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Benthic Macroinvertebrate Composition and Water Quality Status in Sungai Johor, Johor, Malaysia

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Anthropogenic influences on aquatic life community can be identified using biological monitoring approach to assess pollution levels and water quality. This study was conducted for three times from November 2015 to February 2016 to determine the effect of land use on benthic macroinvertebrate assemblages in estuary of Sungai Johor. Five stations were selected and a 500 m reach of the stream was selected for each sampling site. Surber Net measuring 500 micron mesh size combined with a rectangular quadrat of 30 cm x 30 cm (0.09 m^2) was used to sample macroinvertebrates. The results showed that un-disturbed river has complete sensitive taxa namely Ephemeroptera, Plecoptera and Trichoptera (EPT). There were only two sensitive taxa namely Ephemeroptera and Trichoptera were found in the river which flows through palm oil plantation. Similar scenario was found in the river which flows through logging area where there were also two sensitive taxa namely Ephemeroptera and Trichoptera found in this river. The results obtained for urban river was the other way around where there was an absent of all three sensitive taxa (EPT) in the river which flows through urban area. Most of the macroinvertebrate taxa that were found in this station are pollution resistant taxa comprised Diptera, Odonata, Mesogastropoda, Basommatophora, Hirudinea and Haplotaxida. The results can be used as a biological indicator for river water quality assessment.

1. Introduction

Fatimah and Zakaria-Ismail (2005) stated that fresh water is a precious commodity. Water is the essence of life. The demand for clean and portable water has increased tremendously due to rapid development and a growing population. The demand is not only for human beings but also for aquatic life that use water or river as their habitats and this aquatic life eventually become a protein source for humans.

It is imperative that every effort should be made to protect and conserve existing water resources, namely our rivers, for present and future needs. Water is the basic resource upon which society relies for the quality of its life, including its health and recreation. It is also the primary resource upon which social and economic developments are based and sustained. Aquatic ecosystems must, therefore, be effectively protected and managed to ensure that they retain their inherent vitality and remain fit for domestic, industrial, agricultural and recreational uses, for present and future generations.

Brandvold et al. (1976) stated that water quality parameters can be divided in to two major groups namely physical and chemical. An example of physical parameters is total suspended solids (TSS), temperature, colour and turbidity. Example of chemical parameters are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), conductivity, pH, ammoniacal nitrogen (AN), nitrate and phosphate. River water quality status was determined by surrounding sources or surrounding land use. There were a number of studies and papers presented using chemical and physical parameters to determine surface water quality. Among others was studies done by Hun-Kyun et al. (2009).

Currently in Malaysia, only physical and chemical components are used as an indicator for river health monitoring and rehabilitation programme. These attributes were used for many years as a basis and reference in rehabilitating rivers in Malaysia and none of them was proven to be successful. In order to determine the health of the river not only must the physical and chemical qualities of the health of the river be taken into account but also the biological aspects. Biological monitoring is an essential element needed to assess the environmental health of aquatic ecosystems. Biological organisms are diagnostic when determining the health of aquatic ecosystems and they can be measured quantitatively.

The changes of macro benthic populations is not only influenced by the physical and chemical quality of the rivers but also by catchment characterisations such as the catchment covers, hydraulic and hydrology parameters, river bank conditions, river covers and river riparian vegetation. The changes of catchment characteristics are normally due to the disturbance of the catchment areas due to development or anthropogenic activities. This becomes worse if the disturbances have been carried out in the wrong manner without any proper control measures. It is not that easy to use a biological parameter as an indicator to assess river water quality or health. The assessments are unlike physical and chemical parameters, since biological changes specifically with macroinvertebrate benthic species are influenced by various factors. Nevertheless, the main factors are definitely the physical and chemical water qualities while the other factors include the physical habitat quality and river morphology.

Furthermore, Thompson (2005) validated and highlighted that it is important from a biological perspective to not only calculate indices and spatially represent water quality data, but to incorporate more detailed physical habitat quality parameters into biological geo-databases. Results in the form of universal index are not going to help in portraying the real status of pollution. The numbers or indices indicate only differences between stations over distance or time. Works by Braccia and Voshell Jr. (2006) demonstrates the importance of quantitative sampling through time when research goals are to identify relationships between macroinvertebrates and environmental factors.

Fatimah and Zakaria-Ismail (2005) did a water quality sampling for Selai River, which is also situated in Endau Catchment area. In this work, this river is categorised as Class I river. They suggested that, good water quality recorded in Sungai Selai is probably due to the strong buffering capacity of the soil from which the river passes through. A similar study was carried out by a number of researchers around the globe to measure physico-chemical parameters for water quality such as Haiyan et al. (2006). Only few researchers that embarked on the study to determine relationship between river discharge and water quality. Kurunc et al. (2005) determined the effect of discharge fluctuation on water quality variables from the Yesilirmak River.

The small changes in the environment will have considerable response on the benthic community and it avails to measure the degree of pollution (Fernando, 1981). The presence and numbers of the different types of benthic macroinvertebrates provide accurate information about the health of a stream and watershed. The water quality, drift of aquatic insects and common dragonflies and damselflies at the Hulu Selai River, Endau Rompin National park, Johor Malaysia were studied (Fatimah and Zakaria-Ismail, 2005). As there is no assessment on benthic macroinvertebrate in Sungai Pichong, hence the present study has been undertaken to identify the community structure and distribution of benthic macroinvertebrate in relation to physicochemicals water quality.

2. Materials and Methods

2.1 Study Site

This study was conducted within the Sungai Johor Catchment areas in the District of Kota Tinggi in the state of Johor (Figure 1). Three stations were selected from three different rivers, one station from each river, for studying the physical and chemical conditions of water quality and river discharge. River gauging were used to measure river discharge and for the purpose of this study, river gauging station was at the same station with water quality station. Two modes of water sampling were obtained, which was in-situ measurement and water sampling for laboratory analysis.

2.2 Methods

Data were collected for 4 times between the periods from November 2015 till August 2016. At each station, five parameters were measured following the standard procedure of U.S. Environmental Protection Agency. Temperature, Conductivity, Dissolved Oxygen (DO), pH and Turbidity were measured by using a multi parameters probe Model YSI 6920 with 650 MDS Display/Logger as well as single parameter probe was used for in-situ measurement of river water quality. The YSI 650 Multi-parameter Display System (650 MDS) is a hand held microcomputer based instrument that allows the user to display sonde readings, configure sondes, store and recall data, upload data from sondes and transfer data to computers for analysis and plotting. The YSI 6920 Multi-parameter Probe measures the water quality. This probe comprises six (6) sensors to measure six (6) parameters namely DO, salinity, conductivity, ammoniacal nitrogen, temperature and pH.

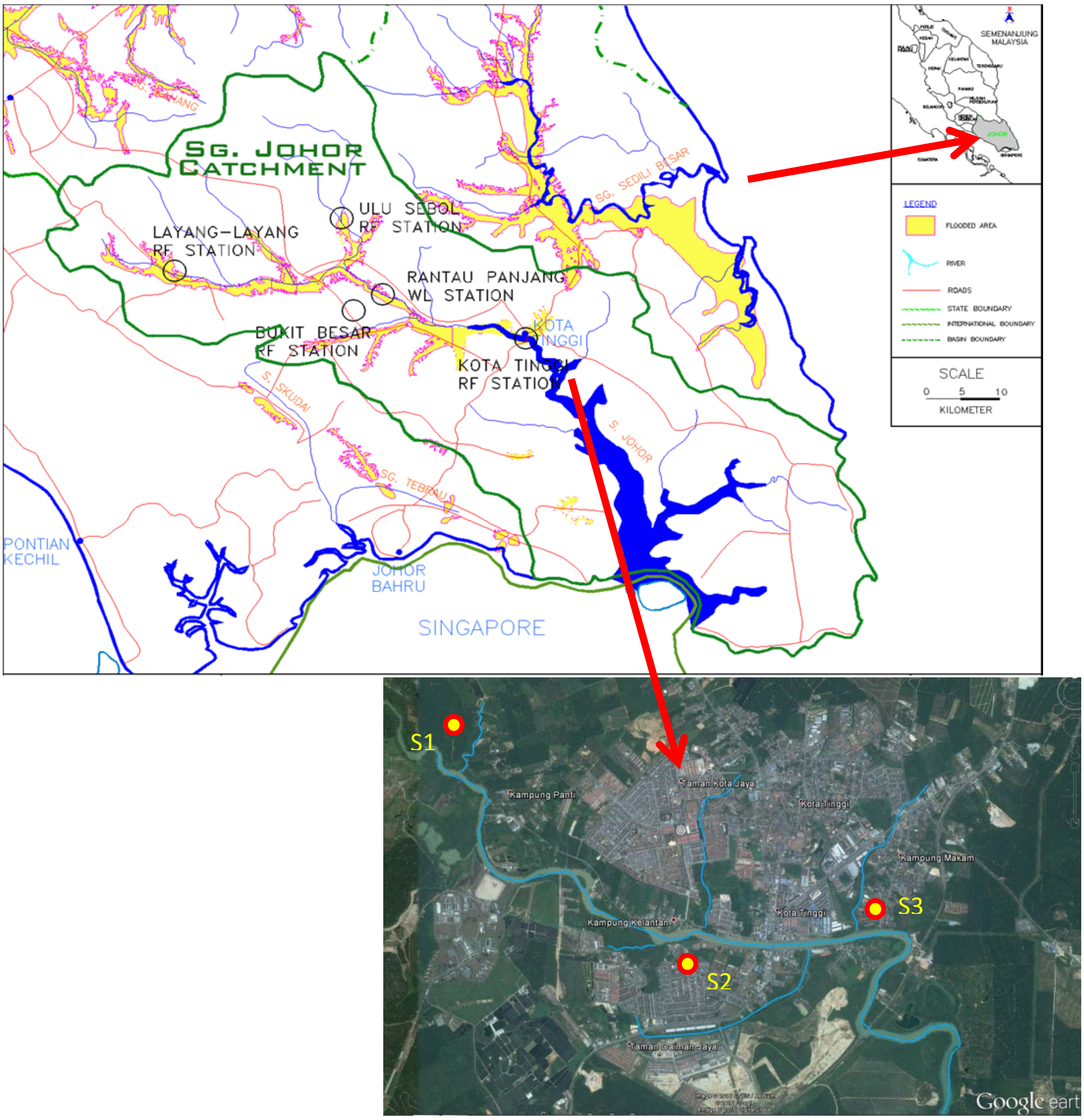

Figure 1: Portion of water quality sampling stations (S1, S2 and S3) at Sungai Johor

2.3 Sampling and Identification

A rectangular dip net with 500 µm mesh size was used to collect the benthic macroinvertebrates. Samples were taken in duplicates at each station. The samples collected were put into polyethelene bottles and preserved with 70 % alcohol for further analysis in laboratory using light microscopy. In the laboratory, benthic macroinvertebrates were sorted, enumerated and identified to the lowest possible taxon. Benthic macroinvertebrate was analysed and calculated according to Biological Water Quality Index, BWQI (DID, 1995), as shown in Eq(1):

$$BWQI = \Sigma S/\Sigma J \qquad (1)$$

where: S = Total score, J = Number of animal type

Water quality parameters (temperature, conductivity, depth, width, DO and pH) were measured in-situ. Dissolved oxygen and pH were determined using YSI meter (Multi sensor) model 610D while others (BOD, COD, TSS and AN) were analysed in laboratory. These parameters were then calculated to obtain the water quality index, WQI, based on Eq(2):

$$WQI = 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.15SIAN + 0.16SISS + 0.12SipH \quad (2)$$

where: SI = Sampling index, DO = Dissolved oxygen, BOD = Biochemical oxygen demand, COD = Chemical oxygen demand, AN = Ammoniacal-N, SS = Suspended solids, pH = acidic value

3. Results and Discussion

3.1 Water Quality of Sungai Johor

The Water Quality Index is a good indicator of any deterioration or improvement of a water body. Most of the parameters indicated low water quality corresponding to the downstream of the river. This is due to the circumstances of the sampling area congested by residential and industrial area, sewerage treatment plant and other land use activities. With regards to the Malaysian Water Quality Index (WQI), Johor River is classified into Class IV with range from 47 - 52 which is only suitable for irrigation purposes (Table 1).

Table 1: The Water Quality of Sungai Johor, Johor

Station No.	SIDO	SIBOD	SICOD	SIAN	SISS	SIpH	WQI	Status
St1	51	32	40	8	92	99	52	IV(P)
St2	45	15	48	0	94	100	47	IV(P)
St3	57	21	27	0	8	100	47	IV(P)

Dissolved Oxygen (DO) is the most important parameter in classifying a river's class in WQI. Based on the coefficient of DO, it influences the water quality index by 22 % (DOE, 1986). When the value of DO is lower, WQI tends to have lower value and if the value of DO is higher, it is vice versa. The average DO recorded for Sungai Johor was 3.16 mg/L. The town area is the main cause of the depletion of DO content in the river due to the high organic pollutants released from the town centre. The rubbish, detergent, grease as well as suspended solids tend to accumulate on the surface of the river which directly affects the surrounding oxygen from dissolving into the river. According to Sholkovitz (1985) during high tide, the flow of the river is stronger and faster therefore more oxygen can easily dissolve in the water, making DO concentration higher compared to during low tide where the flow is quite stagnant.

BOD is related to the dissolved oxygen content in the river and is the main indicator of the organic pollution in the river. A decrease in the DO value usually denotes an increase in the BOD value. BOD is also the second most important parameter in classifying a river in the Water Quality Index as it holds 19 % of the classification (DOE, 1986). Based on study conducted, the average concentration of BOD for Sungai Johor was 13.16 mg/L. The highest BOD (16.47 mg/L) was observed on March at Station 2 while the lowest BOD (10.14 mg/L) was on May at Station 1. BOD concentration was higher in Sungai Johor River due to the commercial activities as well as the residential areas along the river. The untreated sewage from squatters and food waste which is disposed directly into the river will also increase the BOD content in the river.

The accountability of Chemical Oxygen Demand (COD) to the WQI is the third most important parameter when determining a river's WQI as it takes up 16 % together with suspended solid (SS). The average value for COD in rivers are usually ranged from 0 to 150 mg/L. This study found that the average COD concentration for Sungai Johor was 33.3 mg/L. The highest COD was recorded on May at Station 2 with 40.6 mg/L while the lowest COD was 24.0 mg/L on April at Station 1. This result indicated that there were much organic substances which are non-biodegradable and reactive. Even domestic waste also contributes to high COD content. All these effluents are toxic and harmful to living things.

Total Suspended Solid (TSS) contribute 16 % of the amount to the value of WQI. TSS include all the suspended particle which will not pass through the filter paper during the laboratory experiment in determining the TSS. The average of TSS for Sungai Johor was 44.3 mg/L. The highest TSS was on March at Station 3 (132.5 mg/L) meanwhile the lowest (2.6 mg/L) was on April at Station 1. Significant difference in the value of the two months period is influenced by rainfall factor. Sampling in March was done in rainy season. Rain cause water to carry any particle on land into the river, thus contribute in increasing of suspended solid in river.

Ammonia Nitrogen (NH_3N) contributes 15 % of the amount to the value of WQI. One of the sources of NH_3N in a river is come from the microbial degradation of nitrogenous organic material. The other sources of this compound are come from the sewerage treatment plant, the using of fertiliser for agriculture as well as other by products which flow into the river. The average NH_3N for Sungai Johor was 2.86 mg/L. The level of NH_3N significantly increase as it meets with connecting tributaries and drains indicating that the pollutant carried by them is very high.

3.2 Composition and Distribution of Benthic Macroinvertebrate

A total of 77 individuals representing 7 families from 3 orders were successfully sampled from three sampling point at the middle section of Johor River (Table 2). Among all, molluscs and dragonfly nymph were the most diverse group found in each sampling station. High number of organisms were sampled in station 2 (34) followed by station 3 (25) and station 1 (18). Abundance of non-biting midge larvae were also observed in each station. According to Galdean et al. (2000) their abundance usually associated with the amount of detritus, as can be seen whereby silt and clay were the major component of sediment in that area.

The Biological Water Quality Index (BWQI) values in Johor River were in between 3.8 - 4.25, indicating that the water quality of that river was slightly polluted. Based on Family Biotic Index (FBI), the score for station 1 and 3 were 7.44 and 8.0 showed that sampling area were heavily polluted whereas station 2 score was 6.97 (polluted). The changes of the ecosystem especially in the downstream of Johor River might be associated with man-induced activities such as sedimentation, sewage/ nutrients runoff and agricultural pesticides.

Table 2: Classification of water quality in Johor River, Skudai, Johor based on biological indices

Station No.	BWQI	Status	FBI	Status
St1	3.8	Rather dirty - average	7.44	Heavily polluted
St2	4.25	Rather dirty - average	6.97	Polluted
St3	4.25	Rather dirty - average	8.0	Heavily polluted

Using the macrobenthos as a biological indicator is another way in determining the class and status of river. This method classified the river based on the Biological Water Quality Index (BWQI). The analysis of macrobenthos as a biological indicator is an easy, fast and low cost method. Anyone can do it due to this method does not need any special tools. This method requires collecting of macrobenthos at the river with appropriate tools for safety and environmental purpose, and stored it for further identification. The identification on types of macrobenthos is based on the Identification Index as provided by Jabatan Pengairan dan Saliran Malaysia.

This study found that, there were four types of macrobenthos with three family groups which were Nymphs, Larvae and Molluscs populated at vicinity of Sungai Johor. The types of macrobenthos were dragonfly nymphs, rat-tailed maggots, mosquito larvae as category as other fly larvae and pagoda snails. All those types of macrobenthos can live in clean and average river water. Family group Larvae got the highest score of macrobenthos with the value of 8. The rat-tailed maggots and mosquito larvae were grouped in same family. Rat-tailed maggots breathe fresh air through long extending ‘tails’ for their survival. Dragonfly nymphs and pagoda snails shared the same score with the value of 3. Dragonfly nymphs belong to the nymphs family meanwhile pagoda snails belong to molluscs family. Dragonfly nymphs are very active hunters with large jaws. They feed on insect, tadpoles and even small fish, and are probably important natural pest controllers of animals such as mosquitoes and blackflies. The pagoda snails from molluscs family were collected with 5 individuals. Pagoda snails are shell animal that survive by eating plant.

4. Conclusions

The result from chemical and biological analysis conducted shows that water quality of Johor River was degraded with similar result. Pollution factors will also influence the abundance of invertebrates. Organic pollutants such as fertilisers from agricultural activities, residential areas and factories resulted in increased populations of resistant organisms to contamination. Collection for certain macrobenthic species present particularly in polluted and non-polluted parts of a river indicated that they could be employed as suitable bio-indicators for river pollution studies.

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