Water Quality Index (WQI) classification of rivers in agriculture and aquaculture catchments

Fauzi Baharudin¹, Jalina Kassim¹, Siti Nurulhuda Mohd Imran¹ and Mahyun Ab Wahab²

¹Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
²Faculty of Civil Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia
fauzi1956@uitm.edu.my

Abstract. Water quality is always affected by a wide range of human and natural factors which is commonly a result of mismanagement of land, dumping of rubbish and unintentional introduction of chemical material into the river. The rivers in Kuala Selangor and Sabak Bernam districts which lie in active agriculture and aquaculture activities are also not spared from pollution. This study focused on water quality investigation and source of pollution identification in seven rivers in Kuala Selangor and Sabak Bernam. The water quality parameters investigated were Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), pH and Ammoniacal Nitrogen (AN). Water Quality Index (WQI) was then calculated based on Department of Environmental guidelines. Based on the WQI results, Sungai Selangor and Sungai Tengi were classified as Class III showing slightly polluted, while Sungai Buloh, Sungai Nibong, Sungai Haji Dorani, Sungai Besar (Bagan Cina), Sungai Besar (Parit Timur) and Sungai Bernam were classified as Class IV or polluted. The industrial, residential, agricultural activities in the surrounding area of the rivers that were suspected of being sources of river pollution were also identified.

1. Introduction
Water is an essential element in nature which moves all walk of life. Through the evolution and developments of various human activities, the quality of water has become a pivotal attention from time to time. When the quantities of pollutants in the water are abundance, the treatment process will take a longer time and can be difficult. Water quality is always affected by a wide range of natural and human factors. Throughout the ages, nature has been able to balance the ecology such that river pollution, caused by natural factors such as landslides and annual flooding, has been kept to a manageable level. However, when mankind is brought into the equation, the equilibrium can be shattered. River pollution may increase steadily due to various factors. One of the causes of pollution is the discharge of untreated domestic sewage into rivers. Discharging wastewater into rivers without prior treatment process will cause the water quality of the river to drop [1]. This will then affect the aquatic ecosystems and if contaminated water is consumed by humans, it will lead to numbers of health risks, particularly in human diseases [2]. Agricultural activity is also one of the sources identified as a source of river pollution, through the excessive use of fertilizer and pesticide which eventually became source of nutrients abundance in river system [3, 4]. Focus of this study is on the investigation of the quality of the water in the river and identification of the sources that affect the quality of water in the river for
Sabak Bernam and Kuala Selangor area, where the quality of water in the river will be measured in specified parameters.

There are several criteria and characteristics need to be addressed in classifying water quality. Tyagi studied numbers of water quality equations and highlighted the development of a new and globally accepted Water Quality Index in a simplified format, which may be used at large and could represent the reliable picture of water quality [5]. Another study which is related to development of a water quality index was carried out by [6]. The study analyzed 28 parameters related to water quality and then reduced to 9 parameters based on Principal Component Analysis (PCA). The final shortlisted 9 parameters were Dissolved Oxygen (DO), pH, Conductivity, Biochemical Oxygen Demand (BOD), Total Coliform (TC), Chlorides, Magnesium, Sulphate, Total Dissolved Solids (TDS). PCA utilizes the variance in the entire data set and projects it in new dimensions, thereby reducing the number of parameters but retaining maximum variance. The use of statistical techniques in WQI development makes it less biased and more objective in nature and forms the basis of development of a reliable Water Quality Index (WQI) in future. Bao conducted an experimental investigation to determine the value of BOD, COD, Suspended Solids (SS), Ammoniacal Nitrogen (AN), pH and Dissolved Oxygen (DO) during high tide and low tide [7]. The results indicated that the impact of activities such as residential, industrial, and commercial and agriculture have caused environmental degradation to Kuantan River and its adjacent areas. [8]Hussain & Ismail (2001) experimentally investigated the river pollution that contributed to the deterioration of water quality at Sungai Pasir, Sungai Petani, Kedah. The results achieved indicated this river categorised as slightly polluted and polluted which requires efficient operation before being supply as source of drinking water. Therefore, the objectives of this study are (1) to investigate the water quality of river, (2) to establish the water quality index (WQI) based on Malaysian DOE Standard and (3) to establish possible sources of pollution in Kuala Selangor and Sabak Bernam area.

2. Methodology
The process consisted of a preliminary investigation and detailed site investigation of the study area to get an overview so that more detailed planning could be done to ensure smooth operations. The best point for sampling was also determined, including checking for all parameters required for this study.

The location of this study was in Kuala Selangor and Sabak Bernam. Both districts are well known for its active agriculture and aquaculture activities. In Kuala Selangor there were three (3) rivers selected for this study. The first river was Sungai Buloh which is close to the border of Gombak district. It is located 33km from Shah Alam City, and is under the Shah Alam City Council. The second river was Sungai Selangor which runs from the east where the town of Kuala Kubu Bharu is located, and emptying into the Straits of Malacca located in the west, besides the town of Kuala Selangor. This river runs through several residential areas and it was observed that there were major constructions of buildings such as supermarkets along its banks and small wharves for small ships to berth. The last river chosen for Kuala Selangor was Sungai Tengi. This river runs through residential and commercial areas such as the FELDA Sungai Tengi and is adjacent to the border of Perak State.

Four (4) rivers were selected for this study in Sabak Bernam. The first river was Batu 23 Sungai Nibong which is 125 kilometers from Kuala Lumpur; villagers’ houses were located along the river. The second river selected was Sungai Haji Dorani which runs beside a small holiday village with chalets and seafood restaurants within the Sabak Bernam District. The third river chosen was Sungai Besar in the district of Sabak Bernam and it is 120km north-west of Kuala Lumpur. The majority of villagers in this district are fisherman and farmers who reside in the vicinity of the banks of the river where it is convenient to land their catch of fish and tend to their paddy fields respectively. The last river selected was Sungai Bernam, bordering the states of Selangor and Perak; it is the largest river in Sabak Bernam. Figure 1 shows the seven (7) rivers that were selected for this study.
Sampling was done by way of grab sampling technique and brought back to the laboratory for testing. In ensuring accuracy of results when analyzing the samples, a cardinal rule was adhered to: the sample must be in the original condition as when it was first taken. Therefore the samples were kept in boxes that contained ice whilst being transported to the laboratory for testing. The water samples were analyzed in the Environmental Laboratory of the Faculty of Civil Engineering, Universiti Teknologi Mara (UiTM).

Samples were analyzed for Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solid (SS), Ammoniacal Nitrogen (AN) and pH. DO was determined by using DO meter through in-situ measurement. The Biochemical Oxygen Demand (BOD) was determined by following the procedure in Standard Method APHA 5210-B [8]. Chemical Oxygen Demand (COD) were analyzed by Reactor and Spectrophotometer with the addition of Digestion Reagent as a reagent. Suspended Solid (SS) and Ammoniacal Nitrogen (AN) was determined by using spectrophotometer and also Nessler ammonia reagent which consisted undertaken using the spectrophotometer. The Nessler Reagent, Mineral Stabilizer and Polyvinyl Alcohol Dispersing Agent. PH determination was carri

\[
WQI = (0.22 \times SIDO) + (0.19 \times SIBOD) + (0.16 \times SICOD) + (0.15 \times SIAN) \\
+ (0.16 \times SISS) + (0.12 \times SIPH)
\]

3. Results and discussion

Overall, the content of dissolved oxygen (DO) in all water samples was more than 7 mg/l. Changes in value of DO usually depend on organic materials and organisms such as bacteria in the water. Figure 2 shows that Sungai Bernam had the highest value of DO which is 8.11 mg/l while the lowest DO value was 7.83 mg/l at Sungai Buloh. The DO for Sungai Bernam was high because of its distance from agricultural, industrial and residential areas and its surrounding area is abundant with many plants. On the other hand, Sungai Buloh is located near the industrial and residential areas leading to low content
of DO. Possible causes are the leaked oil from the fishermen’s boats as well as the flow of untreated water from the drains of the surrounding residential and industrial areas. Both of these causes might carry dirt and organic matter which lower the DO values. The results show that all the rivers are classified in Class I denoting that they still have high DO content.

![Dissolved Oxygen](image)

**Figure 2.** Dissolved Oxygen (DO) result.

BOD values are influenced by the contents of the DO in the river. BOD increase is inversely proportional with DO. Figure 3 shows the BOD results for all rivers that have been selected for this study. The lowest value of BOD was 2.63 mg/l from Sungai Besar (Bagan Cina) while the Sungai Nibong recorded the highest value of BOD at 7.49 mg/l. The increase in BOD indicated low concentrations of DO. Sungai Nibong had a higher value of BOD due to its close proximity to an oil palm plantation. The use of fertilizers and pesticides from the plantation produces a lot of organic chemicals. In addition this area is also near a village whereby waste organic material from the houses in the village flowed into the river. Sungai Besar (Bagan Cina) showed the lowest value of BOD because it is far from any agricultural area. Thus this river is classified as class II whereby its water can be used as a water supply for humans whilst Sungai Nibong is classified as class IV, indicating that it is not suitable for human consumption because can cause irritations.
Figure 3. Biochemical Oxygen Demand (BOD) result.

Figure 4 shows the results of the COD taken from all rivers. The highest value of 123.75 mg/l was recorded at Sungai Besar (Parit Timur) area which indicated that the river is contaminated and classified into class V. The high value might be contributed by the use of pesticides and fertilizers in the surrounding agriculture area particularly paddy plantation. The lowest COD was recorded at Sungai Selangor with the value of 39.25 mg/l and classified under class III. Although this river is considered as a main river in Selangor, it has less pollution sources from agriculture and industrial area.

Figure 4. Chemical Oxygen Demand (COD) result.

Figure 5 shows the Ammoniacal Nitrogen (AN) results for all selected rivers. Sungai Besar (Parit Timur) recorded the highest value of AN which was 3.25 mg/l and regarded as class V. The value of AN could be high when the river is near to large agricultural areas as the extensive use of fertilizers can increase the AN content in a river. On the other hand, Sungai Selangor had the lowest value of AN which was 1.09 mg/l and fell under class III. Sungai Selangor contained the lowest value of ammonia because
it was far from agricultural areas while the other rivers were in the vicinity of an agricultural area where there is much use of fertilizers and pesticides.

![Figure 5. Ammoniacal Nitrogen (AN) result.](image)

Figure 5. Ammoniacal Nitrogen (AN) result.

Figure 6 shows the results of SS for rivers selected for this study. Sungai Bernam had the highest value of SS which is 326.25 mg/l and classified as class V while Sungai Tengi had the lowest value of SS which is 24.25 mg/l indicating a modest condition region under class II. The high SS value of Sungai Bernam was due to it runs through a forested area, resulting in a high value of SS. High SS values might indicate certain degree of contamination in the surrounding area and eventually can affect the overall value of the WQI.

![Figure 6. Suspended Solid (SS) result.](image)

Figure 6. Suspended Solid (SS) result.
The pH value is used to show whether a river is in acidic, alkaline or neutral condition. The pH value of water which is in the range of 6.5 to 8.5 shows better water quality, cleaner and suitable for domestic consumption. Figure 7 shows the pH results for rivers in Kuala Selangor and Sabak Bernam. Sungai Selangor showed the highest pH value of 7.20 due to this river being located far from any industrial areas and it is also contains a lot of plants which helps in getting rid of heavy metals in turn helps in increasing its pH. Sungai Nibong had the lowest pH value of 4.92 since it runs beside an oil palm plantation and the use of chemical fertilizers and pesticides in the plantation caused an increase in the acidity of the water in the river. The pH testing needed to be done in order to ascertain whether the rivers were in acidic or alkaline condition. The results also showed that generally, all the rivers were in class I, class II and class III. Sungai Selangor and Sungai Tengei had the best pH value because their pH was close to 7 and were in almost neutral condition.

![pH Chart]

**Figure 7.** pH result.

The way WQI works is that the higher the index of a particular river, the cleaner it is. As for the final classification, Sungai Selangor recorded the highest index at 56.67 whilst Sungai Bernam recorded the lowest WQI at 32.91. Nevertheless, Sungai Selangor is still classified as a polluted river because the minimum range of clean river starts from an index of 76.50. The WQI is important for river classification in accordance with Department of Environmental (DOE) guidelines. Low WQI readings showed that river pollution has occurred.
Based on the results shown in figure 8, it can be determined that all the rivers in Kuala Selangor and Sabak Bernam lies within class III and IV. It also shows that water from Sungai Selangor and Sungai Tengi can still be used for domestic consumption whilst water from other rivers are not recommended because they might cause irritation to people. The WQI assessment is depended on the six parameters that had been tested which are pH, SS, DO, BOD, COD, and AN. Any changes in one of the parameter values may affect the classification of the rivers.

In general, river pollution will occur when there is no proper control of land use activities along the river. This pollution will result in a reduction of the river water quality index. Causes of water pollution of the river can be divided into two which is point sources and non-point sources. The point source pollutant is waste that comes from a known source such as domestic waste, industrial, and municipalities. The non-point source pollutant is waste that comes from some unknown source and usually it happens when rainy day such as waste from livestock and agricultural areas.

Pollutants from domestic sewage are a major factor affecting the water quality index. They especially affect the ammoniacal nitrogen (AN) and chemical oxygen demand (COD) parameters and introduce bacteria from human faeces. Untreated domestic sewage when deposited into rivers will reduce the level of dissolved oxygen (DO) in the water and cause rivers to be black and foul-smelling. Domestic sewage can also be a source of various types of diseases caused by organisms and bacteria. Residential urban areas and located near rivers is the main cause of domestic sewage. This situation almost always happens because of the lack of a proper sewerage system.

Agricultural activities such as paddy, oil palm and rubber plantations, as well as the cultivation of many other crops are important agricultural activities for the Kuala Selangor and Sabak Bernam districts. They contribute to the economic growth of these areas and indirectly increase the economy of the Selangor State. Unfortunately, these agricultural activities have a direct effect on river water pollution. This happens due to the indiscriminate use of fertilizers, pesticides and other chemicals used to help plants to grow better and prevent pest attack [10]. Excessive use of fertilizers will flow into the river when rain occurs and cause pollution to rivers. It will affect the pH parameter whereby the value of pH will decrease and make the water river became acidic.

Fishing is another economic activity that brings income for the residents of Kuala Selangor and Sabak Bernam. Unfortunately, the use of boats by fishermen contributes to river pollution due to leaked and spilled oil from the boats. In addition, the fishermen use the river water to wash their boats and nets and which in turn will cause river water to become turbid. Increased turbidity of the river will indirectly increase the suspended solid.
4. Conclusion
The water quality assessment of the rivers in this study has indicated that all the rivers are generally polluted. The results have shown that all the rivers were classified into class III for Sungai Selangor and Sungai Tengi while other rivers were in class IV. Contamination in these areas might occur due to various land use activities such as agriculture and industries in the rivers’ catchments. As an example, any agricultural area will cause pollution due to the overflow of fertilizers and pesticides during rainy seasons into the river. The residential activities could also contribute to river pollution in the form of domestic waste or rubbish thrown indiscriminately into the rivers. Industrial waste is also one of the contributing factor to pollution of the river through the release of effluent that do not follow required standards. It can be concluded that systematic regulations and constant monitoring on economic developments in these area can help to decrease causes of river pollution in these catchments.

Acknowledgement
The authors would like to express special thanks to the Faculty of Civil Engineering, UiTM and School of Environmental Engineering, UNIMAP for all support rendered and valuable comments from all parties involved in this study are very much appreciated.

References
[1] Devane ML, Moriarty EM, Robson B, Lin S, Wood D, Webster-Brown J and Gilpin BJ 2019 Relationships between chemical and microbial faecal source tracking markers in urban river water and sediments during and post-discharge of human sewage Sci. Total Environ. 651 1588-604
[2] Sánchez-Mateos S, Pérez LV, Córdova Suárez MA and Cabrera-Riofrío DA 2020 Heavy metal contamination in the Cotopaxi and Tungurahua rivers: a health risk Environ. Earth Sci. 79 144
[3] Aktar W, Sengupta D and Chowdhury A 2009 Impact of pesticides use in agriculture: Their benefits and hazards Interdiscip. Toxicol. 2 1-12
[4] Kyllmar K, Carlsson C, Gustafson A, Ulén B and Johnsson H 2006 Nutrient discharge from small agricultural catchments in Sweden. Characterisation and trends Agric. Ecosyst. Environ. 115 15-26
[5] Tyagi S, Sharma B, Singh P and Dobhal, R 2013 Water quality assessment in terms of Water Quality Index J. Am. Water Resour. Assoc. 1 34-8
[6] Tripathi M and Singal SK 2019 Use of Principal Component Analysis for parameter selection for development of a novel Water Quality Index: A case study of river Ganga India Ecol. Indic. 96 (1) 430-6
[7] Bao JLK 2010 Water Quality Study and Its Relationship with High Tide and Low Tide at Kuantan River. Thesis for Universiti Malaysia Pahang
[8] APHA (American Public Health Association) 2005 Standard methods for the examination of water and wastewater 21st edn. (Washington DC: American Public Health Association)
[9] DOE 2008 Malaysia Environmental Quality Report 2008 (Kuala Lumpur: Department of Environment, Ministry of Natural Resources and Environment)
[10] Fulazzaky MA, Seong TW and Masirin MIM 2010 Assessment of water quality status for the Selangor river in Malaysia Water Air. Soil Pollut. 205 63