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# ASSESSMENTOF WATER QUALITY OF BALUKHALI STREAM AT CHITTAGONG UNIVERSITY CAMPUS THROUGH WEIGHTED ARITHMETIC WATER QUALITY INDEX

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## ABSTRACT

Bangladesh is blessed with many lentic and lotic water bodies. The present study was conducted to find out the condition of the water quality of the Balukhali stream of Chittagong University Campus (CUC) using the Weighted Arithmetic Water Quality Index (WAWQI). In this regard water samples were collected for one year period during January 2018 to December 2018 from two zones, the riffle zone and the pool zone of the mentioned stream. Water samples were analyzed using standard techniques of APHA to determine the seven physical [Temperature, Strem depth, Turbidity, Water velocity, Stream width, Conductivity and Total Dissolved Solids (TDS)] and five chemical parameters [Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Free Carbon dioxide (free$CO_2$), Calcium ($Ca^{++}$) and pH] out of which nine were used to evaluate the WQI values. The WQI values were 77.856 in the riffle zone and 80.137 in the pool zone which indicated that the water quality was very poor and can only be used for agricultural purposes.

**Key words:** Stream water quality, physicochemical parameters, WAWQI-Weighted Arithmetic Water Quality Index, Balukhali stream, Chittagong University Campus.

## Introduction

In the world over 7.8 billion people rely on freshwater for drinking, agriculture, and industrial purposes. Approximately 10% of all known species on earth depend on freshwater ecosystems, including plants, invertebrates, fish, amphibians, birds, and mammals (Dudgeon *et al*. 2006). Bangladesh is naturally blessed with several freshwater resources, like ponds, lakes, streams, *khal, beel, haor, baor*, and river. But, most of the freshwater resources are being polluted due to human activities. Agricultural run-offs containing pesticide remnants degrade aquatic systems. In this way, our water resources are degraded and impact the water ecology. Nasiruddin *et al*. (2015) noted that physicochemical factors in water bodies significantly impact insect communities, species diversity, and food chain formation. Fluctuations in these factors influence insect populations and influence the structure of the community. There are two streams flowing through the Chittagong University Campus (CUC), namely Balukhali and Mithakhal. Streams play a crucial role in underground aquifers, so, monitoring the water quality and health of these ecosystems at regular intervals is important. Nasiruddin *et al*. (2013) reported water quality of Mithakhalchara of Chittagong University Campus based on aquatic insect communities. Azadi *et al.* (2020) studied the fin and shell fish abundance and diversity impacted by prevailing water quality in the Balukhali stream, a hilly stream at Chittagong University Campus. The Weighted Arithmetic Water Quality Index (WAWQI) method is widely used for water quality assessment. According to Noori (2020), WAWQI is considered more sensitive to the presence of pollutants compared to other indices like the Canadian Council of Ministers of the Environment (CCME) index. This article aims to study the physicochemical parameters of Balukhali stream and evaluate the water quality of the stream using the Weighted Arithmetic Water Quality Index (WAWQI).

## Materials and Methods

Balukhali stream originates from a hilly area, Sonaichori, in Sitakunda about three kilometers west of CUC. The stream runs eastward from its source across the CUC to join the Halda River. Two zones of the stream namely the riffle zone and the pool zones were selected for sampling. The riffle zone was situated between latitudes 22º287'35" North and longitudes 91º47'18.9" East and the pool zone was situated between latitudes 22$^{o}$27'36" North and longitudes 91$^{o}$47'48" East. Sampling was done twice a month for one year period from January 2018 to December 2018. For water quality analysis water was collected between 10-11 amfrom three selected sites from each of the two different zones namely the riffle zone and the pool zone of the stream channel. A total of seven physical parameters (Temperature, Total Depth, Turbidity, Water velocity, Width of the stream, Conductivity and Total Dissolved Solid) and five chemical parameters [Dissolved Oxygen (DO), Biological Oxygen Demand ($BOD_5$), Free Carbon dioxide ($FCO_2$), $Ca^{2+}$, and pH] of the water were measured. Some physical parameters were measured in the field such as water Temperature with a portable centigrade thermometer, total depth and width of the stream using a pole and meter scale, Turbidity with a Secchi disc (20 cm dia), and water Velocity by floating a piece of cork sheet for 5 m distance while maintaining time observed in the stopwatch. The other parameters examined in the laboratory were conductivity (with a conductivity meter, T ds3× 10 T 194, model No. 3303, Singapore made with sensitivity ± 1µs/cm), TDS (with a TDS meter), and pH (with a pH meter, HANNA Ins. Co., Italy). Following APHA (2005), DO, $BOD_5$, free $CO_2$, and $Ca^{2+}$ were measured in the laboratory.

**Procedure of WQI determination:** Weighted Arithmetic Water Quality Index (WAWQI) (Horton 1965 and Brown *et al*. 1972) was followed to determine the Water Quality Index (WQI). Nine water parameters (Temperature, Turbidity, Conductivity, TDS, DO, $BOD_5$, free $CO_2$, $Ca^{2+}$and pH), were utilized for transforming these values into the single index value of WQI. Interpretation and comparison were done with the index level of standards of drinking water quality, recommended by WHO (1992), BIS (1983) and ICMR (1975).

**WQI** was calculated following the Weighted Arithmetic Index method of Brown *et al*. (1972) as:

$$WQI = \sum_{n=1}^{n} qn * Wn \;/\; \sum_{n=1}^{n} Wn$$

Where,
qn is the Quality rating for the nth water quality parameter
Wn is the Unit weight for nth parameters

**Sub Index Quality Rating** (qn) was calculated as: qn= 100[(Vn - Vio) / (Sn - Vio)]

Where,
qn = Quality rating for the n$^{th}$ water quality parameter
Vn = Estimated value of the n$^{th}$ parameter at a given sampling station
Sn = Standard permissible value of n$^{th}$ parameter
Vio = Ideal value of the n$^{th}$ parameter in pure water.
Viowas taken as zero for drinking water except for pH = 7.0 and Dissolved Oxygen =14.6mg/l (Tripathy and Sahu 2005).

**Calculation of Unit Weight (Wn):** Wn was calculated from relation: Wn = K/Sn

Here, Wn is the Unit weight for nth parameter, Sn is the Standard value for nth parameter, and K is the Constant for proportionality.

Table 1 shows the classification of WQI level and status of water quality.

Table 1. Water Quality Index level and water quality status based on Weighted Arithmetic Index WQI method (Source: Brown *et al*. 1972, Chatterjee and Raziuddin 2002)

| Water Quality Index Level | Water Quality Status |
|---|---|
| 0-25 | Excellent |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very Poor |
| >100 | Unsuitable for Drinking |

## Results and Discussion

Among the twelve parameters (7 Physical and 5 Chemical) analyzed, only nine (water Temperature, Turbidity, Conductivity, TDS, DO, $BOD_5$, free $CO_2$, $Ca^{2+}$ and pH), were considered to calculate the WQI. Tables 2-3 show the minimum, maximum, range, and mean values (with SD) of nine physicochemical parameters and WQI of the riffle and pool zones of the Balukhali stream in CUC for 12-month study period.

### Physical Parameters

**Water Temperature:** Water temperature varied between 12.43 to 31.33 ºC (mean 25.578 ± 0.486ºC) in the riffle zone while 12.12 to 29.83 ºC (mean 24.097 ± 0.425ºC) in the pool zone of the studied stream during the 12-month study period (Table 2). These values fall within the optimal range of temperature for tropical freshwater inhabitants. The temperature variation observed was a result of low solar heat radiation across the zones. Inundation by run-off water into the stream also caused a reduction in temperature.

Table 2. Showing the Mean ±SE and range values of physical and chemical parameters of the riffle and pool zones of Balukhalistream (during January 2018 to December 2018)

| Physical factors of Riffle zone (Mean average and SE) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Factors | Temperature (ºC) | Total depth (cm) | Turbidity (cm) | Water velocity (cm/sec) | Width of stream (cm) | Conductivity (µS/cm) | TDS (ppt) |
| Range | (12.43-31.33) | (11.33-28.67) | (12.35-27.67) | (1636.7-2438.3) | (348-804) | (137.7-222.2 | (0.06-0.09) |
| Average Value | 25.578 | 20.207 | 17.931 | 2067.7 | 472.48 | 178.95 | 0.073 |
| | ± 0.486 | ± 1.723 | ± 1.569 | ± 47.543 | ± 21.001 | ± 5.257 | ±0.003 |
| **Physical factors of Pool zone (Mean average and SE)** | | | | | | | |
| Range | (12.12-29.83) | (28.28-57.33) | (6.00-41.27) | (5-1384.33) | (533.33-868.67) | (148.67-218.17) | (0.06-0.10) |
| Average Value | 24.097 | 47.178 | 28.388 | 875.04 | 685.08 | 175.49 | 0.077 |
| | ± 0.425 | ± 4.075 | ± 2.18 | ± 43.559 | ± 35.055 | ± 5.47 | ±0.003 |

| Chemical factors of Riffle zone (Mean average and SE) | | | | | |
|---|---|---|---|---|---|
| Factors | DO (mg/l) | $BOD_5$ (mg/l) | $FCO_2$(mg/l) | $Ca^{2+}$ (mg/l) | pH |
| Range | (4.53-9.4) | (0.47-6.3) | (1.25-4.77) | (1.3-2.42) | (7.0-8.1) |
| Average Value | 7.727 | 2.132 | 2.923 | 1.964 | 7.442 |
| | ± 0.19 | ±0.37 | ±0.17 | ±0.09 | ±0.07 |
| **Chemical factors of Pool zone (Mean average and SE)** | | | | | |
| Range | (4.10-9.52) | (0.40-3.10) | (1.30-5.30) | (1.30-2.50) | (5.40-7.90) |
| Average Value | 7.635 | 1.95 | 2.867 | 2.075 | 7.158 |
| | ±0.166 | ±0.217 | ±0.154 | ±0.078 | ±0.051 |

According to Azadi *et al*. (2020), in Balukhali stream water temperature ranged from 15.75-31.50 $^0$Cduring their study period, from December 2016 to May 2017, with a mean temperature 22.79±2.56 $^0$C in station 1 and 22.58±2.73 $^0$C in station 2.Islam *et al*. (2019) found the range of water temperature between 18 - 33 $^0$C from three ponds of CUC, while the mean temperature was 26.94±3.89 $^0$C, 27.94±3.64 $^0$C, and 28.08± 3.34 $^0$C for the three ponds respectively during their 24-month study period which was normal and within the standard limit. Nasiruddin *et al*. (2015) investigated the water quality of the Mithakhal stream in the CUC and found the range between 16.00 to 28.67 $^0$C in the stream's riffle and pool zones. Mahmud *et al*. (2014) found an average temperature of approximately 20.6 $^0$Cranging from 19.5 to 22.5 $^0$C while experimenting on the surface water of fifteen different water bodies from the CUC. Chowdhury *et al*. (2012) showed a maximum of 10.4 $^0$Cdifferences in temperature i.e., between 23.8 - 34.2 $^0$C in some water bodies (such as lakes, ponds, etc.) in Bangladesh; while the water temperature of Balukhali stream showed almost 18 $^0$C differences.

**Total Depth:** Total depth is another important physical parameter as the insects and aquatic organisms inhabit different habitat zones in an aquatic body. The total depth range varied between 11.33 to 57.33 cm, while the depth of the riffle zone ranged from 11.33to 28.67 cm and the pool zone ranged from 28.28 to 57.33 cm. The mean depth was 20.207±1.723 cm in the riffle zone while 47.178±4.075 cm in the pool zone (Table 2). According to Azadi *et al*. (2020) in the Balukhali stream, mean water depth was 14.83±2.34 cm in station 1 and 14.17± 1.97 cm in station 2. However, the range of the total depth of three ponds in CUC was found between 36.20 to 86.20 cm by Nasiruddin *et al*. (2019), while the mean average±SE was 8.11 ±3.09 cm, 51.30±3.16 cm, and 47.88 ± 1.74 cm for ponds 1, 2 and 3 respectively.

**Turbidity:** Turbidity has a crucial impact on water bodies, as sunlight penetration depends completely on it. It helps phytoplankton and other vegetation which produce food through photosynthesis, which in turn provides food for other aquatic organisms in the food chain of that particular ecosystem. Turbidity ranged from 12.35 to 27.67 and 6.00 to 41.27 cm, respectively in the riffle and pool zones. The mean transparency was 17.931 ± 1.569 cm in the riffle zone while 28.388±2.18 cm in the pool zone. The range or mean transparency of water was not within the standard limit of turbidity according to the Department of Public Health and Engineering (2019), thus might be suitable for drinking after treatment. Transparency of the three ponds in CUC ranged between 14.27 to 50.41 cm while the mean average±SE was 33.89±2.19cm, 25.64±1.59cm, and 22.37±1.83 cm for the three ponds respectively (Nasiruddin *et al*. 2019). Water transparency varied from 14 to72 cm (mean 46.69±13.78 cm), 20.5-85 cm (mean 64.98±14.65 cm), and 16 to75 cm (mean 39.96 ± 12.01 cm) in ponds 1, 2, and 3 respectively when investigated by Islam *et al*. (2019). However, turbidity increases due to contamination by mass use of the water.

**Water velocity:** Water velocity varied between 1636.7 to 2438.3 cm/sec (mean 2067.7± 47.543 cm/sec) in the riffle zone while 5 to 1384.33 cm/sec (mean 875.04± 43.559 cm/sec) in the pool zone of the studied stream throughout the study (Table 2). Azadi *et al*. (2020) found the range of current velocity from 0.225±0.02 to 0.405± 0.02 m/sec (mean 0.303±0.029 m/sec) in station 1 and 0.325±0.01 to 0.52 ± 0.04 m/sec (mean 0.362 ± 0.034 m/sec) in station 2 of Balukhali stream, respectively. Nasiruddin *et al*. (2015) found the range of the velocity from 21 to 100 cm/sec (mean 3±0.02 cm/sec) in the riffle zone while 6 to 37 cm/sec (mean 3 ± 0.01 cm/sec) in the pool zone of the Mithakhal stream. Present observations showed that the Balukhali stream had a high velocity of water.

**Width of stream channel:** Width of a water channel facilitates an increased amount of water flow. Observing the width of the channel helps in understanding the changes in the edge of the channel. Sometimes heavy water flow or natural disasters like heavy rain cause erosion in the channel. However, the width of the Balukhali stream ranged between 348.00 to 868.67 cm with a mean ±SE 472.48 ±21.001 cm in the riffle zone and 685.08 ± 35.055 cm in the pool zone. In the winter season, the current of the stream almost became stagnant but in the rainy season, the water flow was aggressive with strong current. The width of every station was measured for both dry and bank full seasons. Width of the pool zone was recorded as 5m in the dry season and 8m in the wet season while the width of the riffle zone was recorded as 3m in the dry season and 6m in the wet season.

**Conductivity:** Conductivity of the Balukhali stream ranged between 137.7 to 222.2 µS/cm (mean165.37±5.257 µS/cm) in the riffle zone while 148.67 to 218.17 µS/cm (mean 175.49±5.47 µS/cm) in the pool zone during the 12-month study period (Table 2). In both zones, the conductivity was within the standard limit according to ICMR (1975). Azadi *et al.* (2020) found the conductivity range from 131.5± 9.19 to 230.0 ±14.14µS/cm (mean 199.33 ±6.13 µS/cm) in station 1 and 161.5 ±44.55 to 235.0 ±

29.70 µS/cm (mean 202.08 ± 11.19 µS/cm) in station 2 of Balukhali stream. Islam *et al*. (2019) also investigated three different ponds in CUC whereby the electrical conductivity varied from 180 to 423 µS/cm (mean 278.92±69.40 µS/cm), 22 to 85 µS/cm (mean 43.83±14.51 µS/cm) and 44 to 154 µS/cm (mean108.79±34.11 µS/cm) in ponds 1, 2 and 3 respectively. Their study recorded the highest conductivity, which exceeded the standard limit in Pond 1, which was excessively used by the residents of CUC. Nasiruddin *et al*. (2019) found the range of conductivity between 25.67 to 203.33 µS/cm from three ponds of CUC while the mean conductivities were 2.16 ± 6.72 µS/cm, 0.41 ± 0.82 µs/cm, and 0.41 ± 0.41 µS/cm for the three ponds respectively during their 12 months study period. The conductivity ranged between 109.00 to 197.00 µS/cm (mean 0.67 ± 0.57 µS/cm) in the riffle zone while 104.40 to 164.00 µS/cm (mean 0.58 ± 0.33 µS/cm) in the pool zone of the Mithakhal stream (Nasiruddin *et al*. 2015). Mahmud *et al*. (2014) found the conductivity range from 23 to 153 µS/cm with an average value of 83 µS/cm in fifteen different water bodies in CUC, which was also an indication of good water quality in the samples.

**Total Dissolved Solid (TDS):** The total dissolved solid (TDS) varied between 0.06 to 0.09 ppt (mean 0.073 ± 0.003 ppt) in the riffle zone while 0.06 to 0.10 ppt (mean 0.077 ± 0.003 ppt) in the pool zone which was the indication of suitability for drinking (Table 2). Azadi *et al*. (2020) found the TDS range from 0.065 ± 0.01 to 0.125 ± 0.01 ppt (mean 0.097 ± 0.009 ppt) in station 1 and 0.09 ± 0.03 to 0.12 ± 0.14 ppt (mean 0.103 ± 0.005 ppt) in station 2 respectively of Balukhali stream thus agreeing with the present finding. Islam *et al*. (2019) found the TDS range varying from 0.01-0.23 ppt (mean 0.13±0.049 ppt), 0.00-0.02 ppt (mean 0.01±0.006 ppt), and 0.01-0.07 ppt (mean 0.04±0.017 ppt) in Ponds 1, 2, and 3 respectively. Mahmud *et al*. (2014) found the range of TDS from 40 ppt to 80 ppt with an average value of 58.7 ppt in the fifteen water bodies from CUC which were in contradiction with the present findings.

### Chemical Parameters

**Dissolved Oxygen (DO):** The survival and dispersal of aquatic species depend on the DO level of the water in each particular water body (Islam *et al*. 2019). The Water Quality Index value is significantly influenced by the DO level, which is directly linked to the water's clarity, with clear water exhibiting higher DO levels (Kumar and Dua 2009). In the present study, DO varied from 4.53to 9.4 mg/l (mean 7.727± 0.188 mg/l) in the riffle zone and from 4.10to 9.52 mg/l (mean 7.635 ± 0.166 mg/l) in the pool zone (Table 2). The mean values were above the standard limit, which indicated a good amount of oxygen dissolved in the water. Azadi *et al*. (2020) found the DO level ranging from 6.20± 0.85 to 8.05± 0.64 mg/l (mean 7.07± 0.35 mg/l) in station 1 and 5.70± 0.28 to 7.45± 1.06 mg/l(mean 6.73± 0.29 mg/l) in station 2 of Balukhali stream, respectively. The DO ranged from 1.73 to 11.20 mg/l, 1.70 to 11.78 mg/l, and 2.50 to 9.98 mg/l in ponds 1, 2 and 3 respectively, and the DO level was lowest from April to September in the studied year, as observed in the study of Nasiruddin *et al*. (2019). The DO ranged from 0.9-8.2 mg/l (mean 4.06± 1.99l mg/l), 4.4-16.5 mg/l (mean 9.39±3.20 mg/l), and 4.4-14.1 mg/l (7.73±2.76 mg/l) in the three different studied ponds by Islam *et al*. (2019). One of the ponds showed the least amount of DO which might be due to the high rate of contamination occurring due to the addition of contaminating agents during different uses of the pond water. From the values of Nasiruddin *et al*. (2019) and Islam *et al*. (2019), it can be assumed that the inflow of water from the surroundings carried sediments during the rainy season. As observed by Nasiruddin *et al*. (2015), the DO in the Mithakhal stream varied from 6.20 to 10.05 mg/l in the riffle zone, while 6.13 to 8.20 mg/l in the pool zone, which indicated good amount of DO in the water. However, Mahmud *et al*. (2014) found the DO range 8.6-9.1 mg/l (average 8.8 mg/l), and the water quality of the sampling area (fifteen different water bodies from CUC) regarding DO was found suitable for drinking, domestic, irrigation, and industrial purposes.

**Biological Oxygen Demand (BOD):** A low Biochemical Oxygen Demand (BOD) value is often interpreted as an indicator of good water quality due to its association with minimal organic pollution and healthy oxygen levels for aquatic ecosystems. According to Islam *et al*. (2019), BOD shows how much DO aerobic organisms need to gradually decompose organic matter in water. Because bacteria use oxygen to survive, the BOD level falls as the DO level rises.

Table 3. Mean values of nine physicochemical water quality parameters, standard values, and Water Quality Index of the Riffle zone of Balukhali stream for 12 months (from January 2018 to December 2018) study period

| Parameters | Observed Values ($V_n$) [Mean] | Recommended Standard Values ($S_n$) | Recommended Agency of Standard Values | Unit Weights ($W_n$) | Quality Rating ($q_n$) | $q_n$ x $W_n$ | WQI $\sum(q_n \times W_n)$ |
|---|---|---|---|---|---|---|---|
| Temperature (ºC) | 25.578 | 30 | Santhosh and Singh, 2007 | 0.039 | 85.26 | 3.336 | 77.856 |
| Turbidity (cm) | 17.931 | 10 | The Department of Public Health and Engineering (2019) | 0.117 | 179.31 | 21.046 | |
| Conductivity (µS/cm) | 178.95 | 300 | ICMR, 1975 | 0.004 | 59.65 | 0.233 | |
| DO (mg/l) | 7.727 | 6 | The Department of Public Health and Engineering (2019) | 0.196 | 79.919 | 15.634 | |
| $BOD_5$ (mg/l) | 2.132 | 5 | ICMR, 1975 | 0.235 | 42.64 | 10.009 | |
| $fCO_2$ (mg/l) | 2.923 | 5 | Santhosh and Singh, 2007 | 0.235 | 58.46 | 13.723 | |
| $Ca^{2+}$ (mg/l) | 1.964 | 75 | ICMR 1975, BIS 1983 | 0.016 | 2.619 | 0.041 | |
| pH | 7.442 | 6.5-8.5 (7.5) | ICMR 1975, BIS 1983 | 0.156 | 88.4 | 13.834 | |
| TDS (PPT) | 0.073 | 500 | ICMR 1975, BIS 1983 | 0.002 | 0.0146 | 0.00003 | |

Table 4. Mean values of nine physicochemical water quality parameters, standard values, and Water Quality Index of the Pole zone of Balukhali stream for 12 months (from January 2018 to December 2018) study period

| Parameters | Observed Values ($V_n$) [Mean] | Recommended Standard Values ($S_n$) | Recommended Agency of Standard Values | Unit Weights ($W_n$) | Quality Rating ($q_n$) | $q_n$ x $W_n$ | WQI $\sum(q_n \times W_n)$ |
|---|---|---|---|---|---|---|---|
| Temperature (ºC) | 24.097 | 30 | Santhosh and Singh, 2007 | 0.039 | 80.323 | 3.143 | 80.137 |
| Turbidity (cm) | 28.388 | 10 | The Department of Public Health and Engineering (2019) | 0.117 | 283.88 | 33.319 | |
| Conductivity (µS/cm) | 175.49 | 300 | ICMR, 1975 | 0.004 | 58.497 | 0.229 | |
| DO (mg/l) | 7.635 | 6 | The Department of Public Health and Engineering (2019) | 0.196 | 80.988 | 15.843 | |
| $BOD_5$ (mg/l) | 1.95 | 5 | ICMR, 1975 | 0.235 | 39 | 9.155 | |
| $fCO_2$ (mg/l) | 2.867 | 5 | Santhosh and Singh, 2007 | 0.235 | 57.34 | 13.460 | |
| $Ca^{2+}$ (mg/l) | 2.075 | 75 | ICMR 1975, BIS 1983 | 0.016 | 2.767 | 0.0433 | |
| pH | 7.158 | 6.5-8.5 (7.5) | ICMR 1975, BIS 1983 | 0.156 | 31.6 | 4.945 | |
| TDS (PPT) | 0.077 | 500 | ICMR 1975, BIS 1983 | 0.002 | 0.0146 | 0.00003 | |

Alexakis *et al*. (2016) highlighted that low BOD is an important parameter for surface water quality assessment, contributing to its classification as "good" under various indices like the National Sanitation Foundation (NSF) Water Quality Index. Jouanneau *et al*. (2014) noted that BOD reflects the biodegradable organic load in water, with lower values indicating fewer pollutants and higher ecological health. The observed BOD value ranged from 0.47 to 6.3 mg/l (mean 2.132 ± 0.37 mg/l) in the riffle zone while 0.40 to 3.10 mg/l (mean 1.95±0.217 mg/l) in the pool zone of the studied stream during the study period (Table 2). The mean value of BOD indicated the presence of low organic pollution in the water of the stream. However, with respect to BOD, the water quality was good in the riffle zone, while the pool zone showed slightly higher BOD than the standard limit. Nasiruddin *et al*. (2019) experimented with three different ponds and found the BOD value ranging between 0.13 - 2.94 mg/l (mean 1.04 ± 0.28 mg/l), 0.06 - 2.49 mg/l (mean 0.95 ± 0.28 mg/l), and 0.06 - 2.94 mg/l (mean 0.56 ± 0.25 mg/l).The lower BOD value indicated less organic pollution in those three ponds. On the other hand, Islam *et al*. (2019) found the BOD values ranging from 0.4-8.2 (mean 3.46±2.16mg/l) in Pond 1, 0.3-12.3 mg/l (mean 4.52±2.57 mg/l) in Pond 2 and 0.5-9.7 mg/l (mean 4.77±2.50 mg/l) in Pond 3 during their study period. The higher BOD values of the three ponds indicated high organic pollution, as all those values exceeded the standard limit, although the mean values were below the standard limit in the case of all the three ponds. Nasiruddin *et al*. (2015) found a 0.17 to 1.10 mg/l BOD value in the riffle zone while 0.12 to 0.90 mg/l in the pool zone of the Mithakhal stream, which indicated good water quality with less organic pollution in the studied stream.

**Free Carbon dioxide ($fCO_2$):** Free Carbon dioxide varied between 1.25 to 4.77 mg/l (mean 2.923± 0.168 mg/l) in the riffle zone while 1.30 to 5.30 mg/l (mean 2.867±0.154 mg/l) in the pool zone of the studied stream (Table 2), which is an indication of low $fCO_2$ in the water. Islam*et al*. (2019) found the free$CO_2$values varying from 8.99-26.97 mg/l (mean 15.02±5.53 mg/l), 2.00-16.98 mg/l (mean 9.66± 4.73 mg/l), and 4.99-19.98 mg/l (mean 10.20±4.12 mg/l) in the ponds 1, 2, and 3 respectively, whereby the values of $fCO_2$ indicated a moderate concentration of $fCO_2$. However, pond 1 showed a high concentration of $fCO_2$. Nasiruddin *et al*.(2019) found the values of $fCO_2$ranging from 0.64 to 7.16 mg/l (mean 3.11 ± 0.69 mg/l), 0.64 to 7.45 mg/l (mean 3.40 ± 0.78 mg/l), and 0.10 to 7.50 mg/l (mean 2.84 ± 0.69 mg/l) in ponds I, II and III respectively, and whereby observed low to moderate concentrations of $fCO_2$ in the water. Nasiruddin *et al*. (2015) studied the Mithakhal stream and found water with moderate Carbon dioxide concentration, 3.70 - 13.12 mg/l in the riffle zone and 2.90 - 13.06 mg/l in the pool zone.

**Calcium ($Ca^{2+}$):** The dissolved Calcium varied between 1.3 to 2.50 mg/l in the Balukhali stream while the mean± SE value was 1.964 ± 0.091 mg/l in the riffle zone and 2.075 ±0.078 mg/l in the pool zone (Table 2). Calcium is essential for many aquatic organisms, particularly for shell-building species like mollusks and crustaceans as well as insects that rely on Calcium for exoskeleton formation. Low levels (1-3 mg/l) of dissolved Calcium are an indication of low minerals in water and may limit the growth and survival of these organisms. Nasiruddin *et al*. (2019) found the range between 0.08 - 4.61 mg/l from three ponds of CUC while the mean was 0.15 ± 0.46 mg/l, 0.12 ± 0.63 mg/l, and 0.41 ± 0.50 mg/l for the three ponds respectively during their 12-month study period. During the study period of Islam *et al*. (2019) Calcium varied from 9.46-32.68 mg/l (mean 17.85±4.77mg/l), 1.72-18.92 mg/l (mean 7.17±3.47 mg/l), and 5.16-30.96 mg/l (mean 11.57±6.81 mg/l) in the ponds 1, 2, and 3 respectively at CUC. However, Nasiruddin *et al*. (2015) found the range of the dissolved Calcium from 13.87 to 28.33 mg/l (mean 1.23 ± 0.33 mg/l) in the riffle zone, while 10.20 to 23.56 mg/l (mean 1.03 ±0.80 mg/l) in the pool zone of Mithakhal stream, which showed the presence of high amount of minerals in the Mithakhal stream, which differed from the Balukhali stream in this respect. According to Mahmud *et al*. (2014) dissolved Calcium ranged from 0 mg/l to 5.83 mg/l with an average value of 2.26 mg/l. All the previous studies from the above discussion as well as the present study indicated a low level of Calcium in this geographical region.

**pH:** The pH varied between 7.0 to 8.1 (mean 7.442 ± 0.066) in the riffle zone while 5.40 to 7.90 (mean 7.158 ± 0.051) in the pool zone of the studied stream (Table 2), which showed that the value was within the standard limit of 6.5 - 8.5 and in the alkaline range. Nasiruddin *et al*. (2019) found pH range from 6.13 to 8.60 from three ponds of CUC while the mean pH was 7.53 ± 0.21, 7.40 ± 0.22, and7.70 ± 0.20 for the studied three ponds respectively, indicating that the values were within the standard limit during their 12-months study period. The pH varied from 6.7-7.8 (mean 7.25±0.29), 6.1-8.4 (7.48±0.55), and 6.4-7.9 (7.23±0.32) in Ponds1,2, and 3 respectively in the 24months study by Islam *et al*. (2019). Nasiruddin *et al*. (2015) found the range of pH 6.46 to 7.77 (mean 0.03 ± 0.06) in the riffle zone while 6.67 to 8.20 (mean 0.09 ± 0.06) in the pool zone of the Mithakhal stream which was also within the standard limit. Mahmud *et al*. (2014) found the pH range between 6.39 to 7.50 with an average value of 6.69 in their fifteen sampling water bodies.

**Water Quality Index (WQI):** In the present study, the WQI of the stream using the Weighted Arithmetic WQI method was 77.856 and 80.137 in the riffle and pool zones, respectively (Tables 3-4). According to the water quality rating, using the Weighted Arithmetic Index WQI method (Table 1), the water of both zones indicated very poor quality. Nayem *et al*. (2021) assessed the water quality of the Balukhali stream based on the Hilsenhoff's Biotic Index (HBI) values which showed the riffle and pool zone of the studied stream to have very good water quality with possible slight organic pollution. Islam *et al*. (2019), found the water unsuitable for drinking in one pond while the other two experimental ponds had very poor water quality, whereby the WQI values were 98.07, 102.18, and 130.08 for the three studied ponds. Mahmud *et al*. (2014) found the surface water quality of CUC suitable for common uses after examining 15 different water bodies. Their study revealed that most of the physical parameters and inorganic elements were not a serious problem for the water bodies of CUC. The assessment of water quality on the Mithakhal stream by Nasiruddin *et al*. (2013) found excellent water quality with no organic pollution in the riffle zone and good water quality with some organic pollution in the pool zone. The water flow was good at the riffle zone except in the dry season while the pool zone was interrupted by human interruptions in the present studied stream. People had constructed a temporary dam to the pool zone to use the water for irrigation in the dry season, which created organic pollution. Also, the agricultural run-offs were directly added to the channel, which polluted the water.

## Conclusion

A number of surrounding human activities like household operations and agricultural run-offs polluted the stream water. Many harmful chemicals such as insecticides and pesticides were used in agriculture, run-offs of which degraded the water quality of the stream. As such the water quality of the Balukhali stream was found to be very poor and can only be used for common uses like irrigation and domestic uses like washing and cleaning, other than drinking. However, this stream plays a crucial role in the storage of underground aquifers for the campus area. Monitoring of the water quality and the health of this ecosystem at regular intervals is strongly recommended.

## Conflict of Interest

The authors have no conflict of interest.

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