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STUDY OF WATER QUALITY AND ITS HEALTH EFFECTS DUE TO INDUSTRIALIZATION IN NOAPARA AND CHHATIAIN UNION OF HABIGANJ, BANGLADESH

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Abstract

In this paper, an attempt has been taken to assess the water quality and its impact on local inhabitants along with their health problems due to industrialization without treatment plant in Noapara and Chhatiain Union of Habiganj. To assess the water quality, physico-chemical analysis of water was carried out based on their importance in different usage. Water samples of different locations have DO in the ranges of 2.1mg/l to 9.8mg/l. According to WQI, during dry period, about 42% water samples are ranked as "Unsuitable" whereas 28.5% as "Excellent" during monsoon.CDI value from dermal absorption was evaluated using USEPA guidelines and found the highest amount as 140mg and 150mg for children and adult respectively for only elements related with nitrate and ammonia.

Keywords: Corn starch, Poultry feed, Industrial effluent, Water Quality Index, Dermal absorption

1.0 INTRODUCTION

Industrialization without treatment plant causes the impediment of the natural drainage system, which substantially reduces its water quality. In order to cope with the excessive demographic pressure and increasing demand for more job opportunities, the Government of Bangladesh is going to establish more industrial zones. But unplanned industrialization and urbanization cause environmental pollution with degrading the water quality of water bodies [1], [2], [3], [17]. Jafarzadeh et al. [15] tested water parameters of water bodies of industrial zone in Khuzestan Province in Iran and results indicate that waste water imposes degradable organic substances and suspended particle loads to river. Since it is very difficult to assess the water quality only based on parameters' concentration, Water Quality Index (WQI) is globally used in measuring the overall pollution status of water in a drainage system[10], [18].

In this study, industries located in Noapara Union of Habiganj district have been considered to understand the impact of industrialization without treatment plant in nearby rural areas - Noapara and Chhatiain Union, as no such attempt on this regard has been taken before in this area. To achieve this goal, industries have been evaluated based on the intensity of water quality parameters of surrounding water bodies; corresponding consequences of affected ecosystems has been detected; overall suitability of those water in dry and monsoon season for different usage have been calculated based on WQI value; and health effects of local inhabitants depended on those water have been assessed based on WQI and Dermal Absorption.

2.0 METHODOLOGY

2.1 Determination of Water Sample Parameters

Sample bottles were washed with 1:3 HNO3 acid before sample collection and samples were randomly collected from 14 sample sites during dry and rainy seasons in 2.5L plastic containers following APHA (1995) method [4]. Among those 14 sample sites - W2, W5 and W9 were located at the discharge point; and W3 was located at an embankment (Figure 8 and Figure 1). Samples were tested in two different ways, some were with the help of instrument and some were manually in laboratory detailed in Table 1.

Table 1 Illustration of procedures for sample analysis

Parameters	Instrument	Model	Method
pH	HANNA	HI 9125	_______
Dissolve Oxygen (DO)	Lutron	DO-5509; YK-22DO	_______
Biochemical Oxygen Demand (BOD)	__________	__________	_______
Chemical Oxygen Demand (COD)	__________	___________	Titration
Ammonia (NH_3-N)	HACH (UV-Spectrophotometer	DR 6000	Nessler
Nitrate (NO_3-N)	HACH (UV-Spectrophotometer)	DR 6000	Cadmium Reduction
Total Solid (TS)	Hot Air Oven	___________	_______
Total Suspended Solid (TSS)	Hot Air Oven	___________	_______
Total Dissolve Solid (TDS)	Hot Air Oven	___________	_______
Turbidity	HANNA	HI 93703	_______

Source: Laboratory Analysis, 2019

2.2 Calculating WQI

In this study, WQI is determined using the following formula [5]:

Wi = k/Si……… (1)

Where, Si is standard permissible value of ith water quality parameter and k is constant of proportionality and it is calculated by using the expression:

k = [1/ (Σ 1/ Si=1, 2,..i)] …….. (2)

Subsequently, calculation of WQI was carried out using the expression given in Equation (3).

WQI = Σ Qi * Wi / Σ Wi …………. (3)

Where, Qi is quality rating of ith water quality parameter and Wi is unit weight of ith water quality parameter. The quality rating (Qi) is calculated using the expression given in Equation (4).

Qi = [(Vi – Vid) / (Si - Vid)] x 100…………. (4)

Where, Vi is estimated value of ith water quality parameter at a given sample location, Vid is ideal value for ith parameter in pure water (note: Vid for pH = 7, DO = 14.6, and 0 for all other parameters) and Si is standard permissible value of ithwater quality parameter. To generate changes in WQI along the study area, interpolation was used.

Indiscriminate dumping of solid and liquid industrial waste into the natural environment significantly alters the aquatic ecosystem. A comparison of water quality change with the standards may depict the whole scenario. Bangladesh Drinking Water Standards (BDWS), Department of Environment (DOE) and Environment Conservation Rule (ECR, 1997) standards for aquatic ecosystem have been listed below (in Table 2**).**

Table 2 Standard values for water parameters

Parameters	BDWS	DoE	ECR			
			Fisheries	Irrigation	Drinking	Recreational
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6-9.5
DO (mg/L)	6	5	5 or more	5 or more	5 or more	4-5
BOD (mg/L)	0.2	2	6 or less	10 or less	0.2	3
COD (mg/L)	4	4	-	-	4	4
Ammonia (mg/L)	0.5	0.5	1.2	-	0.5	-
Nitrate (mg/L)	10	-	-	-	10	-
TDS (mg/L)	1000	500-1000	-	2000	1000	-
TSS (mg/L)	10	10	-	-	-	-
TS (mg/L)	-	20-500	-	-	-	-
Turbidity (JTU)	10	<29	-	-	28	-

Source: ECR, 1997; Jahan, 2010 and Reza, 2016

2.3 Health Risk Assessment by Dermal Absorption

The dermal absorption is common by surface water exposure [12]. The expression for risk assessment is given as follows:

CDI_{derm}= (C_w *SA* C F* PC* ABS* ET*EF*ED)/(BW*AT) where CDI=chronic daily intake, SA =surface area available for contact (cm 2), CF = volumetric conversion factor (L to cm 3), PC = metal or pollutant sp. dermal permeability constant, ET = exposure time (hr), ABS = absorption factor (%), C w = metal or pollutant concentration in water in mg/l, EF = exposure frequency (days/yr), BW = body weight in kg, AT = average time (days) and ED = exposure duration in year.

3.0 RESULTS AND DISCUSSION

During field survey it has been observed that the industries established just on the bank of streams discharge their untreated effluent directly into the streams near W2, W5 and W9. Effluent of W2 and W5 flow downstream and then accumulate with the stream water near W3 where an embankment impedes the water to flow downstream during dry season. But in monsoon, the authority of the industry lets the water flowing along with the effluent by cutting off the embankment (Figure 1). This unwise activity, ultimately, allows the effluent spreads through the drainage network and enters into the agricultural lands and rural settlement areas located in downstream causing changes in the concentrations of water quality parameters of different water bodies.

Concentration values of different water quality parameters found from physico-chemical analysis of water collected from fourteen sampling sites have been presented here (in Table 3). The parameters exceeding permissible limits are indicators of pollution.

(Dry period) *(Peak monsoon period)*

Figure 1 The presence and absence of the embankment near sample site W3 in two separate seasons
(*Source: Field Survey, 2019)*

Table 3 Concentrations of different parameters of water samples

Stations / Parameters		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
DO (mg/L)	Dry	6.7	4.9	2.4	9.2	2.9	9.1	4.5	8.3	2.9	5.9	6.8	7.8	6.3	8.9
	Monsoon	7.5	7.2	4.5	10.2	4.4	4.6	4.2	5.4	3.2	7.7	6.5	7.5	5.1	5.3
BOD (mg/L)	Dry	0.4	0.3	2.2	1.9	2.5	0.5	0.7	0.7	2.7	4.8	0.6	2.1	0.9	1
	Monsoon	0.2	0.1	1	1.7	0.7	1.1	0.3	0.9	1.1	2.4	0.2	0.8	0.2	0.2
COD (mg/L)	Dry	2.1	4.5	33	3.5	47	8.5	9.8	2	450	12	5	6.5	8.3	9.6
	Monsoon	3.5	3.2	4.6	3.3	8.7	8	7	3.6	275	6.3	5.1	4.3	4.4	8.5
pH	Dry	6.36	6.02	6.17	6.23	6.78	7.93	7.13	6.27	7.53	7.16	7.24	7.29	7.52	7.79
	Monsoon	6.35	6.05	6.39	6.5	7.05	6.16	6.32	6.23	7.45	6.79	6.45	6.53	6.39	7.03
Ammonia (mg/L)	Dry	0.21	0.1	9.33	1.31	81.5	3.6	0.59	0.37	28.67	25.86	0.24	3.36	0.39	1.15
	Monsoon	1.39	1.05	2.21	0.32	2.18	2.34	1.4	0.41	0.39	0.22	0.09	0.19	0.22	0.58
Nitrate (mg/L)	Dry	1.4	0.9	3	4.6	25.8	0.4	2.6	0.5	34.28	Nil	1.1	2.1	0.5	4.4
	Monsoon	Nil	0.7	Nil	Nil	Nil	0.3	Nil	0.7	2.8	Nil	0.6	1	0.1	0.1
T.D.S (mg/L)	Dry	0.1	1.73	0.91	0.18	1.47	2.27	2.27	1.08	1.7	2.45	2.93	1.59	0.37	0.29
	Monsoon	0.18	0.18	0.18	2.28	2.46	1.54	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
T.S.S (mg/L)	Dry	0.04	0.01	0.09	0.02	0.29	0.01	0.02	0.17	0.1	0.01	0.08	0.07	0.11	0.13
	Monsoon	0.19	0.12	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.03
T.S (mg/L)	Dry	0.06	1.74	1	0.2	3.93	2.28	2.37	1.25	1.8	2.46	3.01	1.66	0.48	0.42
	Monsoon	0.37	0.3	0.2	1.49	2.48	2.28	1.56	0.11	0.12	0.21	0.11	0.11	0.11	0.13
Turbidity (JTU)	Dry	13.35	15.75	14.48	13.07	17.07	10.81	40.77	14.43	13.71	14.11	15	13.33	16.43	14.97
	Monsoon	208	15.29	134	160	117	113	59	18.12	1.59	8.16	20	10.84	2.57	16.4

Source: Laboratory analysis, 2019

I Potential of Hydrogen (pH)

pH is an important factor that determines the suitability of water for different purposes [24]. The pH values of sample sites W1, W2, W3 and W8 are below the standard in all seasons. Lower pH also found in rural settlement areas (sample sites W6, W7, W8, W11 and W13) in monsoon season indicates the spread of acidification due to the cutting off the embankment causing damage to aquatic ecosystems (Figure 2).

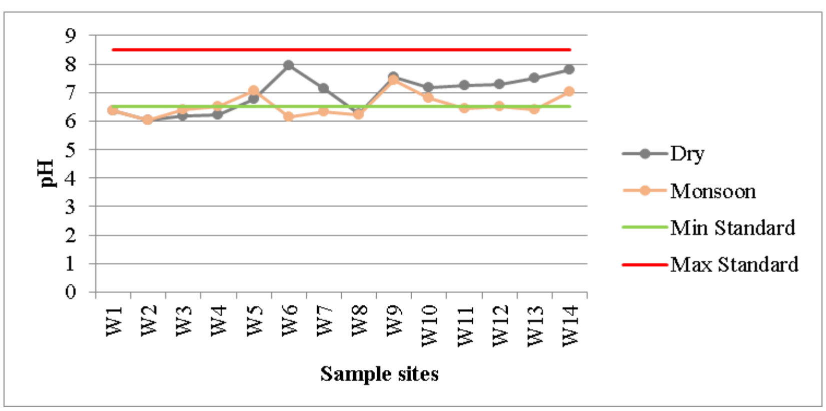

Figure 2 pH value of water samples (

Source: Laboratory analysis, 2019)

ii Dissolved Oxygen (DO)

DO is one of the most important factors in stream health [22]. Oxygen deficiency directly affects the ecosystem of rivers due to bioaccumulations and bio magnifications [7]. In current study, sample sites having DO value less than 5mg/L are not usable for any purpose (Figure 3).

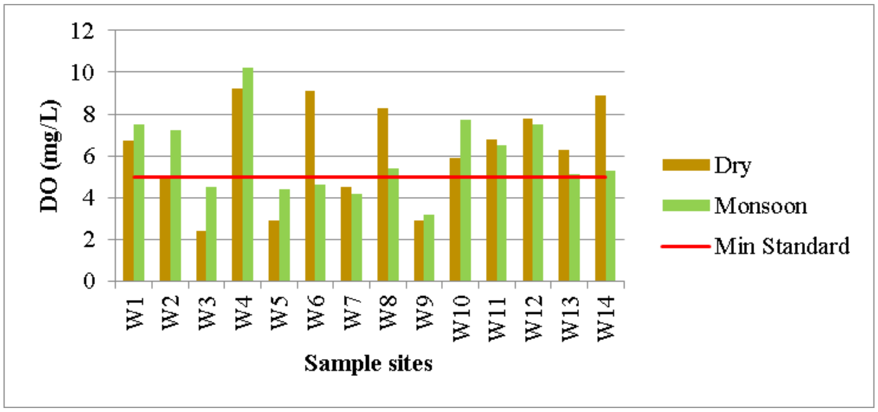

Figure 3 DO of water samples

(Source: Laboratory analysis, 2019)

It is clear from a local survey that soil near the bank of stream turned into blackish due to water pollution. As a result, root of the plants near the stream got rotten and consequently the plant died. The local inhabitants also claimed the polluted water for the damage of the crops and death of the fisheries [13]. It will be worth mentioning that industry located near W5 is not responsible for water contamination of sample site W9 as it is being polluted by a textile industry on its bank.

iii Biochemical Oxygen Demand (BOD_5)

BOD_5 is a strong indicator of the level of organic pollution in the river [7]. High BOD_5 value indicates the presence of organic pollutants that cause oxygen depletion in the water.

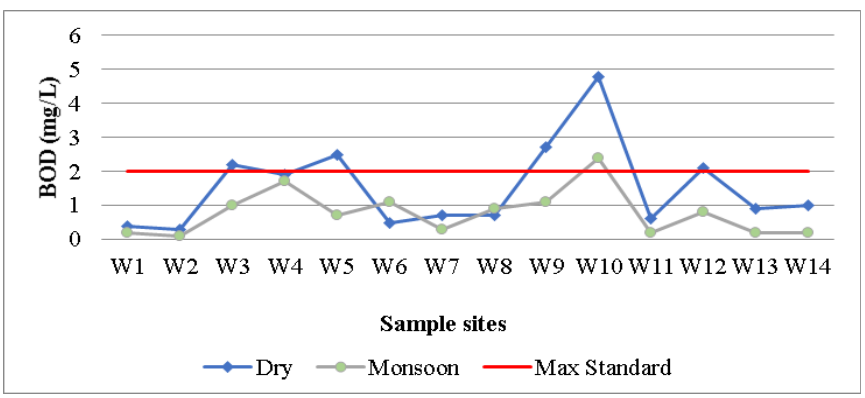

Figure 4: BOD5 of water samples

(Source: Laboratory analysis, 2019)

As the mean BOD_5 value is greater than the standard value for drinking purpose (0.2 mg/L), water of streams is not drinkable (Figure 4). It can be used for irrigation, fisheries and other purposes.

iv Chemical Oxygen Demand (COD)

COD is commonly used to indirectly measure the amount of organic compounds in water [24]. From the laboratory analysis it has been revealed that water of downstream is highly polluted and not suitable for any purpose (Table 2 and Table 3).

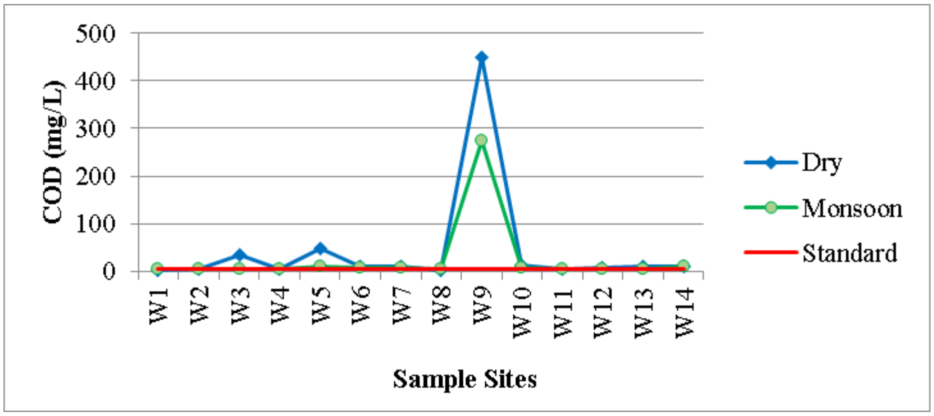

Figure 5 COD of water samples
(Source: Laboratory analysis, 2019)

The high COD value in W9 is an indication of large amount of organic matter in the water due to the gross chemical load of the effluent discharging into the stream and eventually water becomes contaminated (Figure 5).

v Ammonia (NH_3-N)

As ammonium hydroxide, sulphuric acid, sodium bisulfate etc. are used in the production of starch; the effluent consists of proteineous matter, settable matter, sulphide, SO_2, ammonia etc. [19].The highest concentration of ammonia (81.5mg/L)found at W5 during dry season, gives an indication that the industry might have involved in starch production (Table 2 and Figure 6). The concentration beyond the permissible limit also implies that the water of those sites is contaminated and is not suitable for drinking and fish cultivation. Though ammonia and nitrate are the most common forms of nitrogen in aquatic systems; the high concentration of neutral, un-ionized ammonia can cause the loss of fisheries as well as live stock since it is highly toxic to all aquatic lives and terrestrial livestock. Besides, high concentration of ammonia can cause the death of plants and damage of crops by lowering the reproduction and growth of plants.

vii Nitrate

The distribution of nitrate related compounds indicates levels of concentration of ions are very high compared to permissible limits. Impurity with nitrate in downstream water mainly

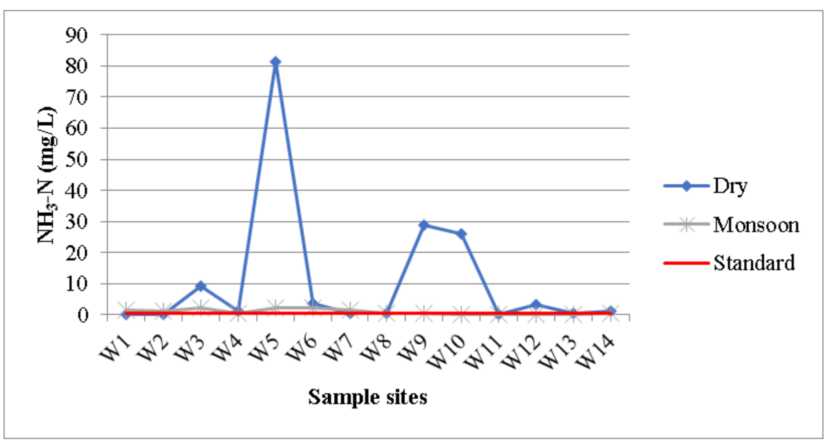

Figure 6 Ammonia of water samples
(Source: Laboratory analysis, 2019)

occurs in dry season making it undrinkable and in monsoon pollutants are diluted with rain water (Figure 7).The concentration of nitrate (25.8mg/L) exceeds the permissible limit in sample site W5 while the concentration has also been found as 34.28mg/L in W9 where a textile industry discharges their effluent. Similar distribution of nitrate related compounds of samples was observed by Gajendran [10] in Nanbiyar river basin due to food industrial zone in India.

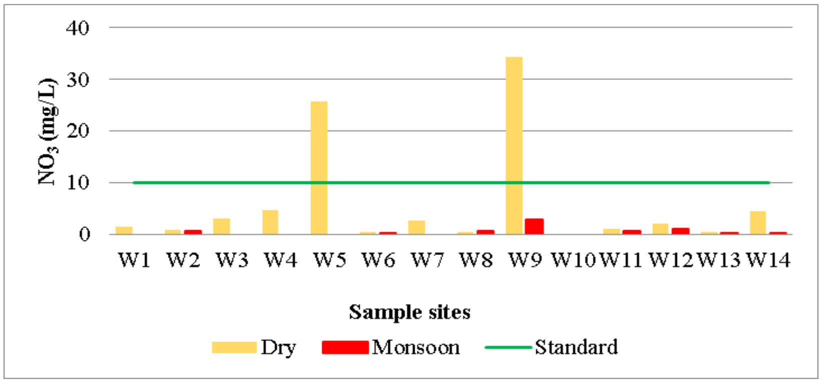

Figure 7: Nitrate of water samples

(Source: Laboratory analysis, 2019)

Usually, nitrate is a natural constituent of the human diet like maize, wheat, barley etc. and an approved food additive [11]. Moreover, it is also found in arrowroot waste fiber used in textile materials [6].The starch and agro-feed industries use potatoes, maize, wheat and tapioca as their basic raw material for starch production [8] and feed ingredients such as maize, wheat, barley, soybean meal, sunflower cake, rape seed meal, canola meal, wheat bran, deoiled rice bran etc. for the preparation of diet for poultry boilers and layers [21]. So, nitrate can be produced as a byproduct from poultry feed production and textile industry; and is mobile when soluble in water and can therefore be rapidly transported through the soil, reaching the ground water and contaminating drinking water supplies [16]. This implies that the industry near W5 is a starch and poultry feed production industry.

Besides all the above parameters, the turbidity value of W1, W3, W4, W5 and W6 is so high in monsoon while Total Dissolve Solid (T.D.S), Total Suspended Solid (T.S.S) and Total Solid (T.S) values are within the standard level ranging from 0.1 to 2.93 mg/L, 0.01 to 0.29 mg/L, and 0.2 to 3.93 mg/L respectively for the dry as well as monsoon season s(Table 3).

3.1 WQI

Conventional analysis of water quality parameters is too detailed, so it cannot be able to supply a comprehensive assessment of water quality. To overcome this gap, WQI is a suitable tool. WQI is considered as one of the criterion for the classifications of surface water, on the basis of the usage of standard parameters for water evaluation and characterization. It may provide an accurate perception about the pollution based on field survey or public opinion.

In current study, calculation of WQI is based on ten important physico-chemical parameters at fourteen different sites and an example calculation is presented in Table 4.WQI calculations for other sample sites are calculated accordingly and the WQI values have been presented in Table 5. Finally, the suitability of water has been evaluated based on WQI value following the schemes (Table 6) prescribed by Vasanthavigar et al. [25].

In this current study, the computed WQI values ranges from 24.9 to 720 during dry season whereas it ranges within 12.13 to 320 during monsoon season. Therefore, it can be categorized into five types “excellent water” to “water unsuitable for drinking and another purpose”. The high value of WQI at these stations has mainly been found due to the higher values of ammonia and turbidity in the stream water. Table 6 shows the percentage of water samples that falls under different quality. During dry period, about 42% of water samples are “Unsuitable” in quality whereas 28.5% ranked as “Excellent” during monsoon.

Table 4: An example calculation of WQI for the sample site W1 (Dry & Monsoon)

Parameter	Observed value (Vi)		Standard value (Si)	Ideal value (Vid)	k value	Unit weight (Wi)	Quality Rating (Qi)		Qi*Wi	
	Dry	Monsoon					Dry	Monsoon	Dry	Monsoon
pH	6.36	6.35	6.5-8.5 mean=7.5	7	0.3	0.04	128	130	5.12	5.2
DO	6.7	7.5	5	14.6	0.3	0.06	82.29	73.95	4.93	4.43
BOD	0.4	0.2	2	0	0.3	0.15	20	10	3	1.5
COD	2.1	3.5	4	0	0.3	0.07	52.5	87.5	3.67	6.12
NH_3-N	0.21	1.39	0.5	0	0.3	0.6	42	278	25.2	166.8
NO_3	1.4	0	10	0	0.3	0.03	14	0	0.42	0
TDS	0.1	0.18	750	0	0.3	0.0004	0.01	0.02	0.000004	0.000008
TSS	0.04	0.19	10	0	0.3	0.03	0.4	1.9	0.01	0.5
TS	0.06	0.37	350	0	0.3	0.0008	0.02	0.1	0.00001	0.00008
Turbidity	13.35	208	28	0	0.3	0.01	47.67	742.85	0.47	7.42
						ΣWi=1			ΣQi*Wi= 42.82	ΣQi*Wi= 191.97
WQI = ΣQi*Wi / ΣWi = 42.82 in dry season (Excellent) and 191.97 in monsoon season (Poor)										

Source: Laboratory analysis, 2019 *** Si values are taken as per DOE & ECR standard*

Table 5 WQI values for all sample sites in two different seasons

Sample sites	Dry season	Monsoon season
W1	42.82	191.97
W2	36.80	143.77
W3	540	297.22
W4	184.45	69.41
W5	720	247.22
W6	441.6	320.13
W7	145.92	624.54
W8	102.37	115.39
W9	680	222
W10	610	28.57
W11	24.9	12.13
W12	411	33.13
W13	76	25
W14	136	58.84

Source: Laboratory analysis, 2019

Table 6 Water quality classification based on WQI value

WQI Levels	Rating	(%) of Water Samples	
		Dry	Monsoon
<50	Excellent	21.43	28.5
50-100	Good	7.14	14.28
100-200	Poor	28.5	21.43
200-300	Very poor (bad)	0	21.43
>300	Unsuitable (Unfit)	42	14.28

Source: Laboratory analysis, 2019

WQI is considered as the most effective tool for public understanding of pollution status of water. To generate changes in WQI along the study area, interpolation was used. Inverse distance weight (IDW) method was applied for interpolation. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. Measured values which are the closest to the predicted location will have more influence on the predicted value than values at the outer most points. So, IDW assumes that each measured point has a local influence that diminishes with distance. IDW interpolation method determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance [14]. Figure 8 shows the spatial distribution of water quality in the study area.

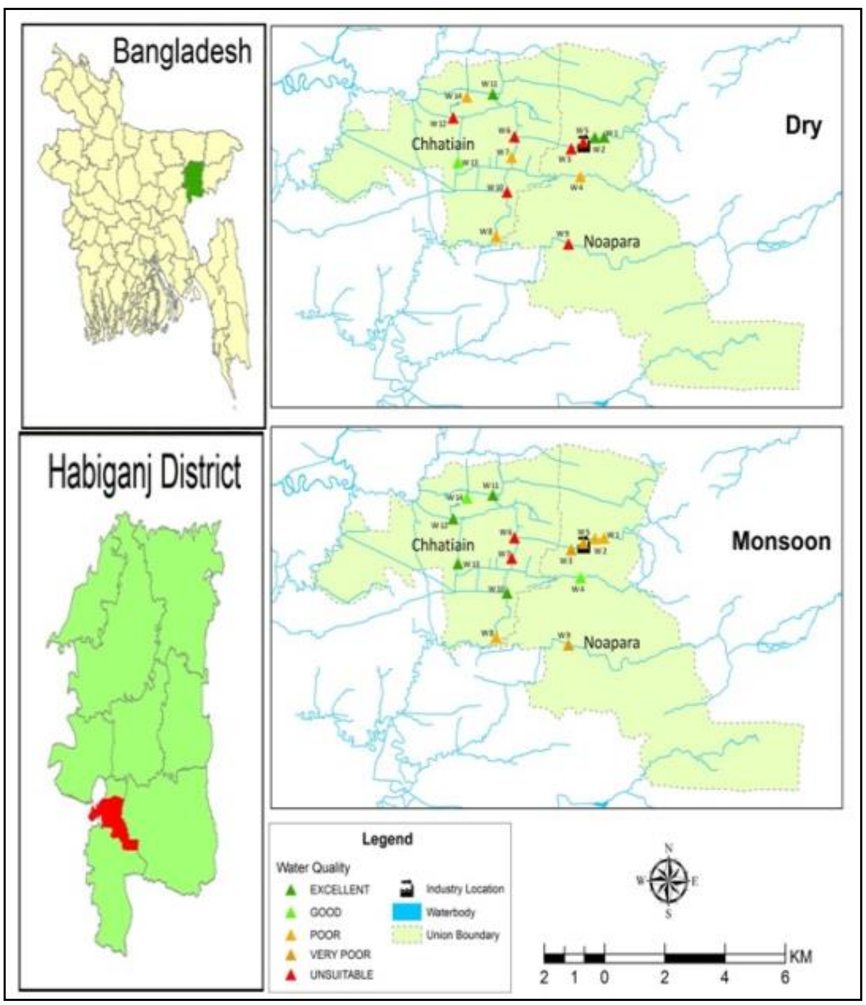

Figure 8 Seasonal Variation of WQI
(Source: Laboratory analysis, 2019)

3.2 Health Impact Based on WQI

Low DO, high BOD and high nitrate concentration indicates the eutrophic status of the water body. A relatively higher concentration of Chlorides and Sulphates indicates unsuitability for domestic use [26]. Qualitative health risk due to polluted water can be evaluated from human exposure to pathogens of an individual. Human health risk is a function of direct ingestion and dermal absorption through skin exposure. But for polluted water, only dermal exposure is a matter of concern and health risk from dermal absorption is a function of dermal permeability, exposure time, exposure frequency etc. [9]. Since there is no study on the coefficient of exposure, exposure frequency and dermal permeability in our country, an indirect health risk is evaluated in this study following Table 7.

Table 7 Definition for classification of surface water quality

WQI	**Description**
WQI<10	Usually oxygen saturated, nutrient poor water, low bacteria content
WQI<25	Small amount of organic and inorganic nutrients without or with slight oxygen depletion, low bacteria
WQI<40	Not a good oxygen supply, inputs organic and inorganic nutrients, presence of bacteria
WQI<75	Usually low oxygen content, presence of micro-organisms, periodic fish killing occurs
WQI>75	Excessively polluted by organic oxygen depleting substances, prolonged periods of very low oxygen concentrations, no fish stocks, lots of bacterial life, cannot use for any purpose.

Source: Jafarabadi et al., 2016

Comparing the WQI values from Table 5 with Table 7 it is clear that water of those sites having WQI>75 is unfit for irrigation purpose and also unsuitable for laundry. CDI value for dermal absorption was evaluated using USEPA guidelines [23] based on following Table 8 and found the highest amount as 140mg and 150mg for children and adult respectively considering only the elements related with nitrate and ammonia. It should be compared to WHO recommended ADI (Acceptable Daily Intake). If it is less than the ADI value, health risk will be insignificant. But cumulative effects of pollutants should be assessed before concluding any comment.

Table 8 Standard values for assessment of dermal absorption

Variable	**Children**	**Adult**	**Variable**	**Children**	**Adult**
SA. cm^2 /event	5140	10,000	ED in yrs	5	15
ABS (unit-less)	1	1	BW in kg	13.2	70
ET hrs/day	8	20	AT in days	365*ED	365*ED
EF days/hr	225	225			

Source: USEPA Handbook, 2001

4.0 CONCLUSION

The presence of nitrate in the effluent discharged to the stream water is clear evidence that the industry near sample site W5 produces corn starch and poultry feed. Besides nitrate, ammonia is found as a byproduct in the effluent of which some portion exists as free nitrogen and/or ammonia in aquatic medium, some portion transform into nitrate and some portion release to atmosphere in gaseous form. The lower DO values (2.4mg/L-4.5mg/L) in relation to both DoE and ECR standards indicate that water from sample sites-W3, W5, W7, W9 in dry season and sample site W6 in monsoon season is not suitable for any purpose which is one of the reasons for loss of fisheries, livestock deaths and crop damage. According to WQI, during dry period, about 42% water samples are “Unsuitable” whereas 28.5% as “Excellent” during monsoon. Pollution intensity is higher in dry season rather than monsoon. In monsoon, effluent mix with rain water and extent of pollution spreads over a large area.

In conclusion, it has been revealed that the corn starch and poultry feed processing industry situated in Noapara union is contaminating water of its adjacent areas which is ultimately responsible for creating different types of problems of the local community. Though this study is an attempt to address those problems and investigate the causes behind the problems, it has been felt that more comprehensive researches are required on this issue.

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