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Water Quality of Boalia Khal Tributary of Halda River by Weighted Arithmetic Index Method

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Abstract Water quality index is a helpful tool to understand the pollution level of any water body. Out of 16 tributaries in lower Halda, Boalia Khal (canal) is one of the important tributaries, well known for capture fishery and also for carrying local agricultural and urban discharges to the Halda River, a well-known spawning ground of Indian major carps. This study was undertaken to know the water quality status of Boalia Khal by weighted arithmetic index method. For knowing this status ten physicochemical parameters from three selected stations of the tributary were studied for two years period from January 2017 to December 2018, which ranged as: water temperature 24.84±2.96°C to 29.71±1.72°C, transparency 24.17±4.40cm to 36.89±5.67cm, Electrical Conductivity 86.39±33.86µS/cm to 161.11±11.52µS/cm, TDS 30±10mg/l to 70±10mg/l, pH 7.04±0.18 to 7.44±0.06, DO 3.91±0.81mg/l to 7.93±1.98mg/l, Calcium 5.03±2.00mg/l to 10.78±2.40mg/l, Total Hardness 23.83±9.1mg/l to 47.83±4.69mg/l, Total Alkalinity 34.89±15.93mg/l to 44.22 ±11.56mg/l and BOD_5 1.23±0.83mg/l to 1.55±1.06mg/l. The Water Quality Index (51.72±4.36 to 54.68±7.11) classified the water of three stations as poor (Grade-C) during different seasons except in winter (47.36±1.17) (Grade-B). However, annually, overall water quality of Boalia Khal was poor (53.24±1.31) (Grade-C) and detected as unsuitable for drinking without treatment, but could be used for irrigation and fish culture. The condition of water quality in present study felt the necessity to adopt proper management policy and conservation efforts to protect the water of the tributary from further deterioration and hence to protect the River Halda. This study might help to grow awareness among the users and policy makers to save the Halda River by keeping well its source water like Boalia Khal and also other tributaries.

Keywords: *Boalia Khal, Halda River, physicochemical parameters, WAWQM, WQI*

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1. Introduction

Tidal River Halda is well known as a major natural breeding ground of Indian major carps in southeastern Bangladesh, source of water of which is a lot of hilly origin streams and tidal water itself. Many small to big streams originating from the nearby hills join the Halda River and act as source water of the river. As such out of 16 tributaries at lower Halda, Boalia Khal (downstream: 22°31´3.88"N; 91°50´18.71" E; to upstream: 22°35´51.11" N; 91°48´49.14" E) is one of the big tidal tributaries of Halda River. This tributary is important for local capture fisheries mainly fin and shell fishes and also carrying dumping materials of surrounding areas to the Halda river. Boalia Khal tributary is situated about 25 kilometer upstream of Halda mouth and originated from the hills of western parts of Hathazari Upazilla and after traversing in a zigzag fashion about for 15 km, it meets with the western side of Halda river (22°31´3.88" N; 91°50´18.71" E) about 200 yards north of Sarta Ghat bridge on Chattogram- Rangamati highway.

Local people use its water for different purposes including irrigation, bathing, fishing, washing utensils and discharging household wastes. It also receives agricultural, urban and poultry wastes throughout the year directly and also through ten canals at different points, namely Fatika Khal, Charia Khal, Char Jura, Baissa Jura, Konijje Khal, Seranger Jura, Gura Chora, Zillani Chora, Kabir Khal, and Noa Khal.

The water quality of a water body largely depends on the interactions of various physicochemical factors [1]. Physicochemical characteristics of any water body should be well known before using its water for different domestic purposes and also for different management needs [2]. With the passage of time, due to increasing number of communities, pressures upon water resources are increased and detection of abnormal changes in water quality conditions has also increased [3]. Water quality index (WQI) is one of the most effective ways to inform the policy makers and environmentalists about status of

water quality for taking protection measures. WQI is a tool for assessing water quality through the determination of physicochemical parameters of surface water. It can act as an indicator of water pollution because of natural inputs and anthropogenic activities [4]. WQI is generally applied to compare the quality of different water bodies of a particular region which gives an idea to the users regarding the quality of water [5,6]. Water quality assessment is essential to prevent and control river pollution and to get reliable information on the quality of water for effective management [7].

There are five methods to detect the WQI, i.e. (1) US- National Sanitation Foundation Water Quality Index (NSFWQI), (2) Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), (3) British Columbia Water Quality Index (BCWQI), (4) Oregon Water Quality Index (OWQI) and (5) Weighted Arithmetic Water Quality Index (WAWQI). In this study WAWQI is used to evaluate the quality of water because in this method multiple physicochemical parameters are integrated into a mathematical equation and effectively convert them into single value that indicates the overall status of quality of a water body.

In Bangladesh, some research works have been done on the WQI, such as Islam et al. [6] in Halda River, Islam et al. [5] in three ponds, Hossen et al. [8] in Karnafully River, Karim et al. [9] in Halda River and Karim et al. [10] in Karnafully River, but no research work has been done on the water quality of Boalia Khal Tributary or any other source waters of Halda River. The key purpose of this study is to assess the water quality of Boalia Khal by WQI, which is very important to know the source water status of Halda River, which will help to protect the Halda River from any pollutants falling to the Halda from its' source water.

2. Materials and Methods

Study area: Out of 16 tributaries in lower Halda, Boalia Khal is one of the biggest tributaries of the River Halda. This canal is originated from the hills of western parts of Hathazari Upazilla and after traversing 15 km through the different villages of Hathazari Upazila it meets with the western side of Halda river about 200 yards north of Sarta Ghat bridge on Chattogram- Rangamati highway. It is subjected to organic pollution by domestic household, agricultural and poultry wastes. To evaluate overall water quality of Boalia Khal, three sampling stations from downstream to upstream were selected namely:

Station-1: at Chandgazi Bridge (22°31´3.88" N; 91°50´18.71" E). Here water depth is 5.64 m during high tide (HT) and 2.5 m during low tide (LT), canal width 34.63m during HT and 10m during LT. This station is near to Boalia Khal mouth. Bottom is muddy.

Station-2: at **Loharpul Bridge** (22°31´52.16" N; 91°49´50.33" E). Water depth is 3.96m during HT and 2m during LT, canal width 24.69m during HT and 8m during LT. Bottom is muddy.

Station-3: at **Zillanibazar Bridge** (22°32´38.04" N, 91°49´24.94" E). Water depth is 2.9 m during HT and 1.7m during low tide LT, width 30m during HT and 10 m during LT. Bottom is muddy.

2.1. Sample Collection and Analysis Procedure

Water samples were collected in 500 ml nine brown glass bottles from 20-50 cm depth of subsurface layer of water from each sampling stations at regular monthly intervals from January 2017 to December 2018 within 9-11 am to assess the water quality. Physicochemical parameters of water like temperature, Total dissolved solids (TDS), pH, Conductivity were measured in the field immediately after taking 200 ml of water in a beaker then dipping different digital meters in that water. Water temperature was assessed by a centigrade thermometer (Taylor Rochester, New York, USA), Electrical Conductivity (EC) by a digital meter (ATC meter AP-2, China), TDS by a digital TDS meter (Dist-2 digital, HANNA instruments, Italy), and pH by a digital pH meter (HANNA Instruments, Italy). Transparency was measured by dipping a 20 cm diameter Secchi disc in the water body. Water samples for Dissolved Oxygen (DO) was preserved in the field following APHA [11] and estimated in the laboratory within 4-6 hours of collection by Azide modification of Iodometric method and water for Biological Oxygen demand (BOD_5) was taken in 500 ml black bottle and taken to the laboratory and was kept for 5 days in dark at 20°C and after that analyzed following APHA [11]. Water for assessing Calcium (Ca^{+2}), Total Alkalinity (TA) and Total Hardness (TH) were collected in three 500 ml glass bottles and taken to the Fisheries and Limnology laboratory of Department of Zoology, University of Chittagong and analysed within 4-6 hours of collection. Calcium was analysed by EDTA titrimetric method [11], TA of water was determined by using the standard sulfuric acid as a titrant and Bromocresol green as an indicator [11, 12 & 13] and TH by EDTA titrimetric method [11]. Statistical analysis (correlation coefficient, significant level and standard deviation) was done following MS Excel version 2013.

2.2. Calculation of Water Quality Index (WQI):

WQI was calculated using the Weighted Arithmatic Water Quality Index method proposed by Horton [14] and developed by Brown et al. [15] and then Cude [16] in which water parameters are multiplied by a weighting factor. The WQI values were found out for above mentioned ten physicochemical parameters by using following equations:

$$WQI = \sum_{n=1}^{n} W_n Q_n / \sum_{n=1}^{n} W_n \quad (1)$$

$$Q_n = 100\left[\left(V_n - Vio\right)/\left(S_n - Vio\right)\right] \quad (2)$$

$$W_n = k / S_n \quad (3)$$

Q_n is the Quality rating for the n^{th} water quality parameter' 'W_n is the Unit weight for n^{th} parameters, n= water quality parameters

Vn = estimated value of n^{th} parameter at a given water sampling station

Sn = standard permissible value for n^{th} parameter,

Vio = ideal value of n^{th} parameter, (0 for all) except pH=7 and DO =14.6 mg/l [17].

Monthly obtained results are presented seasonally. Yearly twelve months are divided into four seasons, namely Pre-monsoon (February–April), Monsoon (May-July), Post-monsoon (August–October) and Winter (November- January).

Water Quality Index level and water quality status based on Weighted Arithmetic Index method was determined following Table 1.

Table 1. Water Quality Index (WQI) range, status and possible usage of water [18]

Water Quality Index Level	Water Quality Status (WQS)	Water Quality Grading	Possible uses
0-25	Excellent	A	Drinking, irrigation and industrial purpose
26-50	Good	B	Drinking, irrigation and industrial purpose
51-75	Poor	C	Irrigation and industrial purpose
76-100	Very Poor	D	For irrigation purpose
>100	Unsuitable for Drinking and fish culture	E	Proper treatment required for any kind of usage

3. Results and Discussion

Table 2 shows the seasonal ranges and mean values (with±SD) of different physicochemical parameters at three stations of Boalia Khal. Table 3 shows the unit weight (Wn) of different parameters and their standards used for WQI determination. Tables 4-6 show the seasonal WQI at three stations (S1-S3) during four seasons. Table 7 represents the WQI of Boalia Khal along with its water quality status (WQS). Table 8 shows the WQI of Boalia Khal during 2017 and 2018 and for two years combined. Figure 1 depicts the WQI at the three stations of Boalia Khal in pre-monsoon, monsoon, post-monsoon and winter seasons, whereas Figure 2 depicts overall WQI rating of Boalia Khal during the four seasons in two years study period from January 2017 to December 2018. Figures 3 and 4 depict the seasonal and yearly WQI of Boalia Khal.

3.1. Water Temperature

During two years study period from January 2017 to December 2018 in three stations, the water temperature varied from 27.57 to 28.12°C (27.81±2.29°C) in pre-monsoon, 29.70 to 29.72°C (29.71±1.72°C) in monsoon, 29.07 to 29.93°C (29.43±2.12°C) in post-monsoon and 24.58 to 25.23°C (24.84±2.96°C) in winter (Table 2). The lowest water temperature (24.84±2.96°C) was recorded in the winter while the highest (29.71±1.72°C) in the monsoon (Table 2). The results of the present study agreed with the findings of Islam et al. [6] and Patra and Azadi [19] in the Halda River, Islam [20] in the Halda and Karnaphuli Rivers, and Islam [21] in the Madari Khal and Halda River. The water temperature did not show much variation in all the seasons except winter.

3.2. Transparency (Seechi Disc Visibility)

Water transparency varied from 31.17 to 42.00 cm (36.89±5.67 cm), 29 to 31.33 cm (29.83±4.72 cm), 21.17 to 26.17 cm (24.17±4.40 cm) and 28.17 to 30.50cm (29.50±6.42cm) in the pre-monsoon, monsoon, post-monsoon and winter seasons respectively (Table 2). The lowest water transparency (24.17±4.40cm) was recorded in the post-monsoon and the highest (36.89±5.67cm) in the pre-monsoon (Table 2). Lowest transparency in post monsoon might be due to the presence of high silt laden water, while highest transparency in pre-monsoon might be due the presence of less turbid materials in water. Almost similar results were recorded by Islam (2011) and Islam (2013) in the Halda River.

3.3. Electrical Conductivity (EC)

EC is the capacity of water to conduct electricity, sound and heat. It is an important physical parameter of water body which indicates the electrolyte and nutrient level of water. EC varied from 151.50 to 159.3 µS/cm (156.55±30.57 µS/cm) in pre-monsoon, 79.83 to 90.50 µS/cm (86.39±33.86 µS/cm) in monsoon, 92 to 93.17 µS/cm (92.50±15 µS/cm) in post-monsoon and 153.83 to 168 µS/cm (161.11±11.52 µS/cm) in winter (Table 2). The lowest EC (86.39±33.86 µS/cm) was observed in monsoon, while the highest in winter (161.11±11.52 µS/cm), which might be due to the dilution of electrolytes in water due to heavy runoff during monsoon and highest conductivity in winter was due to concentration of electrolytes due to no shower in winter. Similar results were also recorded by Azadi [22], Patra and Azadi [19], Islam [20] in the Halda River, Islam [21] in the Halda River and Madari Khal and Islam et al. [6] in the Halda River.

3.4. Total Dissolved Solids (TDS)

TDS varied from 70 to 70 mg/l (70±20 mg/l), 40 to 50 mg/l (40±20 mg/l), 30 to 40 mg/l (30±10 mg/l) and 60 to 70 mg/l (70±10 mg/l) in the pre-monsoon, monsoon, post-monsoon and winter seasons respectively (Table 2). The results of the present study agreed with the findings of Islam [20] in the Karnafully River and Islam [21] in the Madari Khal.

3.5. pH

pH varied from 7.07 to 7.20 (7.12±0.13), 7.02 to 7.08 (7.04±0.18), 7.40 to 7.48 (7.44±0.06) and 7.28 to 7.55 (7.42±0.14) in the pre-monsoon, monsoon, post-monsoon and winter seasons respectively (Table 2). The lowest pH (7.04±0.18) was recorded in the monsoon and highest (7.44±0.06) in the post-monsoon might be due to presence of high decomposed organic matter in monsoon and less in post monsoon. Similar result was recorded by Islam [20] and Islam [21] in the Halda River. The water of Boalia Khal was alkaline in nature.

Table 2. Seasonal ranges and mean values of physicochemical parameters at three stations of Boalia Khal

Parameters	Pre-monsoon		Monsoon		Post-monsoon		Winter	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Water temperature (°C)	27.57-28.12	27.81±2.29	29.70-29.72	29.71±1.72	29.07-29.93	29.43±2.12	24.58-25.23	24.84±2.96
Transparency (cm)	31.17-42.00	36.89±5.67	29-31.33	29.83±4.72	21.17-26.17	24.17±4.40	28.17-30.50	29.50±6.42
Conductivity (µS/cm)	151.50-159.33	156.55±30.57	79.83-90.50	86.39±33.86	92-93.17	92.50±15	153.83-168	161.11±11.52
TDS (mg/l)	70-70	70±20	40-50	40±20	30-40	30±10	60-70	70±10
pH	7.07-7.20	7.12±0.13	7.02-7.08	7.04±0.18	7.40-7.48	7.44±0.06	7.28-7.55	7.42±0.14
DO (mg/l)	5.10-6.37	5.66±2.07	3.88-3.95	3.91±0.81	3.70-4.90	4.38±0.81	7.45-8.47	7.93±1.98
Calcium (mg/l)	8.42-10.42	9.44±2.66	4.68-5.48	5.03±2.00	5.08-6.01	5.39±1.11	9.68-12.87	10.78±2.40
Total Hardness (mg/l)	39.83-43.67	41.67±7.37	22-26.33	23.83±9.10	26.83-29.83	28.44±5.80	42.33-53.17	47.83±4.69
Total Alkalinity (mg/l)	44-44.50	44.22±11.56	33.17-36	34.89±15.93	34.83-37.17	35.72±7.03	34.33-35.50	35.05±8.51
BOD (mg/l)	1.17-1.55	1.39±1.09	1.05-1.40	1.23±0.83	1.27-1.83	1.51±0.81	1.45-1.73	1.55±1.06

3.6. Dissolved Oxygen (DO)

DO varied from 5.10 to 6.37 mg/l (5.66±2.07 mg/l) in pre-monsoon, 3.88 to 3.95mg/l (3.91±0.81mg/l) in monsoon, 3.70 to 4.90mg/l (4.38±0.81mg/l) in post-monsoon and 7.45 to 8.47 mg/l (7.93±1.98mg/l) in winter (Table 2). The lowest DO (3.91±0.81mg/l) was recorded in the monsoon and the highest (7.93±1.98 mg/l) was in the winter (Table 2). Cold water has the capacity to hold more oxygen which was observed in winter, and lowest oxygen in monsoon might be due to high temperature in monsoon and surrounding polluted organic runoff mixing with the river water. This agreed with the findings of Patra and Azadi [19], Islam [20] and Islam [21] in the Halda River. The DO ranges of the water body were suitable for fish as well as other aquatic lives.

3.7. Calcium (Ca^{2+})

In Boalia Khal Ca^{2+} varied from 8.42 to 10.42mg/l (9.44±2.66 mg/l), 4.68 to 5.48 mg/l (5.03±2.00 mg/l), 5.08 to 6.01 mg/l (5.39±1.11 mg/l) and 9.68 to 12.87 mg/l (10.78±2.40 mg/l) in the pre-monsoon, monsoon, post-monsoon and winter seasons respectively (Table 2). The lowest Ca^{2+} (5.03±2.00 mg/l) was found in the monsoon and the highest (10.78±2.40 mg/l) in the winter (Table 2), which might be due to dilution and concentration factors during monsoon and winter respectively. This is more or less similar with the findings of Patra and Azadi [19] in the Halda, Islam [20] in the Karnafully River and Islam [21] in the Madari Khal.

3.8. Total Hardness (TH)

TH ranged from 39.83 to 43.67 mg/l (41.67±7.37 mg/l), 22 to 26.33 mg/l (23.83±9.10 mg/l), 26.83 to 29.83 mg/l (28.44±5.80 mg/l) and 42.33 to 53.17 mg/l (47.83±4.69 mg/l) in the pre-monsoon, monsoon, post-monsoon and winter seasons respectively (Table 2). The lowest TH (23.83±9.10 mg/l) was recorded in the monsoon and the highest (47.83±4.69 mg/l) in the winter (Table 2), which indicated soft nature water of Boalia Khal [2]. This agreed with the findings of Islam [20] in the Halda and Karnafully Rivers and Islam [21] in the Madari Khal.

3.9. Total Alkalinity (TA)

TA ranged from 44 to 44.50 mg/l (44.22±11.56 mg/l) in pre-monsoon, 33.17 to 36 mg/l (34.89±15.93 mg/l) in monsoon, 34.83 to 37.17 mg/l (35.72±7.03 mg/l) in post-monsoon and 34.33 to 35.50 mg/l (35.05±8.51 mg/l) in winter (Table 2). The lowest TA (34.89±15.93 mg/l) was recorded in the monsoon, while the highest (44.22±11.56 mg/l) in the pre-monsoon (Table 2). Similar result was also recorded by Islam [20] in the Karnafully River.

3.10. Biological Oxygen Demand (BOD_5)

BOD_5 ranged from 1.17 to 1.55 mg/l (1.39±1.09 mg/l), 1.05 to 1.40 mg/l (1.23±0.83 mg/l), 1.27 to 1.83 mg/l (1.51±0.81 mg/l) and 1.45 to 1.73 mg/l (1.55±1.06 mg/l) in the pre-monsoon, monsoon, post-monsoon and winter seasons respectively (Table 2). The lowest BOD_5 (1.23±0.83 mg/l) was recorded in the monsoon and the highest (1.55±1.06 mg/l) in the winter (Table 2). More or less similar findings were recorded by Islam [21] in the Madari Khal and Halda River.

The values of all analysed physicochemical parameters of water were found within the permissible limit of BIS [24], ICMR [25] and Santhos and Singh [26].

3.11. Water Quality Index (WQI)

During two years study period from January 2017 to December 2018, in three sampling stations and four seasons, the WQI values ranged from 50.50 (Station-1) to 51.96 (Station-2) in pre-monsoon, 52.93 (Station-1) to 56.38 (Station-3) in monsoon, 56.92 (Station-1) to 63.60 (Station-3) in post-monsoon and 46.53 (Station-1) to 48.70 (Station-2) in winter (Figure 1, Table 4 - Table 7). The mean values of WQI for three sampling stations during different seasons were 51.44±0.82 in pre-monsoon, 54.62±1.73 in monsoon, 59.53±3.57 in post-monsoon and 47.36±1.17 in winter (Figure 3, Table 7). The overall mean values of WQI in different stations were recorded as 51.72±4.36 (Station-1), 53.32±3.97 (Station-2) and 54.68±7.11 (Station-3) (Figure 2, Table 7) and the mean value of WQI for three stations combined during 2017 and 2018 and two years combined (2017-2018) was found to be 52.59, 53.89 and 53.24 respectively (Figure 4, Tables 7-8). This result indicated that the water quality status of Boalia Khal was poor (C-grade) in all the seasons except winter (good condition, B-grade). Almost similar results were reported by Pathak et al. [27] in Bhagirathi River, Ranjith et al. [28] in the Tungabhadra River, and Bora and Gowsami [29] in the Kolong River.

Table 3. Unit weight (Wn) of different parameters and their standards (Sn) used for WQI determination

Parameters	Standards value (Sn)	References for standard values	Unit weight (Wn)
Water temperature (°C)	30	Santhosh & Singh, 2007	0.054977
Transparency (cm)	40	Santhosh & Singh, 2007	0.041233
Conductivity (µS/cm)	300	ICMR, 1975	0.005498
TDS (mg/l)	500	ICMR, 1975/BIS, 1983	0.003299
pH	8.5	ICMR, 1975/BIS, 1983	0.194037
DO (mg/l)	5	ICMR, 1975/BIS, 1983	0.329862
Calcium (mg/l)	75	ICMR, 1975/BIS, 1983	0.021991
Total Hardness (mg/l)	300	ICMR, 1975/BIS, 1983	0.005498
Total Alkalinity (mg/l)	120	ICMR, 1975	0.013744
BOD (mg/l)	5	ICMR, 1975	0.329862

Table 4. Water Quality Index (WQI) at station-1 (Chandgazi Bridge) of Boalia Khal in different seasons

Parameters	Pre-monsoon			Monsoon			Post-monsoon			Winter		
	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n
Water temperature (°C)	28.12	93.73333	5.153181	29.7	99	5.442727	29.3	97.66667	5.369424	25.23	84.1	4.623569
Transparency (cm)	31.17	77.925	3.213064	29	72.5	2.989376	21.17	52.925	2.182245	29.83	74.575	3.074935
Conductivity (µS/cm)	151.5	50.5	0.277634	79.83	26.61	0.146294	92	30.66667	0.168596	153.8	51.26667	0.281849
TDS (mg/l)	68	13.6	0.044861	35	7	0.02309	35	7	0.02309	62	12.4	0.040903
pH	7.2	13.33333	2.587155	7.017	1.133333	0.219908	7.45	30	5.821098	7.55	36.66667	7.114676
DO (mg/l)	6.4	85.41667	28.17573	3.95	110.9375	36.59409	4.9	101.0417	33.32983	8.47	63.85417	21.06308
Calcium (mg/l)	8.42	11.22667	0.246884	4.68	6.24	0.137223	5.08	6.773333	0.148951	9.78	13.04	0.28676
Total Hardness (mg/l)	41.5	13.83333	0.076052	22	7.333333	0.0403	26.83	8.943333	0.049168	42.33	14.11	0.077573
Total Alkalinity (mg/l)	44	36.66667	0.503956	36	30	0.412328	34.83	29	0.398584	35.33	29.44167	0.404654
BOD (mg/l)	1.55	31	10.22573	1.05	21	6.927107	1.43	28.6	9.43406	1.45	29	9.566005
			$\sum W_nQ_n$= 50.504			$\sum W_nQ_n$= 52.932			$\sum W_nQ_n$= 56.925			$\sum W_nQ_n$= 46.534
			WQI= 50.50			WQI= 52.93			WQI= 56.93			WQI= 46.53

Table 5. Water Quality Index (WQI) at station-2 (Chandgazi Bridge) of Boalia Khal in different seasons

Parameters	Pre-monsoon			Monsoon			Post-monsoon			Winter		
	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n
Water temperature (°C)	27.57	91.9	5.05239	29.7	99	5.442727	29.07	96.9	5.327275	24.58	81.93333	4.504452
Transparency (cm)	37.5	93.75	3.865573	31.33	78.325	3.229557	26.17	65.425	2.697655	30.5	76.25	3.143999
Conductivity (µS/cm)	158.8	52.93333	0.291012	90.5	30.16667	0.165847	93.17	31.05667	0.17074	161.5	53.83333	0.29596
TDS (mg/l)	70	14	0.046181	38	7.6	0.02507	32	6.4	0.021111	65	13	0.042882
pH	7.083	5.533333	1.073669	7.017	1.133333	0.219908	7.483	32.2	6.247979	7.433	28.86667	5.60119
DO (mg/l)	5.52	94.58333	31.19947	3.9	111.4583	36.76589	4.53	104.8958	34.60117	7.45	74.47917	24.56786
Calcium (mg/l)	9.49	12.65333	0.278257	5.48	7.306667	0.16068	5.08	6.773333	0.148951	9.68	12.90667	0.283828
Total Hardness (mg/l)	43.67	14.55667	0.080028	26.33	8.776667	0.0483	28.67	9.556667	0.05254	48	16	0.087963
Total Alkalinity (mg/l)	44.17	36.80833	0.505903	33.17	27.64167	0.379914	37.17	30.975	0.425728	35.5	29.58333	0.406601
BOD (mg/l)	1.45	29	9.566005	1.23	24.6	8.114611	1.27	25.4	8.378501	1.48	29.6	9.763922
			$\sum W_nQ_n$= 51.958			$\sum W_nQ_n$= 54.552			$\sum W_nQ_n$= 58.072			$\sum W_nQ_n$= 48.699
			WQI= 51.96			WQI= 54.55			WQI= 58.07			WQI= 48.70

Table 6. Water Quality Index (WQI) at station-3 (Chandgazi Bridge) of Boalia Khal in different seasons

Parameters	Pre-monsoon			Monsoon			Post-monsoon			Winter		
	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n	V_n	Q_n	W_nQ_n
Water temperature (°C)	27.75	92.5	5.085376	29.72	99.06667	5.446392	29.93	99.76667	5.484876	24.7	82.33333	4.526443
Transparency (cm)	42	105	4.329442	29.17	72.925	3.0069	25.17	62.925	2.594573	28.17	70.425	2.903818
Conductivity (µS/cm)	159.3	53.1	0.291928	88.83	29.61	0.162787	92.33	30.77667	0.169201	168	56	0.307871
TDS (mg/l)	72	14.4	0.0475	47	9.4	0.031007	33	6.6	0.021771	65	13	0.042882
pH	7.067	4.466667	0.866697	7.083	5.533333	1.073669	7.4	26.66667	5.17431	7.283	18.86667	3.660824
DO (mg/l)	5.1	98.95833	32.64262	3.88	111.6667	36.83462	3.7	113.5417	37.45311	7.87	70.10417	23.12472
Calcium (mg/l)	10.42	13.89333	0.305526	4.94	6.586667	0.144846	6.01	8.013333	0.17622	12.87	17.16	0.377362
Total Hardness (mg/l)	39.83	13.27667	0.072991	23.17	7.723333	0.0425	29.83	9.943333	0.054666	53.17	17.72333	0.097438
Total Alkalinity (mg/l)	44.5	37.08333	0.509683	35.5	29.58333	0.406601	35.17	29.30833	0.402821	34.33	28.60833	0.3932
BOD (mg/l)	1.17	23.4	7.718776	1.4	28	9.236143	1.83	36.6	12.07296	1.73	34.6	11.41323
			$\sum W_nQ_n$= 51.871			$\sum W_nQ_n$= 56.385			$\sum W_nQ_n$= 63.605			$\sum W_nQ_n$= 46.848
			WQI= 51.87			WQI= 56.38			WQI= 63.60			WQI= 46.85

Table 7. Summary of WQI and water quality status (WQS) of Boalia Khal

Sampling Station	Pre-monsoon		Monsoon		Post-monsoon		Winter		Mean	
	WQI	WQS	WQI	WQS	WQI	WQS	WQI	WQS	WQI±SD	WQS
Station-1	50.50	Good	52.93	Poor	56.92	Poor	46.53	Good	51.72±4.36	Poor
Station-2	51.96	Poor	54.55	Poor	58.07	Poor	48.70	Good	53.32±3.97	Poor
Station-3	51.87	Poor	56.38	Poor	63.60	Poor	46.85	Good	54.68±7.11	Poor
Mean ±SD	51.44±0.82	Poor	54.62±1.73	Poor	59.53±3.57	Poor	47.36±1.17	Good	53.24±1.31	Poor

Table 8. WQI of Boalia Khal during 2017, 2018 and combined for two years (2017-2018)

PARAMETERS	**2017**			**2018**			**2017-2018**		
	Observed Value (V_n)	**Quality rating (Q_n)**	**W_nQ_n**	**Observed Value (V_n)**	**Quality rating (Q_n)**	**W_nQ_n**	**Observed Value (V_n)**	**Quality rating (Q_n)**	**W_nQ_n**
Water Temperature (^{0}C)	27.72	92.4	5.079878	28.17	93.9	5.162344	27.945	93.15	5.121111
Transparency (cm)	30.45	76.125	3.138845	29.75	74.375	3.066688	30.1	75.25	3.102767
Conductivity (µS/cm)	118.39	39.46333	0.216958	129.89	43.29667	0.238032	124.14	41.38	0.227495
TDS (mg/l)	50	10	0.032986	52.67	10.534	0.034748	51.335	10.267	0.033867
pH	7.16	10.66667	2.069724	7.35	23.33333	4.527521	7.255	17	3.298622
DO (mg/l)	5.83	91.35417	30.13429	5.11	98.85417	32.60826	5.47	95.10417	31.37127
Calcium (mg/l)	7.23	9.64	0.211991	8.083	10.77733	0.237002	7.6565	10.20867	0.224497
Total Hardness (mg/l)	32.28	10.76	0.059155	38.61	12.87	0.070755	35.445	11.815	0.064955
Total Alkalinity (mg/l)	37.67	31.39167	0.431455	37.28	31.06667	0.426988	37.475	31.22917	0.429222
BOD (mg/l)	1.70	34	11.21532	1.14	22.8	7.520859	1.42	28.4	9.368087
			$\sum W_nQ_n$= 52.591			$\sum W_nQ_n$= 53.893			$\sum W_nQ_n$= 53.242
			WQI= 52.59			WQI= 53.89			WQI= 53.24

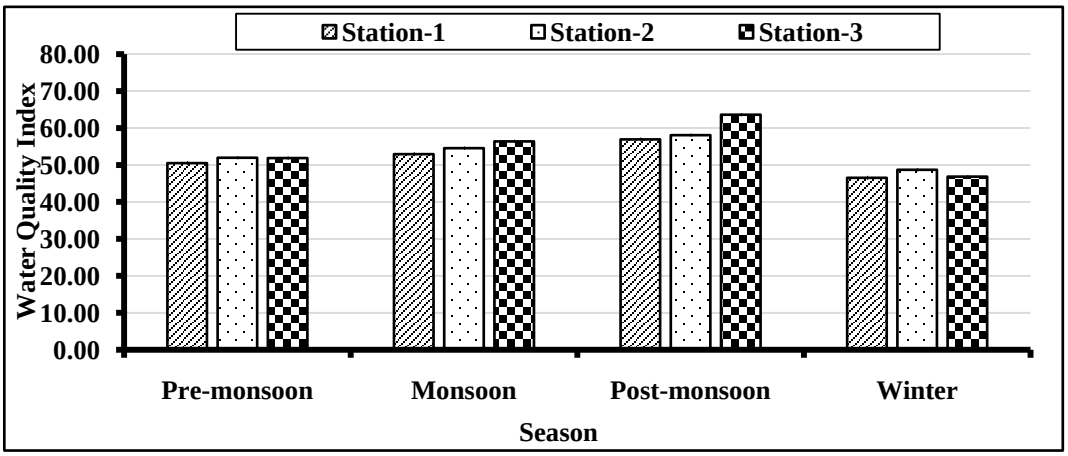

Figure 1. Water Quality Index (WQI) at the three stations of Boalia Khal in different seasons

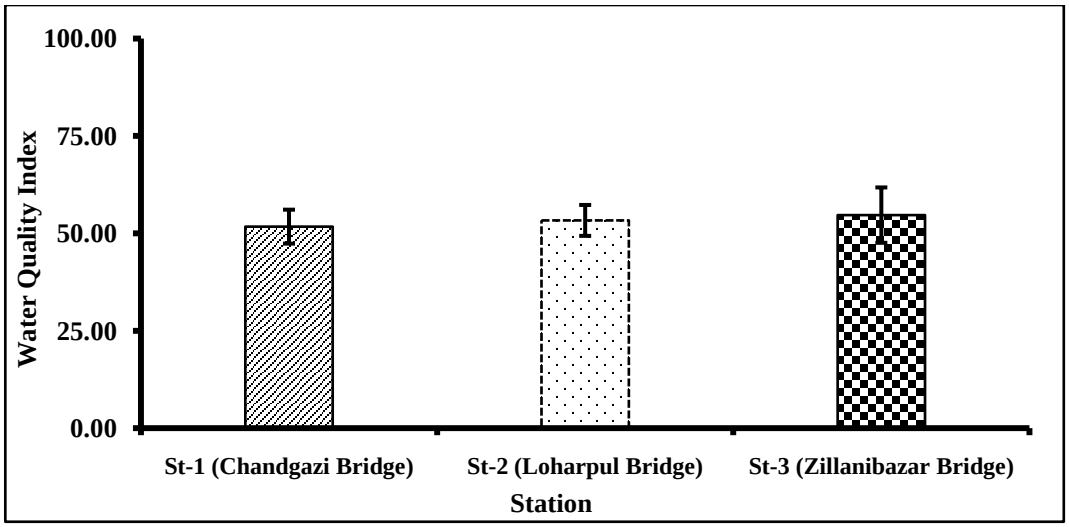

Figure 2. WQI at three stations of Boalia Khal for two years period from January 2017 to December 2018

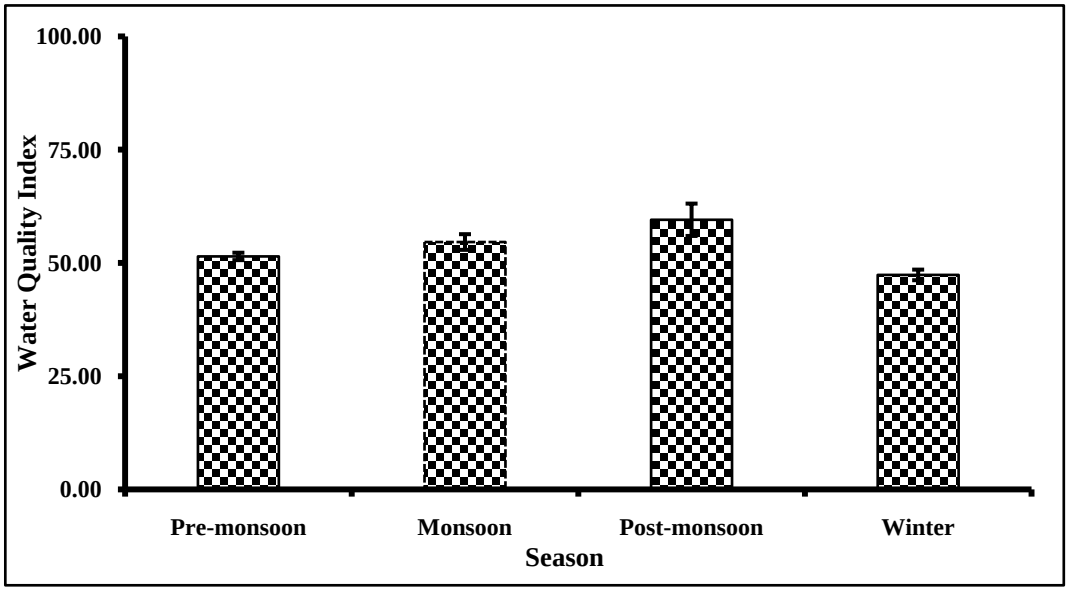

Figure 3. WQI of Boalia Khal in different seasons for two years (2017-2018)

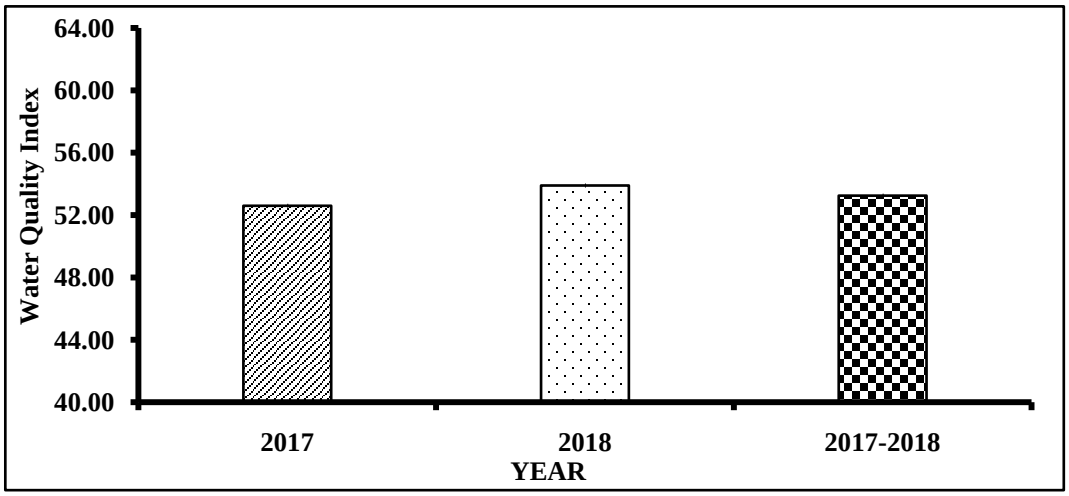

Figure 4. Yearly (2017 & 2018) WQI and overall for two years (2017-2018) WQI of Boalia Khal

WQI in the three studied stations were poor during all the seasons except winter due to dumping of organic matters i.e. poultry litters and Upazila level urban pollutants in to the Khal. Boalia Khal finally joined the Halda River, thus assisted to contaminate the River Halda, which was indicated by poor water quality round the year in the lower region of Halda [6].

4. Conclusion

From the two years study (January 2017-December 2018), it can be concluded that the water quality of Boalia Khal was poor at all the three stations and unfit for human drinking without treatment but can be used for other consumptions i.e. irrigation and industrial purposes. However, for keeping the Halda River pollution free, the spawning ground of major carps, its source water like Boalia Khal tributary and other Khals (canals) should be kept pollution free, for which dumping of poultry litters and urban pollutants through Fatika Khal and other canals should be stopped or treated before discharging to the Khal. Awareness program should be taken among the community peoples residing in the vicinity of Boalia Khal and Halda River to keep the Khal free from pollution, which finally will save the River Halda from contamination.

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