REVISED WATER QUALITY INDICES FOR THE PROTECTION OF RIVERS IN MALAYSIA

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ABSTRACT

Inconsistencies were observed between the existing water quality index (WQI) and the effluent discharge standards of the environmental quality act (EQA) in Malaysia. For instance, Ammoniacal Nitrogen (NH₃-N) is identified as one of the main pollutants to render many of the rivers polluted, whereas there is no limit in the effluent discharge standard for this parameter. On the other hand, this parameter plays a significant role in determining the Class of water. It was observed from the long-term data that pH is not a problem for the rivers in Malaysia. Therefore, this parameter could be replaced with other important parameter. Alternate water quality index (NWQI) is proposed in this study to suit the local water quality problems and objectives. The easiness in water quality sampling and testing was another factor considered in selecting the parameters for the proposed NWQI. Case studies revealed that, on average, during the dry days the NWQI produced 8 to 10 points less than those produced by the existing WQI equations. During the rainy days the difference was higher, which varied between 13 and 20 points (index values). The NWQI was found to be slightly more stringent than the existing WQI equations. However, this modification is necessary to assure good river water quality to suit government’s intention to increase aqua-tourism and river related activities in the country.

Keywords: Environmental Quality Act (EQA), Point and Non-point Source Pollution, Wastewater, Water Quality Index (WQI).

INTRODUCTION

One of the main objectives of any water pollution study is to determine or assess overall status of the waterbody concerned. Water quality can be judged either by individual parameter for any specific interest or by a few selected important parameters to judge the overall quality of the water. Many countries use water quality...
indexing (WQI) method to assess the overall status of their rivers. These indices differ from country to country (Silvia and Daniel, 2000; Chapman, 1992; Bhargava, 1983) but the concept is similar, where a few important parameters are selected and compounded to numerical rating for the evaluation of the river water quality.

Classification of river water quality has administrative and other uses and can be an integral part of water pollution control programs. A river may be classified into various grades indicating the beneficial use(s) to which it may be put. The grades are based on the permissible limits of relevant pollution parameters (water quality variables) or standards set by the relevant authorities. Depending on the quality of water in various stretches of a river, the river can be zoned according to each stretch's suitability for the beneficial use(s). The assigning of a class to a river reach is not simple. Only in rare cases are all the relevant variables found to be within the permissible limits of a given class. In other words, in most cases, the river water would be classified into one grade with regard to one set of variables and into another class with regard to another variable or set of variables.

According to the US Atomic Energy Commission standards (USAEC, 1974) classification of raw water sources for domestic supply can be Group I (Excellent, requiring only disinfection), Group II (Good, requiring usual treatment such as filtration and disinfection), Group III (Poor, requiring special or auxiliary treatment and disinfection) would, respectively, require BOD = 0.75-1.5 mg/L, 1.5-2.5 mg/L, more than 2.5 mg/L; DO = 4.0-7.5 mg/L, 4.0-6.5 mg/L, 4.0 mg/L; coliform MPN = 50-100 /100 mL, 50-5000 /100 mL, more than 5000 /100 mL; and chloride = 50 mg/L or less, 50-250 mg/L, more than 250 mg/L. Therefore, a river may be placed in Group I with respect to chloride, in Group II with respect to coliform MPN, in Group III with respect to BOD and in no group at all with respect to DO. Hence, one can classify the river either in a lower class, thus underestimating the river's utility potential, or in a higher class, in which case the safety or value of the higher class may be questionable. Otherwise, the classification would arbitrarily be made on the basis of judgment, importance of each variable to a use, reliability of monitoring, etc. To avoid use in a questionable grade, one would tend to place the river in the lower grade, which may not result in the full exploitation of the river.

In view of the above, it would be appropriate to base river classification on the ranges of an index representing the integrated effect of the concentrations and importance values of the relevant variables for a use. Bhargava (1983) has reported that the important requirements of such a Water Quality Index (WQI) are as follows: (1) It should be sensitive to changes in the relevant variables' value(s). (2) It should provide greater change in the WQI by a change in the value of a variable of greater relevance to the beneficial use; that is, the variable's weight representing the relevance of the variable to a given beneficial use should be incorporated in the WQI. (3) It should attain a very low value (perhaps zero), when a relevant single variable reaches a certain value beyond which the water quality for a given use is considered unsuitable. (4) It should remain unchanged when a relevant variable reaches a value beyond which
further change does not affect water use. (5) Variation in the index should reflect the
different levels of importance of a single variable for the use(s).

Malaysia also follows compound Water Quality Index (WQI) to evaluate overall water
quality of the rivers. The existing WQI equations are proposed by the Department of
Environment Malaysia. This index is being practised in Malaysia for more than 25
years. Despite having significant amount of data, no review of the existing practice
was done within this long period of time. Only recently Idris, et al. (2003) highlighted
a few shortcoming of the existing WQI method but did not recommend any improved
or more relevant version of water quality index. Therefore, main objective of this
paper was to review the existing WQI related procedures being practised and also to
recommend a new water quality index (NWQI) for the protection of rivers in
Malaysia.

EXISTING WQI PROCEDURE

Six parameters, namely dissolved oxygen (DO), biochemical oxygen demand (BOD),
chemical oxygen demand (COD), suspended solids (SS), ammoniacal nitrogen (AN)
and pH, are considered for the evaluation of overall status of the river waters. The
WQI approved by the DOE, Equation (1), is calculated based on the above six
parameters. Among them DO carries maximum weightage of 0.22 and pH carries the
minimum of 0.12 in the WQI equation. The WQI equation eventually consists of the
sub-indices, which are calculated according to the best-fit relations given in Equations
(2)-(7). These equations are graphically presented in Figure 1. The formulas used in
the calculation of WQI are:

\[
WQI = 0.22 \times SDO + 0.19 \times SIBOD + 0.16 \times SICOD + 0.16 \times SISS + 0.15 \times SIAN + 0.12 \times SIpH (1)
\]

where, \( WQI \) = Water quality index; \( SDO \) = Sub-index of DO; \( SIBOD \) = Sub-index of
BOD; \( SICOD \) = Sub-index of COD; \( SIAN \) = Sub-index of AN; \( SISS \) = Sub-index of
TSS; \( SIpH \) = Sub-index of pH.

Sub-index for DO (in % saturation):
\[
SDO = \begin{cases} 
0 & \text{for } DO < 8 \\
100 & \text{for } DO > 92 \\
-0.395 + 0.030DO^2 - 0.00020DO^3 & \text{for } 8 < DO < 92 
\end{cases} (2a)
\]
\[
SDO = \begin{cases} 
100 & \text{for } DO > 92 \\
-0.395 + 0.030DO^2 - 0.00020DO^3 & \text{for } 8 < DO < 92 
\end{cases} (2b)
\]
\[
SDO = \begin{cases} 
-0.395 + 0.030DO^2 - 0.00020DO^3 & \text{for } 8 < DO < 92 
\end{cases} (2c)
\]

Sub-index for BOD:
\[
SIBOD = 100.4 - 4.23BOD \quad \text{for } BOD < 5 \quad (3a)
\]
\[
SIBOD = 108e^{-0.055BOD} - 0.1BOD \quad \text{for } BOD > 5 \quad (3b)
\]

Sub-index for COD:
\[
SICOD = -1.33COD + 99.1 \quad \text{for } COD < 20 \quad (4a)
\]
\[
SICOD = 103e^{-0.0157COD} - 0.04COD \quad \text{for } COD > 20 \quad (4b)
\]
Sub-index for AN:

\[ S_{\text{IAN}} = \begin{cases} 100.5 - 105AN & \text{for } AN < 0.3 \\ 94e^{-0.573AN} - 5 & \text{for } 0.3 < AN < 4 \\ 0 & \text{for } AN > 4 \end{cases} \]  

Sub-index for SS:

\[ S_{\text{ISS}} = \begin{cases} 97.5e^{-0.00676SS} + 0.05SS & \text{for } SS < 100 \\ 71e^{-0.0016SS} - 0.015SS & \text{for } 100 < SS < 1000 \\ 0 & \text{for } SS > 1000 \end{cases} \]  

Sub-index for pH:

\[ S_{\text{pH}} = \begin{cases} 17.2 - 17.2pH + 5.02pH^2 & \text{for } pH < 5.5 \\ -242 + 95.5pH - 6.67pH^2 & \text{for } 5.5 < pH < 7 \\ -181 + 82.4pH - 6.05pH^2 & \text{for } 7 < pH < 8.75 \\ 536 - 77.0pH + 2.76pH^2 & \text{for } pH > 8.75 \end{cases} \]  

LIMITATIONS OF THE EXISTING WQI

A few limitations were identified while reviewing the existing water quality index procedure and the long term data recorded in various river basins in Malaysia. These are given below:

a. pH is not a problem for Most of the Malaysian rivers and thus can be eliminated from the existing WQI equations. However, pH should be monitored to assess the suitability of water for other usages as required by the Interim National Water Quality Standards – INWQS (DOE, 1994);

b. Instead of two oxygen demand measuring parameters (BOD and COD) only one could be used in the WQI procedure and BOD could be preferred over COD because BOD represents better the biodegradable pollutants in the waterbody and most of the water quality models can simulate this parameter;

c. No nutrient (phosphorus, nitrogen, etc.) is considered in the existing WQI equation;

d. Ammoniacal Nitrogen (AN) is identified as one of the main pollutants to render many of the rivers polluted but there is no limit in the effluent discharge standard (DOE, 1974) for this parameter. However, it plays a significant role in determining the Class of water;

e. Concentration of AN set for the Classes seemed to be very stringent because high concentration of AN may occur in the nature, which is not due to the effect of human activities (Inchem, 2005);

f. Aesthetically the river water should be attractive to the citizen. There are suspended solids (SS) in the existing WQI procedure but SS do not always represent the clarity of the water. Thus, one parameter could be included to indicate the transparency of water;

g. The existing sub-index equations are not user-friendly for the general users;

h. The weighing factors for the six parameters and distribution of WQI values are not uniform for five Classes set for the assessment of water quality in Malaysia.
METHODOLOGY

This study did not involve any field data collection or laboratory water quality analysis. The existing water quality evaluation procedures and the available long-term water quality data of various rivers were analysed to assess the important parameters and issues. The effluent discharge standards (DOE, 1974) and the interim national water quality standards – INWQS (DOE, 1994) were also reviewed for the study.

A questionnaire was prepared and distributed to the national and international water quality experts, universities and department of environment (DOE) offices in Malaysia. Out of 16 DOE State offices only one DOE official returned the questionnaire and another officer advised that the DOE Federal Office is responsible to take any decision regarding the change in the existing WQI. No reply was received from 14 other DOE offices. The questionnaire was also distributed to 38 foreign experts of 12 nations who are involved in water quality related activities (both in the field of point and nonpoint source pollution problems). Only three people returned the questionnaire and others did not reply.

The new water quality index (NWQI) presented in this paper is based on the comments received through the questionnaire survey and river water quality data collected from DOE.

NEW WATER QUALITY INDEX (NWQI)

From the comments made by the foreign experts it was realised that parameters and ranking to be set for the WQI depend largely on the water quality usage and objectives of the nation. There was a slight difference in opinion given by the water quality practitioners. Generally the respondents did not recommend to include turbidity, as TSS indirectly represents turbidity. However, in Malaysian environment there are many situations when TSS may not be strongly related to turbidity (e.g. storm runoff from paved/urbanised areas which contain sands as high TSS but indicates low turbidity. On the other hand, runoff from bare soils which contain very fine particles with low TSS can exhibit high turbidity due to fine suspended particles). If the wastewaters contain organic particles then the TSS value will be low but the turbidity would be high due to fine and light suspended particles (e.g. domestic sewage and sullage). Besides these factors, turbidity was considered in the NWQI to increase the aesthetics of rivers, which would help the Government’s mission to increase the river-based tourism activities. A few of the respondents also recommended to include pathogen (E. Coli) as one of the monitoring parameters for WQI. From the review of the long-term data it was observed that Malaysian rivers exhibits high level of microbial pollution. The high counts of pathogens can be attributed to the domestic (PS) and poultry (PS/NPS) wastes for which there is no guideline or law for disinfection process. In addition to that the climate is very suitable for the fast growth
of pathogens. Sampling and laboratory testing for bacterial pathogens are also a tedious and costly process. Therefore, this study did not include *E. Coli* for the proposed NWQI. DOE data reflected that heavy metals are not a common problem for Malaysian rivers. Thus, this parameter was not included in the NWQI.

Therefore, the proposed NWQI parameters and their rankings were proposed to suit the local water quality problems and objectives. The easiness in water quality sampling and testing was another factor considered in selecting the parameters for the proposed NWQI.

The NWQI also consists of six parameters, as given in Equation (8). However, their relative weightage is different compared to the existing WQI Equation (1). In addition, pH and COD are replaced with Turbidity (TUR) and Total Phosphorus (TP). Ranges of the pollutants for which the equations are valid also shown in Figure 2.

\[
\text{NWQI} = 0.18\text{SIDO} + 0.18\text{SITSS} + 0.17\text{SIBOD} + 0.17\text{SIAN} + 0.15\text{SITP} + 0.15\text{SITUR}
\]

(8)

where, NWQI= New water quality index; SIDO= Sub-index of DO; SITSS= Sub-index of TSS; SIBOD= Sub-index of BOD; SIAN= Sub-index of AN; SITP= Sub-index of Total Phosphorus and SITUR= Sub-index of Turbidity.

DO (in % saturation):

\[
\text{SIDO} = -9\times 10^{-5} \text{DO}^3 + 0.0177 \text{DO}^2 + 0.2058 \text{DO} - 3.8919
\]

(9)

Sub-index for Turbidity:

\[
\text{SITUR} = 9\times 10^{-5} \text{TUR}^3 - 0.0126 \text{TUR}^2 - 0.6332 \text{TUR} + 99.796
\]

(10)

Sub-index for BOD:

\[
\text{SIBOD} = 0.0112 \text{BOD}^3 - 0.3161 \text{BOD}^2 - 3.1537 \text{BOD} + 99.781
\]

(11)

Sub-index for AN:

\[
\text{SIAN} = 3.4481 \text{AN}^3 - 14.791 \text{AN}^2 - 19.769 \text{AN} + 99.163
\]

(12)

Sub-index for SS:

\[
\text{SITSS} = 7\times 10^{-7} \text{SS}^3 - 0.0005 \text{SS}^2 - 0.1261 \text{SS} + 99.781
\]

(13)

Sub-index for TP:

\[
\text{SITP} = 26.523 \text{TP}^3 - 56.201 \text{TP}^2 - 42.049 \text{TP} + 99.781
\]

(14)

All pollutant concentrations are in mg/L for all parameters except Turbidity (in NTU). The sub-index value cannot be negative. In the case of any negative result please use zero (0). These equations (from 9 to 14) are graphically presented in Figure 2 and valid for the pollutant concentration range shown in the Figure. If the pollutant concentration is out of the range shown in Figure 2 then zero (0) to be used for the
sub-index value. However, in the case of DO if the saturation (%) is higher than 100 then use DO sub-index of 100.

The proposed equations, from (9) to (14), are simpler compared to the existing Equations (2)-(7). The parameters are selected such that the water quality is assessed based on the common and important physical and chemical parameters of surface water. The NWQI also proposed to maintain five (5) classes of river water as practised for the existing WQI (Table 1). However, uniformity was maintained in dividing the ranges of water quality classes (from I to V in Table 2), which was not considered in the previous classes.

**CASE STUDY**

The existing and proposed water quality index equations are applied to the recent water quality data of a mostly urban (Sg. Damansara) and a mostly rural (Sg. Melaka) river basin for rainy and non-rainy days. Sg. is the short form of “Sungai”, which means river in Malay Language. The statistical summary to compare the old and new WQI values on the river basins are given in Table 1 and Table 2, respectively. Comparison was made using the existing WQI classes and ranges (as given in Table 3) and also using the proposed NWQI classes and ranges (as proposed in Table 4). According to the first case study, it was observed that the median NWQI values of Sg. Damansara during dry days were less by about 8 points from the WQI values (Table 1). In the case of rainy day the NWQI values were less by about 13 points, which indicated that the proposed new water quality indices were slightly stricter compared to the existing WQI equations. In the case of Sg. Melaka the difference was slightly more than those of Sg. Damansara. The proposed NWQI values for non-rainy and rainy day river water quality data of Sg. Melaka were less by 10 and 20 points compared to the existing WQI values (as given in Table 2).

Results of the case study indicated that the assessment of water quality by the NWQI equations is comparable to the results obtained from the existing WQI (comparing summary in Tables 1 and 2). This comparability would help easy implementation of the proposed NWQI. The study recommends to use the new ranges of NWQI values as given in Table 4.

The higher differences in WQI values during the rainy days indicted that the proposed NWQI equations are more sensitive to the nonpoint source pollution, which is identified as the main causes of river pollution loading in Malaysia (DOE, 2003a; 2003b and 2004). The proposed modifications for the determination of water quality index is necessary to assure good river water quality to suit government’s mission to increase aqua-tourism and river related activities in the country.
Table 1: Statistical Summary of the WQI and NWQI Values and Classes for Sg. Damansara

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rainy Day</th>
<th>Non-rainy Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NWQI</td>
<td>WQI</td>
</tr>
<tr>
<td>Mean</td>
<td>39.4</td>
<td>49.7</td>
</tr>
<tr>
<td>Median</td>
<td>39.9</td>
<td>49.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>13.1</td>
<td>29.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>74.8</td>
<td>76.7</td>
</tr>
<tr>
<td>10 %tile</td>
<td>19.7</td>
<td>37.2</td>
</tr>
<tr>
<td>90 %tile</td>
<td>55.1</td>
<td>60.5</td>
</tr>
</tbody>
</table>

Table 2: Statistical Summary of the WQI and NWQI Values and Classes for Sg. Melaka

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rainy Day</th>
<th>Non-rainy Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NWQI</td>
<td>WQI</td>
</tr>
<tr>
<td>Mean</td>
<td>38.8</td>
<td>57.9</td>
</tr>
<tr>
<td>Median</td>
<td>36.6</td>
<td>58.5</td>
</tr>
<tr>
<td>Minimum</td>
<td>24.3</td>
<td>48.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>59.2</td>
<td>69.5</td>
</tr>
<tr>
<td>10 %tile</td>
<td>28.6</td>
<td>51.1</td>
</tr>
<tr>
<td>90 %tile</td>
<td>52.2</td>
<td>65.5</td>
</tr>
</tbody>
</table>

Table 3: Existing Parameters and Water Quality Index (WQI) Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
<th>Class V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammoniacal Nitrogen</td>
<td>&lt; 0.1</td>
<td>0.1 – 0.3</td>
<td>0.3 – 0.9</td>
<td>0.9 – 2.7</td>
<td>&gt; 2.7</td>
</tr>
<tr>
<td>BOD</td>
<td>&lt; 1</td>
<td>1 – 3</td>
<td>3 – 6</td>
<td>6 – 12</td>
<td>&gt; 12</td>
</tr>
<tr>
<td>COD</td>
<td>&lt; 10</td>
<td>10 – 25</td>
<td>25 – 50</td>
<td>50 – 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>&gt; 7</td>
<td>5 – 7</td>
<td>3 – 5</td>
<td>1 – 3</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>pH</td>
<td>&gt; 7</td>
<td>6 – 7</td>
<td>5 – 6</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>&lt; 25</td>
<td>25 – 50</td>
<td>50 – 150</td>
<td>150 – 300</td>
<td>&gt; 300</td>
</tr>
<tr>
<td>Water Quality Index</td>
<td>&gt; 92.7</td>
<td>76.5 – 92.7</td>
<td>51.9 – 76.5</td>
<td>31.0 – 51.9</td>
<td>&lt; 31.0</td>
</tr>
</tbody>
</table>

Table 4: Proposed Parameters and New Water Quality Index (NWQI) Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
<th>Class V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammoniacal Nitrogen</td>
<td>&lt; 0.3</td>
<td>0.3 – 0.9</td>
<td>0.9 – 1.6</td>
<td>1.6 – 2.3</td>
<td>2.3 – 3.0</td>
</tr>
<tr>
<td>BOD</td>
<td>&lt; 2.0</td>
<td>2 – 6.5</td>
<td>6.5 – 11</td>
<td>11 – 15.5</td>
<td>15.5 – 20</td>
</tr>
<tr>
<td>Turbidity</td>
<td>&lt; 10</td>
<td>10 – 30</td>
<td>30 – 50</td>
<td>50 – 70</td>
<td>70 – 100</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>&gt; 7.0</td>
<td>7.0 – 6.0</td>
<td>6.0 – 5.0</td>
<td>5.0 – 4.0</td>
<td>4.0 – 2.0</td>
</tr>
<tr>
<td>TP</td>
<td>&lt; 0.15</td>
<td>0.15 – 0.5</td>
<td>0.5 – 0.8</td>
<td>0.8 – 1.2</td>
<td>1.2 – 1.5</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>&lt; 50</td>
<td>50 – 160</td>
<td>160 – 270</td>
<td>270 – 380</td>
<td>380 – 500</td>
</tr>
<tr>
<td>Water Quality Index</td>
<td>&gt; 93.2</td>
<td>72.1 – 93.2</td>
<td>47.4 – 72.1</td>
<td>22.9 – 47.4</td>
<td>&lt; 22.9</td>
</tr>
</tbody>
</table>
ALTERNATE FORM OF THE NWQI

Although the BOD is a very important indication of the suitability of river water for aquatic fauna COD is advantageous due to its high accuracy and quick testing procedure compared to that of BOD. Therefore, the subindex for BOD (SIBOD) in Eqn 8 can be replaced with subindex of COD (SICOD) as shown in Eqn. 15 and Eqn. (16).

\[
NWQI = 0.18SIDO + 0.18SITSS + 0.17SICOD + 0.17SIAN + 0.15SITP + 0.15SITUR \tag{15}
\]

\[
SICOD = 3E^{-0.5}COD^3 - 0.0056COD^2 - 0.4205COD + 99.781 \tag{16}
\]

where, SICOD = Subindex for COD.

With the replacement of COD, the NWQI can be determined on the same day of sampling and testing while if the BOD is used it would be necessary to wait for at least 5 days to determine the BOD. If the equipment is available then total organic carbon can be used instead of COD and BOD. However, COD is more advantageous over TOC due to its simple testing procedure and reliable result.

CONCLUSIONS

The water environment is a dynamic system. Occasional review of monitoring requirements, effluent discharge standards and water quality indices is deemed necessary for the sustainable management of water resources. The evaluation should be done in the context of point and non-point pollution sources. The existing Water Quality Index (WQI) proposed by the Department of Environment (DOE) Malaysia was reviewed and found to have a few limitations. New Water Quality Index (NWQI) was proposed in the study for a better safeguard against the river water pollution during rainy and non-rainy days. The proposed NWQI was applied to the water quality data of two river basins in Malaysia. The case studies revealed that, on average, during the dry days the NWQI produced 8 to 10 points less than those produced by the existing WQI equations. During the rainy days the difference was higher, which varied between 13 and 20 points (index values). The NWQI was found to be slightly more stringent than the existing WQI equations. However, this modification is necessary to assure good river water quality to suit government’s intention to increase tourism and river related activities in the country.

ACKNOWLEDGEMENTS

The author is grateful to DOE Malaysia for providing the river water quality data. The support provided by the respondent who took part in the questionnaire survey is also highly appreciated.
Figure 1: Variation of Sub-indices with Pollutant Concentrations for the Parameters Required to Determine WQI of Malaysian Rivers (Existing Equations)
Figure 2: Variation of Sub-indices with Pollutant Concentrations for the Parameters Required to Determine NWQI in Malaysian (Proposed Equations)

(a) Dissolved Oxygen (DO)

(b) Turbidity (NTU)

(c) Bio-chemical Oxygen Demand (BOD)

(d) Ammoniacal Nitrogen (AN)

(e) Suspended Solids (SS)

(f) Total Phosphorus (TP)
REFERENCES


