Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

EVALUATION OF DRINKING WATER QUALITY IN TERMS OF WATER QUALITY INDEX FOR FARIDPUR SADAR UPAZILA

Md. Aminul Islam Khan[1] and Anika Tahsin*[2]

[1]Graduate student, Institute of Water and Flood Management, BUET, Dhaka-1000, Bangladesh, e-mail: aminulislam381@gmail.com
[2]Graduate student, Institute of Water and Flood Management, BUET, Dhaka-1000, Bangladesh, e-mail: anika010cee@gmail.com

Corresponding Author

ABSTRACT

The quality of drinking water plays a vital role in public health. In this study, the quality of drinking water at Faridpr Sadar Upazila was evaluated by the water quality index (WQI). As the local people mainly rely on groundwater as a source of drinking water, eight groundwater stations were selected for sample collection within the locality. The water quality index was assessed using two widely used methods: Canadian Council of Ministers of the Environment (CCME) WQI and Weighted Arithmetic Index Method (WAM). To assess WQI, nine input parameters were used; which are pH, turbidity, nitrate, temperature, dissolved oxygen (DO), total dissolved solids (TDS), iron, arsenic and biochemical oxygen demand (BOD_5). According to the CCME WQI method, WQI varied from 65.1 to 82.1 and by the weighted arithmetic index method, the value of WQI varied between 20.4 and 151.1. The study revealed that, by both methods, WQI indicates that water of the maximum stations is not up to the mark and a sample of only one station (S3 sample from Faridpur Chowdhury Bari) was found to be excellent or good for drinking purpose. Besides the above findings, BOD5 was the parameter, which was found to cross the acceptable limit for all the stations. Moreover, while comparing the result of WQI by both methods, it was found when low acceptance ranged parameters (i.e. Arsenic, BOD, Iron, etc.) dominate, water is categorized in a wider range in the WAM WQI method than by CCME WQI method. This because weights are assigned to each parameter according to their acceptance range. However, it is expected that this paper may assist in raising awareness among policymakers and local people on the quality of the drinking water of the study area.

Keywords: *Water quality, Water quality index, Weighted arithmetic method, CCME method, Faridpur.*

1. INTRODUCTION

Water is a vital natural element that is a prerequisite for the proper functioning of the ecosystem. Being a two-third portion of the earth along with covering 75% of the human body, the role of water in our earth becomes evident. As it plays a vital role in maintaining every life form ensuring the stability of the earth system, access to clean water has become one of the six sustainable development goals of the United Nations (DISLEY, 2013). Water quality is not only essential for the functioning of the environment but also plays a crucial role in maintaining the health of human life in every sphere including drinking, agriculture, forestry, industrial activities, recreation, and others. Among all kinds of human diseases, around 80% are caused by water (Ramakrishnaiah et al., 2009). For maintaining the health of these sectors, ensuring sustainable quality of groundwater is very important as in Bangladesh majority of the water sources lie underground (Bodrud-Doza et al., 2016; Biswas et al., 2014). Unfortunately, population growth along with increased agricultural activity, rapid urbanization, and industrialization along with geogenic contamination, there has been a drastic change in both quantity and quality of groundwater in Bangladesh (Islam et al., 2017). Bangladesh is now facing serious health hazards due to water pollution (Alam, 2009). Assessment of the quality of drinking water has become a necessity for protecting public health. For evaluating water quality index (WQI) is considered as the most effective method as it the capability to integrate a wide range of information into a simpler form (Akhter et al., 2016). Moreover, water quality indices have become a convenient tool for water managers and policymakers for anticipating the quality and potential use of an aquifer system (Bozdağ et al., 2015). Many types of water quality indices have been developed to assess water quality for different purposes taking into consideration different types of parameters.

Even though in recent times, different types of studies and assessments were carried out in different regions of Bangladesh to evaluate the quality of aquifers (Shahidullah et al., 2000; Rahman et al., 2012; Bhuiyan et al., 2010; Hossen et al., 2019), most of them were focused on quality of irrigation water or evaluation of heavy metal pollution. However, some studies were found on the evaluation of water quality for drinking purpose (Saha et al., 2018; Rahaman et al., 2019), where only a few elaborated works focus on small administrative units so that the people of that area can identify the best water source available within their region. The present study targets to evaluate the suitability of aquifers for the drinking purpose of Faridpur Sadar Upazila of Bangladesh in the form of water quality index in two different methods which are: Weighted Arithmetic method and Canadian Council of Ministers of the Environment (CCME) WQI method. The aim was to provide necessary information to the local people and the policy makers so that they can mark the best source available and during an emergency, they can determine the level of treatment for alternate sources.

1.1 Study area

For investigating the water quality index, a small administrative unit of Bangladesh, Faridpur Sadar was chosen (Figure-1). It is an Upazila under Faridpur district and lies between 23°29' and 23°34' north latitudes and 89°43' and 89°56' east longitudes. The total number of households is 103535 with a population of 469410 and the population density is 1137 per sq. km (Bangladesh Bureau of Statistics[BBS], 2011) It has a total area of about 412.86 square km where a riverine area is 10.44 sq. km. Kumar river runs beside the Upazila town. The area is currently facing several water related problems including arsenic contamination and presence of salinity, iron, and manganese in groundwater, non-availability of suitable aquifer and lowering of water table (Department of Public Health Engineering[DPHE], 2012) Moreover, infiltration of wastewater into the groundwater is resulting from mismanagement of waste from garbage and small scale industries. As, the local people of the area mainly rely on groundwater, thus groundwater needs to be evaluated carefully in terms of water quality index for drinking.

Figure-1: Map of study area

2. METHODOLOGY

2.1 Collection of samples and testing of parameters

A total of eight sampling points in the Faridpur Sadar were selected. Four samples were collected from each sampling point. The samples were collected only during the post-monsoon period (November-2017) as change of water quality along with time was not the prime focus of the study. A portable global positioning system (GPS) meter was used to record the geographical location of the sampling stations. The sampling points are shown in Figure 2.

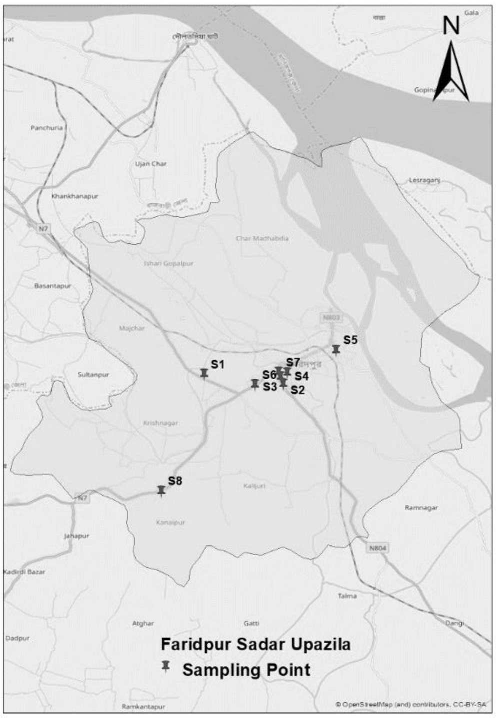

Figure-2: Sampling points in Faridpur Sadar

A total of nine parameters were selected to test WQI (table-1). The parameters are- pH, turbidity, nitrate, temperature, dissolved oxygen (DO), total dissolved solids (TDS), iron, arsenic and biological oxygen demand (BOD). Among these parameters, temperature and pH were measured immediately at the sampling points using a thermometer and digital pH meter. The other parameters were evaluated at the laboratory after carrying the samples to the laboratory.

The GPS location of the sampling points along with the sample names of the locations are presented in table-1:

Table-1: Sampling location and name along with latitude and longitude

Location	Latitude	Longitude	Sample Name
Faridpur dhaka highway	23.598094	89.790735	S1
Faridpur vanga highway	23.593173	89.830853	S2
Faridpur chowdhury bari	23.596809	89.829397	S3
Faridpur Ambika Road	23.598832	89.83297	S4
Faridpur Tepakhola	23.610315	89.857498	S5
Faridpur municipal water supply	23.592767	89.816582	S6
Goalchamot near bus stand	23.599045	89.828608	S7
Knaipur Bazar	23.539072	89.769213	S8

From table-1, calculation of WQI was done by two widely used methods: Weighted Arithmetic Index Method and Canadian Council of Ministers of the Environment (CCME) WQI method.

2.2 Assessment of Water Quality Index (WQI)

Evaluation of water quality from the value of the individual parameter is difficult not only for common people but also for policymakers (Akoteyon et al., 2011). To overcome this complexity, WQI is the most effective tool (Tyagi et al., 2013). Water quality index is a method that summarizes several numbers of water quality parameters into a simple term, which indicates a certain level of water quality (Katyal, 2011). It means WQI is capable of transforming a bulk of information into a simplified, logical and single form. Horton first measured water quality index during the mid-twentieth century by using ten water quality variables where the index weight ranged from 1 to 4. From then, various modifications along with newer approaches to calculate WQI have been developed to evaluate water quality for different purposes (Brown et al., 1970). Among them, to evaluate the quality of water for drinking purpose, the most successful attempt till now appears to be the weighted arithmetic method index developed by Brown et al (1972) which was originally developed by Horton and British Columbia Ministry of Environment, Lands and Parks names as Canadian Council of Ministers of the Environment (CCME) WQI. These two methods are widely used among the researchers (Tyagi et al., 2013) to evaluate WQI. In this study, Weighted Arithmetic water quality index method and CCME WQI method were used for evaluating water quality index.

2.2.1 Calculation of WQI by Weighted Arithmetic Method

The weighted arithmetic water quality index method is widely used for evaluating the quality of groundwater for human consumption. It is one of the most convenient methods for calculating WQI because it classifies water quality by using the most commonly used water quality parameters. Moreover, it also requires less number of parameters compared to other water quality parameters. This method is very useful for communicating with the public and policymakers. The calculation of WQI by weighted arithmetic method involves the following steps:

2.2.1.1 Calculation of quality rating scale (Qi) for each parameter:

If there are i number of water quality parameters, the quality rating scale Qi corresponding to the i^{th} parameter indicates the relative value of this value in polluted water with respect to its standard permissible value. The value of Qi is calculated by equation (1).

$$Qi = 100 \times \frac{Vi - Vo}{Si - Vo} \qquad (1)$$

Where,

Q_i= Quality rating scale for i^{th} parameter
V_i= Estimated concentration of i^{th} parameter in the sample
S_i= Recommended standard value for i^{th} parameter
V_o= Ideal value of the i^{th} parameter in the pure water
Here, for all the parameters ideal value, V_o is taken as zero except for pH=7.0 and DO= 14.6 mg/L.

2.2.1.2 Calculation of unit weight (W_i) for each parameter:

The unit weight (W_i) of each parameter represents the value which is inversely proportional to the recommended standard value of the corresponding parameter. It is calculated by equation (2) as follows:

$$Wi = {}^{K}\!/_{Si} \qquad (2)$$

Where,

W_i= Unit weight for i^{th} parameter

K= proportionality constant $= \frac{1}{\sum \frac{1}{Si}}$

2.2.1.3 Calculation of WQI

The overall WQI is calculated from the quality rating and the unit weight by equation (3). The equation is as follows:

$$WQI = \sum QiWi \Big/ \sum Wi \quad (3)$$

After calculating the value of WQI, the categorization of water quality according to this method is done by the following table-2:

Table-2: WQI index categorization according to weighted arithmetic method

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

2.2.2 Calculation of WQI by CCME WQI Method

To represent a variety of variables into a single number combining various measurements, the Canadian Council of Ministers of the Environment (CCME) WQI is one of the most effective methods which is universally well-accepted (Damo et al., 2013). The index is established based on a formula developed by the British Columbia Ministry of Environment, Lands, and Parks and modified by Alberta Environment (Canadian Council of Ministers of the Environment, 2001). The prime advantage of this method is it's adaptability to the different legal requirements for which this method can be applied in different regions with a slight adjustment. The calculation of WQI by CCME method is done by the following equation:

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (4)$$

Equation (4) involves calculation of three factors- Scope (F_1), Frequency (F_2) and Amplitude (F_3). The calculation procedure of these factors are mentioned bellow:

2.2.2.1 Calculation of Scope (F_1)

Scope represents the extent of variables with non-compliance over time. It is calculated by the following equation (5):

$$F_1 = \frac{Number\ of\ Failed\ Variables}{Total\ Number\ of\ Variables} \times 100 \quad (5)$$

2.2.2.1 Calculation of Frequency (F_2)

The percentage of individual tests that failed to meet the objectives is represented by frequency and it is calculated by equation (6).

$$F_2 = \frac{Number\ of\ Failed\ tests}{Total\ Number\ of\ tests} \times 100 \quad (6)$$

2.2.2.1 Calculation of Amplitude (F_3)

Amplitude specifies the amount by which the failed tests did not meet their objectives. It includes three steps of calculation:

Step: 1- Calculation of excursion

The number of times by which an individual concentration value deviates than (or less than, when the objective is a minimum) the objective is called "excursion". When the test value must not exceed the objective, it is calculated by equation (7) and when the test value must not fall below the objective, it is calculated by equation (8).

$$Excursion_i = \frac{Failedtestvalue_i}{Objective_j} - 1 \quad (7)$$

$$Excursion_i = \frac{Objective_j}{Failedtestvalue_i} - 1 \quad (8)$$

Step: 2- Calculation of Normalized sum of excursion (nse)

The collective total by which the individual test deviated from the objective is named as normalized sum of excursion (nse). It is calculated after calculation total excursions by the equation (9).

$$nse = \frac{\sum excursion\ i}{Number\ of\ tests} \quad (9)$$

Step: 3- Calculation of Amplitude (F_3)

After calculating nse, F_3 is then calculated by an asymptotic function mentioned below:

$$F_3 = \frac{nse}{.01nse + .01} \quad (10)$$

After getting the values of F_1, F_2 and F_3, WQI is calculated by equation (4) and the final score is then categorized based on the following classification mentioned in table-3:

Table- 3: WQI index categorization according to CCME method (Canadian Council of Ministers of the Environment, 2001)

WQI Value	Rating of Water Quality	Description
95-100	Excellent water quality	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
80-94	Good Water quality	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
60-79	Fair water quality	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45-59	Marginal water quality	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0-44	Poor water quality	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3. RESULT

After collection and testing of the water quality parameters, following table-4 was obtained based on which water quality index was calculated following the standards of drinking water quality recommended by Bangladesh Environmental conservation Rule, 1997 (Standard, 1997). The recommended values of the input parameters according to ECR, 1997 is tabulated in table-5.

Table- 4: Estimated concentration of parameters in the sampling points

Sample Name	pH	Turbidity (NTU)	Nitrate (mg/L)	Temp (Degree Celsius)	DO (mg/L)	TDS (mg/L)	Iron (mg/L)	Arsenic (mg/L)	BOD (mg/L)
S1	7.47	6.54	0	23	1.3	477	1.1	0	0.5
S2	7.43	7.28	0	24.63	1.77	696	0.7	0.06	0.6
S3	7.2	6.45	0	23.67	1.4	712	0.9	0	0.17
S4	7.33	7.46	0	23.58	1.33	557	0.7	0.07	0.3
S5	7.39	1.41	0	24.33	1.37	462	0.2	0.03	0.2
S6	7.41	9.83	0	25.1	1.8	724	0.3	0.01	0.43
S7	7.09	12.4	0	25.3	1.63	941	0.6	0.02	0.6
S8	7.32	6.34	0	24.9	1.92	802	1.2	0	0.4

Table- 5: Standard values of the parameters according to ECR, 1997

Parameter Name	Lower Limit	Upper Limit	Unit
PH	6.5	8.5	-
Turbidity	-	10.0	NTU
Nitrate	-	10.0	mg/L
Temperature	20.0	30.0	Degree Celsius
DO	6.0	-	mg/L
TDS	-	1000	mg/L
Iron	0.30	1.0	mg/L
Arsenic	-	0.05	mg/L
BOD	-	0.20	mg/L

3.1 pH in drinking water

pH is the indicator of whether the water is hard or soft. The pH of pure water is 7. When pH value is lower than 7, it is considered as acidic and it may impart metallic taste or contribute to fixture corrosion. When pH value is greater than 7, it is considered to be basic and tastes a bit like baking soda along with leaving deposits on fixtures. For all our samples, pH level fluctuated from 7.09 for S7 to 7.47 for S1, which is found to be satisfactory according to ECR, 1997.

3.2 Turbidity in drinking water

Turbidity is the degree of how much clear a liquid is and how much light is scattered by the sample. It can create both aesthetic and health issues by creating objectionable appearances, tastes, and odors along with interfering during disinfection. According to ECR, 1997, the standard value of turbidity in drinking water is 10 NTU. The concentration of turbidity was found to be satisfactory for all the samples except for S7 and S6 where turbidity was 12.4 NTU and 9.83 NTU respectively.

3.3 Nitrate in drinking water

The nitrate toxicity mainly affects human health by transforming into nitrite that prohibits transport of oxygen to tissues in human body. This phenomena causes cyanosis and at higher concentration asphyxia. Fortunately, in all our samples, there was no trace of nitrate poisoning. In all the samples nitrate concentration was found to be 0 mg/L.

3.4 Temperature in drinking water

Temperature of water effects bio-chemical reactions in aquatic organisms. An increase in temperature of water leads to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies the tastes and odors. The temperature of the samples fluctuated from minimum 23^0c for S1 to maximum 25.3^0c for S7 which are within the guideline of ECR, 1997.

3.5 Dissolved Oxygen (DO) in drinking water

Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophs (Rani et al., 2012). By presence of oxygen demanding wastes in water, oxygen level falls. As, DO makes drinking water tastes better, higher level of DO is desirable. In our samples, the concentration of DO was found to be far below than the recommended lower limit in all samples. In place of recommended value of DO being 6.0 mg/L by ECR, 1997, among all the eight samples, maximum value was found to be only 1.92 mg/L for S8.

3.6 Total Dissolved Solid (TDS) in drinking water

TDS is the measure of total amount of inorganic salts along with small amount of organic matter which are soluble in water (World Health Organization [WHO], 1996). As, higher level of TDS imparts objectionable taste and cause scaling in water pipes and household appliances, maximum level is considered to be 1000mg/L. The maximum value of TDS among the eight samples was found to be 941 mg/L in sample S7. So, the value of TDS can be deduced as satisfactory for all the samples.

3.7 Iron in drinking water

Though presence of iron is not hazardous to health, excessive amount makes it secondary or aesthetic contaminant. Apart from that, iron helps in transport of oxygen in blood which is essential for good health. The iron concentration in the samples were within permissible limit except for sample S1 and S8. In this two samples iron concentration was found to slightly cross the prescribed limit. Where the upper limit of iron concentration is 1mg/L, in this two stations iron concentration were 1.1mg/L and 1.2 mg/L respectively.

3.8 Arsenic in drinking water

Arsenic has been demonstrated to be carcinogenic to human health if it is ingested for a longer period of time. Long term exposure to arsenic increases risk of cancer in skin, bladder, lungs and kidney (Fawell et al, 2011). Among our eight samples, two samples exceeded the permissible limit of arsenic concentration (.05 mg/L). These two samples are S2 and S4 where iron concentration is 0.06mg/L and 0.07 mg/L respectively.

3.9 Biological oxygen Demand(BOD) in drinking water

BOD is the measure of level of pollution in water due to presence of organic matter. So, the higher the BOD, the water us more polluted with the presence of oxygen demanding organisms. In our samples, except for having almost marginal value in sample S3 (0.17 mg/L) and marginal value in sample S5 (0.2 mg/L), all the samples exceeded the permissible limit of BOD. Among these, sample S7 contains highest concentration of BOD which is 0.6 mg/L.

3.10 Result of WQI by Weighted Arithmetic Method

By weighted arithmetic method, total five categories of water qualities were found among eight samples. Among them, one excellent, one good, three poor, one very poor and two samples were found unsuitable for drinking purpose (table-7). The calculation of quality rating scale is mentioned below in (table-6).

Table- 6: Calculation of quality rating scale (Q_i) by Weighted Arithmetic Method

Sample Name	pH	Turbidity	Nitrate	Temperature	DO	TDS	Iron	Arsenic	BOD
S1	31.33	65.40	0.00	30.00	154.65	47.70	110.00	0.00	250.00
S2	28.67	72.80	0.00	46.30	149.19	69.60	70.00	120.00	300.00
S3	13.33	64.50	0.00	36.70	153.49	71.20	90.00	0.00	85.00
S4	22.00	74.60	0.00	35.80	154.30	55.70	70.00	140.00	150.00
S5	26.00	14.10	0.00	43.30	153.84	46.20	20.00	60.00	100.00
S6	27.33	98.30	0.00	51.00	148.84	72.40	30.00	20.00	215.00
S7	6.00	124.00	0.00	53.00	150.81	94.10	60.00	40.00	300.00
S8	21.33	63.40	0.00	49.00	147.44	80.20	120.00	0.00	200.00

Among eight samples, only sample S3, which is from Faridpur chowdhury bari, was found to be of excellent quality. After that, the sample S8 which is from Knaipur Bazar was found to be of C grade which indicates the quality to be good. The samples, S1, S5 and S6 from Faridpur Dhaka highway, Faridpur Ambika Road and Faridpur Tepakhola respectively, were found to be of grade C which is poor water quality. The sample S7 of Goalchamot near bus stand was found to be of very poor water quality. sample S2 and S4 from Faridpur Vanga highway and Faridpur Ambika Road were found as unsuitable for drinking purpose.

Table- 7: WQI by Weighted Arithmetic Method

Location	Sample Name	WQI	Remarks	Category
Faridpur Dhaka highway	S1	52.68	C	Poor water quality
Faridpur Vanga highway	S2	151.11	E	Unsuitable for drinking purpose
Faridpur Chowdhury bari	S3	20.74	A	Excellent water quality
Faridpur Ambika Road	S4	137.90	E	Unsuitable for drinking purpose
Faridpur Tepakhola	S5	66.05	C	Poor water quality
Faridpur municipal water supply	S6	58.25	C	Poor water quality
Goalchamot near bus stand	S7	90.51	D	Very Poor water quality
Knaipur Bazar	S8	43.56	B	Good water quality

3.10 Result of WQI by CCME Method

According to CCME method, two categories of water quality were found among eight samples. Except for sample S3 at Faridpur chowdhury bari, the rest of the samples were found to be fair.

Table- 8: Calculation of WQI by CCME Method

Location	Sample Name	F1	F2	F3	CCME WQI	WQI Category
Faridpur dhaka highway	S1	33.3	33.3	36.7	65.5	FAIR
Faridpur vanga highway	S2	33.3	33.3	33.8	66.5	FAIR
Faridpur chowdhury bari	S3	11.1	11.1	26.7	82.1	GOOD
Faridpur Ambika Road	S4	33.3	33.3	32.9	66.8	FAIR
Faridpur Tepakhola	S5	22.2	16.7	27.3	77.5	FAIR
Faridpur municipal water supply	S6	22.2	22.2	27.9	75.7	FAIR
Goalchamot near bus stand	S7	33.3	33.3	35.4	66	FAIR
Knaipur Bazar	S8	33.3	33.3	27	68.6	FAIR

4. DISCUSSION

From the table-9, it is evident that the water quality of Faridpur Sadar is not satisfactory. According to WAM WQI value, most of the sampling points do not hold any good score. Among the eight sampling locations, six locations have a WQI value of more than 50, which indicates the water quality is not suitable for drinking purposes. Furthermore, out of the six bad scores that are greater than 50, three locations have poor water quality, one location having very poor quality and two marked as fully unsuitable for drinking purpose. Only one water quality at sampling point S3 has excellent water quality and one at S8 has good water quality. The scenario is different when the CCME WQI value is considered. According to CCME WQI, all the results hold satisfactory scores falling under the fair category except for S3, which falls in good water quality. Even though, the arsenic value of sample S2 and S4 crosses the acceptable limit, according to CCME method, they are fair, similar to other samples which do not cross the acceptable limit of arsenic. This interrupts to discern for which parameter the water quality fluctuates and which is the most deleterious parameter.

Table- 9: Location specific WQI by Weighted Arithmetic and CCME Method

Location	**Sample Name**	**WQI by Weighted Arithmetic Method**		**WQI by CCME Method**	
		WQI Value	Category	WQI Value	Category
Faridpur dhaka highway	S1	52.68	Poor water quality	65.5	FAIR
Faridpur vanga highway	S2	151.11	Unsuitable for drinking purpose	66.5	FAIR
Faridpur chowdhury bari	S3	20.74	Excellent water quality	82.1	GOOD
Faridpur Ambika Road	S4	137.90	Unsuitable for drinking purpose	66.8	FAIR
Faridpur Tepakhola	S5	66.05	Poor water quality	77.5	FAIR
Faridpur municipal water supply	S6	58.25	Poor water quality	75.7	FAIR
Goalchamot near bus stand	S7	90.51	Very Poor water quality	66	FAIR
Knaipur Bazar	S8	43.56	Good water quality	68.6	FAIR

While, in CCME method water quality index falls only in two categories (i.e. good & fair), in WAM index same numbers can be categorized into five classes which becomes more convenient in comparing the quality of different sources.

Table- 10: Unit Weight (W_i) assigned to parameters by Weighted Arithmetic in descending order

Parameter	**Weightage (Wi)**
Arsenic	0.754186
BOD	0.188547
Iron	0.037709
DO	0.006285
PH	0.004436
Turbidity	0.003771
Nitrate	0.003771
Temp	0.001257
TDS	0.000038

In WAM, weights are given to each parameter according to their acceptance range. The parameter which has a low range of acceptance gets the highest weight. On the contrary, parameter having the highest acceptance range gets the lowest scores. In this case, as arsenic has the lowest acceptance range (0.05 ppm), it got the highest weight of 0.754186. On the other hand, TDS having the highest acceptance range (1000 ppm) has the lowest weight of 0.000038 (table-10). This means that a slight change in the value of the higher weight parameter (i.e. Arsenic, BOD, Iron, etc.) will affect more on the index value than the same amount of change in the lowest weight parameters. In our cases, it can be seen that the value of the higher weightage parameters differs much from one sampling point to another compared to lower weight parameters. This change in value has a great impact on the water quality index value. Therefore, in WAM, the WQI value differs much at different sampling locations.

On the other hand, in the CCME Method, no such weight is assigned to the parameters. The scope, frequency, and amplitude are only considered calculating WQI value. Having all the parameters the same weight, a small change in the value of one parameter (which got higher weightage in WAM, i.e. Arsenic, Iron, BOD) does not have the same impact as like as WAM.

From the WQI values, it can be inferred that the poorest category of WQI at sample S4 was due to the presence of the highest concentration of arsenic and at sample S2 was due to high concentration of both arsenic and BOD. The abundance of iron and BOD made sample S7 holding very poor water quality. The higher concentration of BOD with the lowest amount of DO at sample S1, the marginal value of BOD and arsenic concentration at sample S5 and a higher concentration of BOD at sample S6, categorized them as a poor category. Here, interestingly, in sample S1 though there is no presence of arsenic, a higher concentration of BOD and iron classified the water quality as poor. Subsequently, the absence of arsenic in sample S8 rated it to be good and the absence of arsenic and the lowest concentration of BOD at S3 rated it to be excellent.

5. CONCLUSIONS

From the above study, it can be concluded that both natural lithology and anthropogenic activities are contaminating the groundwater in Faridpur Sadar. As among eight samples, only one sample was found to be excellent according to the WAM WQI method and fair according to the CCME method, the majority of the groundwater sources need some degrees of treatment before consuming it and protection also needed to halt prevailing and further contamination. The study hopes that the policymakers will find the result as a reference while planning programs for the welfare for the community people and the quantification of water quality along with the parameters will help the local people to choose the better source available and raise awareness among them.

REFERENCES

Akoteyon, I. S., Omotayo, A. O., Soladoye, O., & Olaoye, H. O. (2011). Determination of water quality index and suitability of urban river for municipal water supply in Lagos-Nigeria. European Journal of Scientific Research, 54(2), 263-271.

Akter, T., Jhohura, F. T., Akter, F., Chowdhury, T. R., Mistry, S. K., Dey, D., & Rahman, M. (2016). Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross-sectional study. Journal of Health, Population and Nutrition, 35(1), 4.

Alam, G. J. (2009). Environmental pollution of Bangladesh—it's effect and control. Pulp and Paper, 51, 13-7.

Bangladesh Bureau of Statistics. (2011). District Statistics 2011 Faridpur District. Dhaka, Bangladesh:

Bhuiyan, M. A., Islam, M. A., Dampare, S. B., Parvez, L., & Suzuki, S. (2010). Evaluation of hazardous metal pollution in irrigation and drinking water systems in the vicinity of a coal mine area of northwestern Bangladesh. Journal of Hazardous Materials, 179(1-3), 1065-1077.

Biswas, R. K., Roy, D. K., Islam, A. R. M. T., Rahman, M. M., & Ali, M. M. (2014). Assessment of drinking water related to arsenic and salinity hazard in Patuakhali district, Bangladesh. Int J Adv Geosci, 2(2), 82-85.

Bodrud-Doza, M., Islam, A. T., Ahmed, F., Das, S., Saha, N., & Rahman, M. S. (2016). Characterization of groundwater quality using water evaluation indices, multivariate statistics and geostatistics in central Bangladesh. Water Science, 30(1), 19-40.

Bozdağ, A. (2015). Combining AHP with GIS for assessment of irrigation water quality in Çumra irrigation district (Konya), Central Anatolia, Turkey. Environmental earth sciences, 73(12), 8217-8236.

Brown, R. M., McClelland, N. I., Deininger, R. A., & Tozer, R. G. (1970). A Water Quality Index- Do We Dare.

Canadian Council of Ministers of the Environment. (2001). Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0, User's Manual. Canadian Environmental Quality Guidelines.

Damo, R., & Icka, P. (2013). Evaluation of Water Quality Index for Drinking Water. Polish Journal of Environmental Studies, 22(4).

Department of Public Health Engineering.(2012). Union wise water technology mapping [Faridpur Circle].Dhaka, Bnagladesh: Author.

DISLEY, Y. P. (2013). Sustainable development goals for people and planet. NATURE, 495, 21.

Fawell, J. K., & Mascarenhas, R. (2011). Arsenic in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. Guidelines for Drinking-water Quality, 24.

Hossen, M. A., Rafiq, F., Kabir, M. A., & Morshed, M. G. (2019). Assessment of Water Quality Scenario of Karnaphuli River in Terms of Water Quality Index, South-Eastern Bangladesh. American Journal of Water Resources, 7(3), 106-110.

Islam, A. T., Shen, S., Bodrud-Doza, M. D., & Rahman, M. S. (2017). Assessing irrigation water quality in Faridpur district of Bangladesh using several indices and statistical approaches. Arabian Journal of Geosciences, 10(19), 418.

Katyal, D. (2011). Water quality indices used for surface water vulnerability assessment. International journal of environmental sciences, 2(1).

Rahaman, M. F., Ali, M. S., Arefin, R., Mazumder, Q. H., Majumder, R. K., & Jahan, C. S. (2019). Assessment of drinking water quality characteristics and quality index of Rajshahi city, Bangladesh. Environment, Development and Sustainability, 1-15.

Rahman, M. S., Molla, A. H., Saha, N., & Rahman, A. (2012). Study on heavy metals levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. Food Chemistry, 134(4), 1847-1854.

Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. Journal of Chemistry, 6(2), 523-530.

Rani, J., Kannagi, A., & Shanthi, V. (2012). Correlation of total heterotrophic bacterial load in relation with hydrographical features of Pazhayakayal estuary, Tuticorin, India. Journal of environmental biology, 33(4), 769.

Saha, R., Dey, N. C., Rahman, S., Galagedara, L., & Bhattacharya, P. (2018). Exploring suitable sites for installing safe drinking water wells in coastal Bangladesh. Groundwater for Sustainable Development, 7, 91-100.

Semiromi, F. B., Hassani, A. H., Torabian, A., Karbassi, A. R., & Lotfi, F. H. (2011). Water quality index development using fuzzy logic: A case study of the Karoon River of Iran. African Journal of Biotechnology, 10(50), 10125-10133.

Shahidullah, S. M., Hakim, M. A., Alam, M. S., & Shamsuddoha, A. T. M. (2000). Assessment of a Groundwater Quality in a Selected Area of Bangladesh. Pakistan J. Bio. Sci, 3(2), 246-249.

Standard, B. (1997). The environment conservation rules 1997. Government of the People's Republic of Bangladesh, Dhaka.

Swarnokar, S. C., Hassan, N., Rahman, M., Islam, M. M., & Ara, M. H. (2019). Assessment of Groundwater Quality in a Tidal River Basin of the Ganges Delta in Bangladesh. Journal of Geoscience and Environment Protection, 7(5), 131-151.

Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water quality assessment in terms of water quality index. American Journal of Water Resources, 1(3), 34-38.

World Health Organization (WHO). (1996). Guidelines for Drinking Water Quality. 2nd Edn, Vol. 2. Health Criteria and Other Supporting Information. Geneva, Switzerland: World Health Organization.