Assessment of Water Quality of Goalichara: A Water Quality Index Based Approach

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ABSTRACT

This study provides the assessment of the present status of water quality of Goalichara and downstream points of this canal at the Surma River based on analysis of water sample collected from the chara and its downstream points. The investigation was based on laboratory tests on water samples obtained from five sampling points. The test parameters were pH value, turbidity, alkalinity, biochemical oxygen demand, dissolved oxygen, total solids, total dissolved solids, and chloride. The individual water quality index was calculated based on CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index) formula for different locations at Goalichara. The index values found for agriculture purpose ranged from 53.18 to 61.33, for aquatic life ranged from 47.86 to 60.37, and for drinking purpose ranged from 46.33 to 50.19. It was found that CCME WQI value for drinking purposes, agriculture purpose, and aquatic life indicate more or less marginal water quality. Also, NSF WQI (National Sanitation Foundation Water Quality Index) was applied to the same location. The overall NSF WQI value at different sampling points of Goalichara was in the range 34 – 58, indicates more or less bad water quality in the canal. The study showed that different parameters analyzed at the same locations do not change significantly in different seasons and the water quality of this chara is unsafe for human and aquatic life.

Keywords: Water quality, CCME index, NSF index

1. INTRODUCTION

Ground water and river water are the main water sources of Bangladesh. However, in some hilly areas of Bangladesh small local canals transport water from upstream water bodies which are the main water sources for peoples living nearby. The quality of these surface water sources are often found inappropriate for use, hence need to be justified. However, surface water quality assessment often becomes complex due to the presence of numerous indicating parameters. On the other hand, assessing water quality on the basis of single statistical analysis concerning individual parameters remains cumbersome, hence not popular and difficult to understand by mass people [1, 2]. Oppositely, Water Quality Index (WQI) is an effective tool that combines composite influence of each parameter with a single value indicating the overall quality of water. Various researchers developed numbers of WQI for various regions after the concept was originally introduced by Horton [3]. For being easily understandable and due to its capacity of reducing the bulk of information, the system gets increased importance worldwide. Water Quality Index increases the ability of understanding of certain water quality in a glimpse that is useful to the policy makers, as well as users of the water resource [4].

Horton initially introduced water quality index (WQI) in United States by selecting 10 most commonly used water quality variables [3]. Since then it has been widely applied and accepted in European, African and Asian countries [5–8]. Later, in 1970 Brown [9] proposed an approach based on weights to individual parameter. A general WQI approach [10] is based on the most common factors, which are described in the following three steps:

Parameter Selection [11], Determination of Quality Function (curve) for Each Parameter Considered as the Sub-Index and Sub-Indicies Aggregation with Mathematical Expression [12]. However, since its first application there have been variety of modifications for water quality index for various purposes. Modification for local (regional) purposes is also often applied.

2. MATERIALS AND METHODS

2.1 Study Area

Sylhet is a major city in north-eastern Bangladesh located on the banks of the Surma River and surrounded by the Jaintia, Khasi and Tripura hills. The city has nine local canals (called Chara) flowing through it. Among nine, two main canals are called Malnichara and Goalichara. These two main canals are combined with the estuary of the River Surma at their ends. It is observed that the Malnichara and Goalichara receive a considerable pollution load mainly from domestic waste water including human waste and food waste, but also industrial waste water including power station, tea industries and food processing industries. The ultimate result of this pollution is the deterioration of Surma water quality. Despite having pollution load, the water of these two canals is the source of various water demand of nearby people. Considering the water uses importance from these canals, assessment of water quality for this area is a demand of time.

The study of seasonal variation in water quality of natural canals as well as Surma River indicated that pollution in dry season is much higher than in wet season in Surma River [13].
3. WATER QUALITY INDEX (WQI)

Among various modifications of WQI systems the following two were used in this study:

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

This consistent method was formulated by Canadian jurisdictions to convey the water quality information for both management and the public. A committee, established under the jurisdiction of Canadian Council of Ministers of the Environment (CCME) has developed this Water Quality Index. This formula is proved useful for many water agencies in various countries with slight modification [14–16]. Besides of determining WQI for drinking purpose, this method support water quality assessment for both aquatic life and agricultural use in accordance with specific guidelines. The parameters related with various measurements may vary from one station to the other while sampling protocol requires at least four parameters, sampled at least four times [17, 18]. The calculation of index scores in CCME WQI method can be obtained by using the following relation:

\[
WQI = 100 - \frac{F_1 + F_2 + F_3}{1.732} \tag{1}
\]

Where three factors \( F_1 \), \( F_2 \), and \( F_3 \) are defined as scope, frequency and amplitude respectively. The factor of 1.732 arises because each of the three individual index factors can range as high as 100. This means that the vector length can reach 173.2 as a maximum. Division by 1.732 brings the vector length down to 100 as a maximum.

A brief description of calculation of scope frequency and amplitude is given below:

Factor 1: Scope

\( F_1 \) (Scope) represents the extent of water quality guideline non-compliance over the time period of interest. It has been adopted directly from the British Columbia Index:

\[
F_1 = \left( \frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100 \tag{2}
\]

Where variables indicate those water quality variables with objectives which were tested during the time period for the index calculation.

Factor 2: Frequency

\( F_2 \) (Frequency) represents the percentage of individual tests that do not meet objectives (“failed tests”):

\[
F_2 = \left( \frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100 \tag{3}
\]

Factor 3: Amplitude

\( F_3 \) (Amplitude) represents the amount by which failed test values do not meet their objectives. \( F_3 \) is calculated in three steps.

a. The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

\[
\text{excursion}_j = \left( \frac{\text{Failed test value}}{\text{Objective}} \right) - 1 \tag{4}
\]

For the cases in which the test value must not fall below the objective:
The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both of those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions or nse, is calculated as:

\[ nse = \frac{\sum_{i=1}^{n} excursion_i}{\text{Number of tests}} \]  

(6)

c. \( F_3 \) is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100.

\[ F_3 = \left( \frac{nse}{0.01nse + 0.99} \right) \]  

(7) [14–16].

A more detailed description of computation method and water quality rating as per different Water Quality Index methods can be found in the literature [12].

### 3.2 National Sanitation Foundation Water Quality Index (NSFWQI)

A usual water quality index method was developed by paying great rigor in selecting parameters by Brown et al., developing a common scale and assigning weights. The challenge was supported by the National Sanitation Foundation (NSF) and therefore termed as NSFWQI in order to calculate WQI of various water bodies that are critically polluted. Total nine water quality parameters such as temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total solids are used while comparing water quality for different water bodies [9, 19]. Collected water quality data are transferred to a weighting curve chart, where a numerical value of \( Q_i \) is obtained. A detailed description of the method can be found elsewhere [20]. The mathematical expression for NSF WQI is as follows:

\[ \text{WQI} = \sum_{i=1}^{n} Q_i W_i \]  

(8)

Where,

- \( Q_i \): sub-index for \( i^{th} \) number of water quality parameter;
- \( W_i \): weight associated with \( i^{th} \) number of water quality parameter;
- \( n \): number of water quality parameters.

To complete the determination of Water Quality Indices, a number of water quality parameters were tested. The test parameters were pH value, turbidity, alkalinity, bio oxygen demand, dissolved oxygen, total solids, total dissolved solids, and chloride.

### 4. RESULTS AND DISCUSSION

Water sample collected from five different locations of Goalichara were tested to determine the Water Quality Index (WQI). To calculate desired WQI, each parameter were multiplied by weightage factors according to their relative importance in determining quality index as prescribed in NSF and CCME index. Results obtained from analysis are given in following sections.

#### 4.1 The CCME WQI

CCME Water Quality Index for Goalichara was calculated in the context of drinking purpose, aquatic life, and agricultural use. CCME WQI is desirable in that sense that it compares observations with a benchmark instead of comparing to a rating curve [14]. This advantage of CCME index makes this more representative for evaluation of drinking water quality. While calculating WQI, average values calculated for different seasons for each parameter were used.

Table 1 shows the classification of water quality index for water from Goalichara used for drinking purpose, based on CCME WQI value. The CCME WQI value of 45 to 64 indicates marginal water quality. The water quality index of \( S_1 \), \( S_2 \), \( S_3 \), \( S_4 \), and \( S_5 \) was found within 46.33 to 50.19, representing water of marginal quality.

<table>
<thead>
<tr>
<th>Station</th>
<th>Period</th>
<th>CCME WQI</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>2012 - 2013</td>
<td>50.19</td>
<td>The CCME WQI Value is in between 45 to 64. So the water quality is marginal.</td>
</tr>
<tr>
<td>S2</td>
<td>2012 - 2013</td>
<td>50.14</td>
<td>The CCME WQI Value is in between 45 to 64. So the water quality is marginal.</td>
</tr>
<tr>
<td>S3</td>
<td>2012 - 2013</td>
<td>48.61</td>
<td>The CCME WQI Value is in between 45 to 64. So the water quality is marginal.</td>
</tr>
<tr>
<td>S4</td>
<td>2012 - 2013</td>
<td>47.30</td>
<td>The CCME WQI Value is in between 45 to 64. So the water quality is marginal.</td>
</tr>
<tr>
<td>S5</td>
<td>2012 - 2013</td>
<td>46.33</td>
<td>The CCME WQI Value is in between 45 to 64. So the water quality is marginal.</td>
</tr>
</tbody>
</table>
Calculation of CCME index for aquatic life was done using the alkalinity, DO, BOD₅, TS, TDS, and chloride. While pH, turbidity, alkalinity, DO, BOD₅, TS, TDS and chloride were used for the calculation of CCME index for agricultural use. All the results indicate below marginal water quality for aquatic life and agriculture purpose in Goalichara. Results for the CCME index for aquatic life and agricultural use are given in Figure 2.

Deteriorated water quality from Goalichara in CCME index shows no usability of this water for drinking purposes, but the water may be used for agricultural purposes. However, below marginal standard is not recommended if the alternative supply is available.

4.2 NSF WQI for Overall Water Quality

Water quality index at five different locations at Goalichara (S₁, S₂, S₃, S₄, and S₅) was estimated using the formula proposed by NSF WQI. It is indicated in the Table 2 that almost all samples were found to be marginal in quality. This may be due to the presence of various non-point source pollutants. Moreover, the area is densely populated around the water body.

| Table 2: Water quality index for four different seasons in Goalichara |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Station | November-2012 | February-2013 | May-2013 | June-2013 |
| | NSF WQI | Remarks | NSF WQI | Remarks | NSF WQI | Remarks | NSF WQI | Remarks |
| S₁ | 58 | Fair | 49 | Bad | 41 | Bad | 42 | Bad |
| S₂ | 49 | Bad | 50 | Fair | 38 | Bad | 45 | Bad |
| S₃ | 41 | Bad | 47 | Bad | 40 | Bad | 43 | Bad |
| S₄ | 35 | Bad | 39 | Bad | 34 | Bad | 44 | Bad |
| S₅ | 45 | Bad | 41 | Bad | 41 | Bad | 47 | Bad |

5. CONCLUSION

The results from data analysis show that the water is unfit for drinking purposes without any form of treatment and the water is undoubtedly undesirable for aquatic life and agriculture. Several important water quality parameters like pH, turbidity, alkalinity and DO value were found to be unusual for Goalichara. However, BOD, TDS, TS, and chloride were found more or less tolerable for aquatic life. Clear evidence is that usability of water for drinking purpose decreased at the vicinity of the Surma River. This may be due to the gradual organic pollution load from the nearby areas. In the recent years, this area has been rapidly habituated by local tea gardener’s causing incremental waste disposal in Goalichara. It is evident that, since the current trend of pollution is likely to continue, the water quality in the Surma River is likely to get worse in the coming years, especially in the dry season.

REFERENCES


