source, Station 11 at Jambatan Taman LA21 is under Class I with the lowest TSS value of 19 mg/l. All the other stations ie stations 2, 5, 7, 10 and 12 fall under Class III in which the activities involved are rural-based and catfish breeding. Past studies have shown that suspended solids content from point and non-point sources reveals 3 results that classify Malaysian rivers falling into Class I while the rest falls under Class II and above. If a comparison is made with the average suspended solid parameter of Sungai Batang Melaka which is under Class III, Sungai Batang Melaka shows a level of pollution that is relatively high compared with the location stated in past studies in Malaysia.

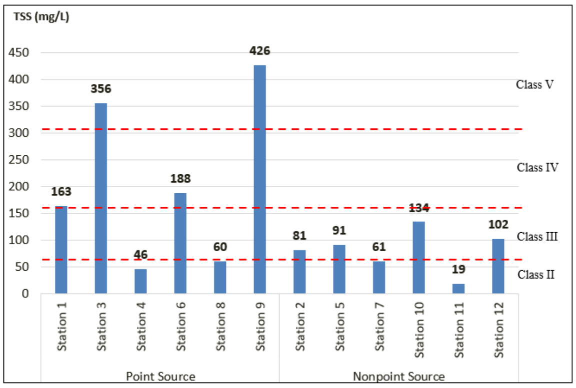

Fig. 3. Total suspended solid profile

3.1.3 *Dissolved Oxygen (DO)*

The dissolved oxygen (DO) readings can indicate the degree of pollution in a particular sample of water. It is one of the most important indicators of water quality on which the survival of aquatic life depends. When DO becomes too low, fish and other aquatic organisms cannot survive [21]. The lower the dissolved oxygen level, the more polluted is the water. The DO level of Class V deduced from the data obtained for Sungai Batang Melaka indicates a very severe level of pollution. Figure 4 shows the DO readings obtained from this study. At point source location, from observation, the highest DO level is at station 1 which is at the Gadek WTP intake with a reading of 5.2 mg/l. One station falls under Class III which is station 8 with a reading of 4.01 mg/l. The high readings observed at stations 1 and 8 may be due to a minimal economic activity at those stations whereby station 1 is located downstream of Sungai Batang Melaka while station 8 is located near an abandoned sand mining site that has ceased its activity. Low DO levels under category Class V are observed at stations 3, 4, 6 and 9 where it is observed that catfish breeding activities are in operation within the vicinity of these stations. This indicates that the activities in operation have resulted in low DO levels due to the process of microbe decomposition occurring at those locations.

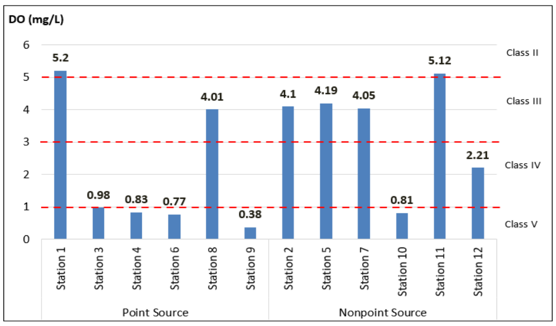

Fig. 4. Dissolved oxygen profile

In contrast, the DO reading at the location of the non-point source, it is found that the highest DO level is at station 11, LA Park Bridge 21 with a reading of 5.12 mg /L. Low DO readings and being in class V were found to occur at station 10 where the location was the location of catfish farming activities. One (1) station is in class IV which is station 12, four (4) stations are in class III which is station 2,5,7 while station 11 is in class II. The results obtained show that the DO content at the stations is affected as a result of economic activities carried out in those areas. This is in line with the theory that dissolved oxygen is the amount of oxygen that needs to be used to ensure that the process of microbial decomposition can be done in aqueous systems. If oxygen is not continuously supplied in water, DO will decrease, depending on the amount of decomposition of organic matter produced [22, 23].

3.1.4 Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is a parameter that determines the strength of pollutants in terms of oxygen use to stabilize domestic and industrial wastes. Usually, the BOD value in the river is around 2 to 7 mg/l [24]. From the data obtained, the BOD values are at a very unsatisfactory level. The BOD parameter is very closely related to the DO. If the DO value is low, the BOD value will be high as it is required in the decomposition of food for the bacteria. Referring to Figure 5 a total of five (5) stations displayed high BOD values and fall under the Class V river category comprising of stations 3, 4, 6, 9 and 10. BOD directly affects the amount of dissolved oxygen in water bodies. As expected the relationship between the BOD and DO values at those stations are similar and most of those locations are affected due to the catfish breeding activities. The greater demand for BOD more rapidly depletes the oxygen in the water bodies making lesser availability of oxygen for higher forms of aquatic life [21]. The remainder of the stations shows one (1) station falls under Class IV which is station S12 whilst four (4) other stations are under Class III which are stations 2, 5,7,8 and two (2) stations are under Class II which are stations 1 and 11.

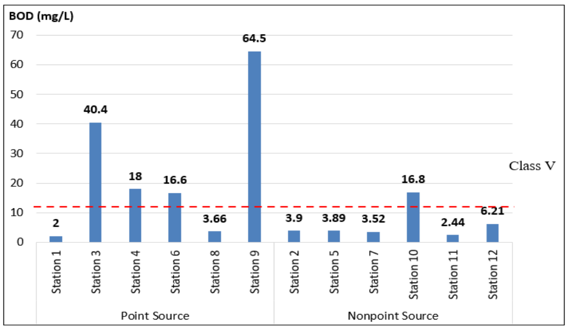

Fig. 5. The biological oxygen demand profile

In theory, the BOD is an indicator of the estimated oxygen consumption. The higher the oxygen consumption is, the more is the organic pollutant content. A high BOD value means the oxygen consumed by the bacteria for the decomposition process of the organic material is high. This indicates that the higher the BOD value, the lower is the dissolved oxygen content in the water [25].

3.1.5 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is the quantity of oxygen required by the oxidation agent for the oxidation process of all the organic materials. The organic materials will be transformed into carbon dioxide, water and ammonia. Figure 6 shows the COD readings for the twelve (12) sampling stations. In general, the readings of all the stations indicate a river classification of Class II, III and IV. The second-highest reading is station 3 with a reading of 88.0 mg/l. The activity carried out at station 3 involves a hot spring recreation and there also exists a chicken coop that occasionally discharges wastewater from the cleaning activity of the chicken coop in a large volume after a heavy downpour. This indicates that the activity taking place contains a high organic polluting substance causing an increase in the COD reading at that location. Stations 1 and 8 are under Class II while under Class III are stations 4 and 6.

For non-point sources, only one station in Class IV, which is station 10 with reading COD is 56 mg/l. The location of station 10 is directly related to station 9. In this case, a high COD reading can be attributed to its origin of flow from station 9 in which the discharge from the catfish breeding pond is discharged directly into the river flow at station 10. Stations 2, 5, 7 and 12 are under Class II while station 11 which registers the lowest reading of 9.2 mg/l is under Class I. Most of the activities operating near these stations are urban and rural-related activities. Due to this, the COD readings in those areas are lower compared to station 9. The COD parameter is an indication of the amount of oxygen needed to oxidize the organic matter chemically which produces carbon dioxide and water throughout its process [26]. COD values also reflect the degree of pollution in a particular water sample that is being tested. The COD value will be higher than the BOD value because all organic matters are oxidized in these tests.

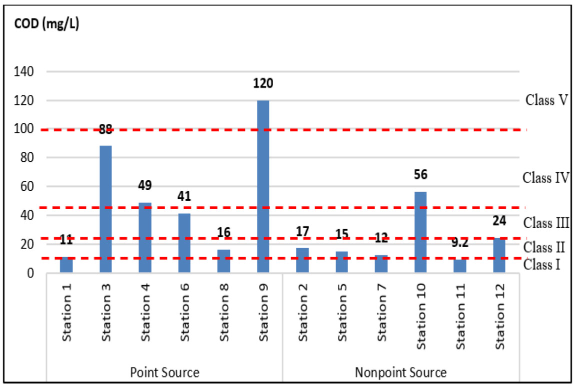

Fig. 6. The chemical oxygen demand profile

3.1.6 Ammoniacal Nitrogen (AN)

Ammonia readings will be high when wastewater and sewage containing the elements $N^{+} + NO^{3} + NO^{2}$ is discharged that results in changes to the colour and smell of the water. Out of the twelve (12) sampling locations, four (4) activities especially catfish breeding activity. The stations concerned are 3, 4, 6, 9 and 10. Five (5) stations are under Class IV and they are 2, 5, 7, 8 and 12 in which the majority of them are involved in urban locations have been identified that can contribute to effluent discharge containing the elements $N^{+} + NO^{3} + NO^{2}$ in which these locations have been identified as carrying out catfish breeding activities. Results of sampling analysis show five (5) stations are within Class V and IV while two (2) stations are under Class III. The stations that are classified under Class V are located in areas with active economic and rural-related activities. Two (2) stations are under Class III which is station 1 with an ammonia reading of 0.58 mg/l and station 2 with a reading of 0.79 mg/l. The location of station 1 is related to the water treatment plant operation and this shows a relief in the sense that the raw water source supplied to the plant complies with the Drinking Water Quality Standard which is less than 1.5 mg/l. This explanation can be summarised as in figure 7.

For non-point source locations, the result of this study shows a high AN content present at the main locations where there are urban-related and catfish breeding activities. The highest AN reading for point source is at S9, at Parit Melana where fish breeding is being carried out. For a non-point source, the highest AN reading is at station 12, Sungai Batang Melaka water intake point. The high content of AN in the water will spur the uncontrolled growth of algae which will cause a eutrophication process and cause the drainage system to become shallow. This phenomenon shows that this parameter can act as an indicator of the degree of pollution generated in the water source [27-29].

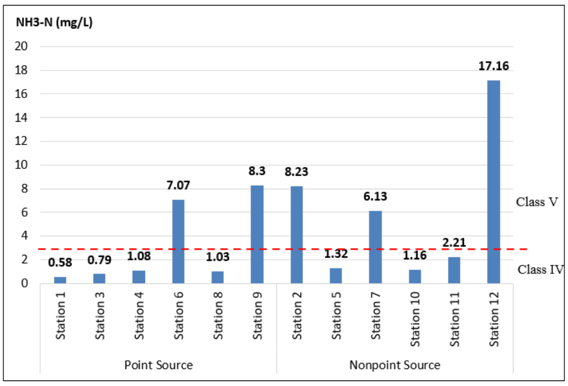

Fig. 7. Ammoniacal nitrogen profile

3.2. River Classification according to Water Quality Index (WQI)

In general, the sampling stations are divided into twelve (12) locations along Sungai Batang Melaka. These twelve locations are categorized into point source and non-point source. Point source locations are at stations 1, 3, 4, 6, 8 and 9. Non-point source locations are at stations 2, 5, 7, 10, 11 and 12. Results obtained from the analysis of the physical-chemical parameters were then used to calculate the Water Quality Index using the calculation of the sub-index parameter. Table 7 show Water Quality Parameters Sungai Batang Melaka in 2016

Table 7
Water quality parameters Sungai Batang Melaka in 2016

Station	**Water Quality Parameters Sungai Batang Melaka (mg/L)**					
	DO	**BOD**	**COD**	**NH_3-N**	**SS**	**pH**
1	5.20	2.00	11.0	0.58	163	5.97
2	4.10	3.90	17.0	1.53	81	6.12
3	0.98	40.4	88.0	7.07	356	6.63
4	0.83	18.0	49.0	6.13	46	6.87
5	4.19	3.89	15.0	1.14	91	7.48
6	0.77	16.6	41.0	8.30	188	6.58
7	4.05	3.52	12.0	1.31	61	6.73
8	4.01	3.66	16.0	2.21	60	6.50
9	0.38	64.5	120.0	17.16	426	7.68
10	0.81	16.8	56.0	8.23	134	7.25
11	5.12	2.44	9.20	0.79	19	7.10
12	2.21	6.21	24.0	1.08	102	7.28

The determination of the WQI index for every parameter obtained is based on the calculation of the sub-index parameter as shown in DOE. Table 8 shows the sub-index data and the Water Quality Index (WQI) obtained. From calculations of the sub-index for all the parameters involved, the WQI value is generated for every sampling station. River classification can be determined based on the WQI values obtained.

Table 8: Subindex data and Sungai Batang Melaka Water Quality Index in 2016

Station	Value Subindeks Water Quality Sungai Batang Melaka 2016						WQI	Class
	SIDO	SIBOD	SICOD	SINH3-N	SITSS	SIpH		
1	0	92	84	75	52	90	61	III
2	0	84	76	41	60	93	55	III
3	0	8	22	0	78	98	32	IV
4	0	38	46	0	74	99	38	IV
5	0	84	79	53	57	97	57	III
6	0	42	52	0	91	98	43	IV
7	0	86	83	48	68	99	59	III
8	0	85	78	25	68	97	55	III
9	0	-3	11	0	30	95	19	V
10	0	41	41	0	55	98	35	IV
11	0	90	87	66	69	99	64	III
12	0	76	70	55	-1	98	46	IV

Figure 8 shows the Water Quality Index for every sampling station. Six (6) stations are found to be under Class III while five (5) more stations are under Class IV. All the five (5) stations under Class IV are actively involved in economic activities in which three (3) of them are located near catfish breeding activity comprising of stations 3, 4 and 10. The other two (2) stations (6 and 12) are actively involved in urban and rural-related activities. One (1) station falls under Class V which is station 9 involving catfish breeding at Parit Melana with a WQI value of 19. This shows a very high degree of pollution due to the economic activity at that location.

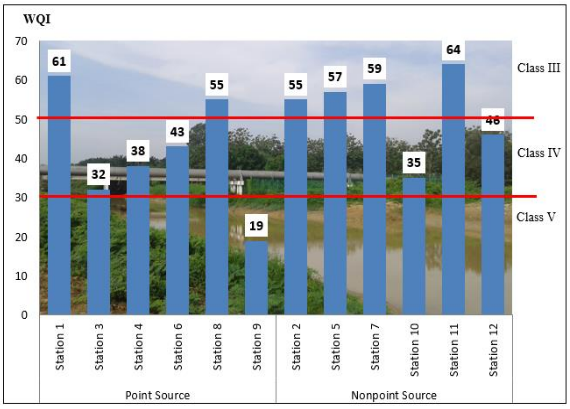

Fig. 8. Sungai Batang Melaka Water Quality Index and River Classification in 2016

3.3 Changes in Water Quality Change at Sungai Batang Melaka

During the period of this study, steps were taken to improve the water quality of Sungai Batang Melaka. Among the agencies involved are the Badan Kawalselia Air Melaka, Jabatan Alam Sekitar Melaka, Jabatan Kesihatan Negeri Melaka, Majlis Perbandaran Alor Gajah Melaka, Jabatan Pengairan dan Saliran Melaka and Syarikat Air Melaka Berhad. Among the drastic steps taken according to the rules and regulation in force is the closure of catfish rearing ponds which is the main factor in the decline of the water of Sungai Batang Melaka. Table 9 shows the parameter readings of the water quality of Sungai Batang Melaka which was observed in 2017 while in Table 10 shows an improvement in the water quality of Sungai Batang Melaka for 2017, which all the stations were under Class III.

Table 9: Water quality parameters Sungai Batang Melaka in 2017

Station	Water Quality Parameters Sungai Batang Melaka (mg/L)					
	DO	BOD	COD	NH_3-N	SS	pH
1	6.66	3.80	12.9	0.08	32	6.71
2	6.59	3.40	66.0	0.33	32	4.27
3	1.93	2.00	50.0	0.14	80	5.02
4	5.12	2.14	10.0	0.26	25	5.14
5	3.22	3.17	11.0	0.53	51	6.99
6	5.07	2.82	8.0	0.54	25	6.02
7	4.01	3.01	10.0	1.20	44	6.68
8	3.99	2.66	12.0	1.17	37	6.23
9	0.72	21.9	30.0	0.05	55	6.28
10	4.11	3.20	9.0	0.22	25	6.01
11	5.17	2.32	8.31	0.68	20	6.88
12	5.04	4.50	14.5	0.11	46	6.59

Table 10**:** Subindex data and Sungai Batang Melaka Water Quality Index in 2017

Station	Value Subindeks Water Quality Sungai Batang Melaka 2017						WQI	Class
	SIDO	SIBOD	SICOD	SINH3-N	SITSS	SIpH		
1	0	84	82	92	80	98	68	III
2	0	86	34	86	80	35	52	III
3	0	92	45	86	61	57	54	III
4	0	91	86	73	84	61	63	III
5	0	87	84	77	72	100	65	III
6	0	88	88	75	84	91	66	III
7	0	88	86	51	75	98	62	III
8	0	90	83	52	78	94	62	III
9	0	30	63	95	70	95	53	III
10	0	87	87	77	84	91	66	III
11	0	91	88	70	86	99	68	III
12	0	81	80	89	74	98	65	III

The changing pattern in the water quality index between 2016 and 2017 is more obvious as shown in Figure 9 in 2017 the WQI of Sungai Batang Melaka registered an average increase of 45% as compared to 2016. All the sampling stations were under Class III in 2017 in comparison to the previous year which was only six (6) locations. Each of the three locations under Class IV and V shows an increase in the river classification to Class III.

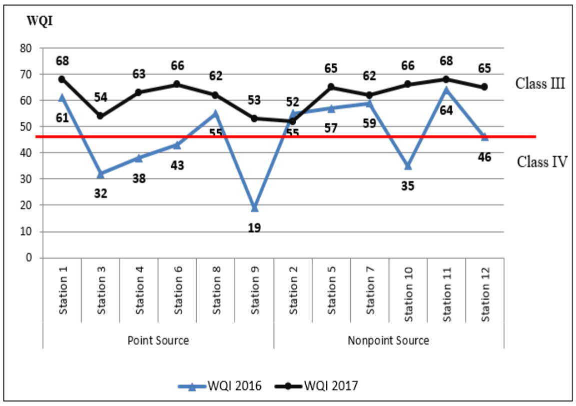

Fig. 9. The pattern of water quality index change at each station

Figure 10 shows the change in river classification for 2016 and 2017 which shows there were changes in six (6) stations, five (5) stations under Class IV and one (1) station underclass V which has increased to Class III. The increase in river classification for 2017 shows that efforts to monitor the situation have been carried out accordingly by the relevant authorities in containing the pollution of Sungai Batang Melaka. Early steps taken by the Badan Kawalselia Air Melaka include the earth filling of the fish ponds and blocking the effluent pipes from discharging directly into the river. Subsequently, the closure of the fish ponds was undertaken in accordance with Section 8. The closure of the unlicensed fish ponds has effectively yielded the desired result in which the prevention of effluent discharge from the fish ponds has successfully overcome the pollution of Sungai Batang Melaka [30, 31].

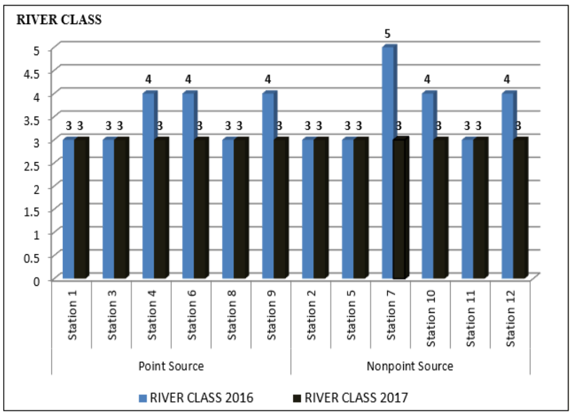

Fig. 10. River class comparison at each station

4. Conclusion

Based on the study undertaken, it can be concluded that the Sungai Batang Melaka is the main artery for the release of flows within the Batang Melaka area. The effects of economic activities undertaken within the area are the main contributor to the river quality in Melaka as Sungai Batang Melaka is located on the upper reaches of Sungai Melaka.

Out of twelve (12) sampling stations chosen, five (5) stations are categorized as a point source and the remaining seven (7) stations are the non-point source. Both categories contribute to the pollution of Sungai Batang Melaka. The main economic activity which has been identified as yielding a bad effect on the water quality of Sungai Batang Melaka is the catfish breeding involving four (4) stations which are stations 4, 5, 9 and 10. All four stations are classified between Class III to Class V. Besides that, another station under Class V is station 3 located at Air Panas Gadek where the ongoing activity at that point is the visits made to utilize the hot spring facility available. For the other stations, the activities undertaken are urban and rural-based in which the river classification is between Class III and IV.

From the results of the quality study for physical, chemical and biological parameters of Sungai Batang Melaka, the calculation of the Subindex Parameter was done and based on the results obtained, the average reading of the twelve (12) stations calculated indicates that Sungai Batang Melaka falls under Class IV. This shows that Sungai Batang Melaka is more polluted in comparison with other rivers mentioned in the previous study which on average are under Class III.

However, the WQI value for 2017 shows that all the twelve (12) stations fall under Class III, an increase of 45% compared to 2016. This shows that the steps taken to control the economic activities which contribute to the decline in river water quality have been successfully implemented in the best manner.

Corrective measures undertaken by the relevant authorities are seen to produce the desired results positively with the increase in the WQI and river classification within one year. However, to ensure that this transformation is continuous and more effective in the future, a continuous effort needs to be actively engaged by all the parties involved.

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Conflicts of interest

The authors declare that there is no conflict of interest

References

[1] T.V. Cech, J.T. Beebe, Principles of water resources: History, development, management and policy, Environments 31(3) (2003) 85.

[2] J.A.S. JAS, Laporan kualiti alam sekeliling Malaysia 2015, (2015).

[3] H.L. Chee, D.T. Tan, N.W. Chan, N.A. Zakaria, 21st Congress of International Association for Hydro-Environment Engineering and Research (IAHR), Asia Pacific Division (APD), 21st Congress of International Association for Hydro-Environment Engineering and Research (IAHR), Asia Pacific Division (APD), IAHR-APD, 2018.

[4] N. Mamat, F.M. Hamzah, O. Jaafar, Hybrid Support Vector Regression Model and K-Fold Cross Validation for Water Quality Index Prediction in Langat River, Malaysia, bioRxiv (2021).

[5] N.A. Bakar, N. Othman, Z.M. Yunus, W.A.H. Altowayti, M. Tahir, N. Fitriani, S.N.A. Mohd-Salleh, An insight review of lignocellulosic materials as activated carbon precursor for textile wastewater treatment, Environmental Technology & Innovation (2021) 101445.

[6] W.A.H. Altowayti, S.A. Haris, S. Shahir, Z. Zakaria, S. Ibrahim, The removal of arsenic species from aqueous solution by indigenous microbes: Batch bioadsorption and artificial neural network model, Environmental Technology & Innovation (2020) 100830.

[7] S. Luong Nguyen, Managing agricultural non-point source pollution in the European Union, New Zealand, and Vietnam, The University of Waikato, 2021.

[8] I. Naubi, N.H. Zardari, S.M. Shirazi, N.F.B. Ibrahim, L. Baloo, Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality, Polish Journal of Environmental Studies 25(1) (2016).

[9] J. Bartram, R. Ballance, Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes, CRC Press1996.

[10] W.A.H. Altowayti, H. Almoalemi, S. Shahir, N. Othman, Comparison of culture-independent and dependent approaches for identification of native arsenic-resistant bacteria and their potential use for arsenic bioremediation, Ecotoxicology and Environmental Safety 205 (2020) 111267.

[11] L. Madsen, M.E. Hansen, M.R. Gjerding, S. Pedersen, Implementation of a Water Vision, (2003).

[12] R.B. Zakariah, N.B. Othman, M.A. bin Mohd Yusoff, W.A.H. Altowayti, Determination of Stage Discharge Rating Curve at Sungai Batang Melaka, Journal of Southwest Jiaotong University 56(3) (2021).

[13] F.W. Mustafar, M.H.D. Hamdan, N. Jusoh, S. Mustafar, PENJAGAAN ALAM SEKITAR MENURUT MAQASID SYARIAH DAN UNDANG-UNDANG, Journal of Law and Governance 3(1) (2020) 96-112.

[14] T.H. Snelder, B.J. Biggs, Multiscale river environment classification for water resources management 1, JAWRA Journal of the American Water Resources Association 38(5) (2002) 1225-1239.

[15] Y. Icaga, Fuzzy evaluation of water quality classification, Ecological Indicators 7(3) (2007) 710-718.

[16] S. Ab Hamid, C.S.M. Rawi, Application of aquatic insects (Ephemeroptera, Plecoptera and Trichoptera) in water quality assessment of Malaysian headwater, Tropical life sciences research 28(2) (2017) 143.

[17] W.A.H. Altowayti, H.A. Algaifi, S.A. Bakar, S. Shahir, The adsorptive removal of As (III) using biomass of arsenic resistant *Bacillus thuringiensis* strain WS3: Characteristics and modelling studies, Ecotoxicology and Environmental Safety 172 (2019) 176-185.

[18] S.A. Haris, W.A.H. Altowayti, Z. Ibrahim, S. Shahir, Arsenic biosorption using pretreated biomass of *psychrotolerant Yersinia* sp. strain SOM-12D3 isolated from Svalbard, Arctic, Environmental Science and Pollution Research 25(28) (2018) 27959-27970.

[19] R.A. Omer, G.O. El-Sayed, Determining Cadmium Activities and Predicting Solid-Phases Which Control Its solubility in the Soil irrigated with Sewage Water, in Egypt, Egyptian Journal of Chemistry 64(7) (2021) 3-4.

[20] E. Iloms, O.O. Ololade, H.J. Ogola, R. Selvarajan, Investigating industrial effluent impact on municipal wastewater treatment plant in Vaal, South Africa, International journal of environmental research and public health 17(3) (2020) 1096.

[21] M. Arif, R. Kumar, Reduction in water pollution in Yamuna river due to lockdown under COVID-19 pandemic, (2020).

[22] R.M. Cory, G.W. Kling, Interactions between sunlight and microorganisms influence dissolved organic matter degradation along the aquatic continuum, Limnology and Oceanography Letters 3(3) (2018) 102-116.

[23] A. Kumar, G. Pandey, A review on the factors affecting the photocatalytic degradation of hazardous materials, Mater. Sci. Eng. Int. J 1(3) (2017) 1-10.

[24] S.M. Avvannavar, S. Shrihari, Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India, Environmental monitoring and assessment 143(1) (2008) 279-290.

[25] A. VYNAVI, P. THANAPALASINGAM, Pollution status of the Sungai Skudai river system through heavy metals, Phd thesis, Universiti Teknologi Malaysia, Johor, 2005.

[26] D.A. Hammer, Creating freshwater wetlands, CRC Press2014.

[27] S.M. El Sayed, M.H. Hegab, H.R. Mola, N.M. Ahmed, M.E. Goher, An integrated water quality assessment of Damietta and Rosetta branches (Nile River, Egypt) using chemical and biological indices, Environmental monitoring and assessment 192(4) (2020) 1-16.

[28] D.V. Chapman, Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring, CRC Press1996.

[29] R. Hranova, Diffuse pollution of water resources: Principles and case studies in the southern African region, CRC Press2005.

[30] I.B. Koki, K.H. Low, H. Juahir, M.A. Zali, A. Azid, S.M. Zain, Consumption of water from ex-mining ponds in Klang Valley and Melaka, Malaysia: A health risk study, Chemosphere 195 (2018) 641-652.

[31] A.K. Hua, An identification source of variation on the water quality pattern in the Malacca River basin using chemometric approach, Archives of Environmental Protection 44(4) (2018).