WATER QUALITY INDEX (WQI) OF SHITALAKSHYA RIVER NEAR HARIPUR POWER STATION, NARAYANGANJ, BANGLADESH

Rumman Mowla Chowdhury*[1], Adib Ashhab Ankon[2] and Md Kamruzzaman Bhuiyan[3]

[1]*Assistant Professor, University of Asia pacific, Dhaka, Bangladesh , e-mail: rumman@uap-bd.edu*
[2]*Teaching Assistant, University of Asia pacific, Dhaka, Bangladesh , e-mail: adibankon50@gmail.com*
[3]*Research Assistant, University of Asia pacific, Dhaka ,Bangladesh , e-mail: bhuiyan8769@gmail.com*

***Corresponding Author**

ABSTRACT

The present investigation is aimed at understanding the water quality parameters and the development of a water quality index (WQI) to assess the quality of the Shitalakshya River near Haripur power station, Narayanganj for five different years (2013-2018) considering monsoon, pre-monsoon, post monsoon seasonal variations. Water quality index (WQI) is a valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. In this study, three different methods were used to evaluate the WQI named as; Weighted Arithmetic Index Method, Canadian Council of Ministers of the Environment Water Quality Index Method and National Sanitation Foundation Method. Essential parameters i.e. pH, total dissolved solids, dissolves oxygen, biochemical oxygen demand, electrical conductivity, chloride, turbidity, color, Silica, Iron, Phosphate were considered for calculating the WQI. According to Weighted Arithmetic Index Method the WQI value varied from 80 to 286 for the last five years. From the National Sanitation Foundation Method the WQI value was found within 36 to 56 for the study duration. The WQI value was varied from 3 to 16 according to Canadian Council of Ministers of the Environment Water Quality Index Method. Based on WQI values, the Shitalakhya river water was being classified as poor water for the above mentioned different years. Furthermore,the water quality were poor for different seasons as well.Among the different parameters, mostly turbidity, electrical conductivity, TSS, Iron were the parameters which caused the situation worst.Moreover, it was found there were no significant differences among the various methods for assessing WQI.

Keywords: *Water quality index, Pre-monsoon, Dissolved oxygen, Biochemical oxygen demand.*

1. INTRODUCTION

In the last few decades, there has been a tremendous increase in the demand for freshwater due to the rapid growth of population and the accelerated pace of industrialization. Most of the industries are growing beside the river because of the fastest accessibility. Furthermore, the expenses for the raw material transport is much cheaper through waterways. However, most of the industries do not maintain effluent treatment plant (ETP), eventually the effluents from those industries are being discharged directly to the rivers without any treatment. This has led to progressive and continual resource degradation and pollution, especially towards the surface water. Polluted water is an important vehicle for the spread of diseases. In developing countries, about 1.8 million people, mostly children, die every year because of water related diseases (WHO, 2004).

For healthy living, potable safe water is essential. It is a basic need of all human beings to get the adequate supply of safe and fresh drinking water. Moreover, Riverine water quality is an important issue for each stakeholder as it affects human uses as well as plant and animal life. A number of indices have been developed to summarize water quality data in an easily expressible and easily understood format. One of the most effective ways to communicate water quality is Water Quality Index (WQI), where the water quality is assessed because of calculated values. Quality of water is defined in terms of its physical, chemical, and biological parameters (Chowdhury & Hossain, 2012). WQI is defined as a rating that reflects the composite influence of different water quality parameters (Sahu & Sikdar 2008). Water Quality Index (WQI) is a very useful and efficient method for assessing the suitability of water quality. It is also a very useful tool for communicating the information on overall quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of water quality (both surface and groundwater). WQI reflects the composite influence of different water quality parameters and is calculated from the point of view of the suitability of (both surface and groundwater) for human consumption. Initially, WQI was developed by Horton in 1965, and improved version by Brown et al. in 1970.

The objective of this paper is to determine the WQI of water of the Shitalakshya River near Haripur power station, Narayanganj for five different years (2013-2018). The study area is shown on a satellite image with the power plant in Figure 1. Shitalakhya is the river which is regarded as one of the feeders of Brahmaputra,The stream of the river is the southwest direction at the initial stage. After that, it shifts its course to Narayanganj in the east and Dhaleswari near Kalagachhiya afterwards. The river is almost 110 kilometers or 68 miles long near Narayanganj in length and having 300-meter width. The Shitalakhya River consorted the Brahmaputra and then fell into Dhaleshwari (Islam & Jamal, 2012). Because of this significant location, at the bank of the Shitalakhya River, many factories and industries are established. However, these industries do not even follow or practice the treatment method of wastewater and toxic water. As a result, by the improper discharging process, a massive amount of toxic and wastewater mixed up in the Shitalakhya River. Besides, household and municipal sewage sludge from the Narayanganj urban areas are mixed up with this river without being treated. Hence, the dominance of pollution is rising at a higher rate day by day due to the heavy metals as well as various toxic substances are carried out by the industrial wastes and effluents (WARPO, 2000).

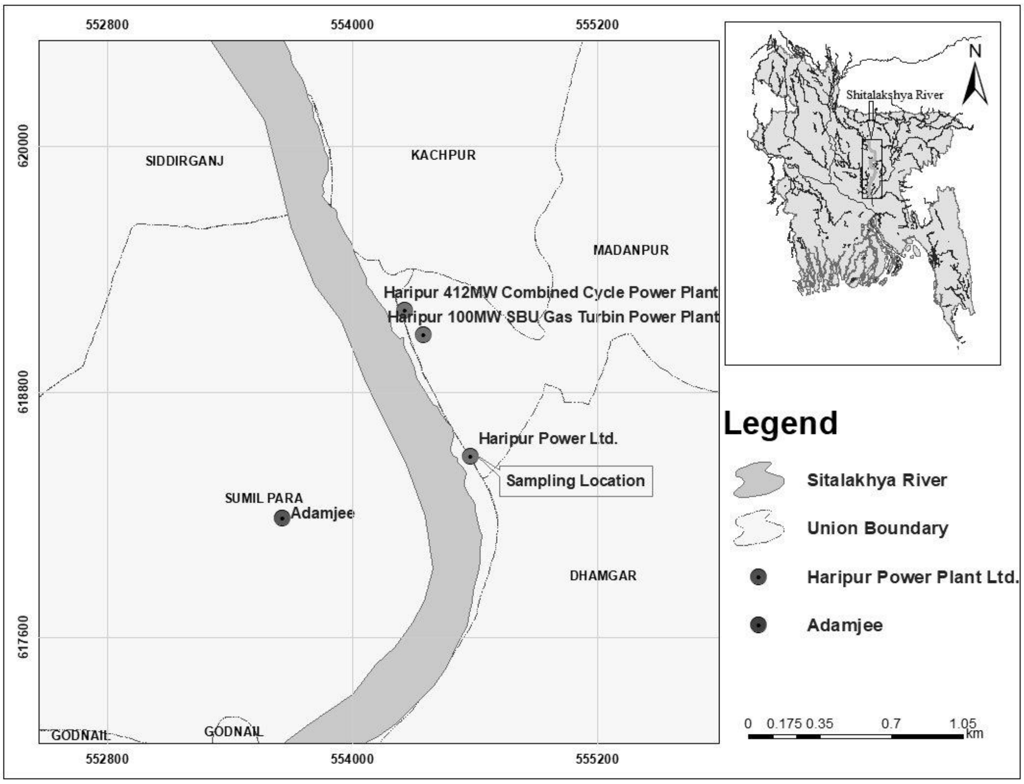

Figure 1: Location of main discharges on Sitalakhya River, Narayanganj.

Moreover, the government for establishing power plant for electricity generation has chosen this place. Power plants need huge amount of water for the cooling purposes and therefore power plants are built beside the river. Nevertheless, due to the pollution over the river, power plants required extensive level of treatment before using river water. Subsequently this increases the cost of treatment units so as the raise in overall cost of power production that affect the economy. Moreover, Local inhabitants of this area are dependent on the water of the Shitalakshya River for various purposes, which made the analysis inevitable. The single value of water quality index value will be useful for understanding the actual situation. Moreover, the trend in seasonal variation might help different stakeholders for stepping towards necessary actions. Foremost, the result might be beneficial for them to take decision for treating the worst parameters especially for the time of shortage in municipal supply water.

Over the years, several WQIs have been proposed and used appropriately by governmental agencies and researchers. These include: Index of River Water Quality, Overall Index of Pollution, Chemical Water Quality Index, Iowa Water Quality Index, Universal Water Quality Index-UWQI, Canadian Council of Ministers of Environment Water Quality Index-CCMEWQI, National Sanitation Foundation Water Quality Index – NSFWQI, Oregon Water Quality Index-OWQI, Weighted Arithmetic Water Quality Index Method WAWQIM. Out of these, the CCMEWQI, NSFWQI, OWQI, and WAWQIM are the commonly *us*ed (Oni & Fasakin,206). In this study, three different methods were used to evaluate the WQI named as; Weighted Arithmetic Index Method, Canadian Council of Ministers of the Environment Water Quality Index Method and National Sanitation Foundation Method. The parameters assessed were water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC), hardness (Ca & Mg), chloride, turbidity, alkalinity, iron and color for measuring the index values.

2. MATERIALS AND METHODOLOGY

2.1 Sample collection:

The samples are collected from the outlet of the power plant throughout the year and analysed immediately at the sampling site using standard equipment.
Water samples were collected once in week from Haripur (Figure 1) of the Narayanganj District of Bangladesh. The analysis was done for five years i.e., January 2013 to December 2018 except 2017.The samples were collected from the surface water of the Shitalakshya River.

2.2 Methodological Approach:

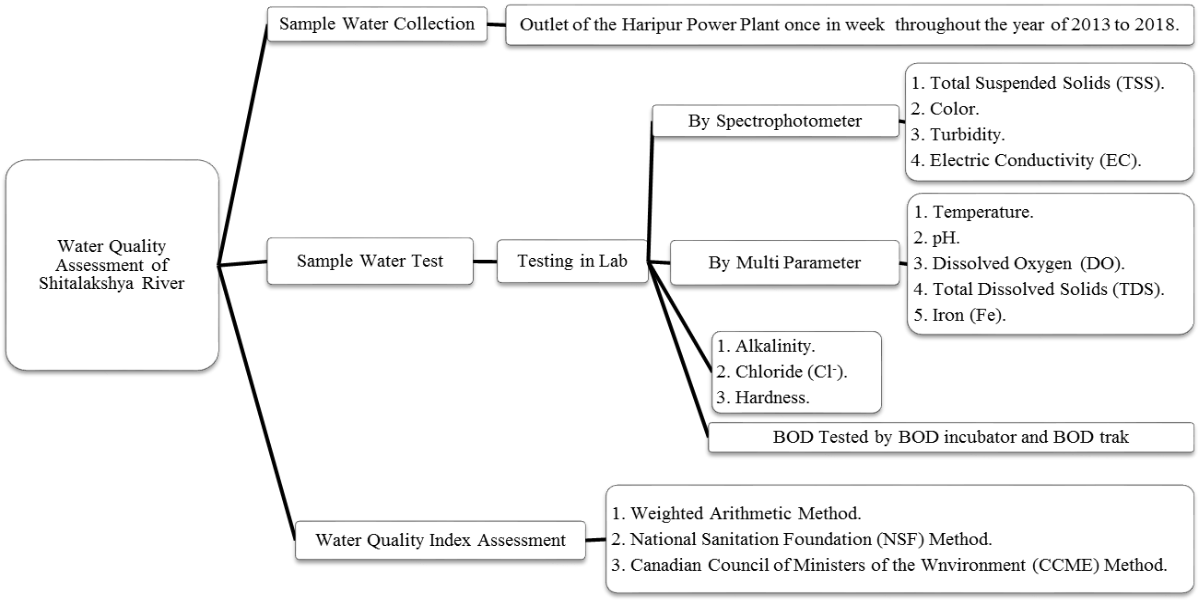

Figure 2: Methodological approach of the study.

2.3 Weighted Arithmetic Water Quality Index Method

The WQI, which is calculated using the weighted arithmetic index method (WAWQIM)is commonly used among researchers in developing countries where data collection infrastructure is not extensive for the database of the water quality parameters to be vast, and reliable rating curves are rare Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables.

The method has been widely used by the various scientists (Balan, Shivakumar & Kumar, 2012) and the calculation of WQI was made (Brown, McClelland, Deininger & O'Connor, 1972) by using the following equation:

$$WQI = \frac{\sum Qi\,Wi}{\sum Wi} \quad (1)$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$$Qi = 100[(Vi - Vo\ Si - Vo)] \quad (2)$$

Where,
V_i is estimated concentration of i^{th} parameter in the analysed water.
V_o is the ideal value of this parameter in pure water.
V_o = 0 (except pH =7.0 and DO = 14.6 mg/l)
S_i is recommended standard value of this parameter
The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$Wi = K/Si \quad (3)$$

Where,
K = proportionality constant and can be calculated by using the following equation:

$$K = \frac{1}{\sum \frac{1}{Si}} \quad (4)$$

The rating of water quality according to this WQI is given in Table 1.

Table 1: Water quality rating as per weight arithmetic water quality index method.

WQI Value	**Rating of Water Quality**
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor water quality
Above 100	Unsuitable for drinking water for supply after conventional treatment

2.4 National Sanitation Foundation Water Quality Index (NSF WQI)

A usual water quality index method was developed by paying great rigor in selecting parameters, developing a common scale and assigning weights. The attempt was supported by the National Sanitation Foundation (NSF) and therefore as NSFWQI in order to calculate WQI of various water bodies which are critically polluted. The proposed method for comparing the water quality of various water sources is based upon nine water quality parameters such as temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total solids (Brown, McClelland, Deininger & Tozer, 1970).

The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Qi is obtained. The mathematical expression for NSF WQI is given by

$$WQI = \sum_{i=1}^{n} QiWi \quad (5)$$

Where,
Q_i = sub-index for i^{th} water quality parameter.
W_i = weight associated with i^{th} water quality parameter.
n = number of water quality parameters.

For this NSFWQI method, the ratings of water quality have been defined by using following Table 3:

Table 2: Water Quality Rating as per National Sanitation Foundation Water Quality Index method.

National Sanitation Foundation Method (NSF WQI)	
WQI Value	**Rating of Water Quality**
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality

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

CCME WQI provides a consistent method, which was formulated by Canadian jurisdictions to convey the water quality information for both management and the public. Moreover, a committee established under the Canadian Council of Ministers of the Environment (CCME) has developed WQI, which can be applied by many water agencies in various countries with slight modification (Boyacioglu, 2010). This method has been developed to evaluate surface water for protection of aquatic life in accordance to specific guidelines. The parameters related to various measurements may vary from one station to the other and sampling protocol requires at least four parameters, sampled at least four times (Khan, Tobin, Paterson, Khan & Warren, 2005) The calculation of index scores in CCME WQI method can be obtained by using the following relation:

$$WQI = 100 - \frac{\sqrt{F_1{}^2 + xF_2{}^2 + F_3{}^2}}{1.732} \quad (6)$$

Where,
Scope (F_1) = Number of variables, whose objectives are not met.
F_1= [No. of failed variables /Total no. of variables] *100.
Frequency (F_2) = Number of times by which the objectives are not met.
F_2 = [No. of failed tests/Total no. of tests] *100.
Amplitude (F_3) = Amount by which the objectives are not met.

a) $Excursioni = [Failed\ test\ valuei\ /Objectivej] - 1.$

$$normalized\ sum\ of excursions, \quad nse = \frac{\sum_{i=1}^{n} excursion}{No.of\ Tests}$$

b) $F_3 = [\mathrm{nse}/0.01\mathrm{nse} + 0.01]$

Five categories have been suggested to categorize the water qualities which are summarized in Table-3.

Table 3: Water quality rating as per Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) method.

Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)	
WQI Value	**Rating of Water Quality**
95-100	Excellent water quality
80-94	Good water quality
60-79	Fair water quality
45-59	Marginal water quality
0-44	Poor water quality

3. RESULTS & DISCUSSION

3.1 Assessment of Water Quality Using Different WQI Methods

In this study Water Quality Index of Shitalakshya River has been calculated by three different methods e.g. Weighted Arithmetic Index Method, Canadian Council of Ministers of the Environment Water Quality Index Method and National Sanitation Foundation Method. Maximum, Minimum, Mean, variance and standard deviation are given in Table 4. The standard deviation and variance indicate that there exists large fluctuation in the values of various parameters contributing the water quality of the river. Correlation matrix of water quality parameters has been shown in Table 5.

Table 4: Maximum, minimum and average values of different water quality parameters.

Parameter	Unit	Maximum Value	Minimum Value	Mean Value	Variance	Standard deviation
pH		7.87	7.13	7.47	0.14	0.37
DO	mg/l	5.87	0.23	2.88	0.48	0.69
Color	Pt-co	52.50	2.73	20.27	4.72	2.17
Conductivity	μ/c	1151.75	130.50	519.89	680.29	26.08
TDS	mg/l	637.25	64.40	277.45	1350.76	36.75
TSS	mg/l	136.25	20.20	63.69	30.55	5.53
Hardness	mg/l	196.50	38.50	107.21	27.32	5.23
Cl^-	mg/l	147.50	9.20	50.72	141.87	11.91
Turbidity	ftu	146.50	17.60	50.57	37.03	6.08
Alkalinity	mg/l	450.00	35.20	170.08	606.98	24.64
Fe	mg/l	10.25	0.02	0.52	0.12	0.34
Temperature	℃	32.08	21.20	28.20	1.26	1.12
BOD	mg/l	6.5	2.8	4.9	0.18	0.42

Table 5: Correlation matrix of water quality parameters of Shitalakshya River

	pH	DO	Color	Conductivity (C)	TDS	TSS	Hardness (H)	Cl^-	Turbidity (Tu)	Alkalinity (Alk)	Iron (Fe)	Temperature (T)	BOD
pH	1.00												
DO	0.84	1.00											
Color	0.13	-0.03	1.00										
C	0.32	-0.05	0.43	1.00									
TDS	0.26	0.15	0.12	0.84	1.00								
TSS	0.11	0.41	0.36	-0.60	-0.58	1.00							
H	0.35	0.17	0.92	0.60	0.38	0.25	1.00						
Cl^-	-0.24	-0.25	0.01	0.65	0.84	-0.67	0.09	1.00					
Tu	-0.05	0.12	0.76	0.04	0.05	0.65	0.76	-0.06	1.00				
Alk	-0.38	-0.73	0.06	0.65	0.48	-0.82	0.10	0.61	-0.23	1.00			
Fe	-0.08	-0.13	0.95	0.39	0.18	0.34	0.83	0.20	0.80	0.09	1.00		
T	0.47	0.47	-0.19	0.09	0.27	0.03	0.17	-0.19	0.11	-0.10	-0.34	1.00	
BOD	-0.60	-0.37	-0.78	-0.48	-0.24	-0.32	-0.92	0.20	-0.62	0.06	-0.59	-0.40	1.00

3.1.1 WQI by Weighted Arithmetic Method

To determine the WQI by Weighted Arithmetic Method (WAM), sub water quality index for various parameters were estimated. The bar chart (Figure 2) compares the seasonal water quality index values for different years. It was found most of the water quality parameters exceed permissible limit throughout the year.Worst scenario was visible in post monsoon season for most of the year. However, water quality parameters were slightly better in monsoon period which eventually made the index value barely within the limit to be considered as good water quality.According to the rating of arithmatic index value (Table 1) only monsoon season of 2018 showed good water quality.

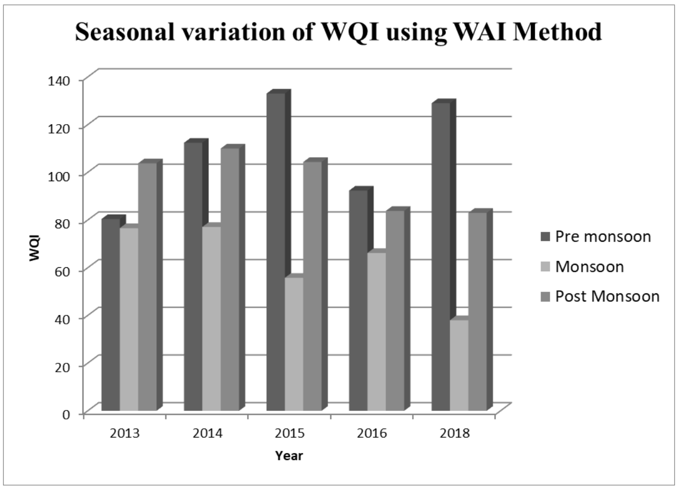

Figure 2: Seasonal variation in the WQI determined by weight arithemetic method.

3.1.2 WQI by NSF

Figure 3 shows the seasonal variation in water quality for the different years by NSF method. According to NSF method the water quality is degreding along with time.Among the 5 different years, the scenario was awful for the year 2018 almost throughout the year.

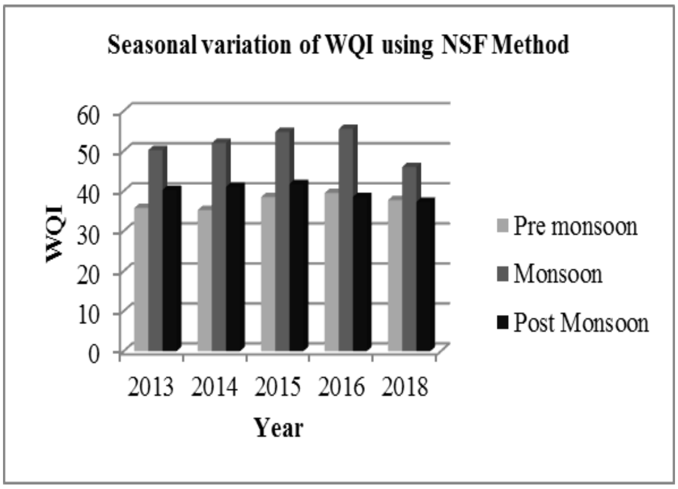

Figure 3: Seasonal variation in the WQI determined by National Sanitation Foundation Water Quality Index (NSF) method.

3.1.3 WQI by CCME

Following Table 6 shows the calculation of factors for the CCME method for the year 2018. It was found mostly there were three to seven parameters among the twelve parameters which were failed to be within permissible limit. For the particular year April was the month which falls within pre monsoon experienced poorest quality. According to the following method F_2 expresses the fact that mostly the parameters were far away from the standard values in post monsoon.

Table 6: Results of WQI founded by CCEM method.

Month	Failed Item	Total Item	F1	No. of Failed test	Total test	F2	Total Excursion	nse	F3	CCMEWQI
JAN	5	13	38.46	23	55	41.8	87.57	1.59	100.01	12.60
FEB	5	13	38.46	20	44	45.5	102.13	2.32	100.01	11.56
MAR	5	13	38.46	20	44	45.5	159.91	3.63	100.01	11.56
APR	7	13	53.85	21	44	47.7	135.10	3.07	100.01	6.38
MAY	3	13	23.08	12	44	27.3	21.23	0.48	100.01	19.30
JUN	3	13	23.08	9	33	27.3	14.58	0.44	100.01	19.30
JUL	6	13	46.15	19	47	40.4	42.95	0.91	100.01	10.85
AUG	4	13	30.77	16	44	36.4	54.45	1.24	100.01	15.83
SEP	5	13	38.46	17	47	36.2	59.14	1.26	100.01	14.07
OCT	5	13	38.46	18	47	38.3	27.67	0.59	100.01	13.54
NOV	6	13	46.15	20	45	44.4	61.81	1.37	100.01	9.75
DEC	6	13	46.15	22	46	47.8	85.11	1.85	100.01	8.76

In this table it has been noticed that in monsoon period number of failures is respectively low, on the other hand in pre monsoon and post monsoon the number of failures is high.

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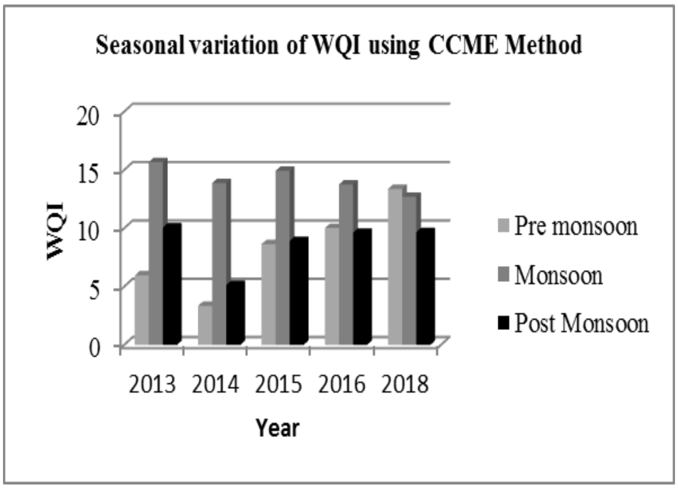

Figure 4: Seasonal variation in the WQI determined by Canadian Council of Ministers of the Environment Water Quality Index (CCME) method

Figure 4 compares the result for different seasons using CCME method. For the year 2014, pre monsoon season was awful according to Table 3.

3.2 Comparison of WQI between different methods

The Table-8 compares the seasonal water quality index method for different years for different methods. There was almost no variation among the three different methods for assessing water quality index values. Not only for almost every season but also for every method the water quality of the particular river water was proved to be unsuitable for domestic, drinking and aquatic species. However, rendering the method WAI, the quality showed good where as for the same season other two methods showed opposite result.

Tabel 7: WQI value for the period of 2013-2018 according to different methods considering corresponding rating.

WQI Method	Season	2013		2014		2015		2016		2018	
		WQI Value	WQI Rating	WQI Value	WQI Rating	WQI Value	WQI Rating	WQI Value	WQI Rating	WQI Value	WQI Rating
WAI	Pre monsoon	80	Very Poor water quality	112	Unsuitable for drinking water for supply after conventional treatment	133	Unsuitable for drinking water for supply after conventional treatment	92	Very Poor water quality	151	Unsuitable for drinking water for supply after conventional treatment
	Monsoon	77	Very Poor water quality	77	Very Poor water quality	56	Poor water quality	66	Poor water quality	87	Good water quality
	Post Monsoon	104	Unsuitable for drinking water for supply after conventional treatment	286	Unsuitable for drinking water for supply after conventional treatment	104	Unsuitable for drinking water for supply after conventional treatment	84	Very Poor water quality	108	Poor water quality
CCME	Pre monsoon	6	Poor water quality	3	Poor water quality	9	Poor water quality	10	Poor water quality	13	Poor water quality
	Monsoon	16	Poor water quality	14	Poor water quality	15	Poor water quality	14	Poor water quality	13	Poor water quality
	Post Monsoon	10	Poor water quality	5	Poor water quality	9	Poor water quality	10	Poor water quality	10	Poor water quality
NSF	Pre monsoon	36	Bad water quality	35	Bad water quality	39	Bad water quality	40	Bad water quality	38	Bad water quality
	Monsoon	50	Bad water quality	52	Medium water quality	55	Medium water quality	56	Medium water quality	46	Bad water quality
	Post Monsoon	40	Bad water quality	41	Bad water quality	42	Bad water quality	39	Bad water quality	37	Bad water quality

4. CONCLUSIONS

In this study, the samples were collected from the Shitalakshya River once in week at the outlet point of the Haripur power plant throughout the year. Assessment of Shitalkhya river water quality was done for past five years (January 2013 to December 2018). Comparison was shown considering different seasons; Pre monsoon, Monsoon, Post monsoon. Water quality parameter such as pH, DO, BOD, EC, colour, turbidity, hardness and some minerals were examined for the evaluation. The main purpose of the research work was to assess the water quality by means of different water quality index methods; Three widely used methods; (WAI method, NSF method, CCME method) were used to calculate the WQI. This kind of surface water rating might help people to have clear understanding of the water quality status for its further use. Besides, WQI integrates the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers. After assessing the results, the study clearly reveals that the quality of the Shitalakshya River possesses poor water quality. The results were similar for the three different methods which proved the validity of the result. Moreover, the water quality status was almost similar throughout the year regardless seasonal variation. Among the different parameters, mostly turbidity, electrical conductivity, TSS, Iron were the parameters which caused the situation worst. This will eventually affect the aquatic ecosystems, recreational and industrial use. Consequently, fish culture has been defused due to this condition. Furthermore, the cost of treatment of water to be used in industries is dramatically increasing. Indirectly, therefore, the worst quality of surface water helps to increase the cost of production and to affect the economy of the country.

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