# ASSESSMENT OF WATER QUALITY INDICES FOR SELECTED MALAYSIAN RIVER

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FACULTY OF ENGINEERING
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KUALA LUMPUR

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**FACULTY OF ENGINEERING**
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**ASSESSMENT OF WATER QUALITY INDICES FOR SELECTED MALAYSIAN RIVER**

## ABSTRACT

Water quality is very crucial in ensuring the sustainability of human activities and survival. In Malaysia, river water quality is constantly monitored and evaluated by the water quality index (WQI) established by Department of Environment (DOE). Water quality index (WQI) is a quantitative indicator that can easily determine the pollution condition of river water. It utilises six critical water quality parameters to portray the river water quality. Weightage is assigned to each parameter to signify the influence of the parameter. The WQI is then quantified to obtain a numerical value, which represents the pollution level of the river water. The pollution status of the river water can also be categorised in various classes, depending on the intended use of the water body. Besides, the water quality index is also compared with other standards used in several countries. The advantages and disadvantages of each standards are determined. A new graphical method, "Eco-Heart Indicator" is proposed to serve as an alternative tool to portray the health of the river water. In this research, Selangor River is selected as the basis of study. The data obtained from Department of Environment (DOE) are used to plot Eco-Heart Indicator and compared with the Water Quality Index (WQI). The graphical representation of the water quality is hoped to become an easier communication tool to the public in addressing the awareness of river water status.

Keywords: Water Quality Index (WQI), Water Quality Standard, Water Quality Parameter, Water Quality Classification, Eco-Heart Indicator.

**PENILAIAN INDEX KUALITI AIR UNTUK SUNGAI TERTENTU DI MALAYSIA**

## ABSTRAK

Kualiti air adalah sangat penting bagi kemampanan kehidupan dan aktiviti manusia. Di Malaysia, kualiti air sungai adalah sentiasa dipantau dan dinilai oleh Indek Kualiti Air (IKA) yang digunakan oleh Jabatan Alam Sekitar (JAS). Indek Kualiti Air (IKA) merupakan satu penunjuk kuantitatif yang mampu menentukan status pencemaran air sungai. Indek ini menggunakan enam parameter kualiti air yang penting untuk menunjukkan kualiti air sungai. Pembahagian diberikan kepada setiap parameter untuk menunjukkan kepentingan parameter tersebut. IKA akan dikira supaya satu nilai ada didapatkan untuk mewakili status pencemaran air sungai tersebut. Status pencemaran air sungai juga dikategorikan dalam beberapa kelas yang berdasarkan penggunaan air tersebut. Selain itu, Index Kualiti Air juga dibandingkan dengan standard lain yang diamalkan oleh beberapa negara lain. Kebaikan dan keburukan standard-standard juga diketahui. Satu kaedah grafik baru, "*Eco-Heart Indicator*" dicadangkan untuk dijadikan satu kaedah alternatif bagi menunjukkan kebersihan air sungai. Sungai Selangor telah dipilih untuk dijadikan asas penyelidikan ini. Data yang diambil daripada Jabatan Alam Sekitar digunakan untuk melukis "*Eco-Heart Indicator*" dan dibandingkan dengan Indek Kualiti Air. Penyampaian informasi melalui kaedah grafik diharap dapat dijadikan kaedah yang lebih senang bag masyarakat umum untuk memahami status air sungai.

Kata-Kata Kunci: Kualiti Air Sungai, Standard Kualiti Air, Parameter Kualiti Air, Klasifikasi Kuailiti Air, *Eco-Heart Indicator.*

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| | | |
|---|---|---|
| AN | : | Ammoniacal Nitrogen |
| BOD | : | Biochemical Oxygen Demand |
| COD | : | Chemical Oxygen Demand |
| DO | : | Dissolved Oxygen |
| DOE | : | Department of Environment |
| SS | : | Suspended Solid |
| WQI | : | Water Quality Index |

# CHAPTER 1: INTRODUCTION

## 1.1 Introduction

Water resource is vital for the survival of human as well as to sustain the economic development of human activities. Malaysia is a country which has a vast supply of water resources, mainly surface water (river water) and underground water. River water, as the primary water resource in Malaysia, contributes up to 97% of the raw water supply for irrigations in agricultural activities, domestic and industrial uses (Perumal, 2017).

However, the quality of river water has deteriorated drastically. The reduction in water quality is contributed by both the natural processes and man-made pollutions. Natural phenomena, such as runoff and erosion, have increased the solid loadings which are then settled down as sediment in the river beds. Heavy sedimentation can harm the entire river ecosystems due to the reduced penetration of sunlight to the river beds, as well as, excessive oxygen consumption by microorganisms in digesting the organic loadings.

Man-made pollutions are mainly caused by rapid population growth, industrial activities and unplanned urbanisation. By having rapid population growth, the water consumption increases significantly and the discharge of wastewater increases as well. Besides, the growing industrial activities cause water pollution in various levels, including physical, chemical and biological pollutions. Unplanned urbanisation, on the other hand, can result in improper sewage discharge and surface runoff (Derek, M., 2015).

Therefore, the need of identifying and monitoring the actual condition of river water has become increasingly important to ensure that the supply and quality of water resources are still within the acceptable limits.

The quality of river water is continuously monitored throughout the year to gather sufficient data for each parameter. A useful indicator, Water Quality Index (WQI) has been established to give an overview of how the water quality changes with the activities carried out upstream by evaluating the measurements obtained for each parameter. The sources and fates of contaminants can be traced and identified accordingly by mapping the measured values to the belonged range proposed by the governing body. The water quality will then be categorised into various classes, so that the intended use of the water body can be identified. In case of any parameter having measured value that exceeds the suggested range, necessary preventive measures shall be taken promptly to avoid the water quality from further deteriorating.

However, the public is not able to understand the significance of the Water Quality Index (WQI) due to the involvement of complicated mathematical calculations coupled with conditions of each parameter.

This research intends to guide the relevance of water quality parameters in justifying the actual water quality status. The comparisons between Malaysia's water quality standard and the standards applied in other countries are compared to provide a clear overview of water studies.

Besides, the research attempts to propose a new method, "Eco-Heart Indicator", which is a graphical representation, to convey the water quality in a more effective manner to the public. The graphical method also shows the status of all the six crucial parameters for a river water sample, instead of lumping the parameters into one figure that hinders the public in understanding the potential risks caused by the outlier(s) of any parameter.

## 1.2 Problem Statement

Water Quality Index (WQI) outlined by the Department of Environment of Malaysia (DOE) appears to be complicated for the society which comprises various educational backgrounds to understand. The complex mathematical calculations and conditions involved appear to be obstacles for the public to understand the actual situation of river water. There is a need for the governing department to derive a simpler method that assists the public in understanding and creating the awareness of water quality.

Apart from that, WQI shows the river condition by lumping all the contributions of pollutants into one numerical value. Such formulation is not user-friendly for the researchers, governing body and laymen to quickly identify the parameter which goes beyond the acceptable limit. Hence, it is better to have a tool that allows the people to get the overall picture of the river water conditions in a fast and simple manner.

## 1.3 Objectives of Research

This research aims to discuss the potential of improving the current Water Quality Index (WQI) adopted by Malaysia's Department of Environment (DOE), so that the river water conditions can be identified faster and better.

The objectives of this research are stated as shown below:

- To compare Malaysia's Water Quality Index (WQI) with the standards adopted by several selected countries in defining water quality.
- To implement the use of a graphical method, "Eco-Heart Indicator" in real situations by selecting a Malaysian river as study basis.
- To evaluate the significance of "Eco-Heart Indicator" over Water Quality Index (WQI) for the public to understand the water quality better. A random survey is carried out to understand the public impression between Water Quality Index and Eco-Heart Indicator.

## 1.4 Scope of Study

In this study, Selangor River is selected as the basis of the research. The parameters involved in the Water Quality Index (WQI), namely pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (AN), suspended solid (SS) and dissolved oxygen (DO), are selected as the reference parameters in the new "Eco-Heart Indicator".

The data of the parameters are retrieved from the database of Department of Environment. Four water monitoring stations along the Selangor River are selected as the basis of study. The range of data obtained covers five samplings (January, March, July, September and November) in Year 2017.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Development of Water Quality Index (WQI)

Water Quality Index (WQI) is an indicator used to assess the quality of a water body in a quantitative manner. It combines the sub-index contribution from the parameters concerned to generate a single value that represents the actual condition of the water studied.

A set of variables are selected to be analysed and the results obtained are converted into the same scale, which will be assigned with the weightages according to their importance. The WQI will be deduced by weighted aggregation or classification methods (Feng, Y. L., et al., 2015).

### 2.1.1 Qualitative Studies in Determining the Water Quality Parameters

Water quality criteria are developed based on the effects of water pollutants to a particular application of water. Depending on the applications of the water source, water quality is set at the minimum acceptable concentration in order to meet the minimum requirement for the specific activity.

Most of the criteria set are based on the quality of raw water intended to be used for drinking water supply, agricultural irrigation, recreational activities or as a habitat for living organisms. However, the requirement on water quality vary with the protection and maintenance required for different uses.

A pH range between 6.5 and 9.0 has been identified to be the optimum range for the survival of aquatic species (Alabaster & Lloyd, 1982).

Dissolved oxygen (DO), when at low concentrations, will increase the toxicity of certain dissolved metals, like copper, lead and zinc, resulting in adverse biological effects to the aquatic life. The minimum dissolved oxygen concentration shall range between 5.0

to 9.5 mg/L, depending on the water temperature. In general, the minimum dissolved oxygen concentration shall range between 5.0 and 6.0 mg/L for warm water, while between 6.5 and 9.5 mg/L for cold water (EPA, 1986).

In terms of Biochemical Oxygen Demand (BOD), according to the quality of freshwater outlined by European Union (EU), the BOD of salmonid water shall be less than 3.0 mg O2/L for salmonid water, while less than 6.0 mg O2/L for cyprinid water (EU, 1978). The standards were derived from the researches done for protection of aquatic life.

Besides, industrial activities will impose water quality requirement, ranging from raw water to demineralized water, depending on the process involved.

As an example, industrial boiler will require very clean water to be used to avoid unwanted situations such as fouling and corrosion. Hence, only demineralized or distilled water to be used as boiler feed water. Condensate recovered from steam applications are not permitted. Besides, it must be treated with trisodium phosphate, so that a thin phosphate film can be formed on the pipe surface during start-up of the boiler system. This thin film will protect the pipes and boiler internals from general corrosion and oxygen pitting at high temperature. Therefore, high pH of water is required to promote the formation of the phosphate film which favours the alkaline conditions. Moreover, the addition of trisodium phosphate can increase the conductivity of water, so that the low water level electrode can function well.

Apart from that, the boiler feed water shall be free from any suspended solids to avoid contamination and fouling situations. Heavy metals such as magnesium and calcium shall be at its minimal concentration such that it will give a very low hardness level (Typically below 0.01 mval/kg), so that scaling can be avoided (Alfa Laval, 2013).

### 2.1.2 Horton's Water Quality Index

Horton's Water Quality Index was the first water quality index developed in year 1965 (Horton, 1965). The index aimed to categorise the water quality by selecting several water quality parameters and applying certain weightage (1 to 4) on each parameter. An aggregated function was then derived to imply the quality of the water sample obtained.

Ten fundamental water quality parameters, such as Dissolved Oxygen (DO), specific conductance, pH, alkalinity, chloride and coliforms, were chosen. Each water quality parameter served as an indicator to represent certain measurements. As an example, specific conductance was used to evaluate the amount of Total Dissolved Solids (TDS). However, the presence of toxic chemicals was not considered.

### 2.1.3 United States National Sanitation Foundation Water Quality Index (NSF WQI)

United States National Sanitation Foundation Water Quality Index (NSF WQI) is the revised version of Horton's Water Quality Index by integrating with Delphi technique. In Delphi's study, up to 35 water quality parameters were surveyed by a panel of 142 water quality scientists and nine crucial parameters were chosen for the index after three rounds of iterative survey (Brown, R. M., et al., 1970). The water quality index is then widely applied in many countries to compare the quality of water body with source water as benchmark.

The water quality index determined the quality of river water based on nine parameters, which are temperature, pH, turbidity, total phosphate (PO4 2-), total nitrate (NO3 -), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and faecal coliform concentration (Mirzaei, M., Nazari, A., Yari, A., 2005).

However, there are some drawbacks associated with this WQI. The WQI is rigid in structure with limited choices of parameters considered. The rating curves applied are subjective in nature and will show different results with different opinions. In addition, the intended use of the water body is not considered and is applicable for general water quality assessment (Mehrnoosh, A., et al., 2015).

Therefore, a more refined water index quality is adopted in order to include the type of water usage. As an example, Drinking Water Quality Index (DWQI) is applied to describe the conditions for domestic water supply. The DWQI gathers the expert opinions to simplify the calculations, while giving it the flexibility to select the target parameters and evaluation requirement (Ramesh, S., et al., 2010).

### 2.1.4 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) compares the measured water quality parameters with the guidelines as benchmarks to characterise quality of drinking water. This index does not require the use of rating curves, which is subjective according to expert opinions.

In this water quality index, the number of measured parameters that do not meet the standards will be identified. Besides, the frequency and the deviation of the outliers of the measured parameters will be determined. The index will then generate a scalar, ranging from 0 (worst scenario) to 100 (best scenario), which will then divide the numbers into five descriptive classes to address the water quality.

However, the input parameters are not awarded with weightages, which will result in equal influence by each parameter. Besides, the water quality index may appear to be bias as the reference guidelines may have different measurement frequencies in other studies (Hurley, T., et al., 2012).

### 2.1.5 Oregon's Water Quality Index (OWQI)

In Oregon's Water Quality Index (OWQI), eight water quality parameters, including temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (AN), total phosphates, total solids and faecal coliform, are analysed and studied (Department of Environmental Quality, 2003).

The results for each parameter will be converted into dimensionless sub-index values to remove the effect of measuring units. A scalar of 10 (worst scenario) to 100 (best scenario) will be awarded to the sub-index values, which will then be calculated to obtain a single OWQI value to evaluate the water quality (Cude, 2002).

### 2.1.6 United Kingdom's The Surface Waters (River Ecosystem) (Classification) Regulations 1994

Under this regulation, the National Rivers Authority (NRA) has established a list of criteria in which the quality of river water shall meet the minimum level of requirements for the five classes of river ecosystems.

Seven water quality parameters, which include pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), total ammonia, unionised ammonia, hardness, dissolved copper and total zinc, are analysed and evaluated (National Rivers Authority, 1994).

However, only physical and chemical properties of the water body are considered. There is no biological characteristic being taken into account in analysis and evaluation.

### 2.1.7 Japan's Environmental Quality Standards for Water Pollution 2003

Japan had established Environmental Quality Standard (EQS) in year 1997 to provide standard values for 26 substances concerning human health effects, and guideline values for 27 monitoring substances.

In general, river water is classified into five different classes based on water use by comparing the measured parameters with the standard values. Five water quality parameters, which are pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Suspended Solids (SS) and total coliform, are analysed and evaluated. In year 2003, total zinc was included as one of the standard parameters to conserve aquatic life (Ministry of the Environment, 2003).

The disadvantage of this standard is having too many parameters to be monitored. This will cost high operating expenditures at the water monitoring stations due to large number of analysis to be carried out. In addition, not all substances mentioned will appear in each water monitoring station. This will cause extra workload in measuring substances that are not existing in the water sample.

### 2.1.8 Singapore's National Sanitation Foundation Water Quality Index (NSF WQI)

The Singapore's National Sanitation Foundation Water Quality Index (NSF WQI) is basically deduced based on the United States National Sanitation Foundation Water Quality Index (NSF WQI). It includes the contribution factors from both physiochemical and biological properties of river water sample.

Nine water quality parameters, which comprises Dissolved Oxygen (DO), Fecal Coliform, pH, Biochemical Oxygen Demand (BOD), Nitrates, Phosphates, Temperature, Turbidity and Total Solids, are assigned with their respective weightages based on consensus by local researchers.

Each parameter almost contributes similar influence to the water quality index, with dissolved oxygen being the most influential parameter (17%), while both turbidity and total solids being the least influential parameter (8%) (Kim, N. I., 2017).

In this index, biological property of river water sample (fecal coliform) is considered as part of the benchmark for river water, due to its significance towards health hazard, especially when the water body is meant to serve as drinking water supply.

## 2.2 Department of Environment Water Quality Index (DOE-WQI) in Malaysia

In Malaysia, the quality of river water is determined based on the Department of Environment–Water Quality Index (DOE-WQI). The Department of Environment (DOE) has been consistently monitoring the rivers in Malaysia since year 1978. There are as much as 1064 manual-operated water station in 143 river basins, as well as a total of 15 automatic water stations for continuous monitoring in critical rivers (Department of Environment, 2017). By having scheduled monitoring, the department is able to establish a database for river water quality. The database also serves as an indicator to identify the potential pollution source.

Water Quality Index (WQI) was introduced by Malaysia's Department of Environment (DOE) since year 1989 to provide a general assessment for the river water quality (Yuk Feng, et al., 2015). In year 2016, out of a total of 477 rivers monitored, there were about 47% (224) rivers found to be in clean condition, while 43% (207) rivers were moderately polluted, and 10% (46) rivers were polluted (Department of Environment, 2016).

### 2.2.1 Parameters Used in DOE-WQI

DOE-WQI is a standard set of parameters used to evaluate the quality of river water. It consists of six critical parameters, namely pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), Suspended Solid (SS) and Dissolved Oxygen (DO). The functions of each parameter are listed down in Table 2.1.

**Table 2.1: Significance of each parameter listed in DOE-WQI**

| Parameter | Functional Description |
|---|---|
| pH | Measure of contamination and acidity. |
| Biochemical Oxygen Demand (BOD) | Determination of oxygen consumption rate by biological organisms in water. |
| Chemical Oxygen Demand (COD) | Identification of the amount of organic pollutants in water. |
| Ammoniacal Nitrogen (AN) | Indication of nitrogen-based nutrient present in water. |
| Suspended Solid (SS) | Presence of tiny solid suspensions as colloids in water. |
| Dissolved Oxygen (DO) | Amount of oxygen dissolved in water. |

pH serves as an indicator for the salinity level in water measured between the scale of 0 and 14. pH of 7 is considered as neutral. The pH value less than 7 shows that the water body is acidic in nature, while the pH value above 7 shows that the water body is alkaline in nature. However, the optimum pH for river water is around 7.4 (The Crooked River Project, 1995). Low pH can harm the aquatic species living in the water body, as well as promote the leaching of heavy metals. On the other hand, calcium and magnesium can be washed away by water with high pH value, resulting in nutrient deficiencies in plant growth.

Biochemical Oxygen Demand (BOD) is an important parameter in determining the amount of organic loading in the water body. Main contributor of BOD is untreated effluent discharged from agricultural and industrial activities. It measures the amount of dissolved oxygen consumed to break down or digest the organic materials present in the water sample by aerobic microbial organisms over a specific time (typically five days). Higher BOD shows high rate of oxygen depletion by microorganisms. This will result in high fatality of aquatic life due to low dissolved oxygen content (APHA, 1992).

Similar to BOD, Chemical Oxygen Demand (COD) provides an indication of the amount of oxidisable organic substances present in the water sample under acidic conditions. With high COD value, the dissolved oxygen content will reduce significantly, which will pose harm to the aquatic life. However, unlike BOD, COD can be measured within a shorter period (about two hours) or even in real-time by using UV-VIS absorbance technology (Clair, N. S., et al., 2003).

Ammoniacal Nitrogen (AN) shows the presence of nitrogen element in the water body, which is a fundamental nutrient for plant growth. High nitrogen content is mainly due to the continuous discharge of domestic sewage into the water body. Excessive nitrogen present in the water will lead to eutrophication (algae bloom) and eventually degrading the water quality. Besides, it will also pose health threat towards human, such as methemoglobinemia that causes suffocation for the infants (Chris, 2004).

Suspended Solids (SS) are solid particles which have a size bigger than 2 microns found in the water sample (Fundamentals of Environmental Measurements, 2014). Most of the suspended solids are inorganic materials. Suspended solids are the major contributor to reduced water clarity. The more solids present in the water body, the less clear the water is. The solids will prevent the sunlight from reaching the river beds, hindering the photosynthesis process carried by the aquatic plants living at the bed of the river. In Malaysia, high suspended solids present in water body is caused by massive land clearance activities carried out upstream.

Dissolved Oxygen (DO) is a crucial element in the survival of aquatic life. With low DO content, aquatic species can hardly survive. High DO content will cause rapid growth of aquatic plants, such as algae, and result in eutrophication phenomena (algae bloom).

Throughout the years, the critical parameters identified to be affecting the quality of river water significantly are Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (AN) and Suspended Solid (SS) (Department of Environment, 2008).

### 2.2.2 Classifications of DOE-WQI for River Water based on Measurement of Parameter

The measurements of the six parameters mentioned above can be done either in-situ or by sending the collected sample to laboratory for analysis (USGS, 2015). There are two means to evaluate the quality of river water, which are either grouping the water quality into various classes with specific measuring ranges for the six parameters, or calculating the water quality index based on the WQI score to evaluate the water pollution status.

Based on the six parameters listed in DOE-WQI, the quality of river water is categorised by the measurable ranges of the parameters in milligram per litre (mg/L) unit, with an exemption where pH is dimensionless in nature. There are five classes of water quality based on National Water Quality Standards in Malaysia with the specifications as stated in

Table 2.2 (Global Environment Centre, 2002).

**Table 2.2: Classifications of DOE-WQI for Malaysian River Water**

| Parameter | Unit | DOE–Water Quality Index Classification | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| pH | – | > 7 | 6 – 7 | 5 – 6 | < 5 | < 5 |
| $BOD_5$ | mg/L | < 1 | 1 – 3 | 3 – 6 | 6 – 12 | > 12 |
| COD | mg/L | < 10 | 10 – 25 | 25 – 50 | 50 – 100 | > 100 |
| AN | mg/L | < 0.1 | 0.1 – 0.3 | 0.3 – 0.9 | 0.9 – 2.7 | > 2.7 |
| SS | mg/L | < 25 | 25 – 50 | 50 – 150 | 150 – 300 | > 300 |
| DO | mg/L | > 7 | 5 – 7 | 3 – 5 | 1 – 3 | < 1 |
| DOE-WQI | – | > 92.7 | 76.5 – 92.7 | 51.9 – 76.5 | 31.0 – 51.9 | < 31.0 |

### 2.2.3 Classification of Water Quality based on Intended Uses of River Water

Different classes of water quality based on National Water Quality Standards in Malaysia are meant for different applications as stated in Table 2.3 (Water Environment Partnership in Asia, 2006).

**Table 2.3: Uses of Various Classes of Water**

| Class of Water | Intended Uses |
|---|---|
| Class I | Conservation of natural environment.<br>Water Supply: No treatment is required.<br>Fishery: Water supply for very sensitive aquatic species. |
| Class IIA<br><br>Class IIB | Water Supply: Conventional treatment is required.<br>Fishery: Water supply for sensitive aquatic species.<br><br>Recreational use with body contact allowed. |
| Class III | Water Supply: Extensive treatment is required.<br>Fishery: Water supply for common aquatic species and as drinking source for livestock. |
| Class IV | For irrigation purpose in agricultural industry. |
| Class V | None of the above. |

### 2.2.4 Water Quality Index (WQI) Calculation

Apart from that, the water quality index can be presented based on the condition of river pollution. The six parameters are awarded with the weightage in an established mathematical equation to achieve the WQI score (Department of Environment, 2017).

$$\mathrm{WQI} = 0.12[\mathrm{pH}] + 0.19[BOD_5] + 0.16[\mathrm{COD}] + 0.15[\mathrm{AN}] + 0.16[\mathrm{SS}] + 0.22[\mathrm{DO}]$$

where:

[pH] = Sub-index of pH

[$BOD_5$] = Sub-index of $BOD_5$

[COD] = Sub-index of COD

[AN] = Sub-index of AN

[SS] = Sub-index of SS

[DO] = Sub-index of DO

From the WQI equation, Dissolved Oxygen (DO) is awarded the highest weightage (22%), followed by $BOD_5$ (19%), COD (16%), SS (16%), AN (15%) and lastly pH (12%). This shows that dissolved oxygen gives the biggest influence to the water quality. This is because dissolved oxygen affects directly to the survival of aquatic species (Janet, R. B., et al., 2016).

### 2.2.5 Water Quality Index based on River Pollution Status

With the WQI score obtained, the pollution status of the river can be identified by referring to the WQI range as stated in Table 2.4.

**Table 2.4: Classification of River's Pollution Status based on WQI**

| Parameter | Pollution Status of River (Score) | | |
|---|---|---|---|
| | Clean | Moderately Polluted | Polluted |
| $BOD_5$ | 91 – 100 | 80 – 90 | 0 – 79 |
| AN | 92 – 100 | 71 – 91 | 0 – 70 |
| SS | 76 – 100 | 70 – 75 | 0 – 69 |
| DOE – WQI | 81 – 100 | 60 – 80 | 0 – 59 |

The river with the WQI score of 81 and above is considered clean, while the river with the WQI score of 60 to 80 is considered moderately polluted and the score below 60 is polluted. In year 2006, out of the 1064 river monitoring stations, only around 60% (638) were found to be clean, 35% (376) were moderately polluted and 5% (50) were polluted (Kementerian Sumber Asli dan Alam Sekitar, 2007).

## 2.3 Comparisons between Malaysia’s DOE-WQI and Other Standards

Comparisons are made in Table 2.5 between Malaysia’s DOE-WQI and other standards used, such as the United States’ NSFWQI, Canada’s CCME WQI, Oregon’s OWQI, United Kingdom’s The Surface Waters (River Ecosystem) (Classification) Regulations 1994, Japan’s Environmental Quality Standards for Water Pollution 2003 and Singapore’s National Sanitation Foundation Water Quality Index (NSF WQI).

**Table 2.5: Comparisons between Malaysia's WQI and standards used by other countries**

| Water Quality Index (WQI) | Advantages | Disadvantages |
|---|---|---|
| Department of Environment Water Quality Index (DOE-WQI) | • Common water quality parameters are included.<br>• Weightage is given to each parameter based on the influence from database. | • No biological parameter is adopted.<br>• The applications of water are not considered. |
| United States National Sanitation Foundation Water Quality Index (NSFWQI) | • All the three aspects, physical, chemical and biological, are considered.<br>• Weightage is given to each parameter to show the importance. | • Limited choices of parameters are used.<br>• Subjective rating curves are used.<br>• Comparing with other water bodies.<br>• Water usage is not considered. |

| | | |
|---|---|---|
| Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) | • Relates the measured parameters to the guidelines.<br>• Outliers are identified, instead of assigning weightage to each parameter. | • No weightage is given to the parameter.<br>• Reference guidelines may have different measuring frequencies. |
| Oregon's Water Quality Index (OWQI) | • Covers the relationships between the parameters measured.<br>• Weightage given is based on the past experience from database. | • The reference weightage is based on data from specific area.<br>• The rating given is subjective to expert opinions.<br>• The intended uses of water are not considered. |
| United Kingdom's The Surface Waters (River Ecosystem) (Classification) Regulations 1994 | • Minimum guidelines are given.<br>• Includes the influence of dissolved metals. | • No biological-based water quality parameter is taken into consideration. |
| Japan's Environmental Quality Standards for Water Pollution 2003 | • Provides standard values and guideline values for a list of substances. | • Expensive operating expenditures due to too many analysis to be carried out. |

| | | |
|---|---|---|
| | • Constantly revises the list of substances with newly identified pollutants. | • Not all parameters are necessary to be analysed. |
| Singapore's National Sanitation Foundation Water Quality Index (NSF WQI) | • All the three aspects, physical, chemical and biological, are considered.<br>• Weightage is given to each parameter to show the importance. | • The parameters are decided based on local studies.<br>• The index focuses more on drinking water use. |

From Table 2.5, it is deduced that Malaysia's Water Quality Index focuses more on physiochemical properties of water body. Biological properties of water body are not considered in defining water quality. Countries like United States of America, Japan and Singapore are considering biological properties, such as faecal coliform concentration in water body, to exhibit the importance of health hazard, particularly when the water supply is meant for drinking purpose. The higher the concentration of coliform bacteria, the higher the chance of the water body to be contaminated with the pathogens.

Apart from that, other physical parameters, such as heavy metals and specific chemicals, are not included in the Water Quality Index (WQI). The water quality may be seriously impaired by other constituents that are not considered in the index. Certain industries may discharge heavy metals and certain chemicals into the river during their productions. As an example, mining activities tend to discharge huge quantity of heavy metals, such as mercury and lead, into the river streams. This will bring devastative effects to human and livestock through contaminated drinking water supply (Smitha, A. D., Shivashankar, P., 2013).

Besides, pesticide manufacturing plants may release effluents with high chemical content to the rivers, resulting in health hazards, such as damages to nervous systems and organs. Hence, the representation of water quality shall include the measurement of heavy metals and chemicals according to the needs by referring to the effluents discharged registered by the factories with the Department of Environment (DOE).

## 2.4 Development of Eco-Heart Indicator

The implementation of Eco-Heart Indicator in Selangor River was first done by Abu Bakar et al. by utilizing the data obtained from the work by Fulazzaky et al. using different set of water quality parameters, which are Temperature, Turbidity, Dissolved Oxygen, Nitrate content, Mineral Micro-Pollutant (Zinc), and Microorganisms (Fulazzaky, M. A., et al., 2010). Fulazzaky's work targeted on the water pollution effects caused by human activities, such as wastewater discharged from industries, wet markets and poultry farms.

Eco-Heart Indicator was then tested by Abu Bakar et al. by using the water quality parameters as outlined in the Water Quality Index (WQI) of Department of Environment (DOE) (Abu Bakar, A., et al, 2016). This effort was made to compare the Eco-Heart Indicator with the Water Quality Index to provide an alternative outlook for river water quality. Similar graph patterns can be observed with healthy river water resembles a perfect heart-shape, while polluted river water shows distorted shape.

Mohd Khairol Hilmi further implemented the use of Eco-Heart Indicator for water quality assessment in two rivers, Sungai Batang Kali and Sungai Kerling (Mat Lazim, M. K. H., 2017). The conditions of river water can be identified directly with the deviations observed for the parameters that cause the distortion of the heart-shape.

# CHAPTER 3: METHODOLOGY

In this research, the methodology used involves the following steps:

a) Data Gathering of Water Quality Parameters

A series of water quality data is required in order to plot the newly proposed Eco-Heart Indicator. The data are retrieved from the Department of Environment (DOE) of Malaysia. The graphs (Eco-Heart Indicator) plotted based on real data will help the public in understanding the significance of the parameters involved.

b) Calculation of Water Quality Index (WQI)

Water Quality Index (WQI) is calculated as per Department of Environment's (DOE) guidelines. The conditions and equations for each sub-index of the water quality parameter are retrieved from the Department of Environment's (DOE) website.

c) Plotting of Eco-Heart Indicator

Eco-Heart Indicator is plotted for each water class as outlined by the Department of Environment (DOE) by using AutoCAD software. The benchmark of each water class is presented in the newly proposed Eco-Heart Indicator to provide an overview of the water quality at various conditions.

d) Evaluation of Significance of Eco-Heart Indicator

The effects of using Eco-Heart Indicator are evaluated by comparing with the Water Quality Index (WQI) calculated for the data obtained from the Department of Environment (DOE). A random survey as shown in Appendix was also carried out to a total of 30 respondents to understand the public impression towards Eco-Heart Indicator.

## 3.1 Data Gathering of Water Quality Parameters

Selangor River is selected as the study basis for this research. There are a number of water monitoring stations operated by Malaysia's Department of Environment (DOE) along the river. Water samplings are collected and the water quality parameters are analysed from time to time.

In this research, four locations of water monitoring stations are randomly selected, which cover the upstream, mid-stream and downstream of the river.

Five sampling dates were chosen to cover January, March, July, September and November of Year 2017 with two-month interval.

The readings of water quality parameters, which are pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), Suspended Solid (SS) and Dissolved Oxygen (DO), are obtained from the database of Malaysia's Department of Environment (DOE) based on the four locations of sampling at water monitoring stations along Selangor River.

### 3.1.1 Study Location

The main stream of Selangor River has an approximate length of 110km (LUAS, 2008). The locations of four selected water monitoring stations along Selangor River are shown in **Error! Reference source not found.** and summarised in Table 3.1 below.

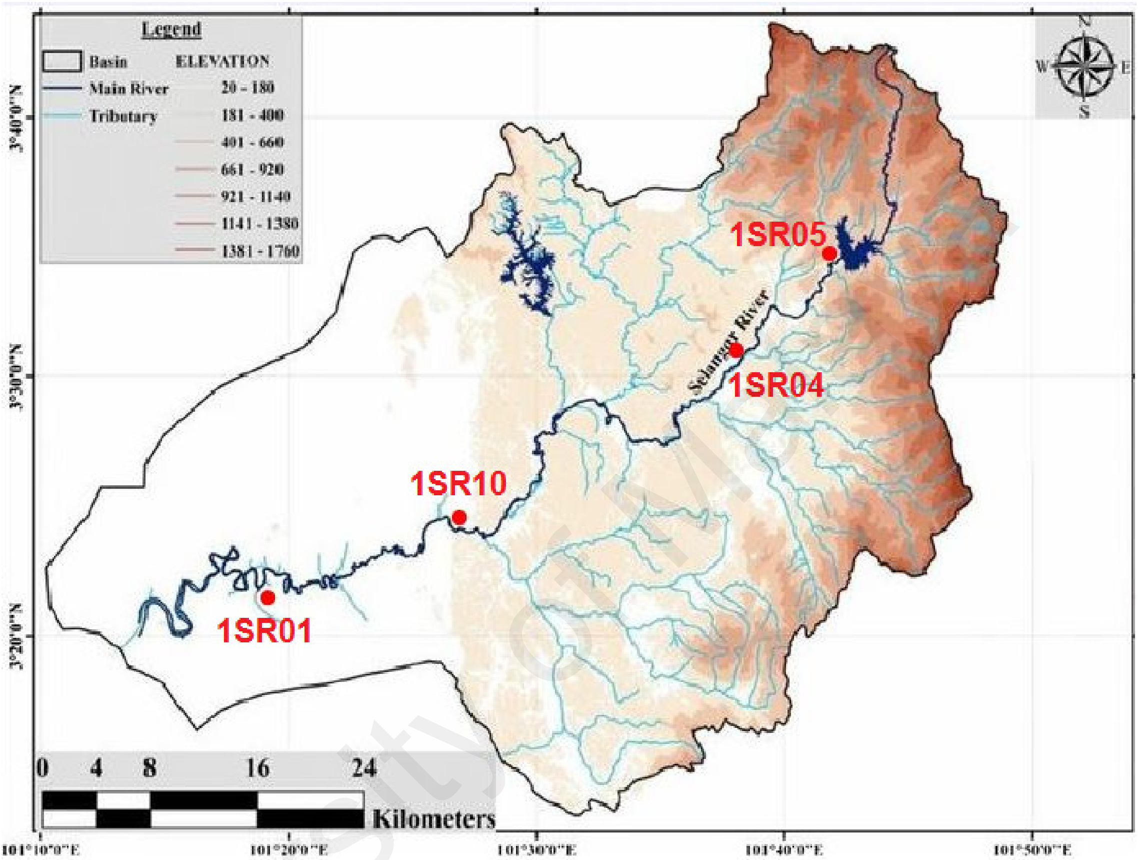


**Figure 3.1: Locations of Selected Water Monitoring Stations along Selangor River (Mohammed, S. and Faridah, O., 2014)**

**Table 3.1: Locations of Selected Water Monitoring Stations along Selangor River**

| Station's Location | Station Number | Latitude | Longitude |
|---|---|---|---|
| Kampung Kelip-Kelip | 1SR01 | N 03° 21.446' | E 101° 18.057' |
| Pekan Rasa | 1SR04 | N 03° 30.445' | E 101° 38.023' |
| Bt 7, Jalan Bukit Fraser | 1SR05 | N 03° 34.370' | E 101° 42.046' |
| Nearby PUAS Rantau Panjang | 1SR10 | N 03° 24.103' | E 101° 26.500' |

From **Error! Reference source not found.** (Daria, M., 2006), Station 1SR05, which is located upstream of Selangor River, is a water monitoring station located right after the Selangor Dam. The water samples collected are showing the properties of the water flowing out of the dam. Station 1SR04 and Station 1SR10 are considered as the mid-stream water monitoring stations. Station 1SR04 is located in villages near a small industrial area, while Station 1SR10 is situated downstream of a water treatment station to supply raw water to the Klang Valley. Lastly, Station 1SR01 is the downstream water monitoring station, which is based near a tourism spot famous of fireflies' appearance.

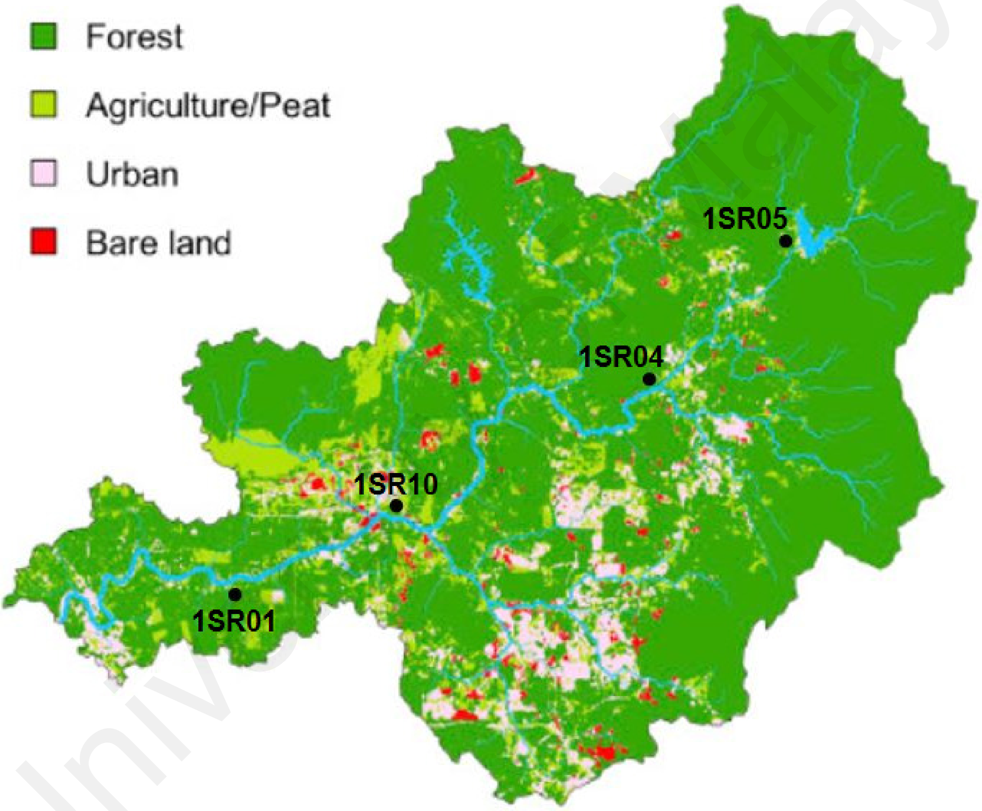


**Figure 3.2: Land Use of Selangor River Basin**

From Figure 3.2 (Nobumitsu, S. et al., 2017), it can be observed that Station 1SR05 experiences minimum land use with a water dam located upstream. For both Station 1SR04 and Station 1SR10, the branch streams that emerge into the main stream of Selangor River experience some agricultural activities and urban development. Station 1SR10, on the other hand, gathers all the pollution loadings from extensive agricultural activities, urban development, as well as rainwater erosions of bare lands.

## 3.2 Calculation of Water Quality Index (WQI)

As outlined by the Malaysia's Department of Environment (DOE), the water quality index (WQI) is calculated based on the mathematical equation as stated below:

$$\mathrm{WQI} = 0.12[\mathrm{pH}] + 0.19[BOD_5] + 0.16[\mathrm{COD}] + 0.15[\mathrm{AN}] + 0.16[\mathrm{SS}] + 0.22[\mathrm{DO}]$$

where:

[pH] = Sub-index of pH

[$BOD_5$] = Sub-index of BOD5

[COD] = Sub-index of COD

[AN] = Sub-index of AN

[SS] = Sub-index of SS

[DO] = Sub-index of DO

**Table 3.2: Sub-Index of pH**

| Conditions | Sub-Index of pH, [pH] (Unit: Unitless) |
|---|---|
| If pH < 5.5 | $[pH] = 17.2 - 17.2pH + 5.02pH^2$ |
| If 5.5 ≤ pH < 7 | $[pH] = -242 + 95.5pH - 6.67pH^2$ |
| If 7 ≤ pH < 8.75 | $[pH] = -181 + 82.4pH - 6.05pH^2$ |
| If pH ≥ 8.75 | $[pH] = 536 - 77pH + 2.76pH^2$ |

**Table 3.3: Sub-Index of BOD**

| Conditions | Sub-Index of $BOD_5$, [$BOD_5$] (Unit: mg/L) |
|---|---|
| If $BOD_5 \leq 5$ | $[BOD_5] = 100.4 - 4.23BOD_5$ |
| If $BOD_5 > 5$ | $[BOD_5] = 108e^{-0.055BOD_5} - 0.1BOD_5$ |

**Table 3.4: Sub-Index of COD**

| Conditions | Sub-Index of COD, [COD] (Unit: mg/L) |
|---|---|
| If COD ≤ 20 | $[COD] = -1.33COD + 99.1$ |
| If COD > 20 | $[COD] = 103e^{-0.0157COD} - 0.04COD$ |

**Table 3.5: Sub-Index of AN**

| Conditions | Sub-Index of AN, [AN] (Unit: mg/L) |
|---|---|
| If AN $\leq$ 0.3 | $[AN] = 100.5 - 105AN$ |
| If 0.3 < AN < 4 | $[AN] = 94e^{-0.573AN} - 5\|AN - 2\|$ |
| If AN $\geq$ 4 | $[AN] = 0$ |

**Table 3.6: Sub-Index of SS**

| Conditions | Sub-Index of SS, [SS] (Unit: mg/L) |
|---|---|
| If SS $\leq$ 100 | $[SS] = 97.5e^{-0.00676SS} + 0.05SS$ |
| If 100 < SS < 1000 | $[SS] = 71e^{-0.0016SS} - 0.015SS$ |
| If SS $\geq$ 1000 | $[SS] = 0$ |

**Table 3.7: Sub-Index of DO**

| Conditions | Sub-Index of DO, [DO] (Unit: %) |
|---|---|
| If DO $\leq$ 8% | $[DO] = 0$ |
| If 8% < DO < 92% | $[DO] = -0.395 + 0.03DO^2 - 0.0002DO^3$ |
| If DO $\geq$ 92% | $[DO] = 100$ |

### 3.3 Plotting of Eco-Heart Indicator

Eco-Heart Indicator is developed based on the six basic water quality parameters involved in Water Quality Index (WQI). The axes of the graph consist of pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), Suspended Solids (SS) and Dissolved Oxygen (DO). The template of Eco-Heart Indicator used in this research is plotted by using AutoCAD software as shown in Figure 3.3 below (Abu Bakar, A., et al, 2016).

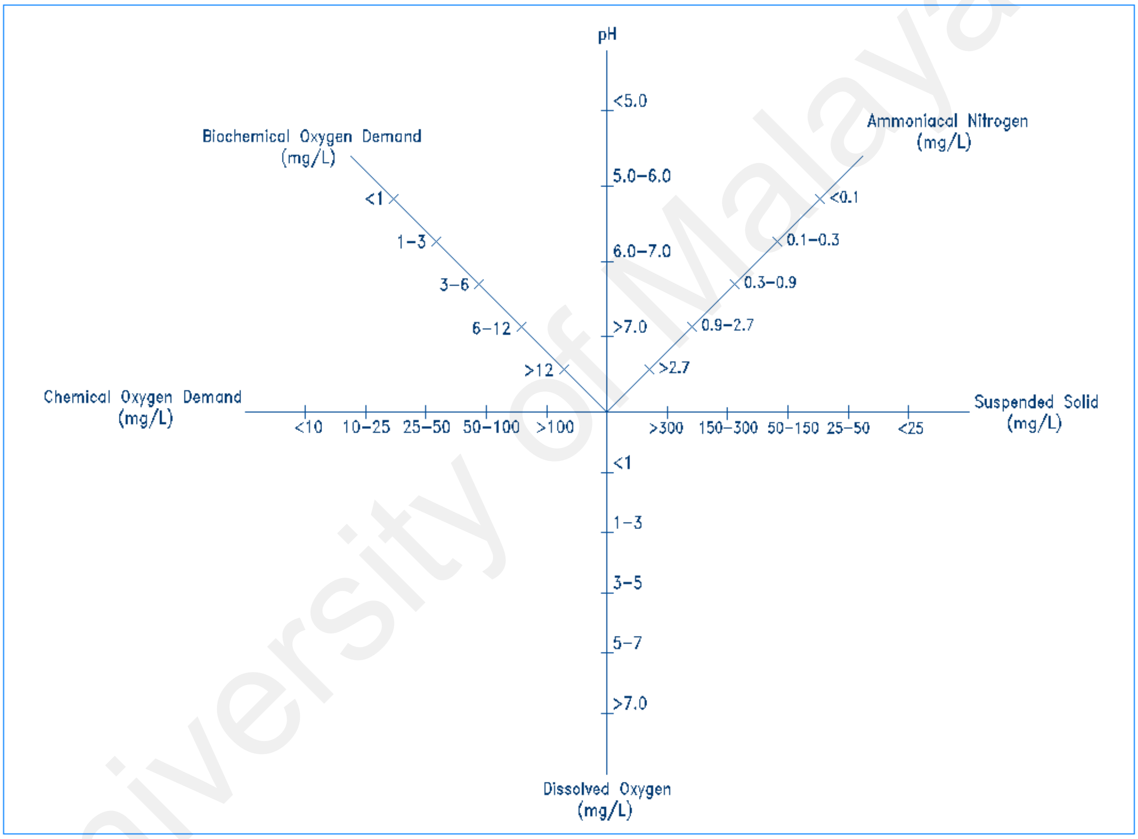


**Figure 3.3: Template of Eco-Heart Indicator based on Abu Bakar, A., et al, 2016**

Eco-Heart Indicator will show a perfect heart-shape graph for the water sample of a healthy river. With the deviation(s) from the water quality parameter(s), the shape of graph obtained will get distorted and eventually shows irregular shape. Polluted river will result in irregular shaped graph, which signify the pollution status of the river water.

### 3.3.1 Eco-Heart Indicator for Class I Water Quality

As outlined by Interim National Water Quality Standards, water quality with Class I status is basically showing clean and healthy river source, which gives a perfect heart-shape for Eco-Heart Indicator as shown in Figure 3.4. It involves the conservation of natural environment, whereby no external treatment is required for the water supply. The water body is safe for drinking or direct consumption, as well as for the survival of aquatic species that react very sensitive to the water conditions.

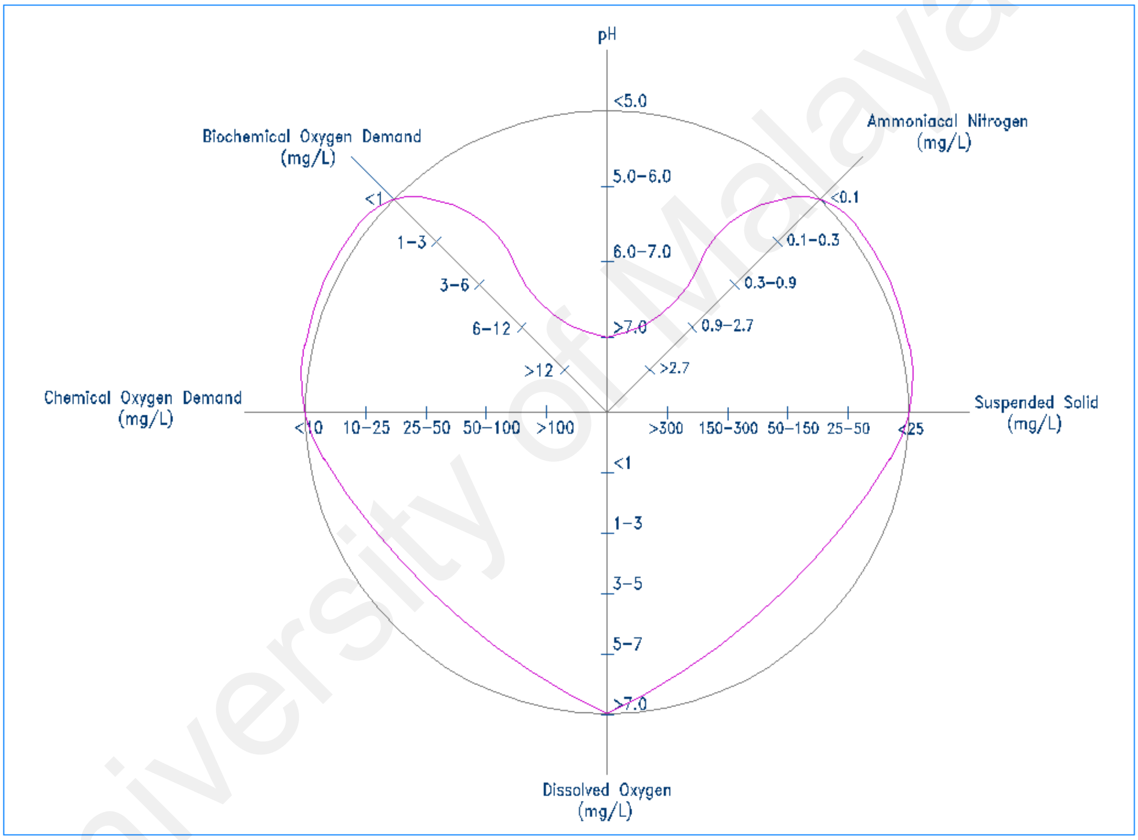


**Figure 3.4: Eco-Heart Indicator for Class I Water Body**

### 3.3.2 Eco-Heart Indicator for Class II Water Quality

For Class II water source, conventional treatment is required due to slight presence of pollutants in the water body. However, the water source can be used as water supply for aquatic species which behaves sensitively to the water environment. No severe health effect will happen with direct body contact for recreational use. Heart-shape is still visible for Class II water source as shown in Figure 3.5, which indicating no significant impact to the human activities and environment.

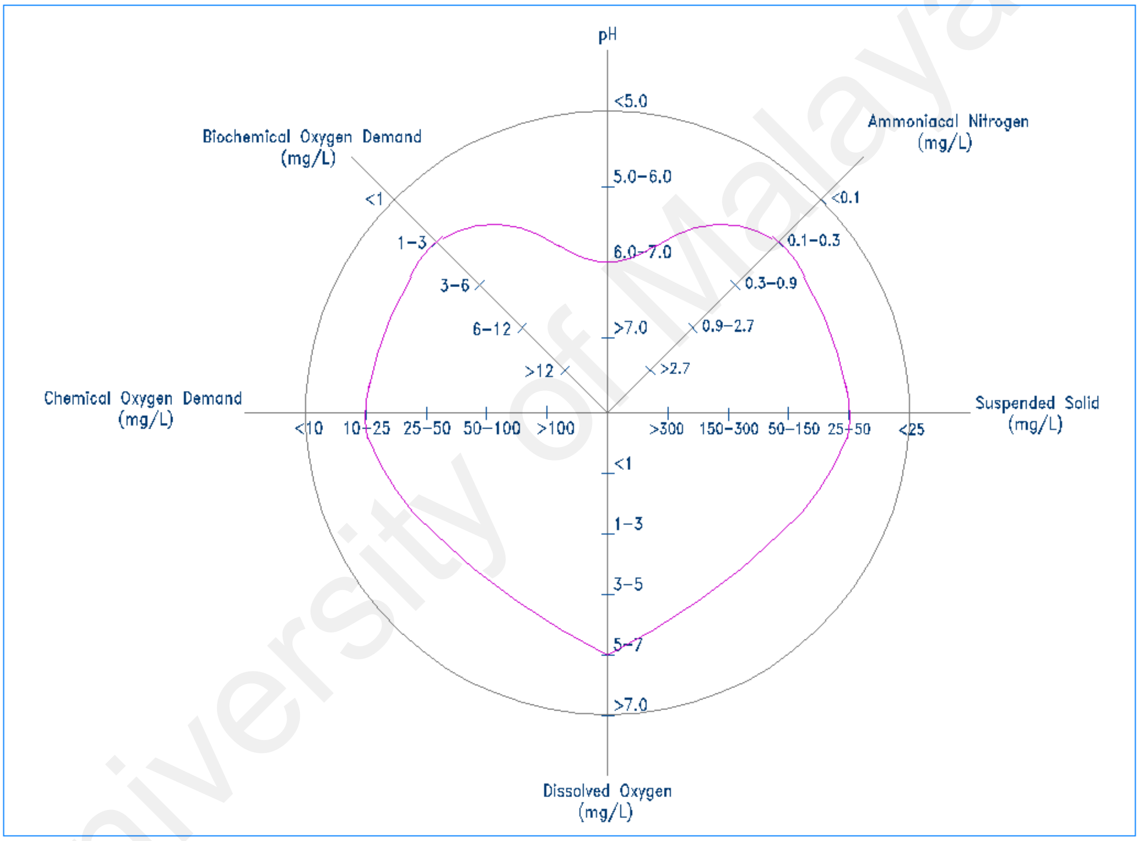


**Figure 3.5: Eco-Heart Indicator for Class II Water Body**

### 3.3.3 Eco-Heart Indicator for Class III Water Quality

Class III water source will deviate from the heart-shape as shown in Figure 3.6 due to significant pollutants present in the water body. BOD, COD, AN and SS show increased trend, while both pH and DO show reduced trend. Extensive water treatment is required in order to use the water source for human activities and direct consumption. The water source is only meant for water supply to common aquatic species, as well as serving as drinking water to livestock.

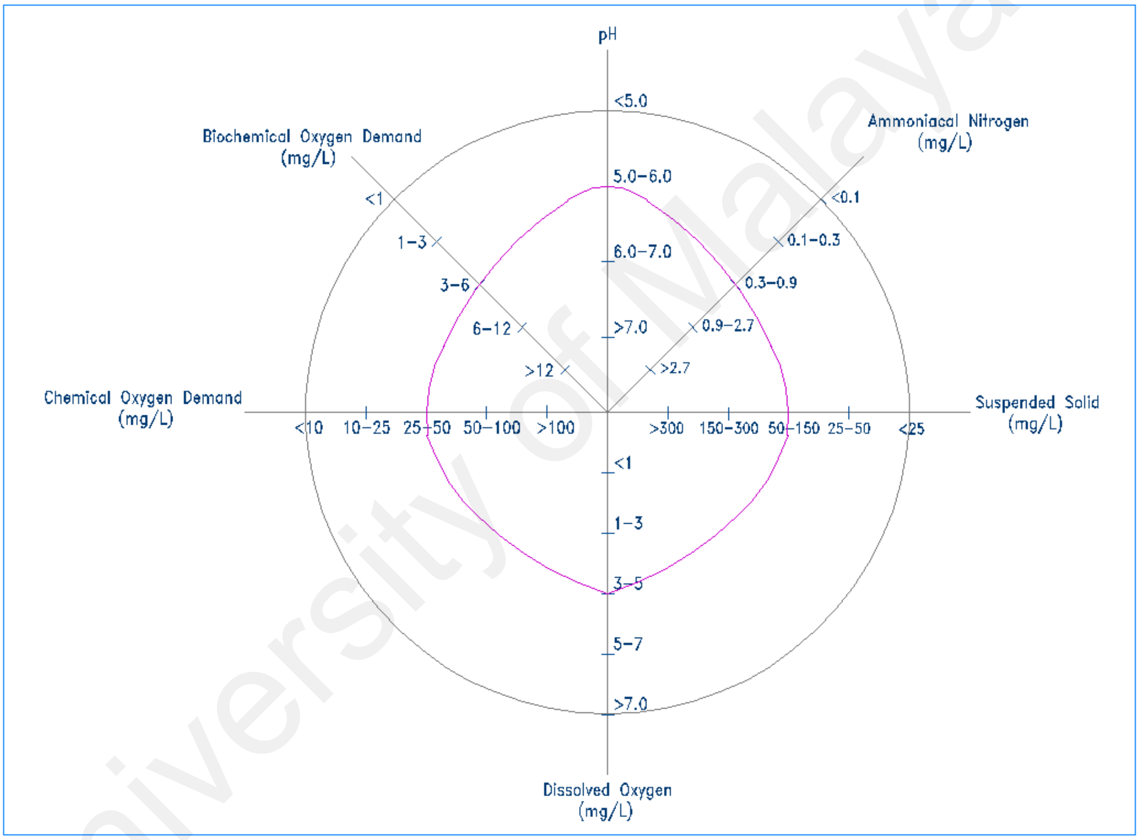


**Figure 3.6: Eco-Heart Indicator for Class III Water Body**

### 3.3.4 Eco-Heart Indicator for Class IV Water Quality

The water body with Class IV water quality shows irregular shape in Figure 3.7. It can only be used as irrigation in agricultural industry. The water will harm the survival of aquatic species, mainly due to low DO in the water body.

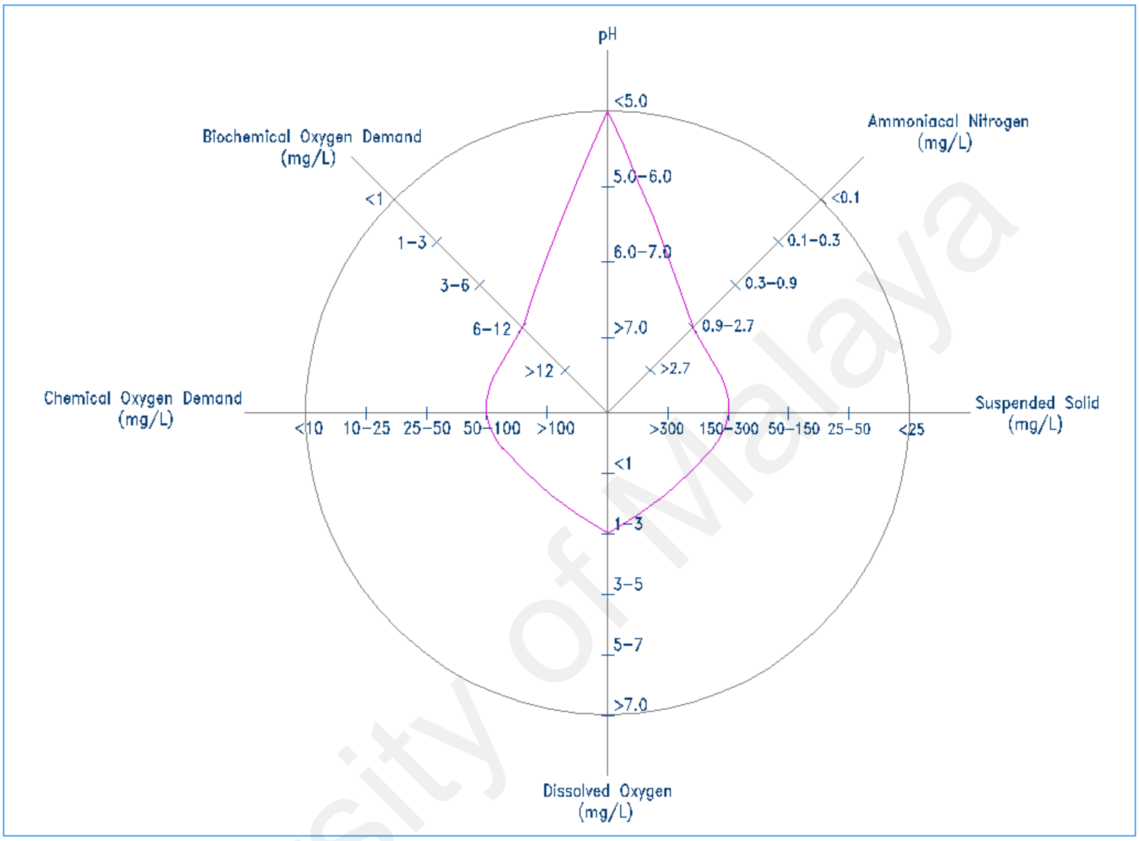


**Figure 3.7: Eco-Heart Indicator for Class IV Water Body**

### 3.3.5 Eco-Heart Indicator for Class V Water Quality

Class V water body is considered as highly polluted water source. The graph shows a very narrow shape in Figure 3.8. The extreme physiochemical conditions have inhibited the potential for human activities and aquatic species. The BOD, COD, AN and SS have exceeded the allowable range, while the pH and DO are at the lower limits.

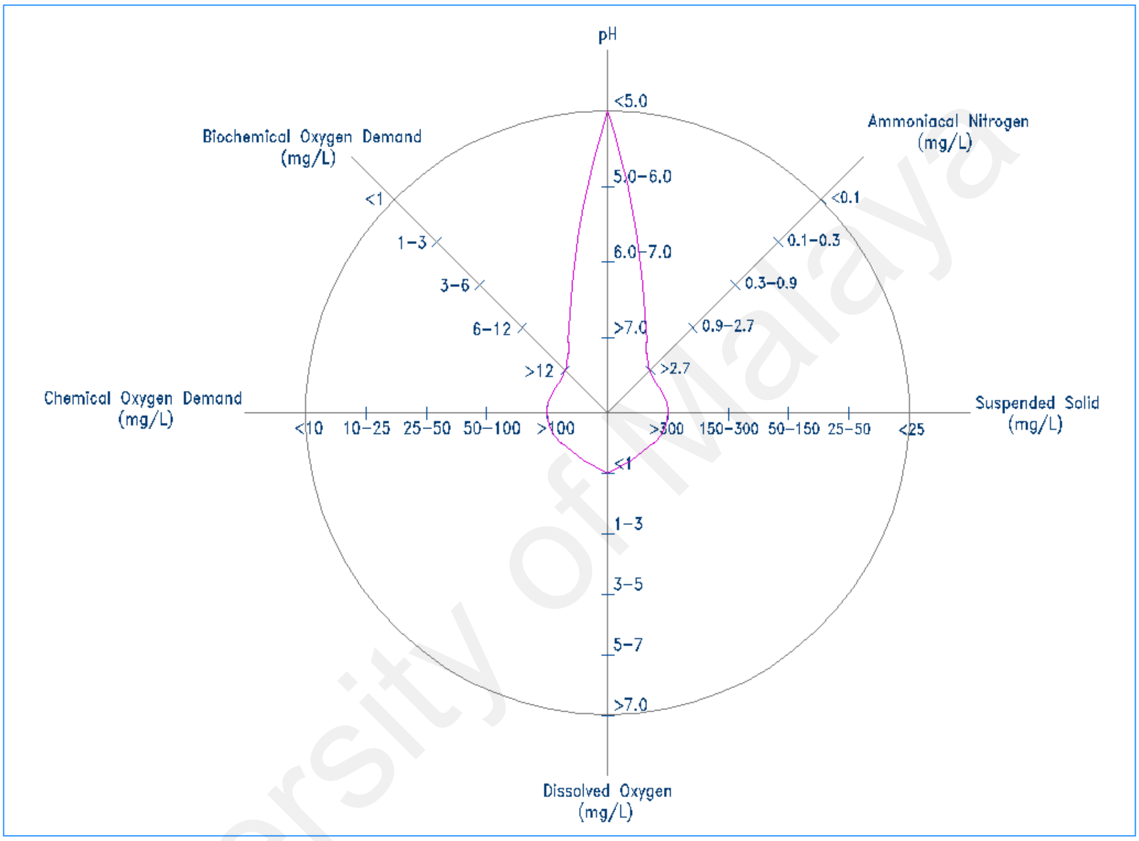


**Figure 3.8: Eco-Heart Indicator for Class V Water Body**

# CHAPTER 4: RESULT AND DISCUSSION

The data collected from the water monitoring stations operated by the Department of Environment (DOE) along the Selangor River with two-month interval in Year 2017 are tabulated and the respective Water Quality Index (WQI) is calculated to evaluate the conditions of the water sample. Eco-Heart Indicator is plotted to study the changes in water samples throughout the year.

## 4.1 Water Quality at Station 1SR05 (Upstream)

Table 4.1 below shows the overview of the water quality data for Station 1SR05 which is located upstream of Selangor River.

**Table 4.1: Water Quality Data for Station 1SR05 (Upstream) in Year 2017**

| Station 1SR05 | pH | BOD (mg/L) | COD (mg/L) | AN (mg/L) | SS (mg/L) | DO (%) | WQI | Class |
|---|---|---|---|---|---|---|---|---|
| January | 6.91 | 4 | 19 | 0.11 | 5 | 94.1 | 90 | II |
| March | 6.79 | 11 | 33 | 0.13 | 11 | 93.6 | 82 | II |
| July | 7.00 | 6 | 17 | 2.31 | 3 | 92.8 | 80 | II |
| September | 7.33 | 3 | 10 | 0.11 | 5 | 94.2 | 93 | I |
| November | 7.68 | 3 | 10 | 0.11 | 17 | 97.8 | 91 | II |

From the data obtained, it is observed that the water condition at Station 1SR05 is generally clean throughout Year 2017, with a slight deviation in July which is slightly polluted. The water body falls between Class I and Class II, where conventional treatment is required at most. The water supply can be used for fishery purpose and recreational use with direct body contact.

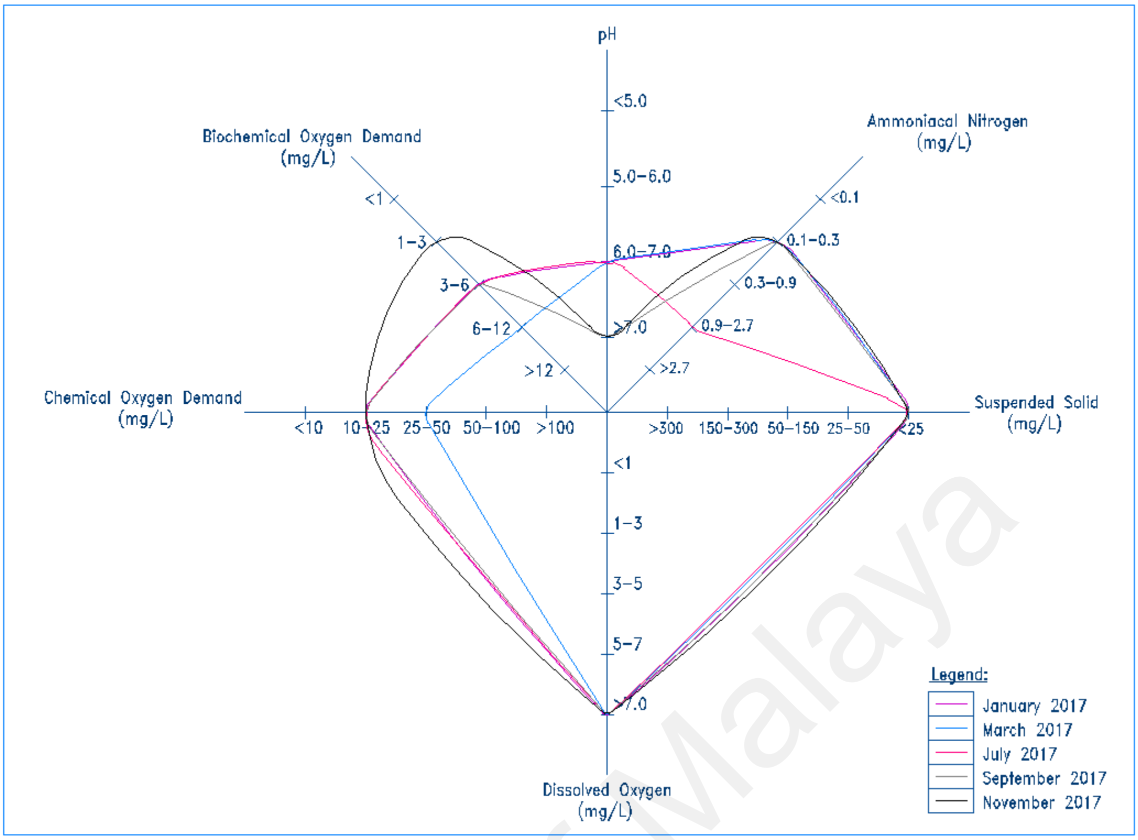


**Figure 4.1: Eco-Heart Indicator for Station 1SR05 in Year 2017**

Figure 4.1 shows the Eco-Heart Indicator plotted for five water samples obtained for Station 1SR05 throughout Year 2017. From the graph plotted, Suspended Solid (SS) and Dissolved Oxygen (DO) fall in healthy range throughout the year. The pH of the water body appears to fluctuate a little between 6.0 and above 7.0, with healthy range of above 7.0 at the end of the year (September and November). This might be due to dilution caused by rain during the raining season.

The Chemical Oxygen Demand (COD) and Ammoniacal Nitrogen (AN) of water samples are generally categorised under the Class II requirement, where only conventional treatment is required. However, the Biochemical Oxygen Demand (BOD) of water samples fall into Class III water quality, which shows extensive water treatment is needed. The water body is not suitable to serve as water supply for human activities in March due to high BOD and COD content.

The water body in Station 1SR05, which is located downstream of Selangor Dam, is considered as clean water generally with Water Quality Index (WQI) of 81 and above, as well as presenting heart-shapes shown in Eco-Heart Indicator throughout Year 2017. This coincides with the fact that the river water begins from the foothills of Fraser Hill and gathers at Selangor Dam before flowing downstream. There is minimum land use discovered along the river stream, with most of the land are still preserved as forest area. Only small portions of the land are used for agricultural activities and urban development around the water dam. Hence, no significant man-made pollution is caused to the water body.

## 4.2 Water Quality at Station 1SR04 (Mid-stream)

Table 4.2 below shows the overview of the water quality data for Station 1SR04 which is located mid-stream of Selangor River.

**Table 4.2: Water Quality Data for Station 1SR04 (Mid-Stream) in Year 2017**

| Station 1SR04 | pH | BOD (mg/L) | COD (mg/L) | AN (mg/L) | SS (mg/L) | DO (%) | WQI | Class |
|---|---|---|---|---|---|---|---|---|
| January | 6.97 | 5 | 18 | 0.29 | 20 | 93.9 | 85 | II |
| March | 6.83 | 6 | 23 | 0.31 | 71 | 99.5 | 81 | II |
| July | 7.41 | 4 | 17 | 0.29 | 7 | 101.2 | 87 | II |
| September | 7.15 | 5 | 17 | 0.85 | 30 | 86.7 | 81 | II |
| November | 7.66 | 4 | 11 | 0.29 | 25 | 100.0 | 87 | II |

From the data obtained, it is observed that the water condition at Station 1SR04 is generally clean throughout Year 2017, with a constant Class II water quality that requires only conventional water treatment. The water body can be supplied for fishery purpose and recreational use with direct body contact.

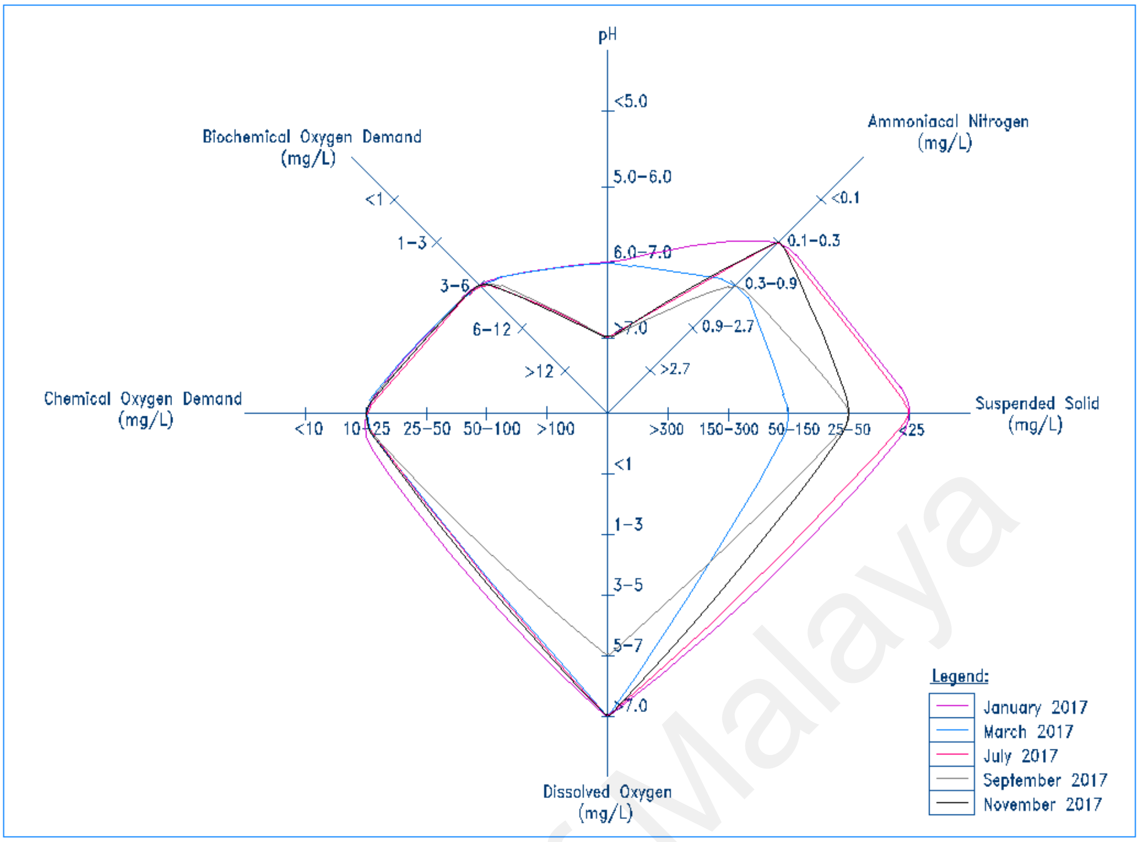


**Figure 4.2: Eco-Heart Indicator for Station 1SR04 in Year 2017**

Figure 4.2 shows the Eco-Heart Indicator plotted for five water samples obtained for Station 1SR04 throughout Year 2017. From the graph plotted, pH, Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD) of the water body fall within Class II water quality, where only conventional treatment is needed.

However, Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (AN) and Suspended Solid (SS) show relatively unhealthy condition with up to Class III water quality. This is mainly due to the agricultural activities carried out by the local residents in the village area, as well as a small industrial area located near the water monitoring station. Extensive water treatment is required to remove the pollutants involved.

Nevertheless, the water body in Station 1SR04 is considered as clean water generally with Water Quality Index (WQI) of 81 and 90, as well as presenting slightly distorted heart-shapes shown in Eco-Heart Indicator throughout Year 2017. This coincides with the fact that the river water gathers the water flowing from the water dam, as well as, some river branches that experience land clearing activities for agricultural activities and urban development with significant amount of bare lands. The water body is exposed to man-made pollutions caused by agricultural and industrial activities. The river pollution is still within the controllable situation.

## 4.3 Water Quality at Station 1SR10 (Mid-stream)

Table 4.3 below shows the overview of the water quality data for Station 1SR10 which is located mid-stream of Selangor River.

**Table 4.3: Water Quality Data for Station 1SR10 (Mid-Stream) in Year 2017**

| Station 1SR10 | pH | BOD (mg/L) | COD (mg/L) | AN (mg/L) | SS (mg/L) | DO (%) | WQI | Class |
|---|---|---|---|---|---|---|---|---|
| January | 6.81 | 4 | 11 | 0.66 | 136 | 72.2 | 76 | III |
| March | 6.66 | 5 | 19 | 0.59 | 247 | 73.8 | 73 | III |
| July | 7.23 | 5 | 12 | 1.11 | 65 | 79.9 | 77 | II |
| September | 7.23 | 9 | 32 | 1.10 | 120 | 60.9 | 64 | III |
| November | 7.63 | 4 | 16 | 0.77 | 59 | 74.7 | 77 | II |

From the data obtained, it is observed that the water condition at Station 1SR10 is moderately polluted throughout Year 2017, which fluctuates between Class II and Class III water quality. Extensive water treatment is required in order to utilise the water body for human activities and drinking consumption.

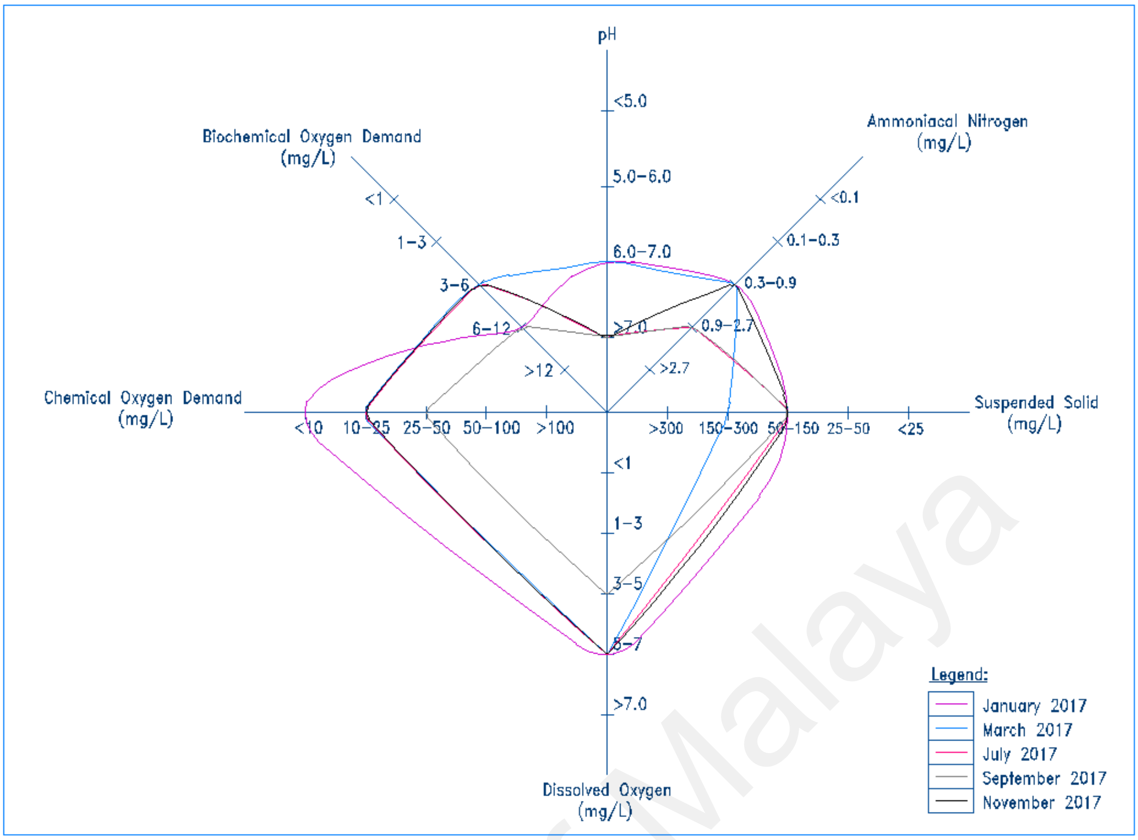


**Figure 4.3: Eco-Heart Indicator for Station 1SR10 in Year 2017**

Figure 4.3 shows the Eco-Heart Indicator plotted for five water samples obtained for Station 1SR10 throughout Year 2017. From the graph plotted, pH and Dissolved Oxygen (DO) of the water body only fall within Class II water quality, where only conventional treatment is needed.

However, other parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN) and Suspended Solid (SS) show unhealthy trend with fluctuations up to Class IV water quality, which is only allowing the water body to serve for irrigation purpose in agricultural sector. This is mainly caused by the presence of mixed industrial activities near the water monitoring station. Extensive water treatment is required to remove the pollutants involved.

The water body in Station 1SR10 is moderately polluted with Water Quality Index (WQI) of 60 and 80, as well as presenting irregular shapes shown in Eco-Heart Indicator throughout Year 2017. This coincides with the fact that most of the river branches emerge to the main river stream at the point of Station 1SR10. The water body is exposed to extensive agricultural and industrial activities along the river branches in the Klang Valley. There are also significant area of bare lands that expose the soil to the natural erosions caused by rainfalls and this results in high suspended solids found in the water samples. Apart from that, it is noticeable that there is one operating landfill, Bukit Beruntung Landfill, which is a Level 0 landfill (open dumpsite) located upstream of the water monitoring station (NAHRIM and NRE, 2010). The landfill has no liner to prevent the leachate from diffusing into the river stream, which is just 5-meter apart (Suratman, S. et al., 2012). Therefore, the river pollution requires extensive water treatment for the removal of pollutants.

## 4.4 Water Quality at Station 1SR01 (Downstream)

Table 4.4 below shows the overview of the water quality data for Station 1SR01 which is located downstream of Selangor River.

**Table 4.4: Water Quality Data for Station 1SR01 (Downstream) in Year 2017**

| Station 1SR01 | pH | BOD (mg/L) | COD (mg/L) | AN (mg/L) | SS (mg/L) | DO (%) | WQI | Class |
|---|---|---|---|---|---|---|---|---|
| January | 5.08 | 3 | 6 | 0.44 | 21 | 76.5 | 81 | I |
| March | 6.93 | 6 | 16 | 0.51 | 475 | 74.0 | 71 | III |
| July | 7.00 | 11 | 40 | 0.04 | 1260 | 47.6 | 56 | III |
| September | 6.97 | 3 | 12 | 0.91 | 478 | 58.9 | 67 | III |
| November | 7.27 | 7 | 26 | 0.68 | 381 | 70.3 | 67 | III |

From the data obtained, it is observed that the water condition at Station 1SR01 is moderately polluted throughout Year 2017. Extensive water treatment is required, so that the water body can be utilised for human activities.

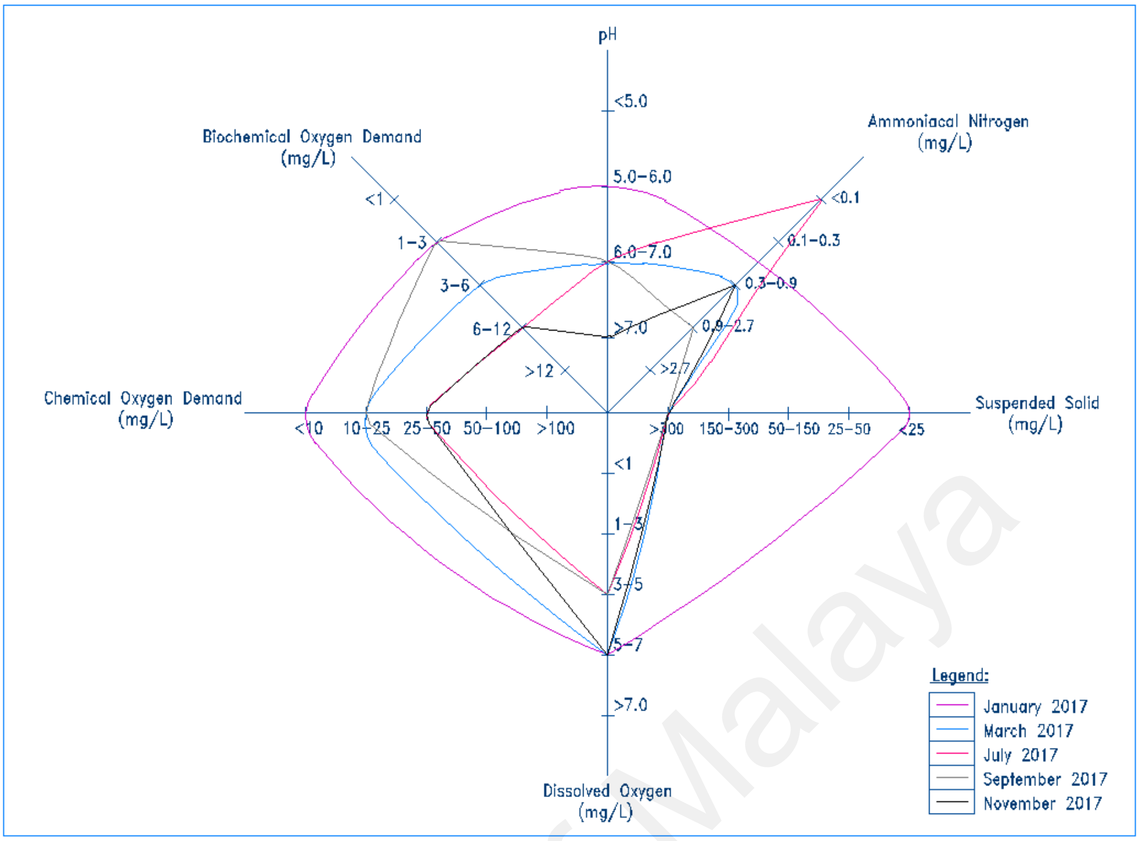


**Figure 4.4: Eco-Heart Indicator for Station 1SR01 in Year 2017**

Figure 4.4 shows the Eco-Heart Indicator plotted for five water samples obtained for Station 1SR01 throughout Year 2017. From the graph plotted, all the six water quality parameters deviate significantly throughout the year. Only Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) fall within Class III water quality.

Other parameters like pH, Biochemical Oxygen Demand (BOD) and Ammoniacal Nitrogen (AN) show unhealthy trend with fluctuations up to Class IV water quality, which is only allowing the water body to serve for irrigation purpose in agricultural sector. Suspended Solid (SS) exhibits Class V water quality most of the time. This is mainly due to the presence of highly-dense industrial activities at the downstream of Selangor River. The water body is not safe for human activities. Extensive water treatment is required to remove the pollutants involved.

The water body in Station 1SR01 is moderately polluted with Water Quality Index (WQI) of 60 and 80, as well as presenting irregular shapes shown in Eco-Heart Indicator throughout Year 2017. Despite the fact that the village is preserved for fireflies, the water body is exposed to uncontrolled water pollutions, as a results from unplanned township development, as well as, dense agricultural and industrial activities. The river requires extensive water treatment for the removal of pollutants, in order to provide safe raw water supply for human activities.

## 4.5 Findings of Survey done for Eco-Heart Indicator

A survey was carried out to a total of 30 respondents, which aimed to understand the public impression towards Eco-Heart Indicator, as well as, to evaluate the level of public awareness towards water quality.

The respondents of the survey are undergraduate students from University of Malaya. In this survey, most of the respondents are from engineering background, with the remaining 6 respondents from science background and 8 respondents from arts, business and other backgrounds.

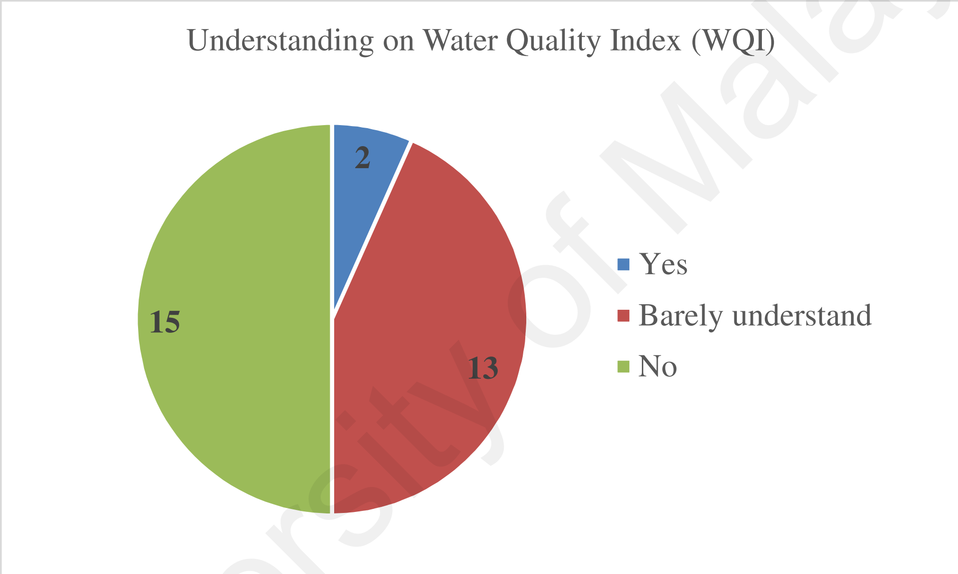


**Figure 4.5: Understanding on Water Quality Index (WQI) by Survey Respondents**

Based on the findings obtained as shown in **Error! Reference source not found.**, only 2 respondents has come across and clearly understood the significance of Water Quality Index (WQI). There are 5 respondents barely understand what is meant by Water Quality Index and its functions. Up to 13 respondents do not understand Water Quality Index at all.

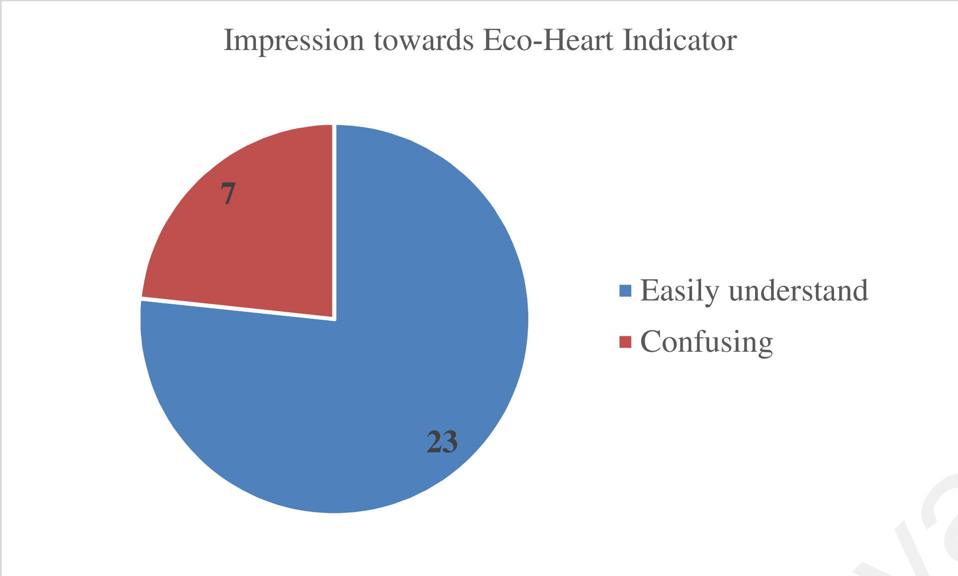


**Figure 4.6: Impression towards Eco-Heart Indicator by Survey Respondents**

As indicated in Figure 4.6, there are 23 respondents feel that Eco-Heart Indicator is easily understood. This is probably due to the graphical representation that shows all the water quality parameters and connects them in shape. The scales used in the graph's axes also indicate the scale ranges used in Water Quality Index (WQI). Unlike the single figure derived from Water Quality Index, the deviation of the water quality parameter can be easily spotted from Eco-Heart Indicator.

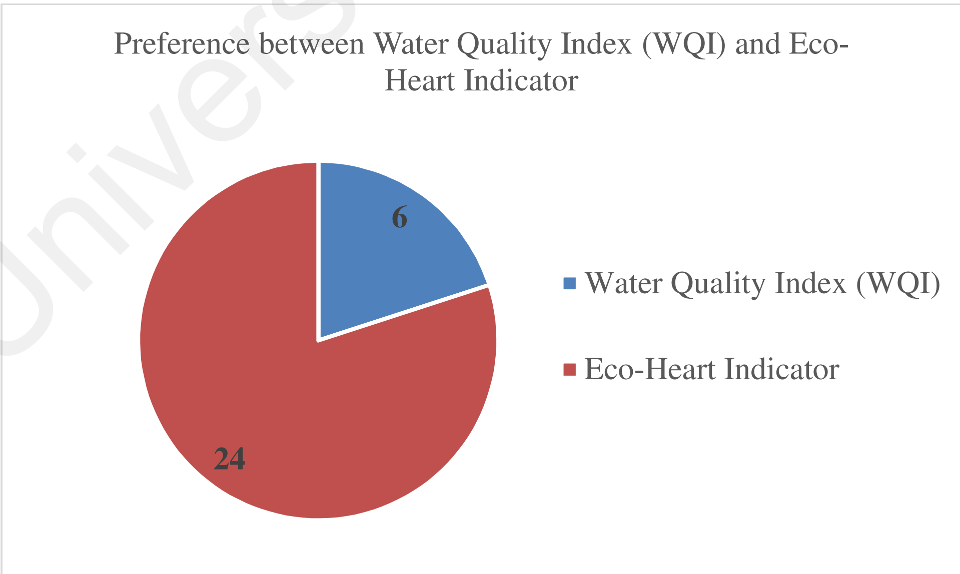


**Figure 4.7: Preference between Water Quality Index (WQI) and Eco-Heart Indicator by Survey respondents**

From the survey done as shown in Figure 4.7, up to 80% (24 people) of the respondents prefer to use Eco-Heart Indicator as the measuring tool in identifying the river water quality. However, the remaining 20% (8 people) of the respondents still prefer using the well-established Water Quality Index (WQI) by the Department of Environment.

As a result, this survey shows that there is huge potential for the policy maker to study the development of alternative tool for river water quality, Eco-Heart Indicator, that helps the public to understand and create the awareness of river water conditions.

# CHAPTER 5: CONCLUSION

From the comparison between Malaysia's Water Quality Index and other standards adopted by several countries, it is deduced that Malaysia's Water Quality Index focuses more on physiochemical properties of water body. Biological properties of water body are not considered in defining water quality. Besides, other physical parameters, such as heavy metals and specific chemicals, which may pose severe health hazards, are not highlighted in defining water quality.

There is a need to make necessary adjustments for the current water quality index in order to reflect the real situation. Such action is required to ensure that water quality is consistently determined in a holistic approach.

The conventional Water Quality Index (WQI) only gives an overview of the water quality with numeric score. Any parameter that exceeds the recommended limit is not able to be observed directly.

By using Eco-Heart Indicator, the audience is able to visualise the current situation of each parameter concerned. Clean water will exhibit a perfect heart-shape, while polluted water will result in distorted or irregular shape. Unlike Water Quality Index (WQI), no weightage is assigned to each water quality parameter. All parameters will be displayed to the public to portray the pollution status of river water. The graph can be refined further into other shapes if additional water quality parameter is to be included in defining water quality in future. This will help in reflecting the water quality conditions more effective and accurate.

Based on the survey carried out, it shows the potential of developing Eco-Heart Indicator as an alternative tool to indicate river water quality. This will help the public to understand and create awareness towards river water quality.

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# APPENDIX

**<u>Survey Questionaire [Please cross ( X ) wherever applicable]</u>**

**Note: This questionnaire will only take you less than 5 minutes to complete.**

1. What is your background of study?

   □ Science

   □ Engineering

   □ Arts, Business and Others

2. Do you understand what is Water Quality Index (WQI) by Department of Environment (DOE)?

   □ Yes

   □ Barely understand

   □ No

3. What is your impression towards Eco-Heart Indicator?

   □ Easily understand

   □ Confusing

4. If you are given a choice to refer to, which water quality representation would you prefer?

   □ Water Quality Index (WQI)

   □ Eco-Heart Indicator

5. Additional comments:

   ______________________________________________

   ______________________________________________

   ______________________________________________

Thank you so much!