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Assessment of Groundwater Quality of Budhjungnagar Industrial Estate and A D Nagar, Dukli & Badharghat Industrial Cluster of Tripura West District, Tripura State, India by Water Quality Index Method

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ABSTRACT

The study was carried out to assess the ground water quality of Budhjungnagar industrial estate and A D Nagar, Dukli & Badharghat Industrial Cluster of Tripura West District, Tripura after collecting samples from different Tube wells used for drinking purposes by analysing various Physico-Chemical parameters such as pH, Turbidity, Electrical Conductivity (EC), Total dissolved solids(TDS), Total Hardness(TH), Calcium, Magnesium, Bicarbonates, Chlorides, Flurides, Sulphates, Nitrates, Iron and Arsenic using standard methods as prescribed by APHA. The observed values of these parameters were compared with the standards given by WHO. The Water Quality Index was calculated from twelve physico-chemical parameters considering their importance and the values varied from 16.07 - 148.69 and 14.1 - 132.90 in pre-monsoon and post-monsoon seasons of the year 2016 respectively. The results of this study indicates that the studied tube well waters of the study area are suitable for drinking except four sampling locations as it contains higher concentrations of iron (Banikya Chowmuhani, Birbal Para, Unnayan Sangha and Kathaltali Madhuban). It was also observed that the drinking water quality in post-monsoon was better than pre-monsoon season.

Keywords: Ground Water, Industrial Cluster, Physico-Chemical Parameters, Water Quality Index, Tube Well.

I. INTRODUCTION

Water plays a vital role in maintenance of life. It is very much essential for human survival which must be free from harmful microorganisms, toxic substances, excessive amount of minerals and organic matter for drinking and other purposes. The ground Water is a valuable renewable natural resource [1&2]. Due to huge population explosion and urbanisation the number of industries is increasing day by day to meet up the demand. The ground water is being used for industrial applications and other purposes such as public water supply, irrigation and domestic purposes [3]. The industrial effluents are being discharged into rivers, lakes and other water bodies leads to environmental degradation [4]. Due to increasing contamination and scarcity of surface water resources, a major stress has been shifted to groundwater resources. The groundwater pollution is being caused due to discharge of Industrial effluents, domestic sewage and solid waste without proper treatment. This leads to adverse health effects in human beings and animals [5]. Various studies have been carried out to assess the seasonal variations of physico-chemical parameters of ground water in many industrial places in India [6 & 7]. The results of investigations have suggested that there is variation in physico-chemical parameters with seasonal variation and industrialization.

From the literature survey, it has been found that there is no any report on ground water quality assessment in the selected industrial areas of Tripura West district of Tripura. Thus, it was thought to undertake the study to assess the seasonal variations in physico- chemical quality of ground water in Budhjungnagar industrial estate and A D Nagar, Dukli & Badharghat Industrial Cluster of Tripura West District, Tripura. The results of our investigations are presented in this paper.

II. STUDY AREA

The present study areas considered here are Budhjungnagar Industrial Estate, A.D. Nagar, Dukli & Badharghat Industrial Cluster which are located in the Tripura West District, Tripura, India. The study areas lie between latitude $23^0$16' - $24^0$14' north and longitude

$91^0$09' - $91^0$47' east. The Budhjungnagar Industrial Estate, having area 535.73 acres, is located in rural area. The three other industrial areas A.D. Nagar (8.41 acre), Dukli (45.77 acre) and Badharghat (20.525 acre) taken together as industrial cluster are located in urban area and the distance between these industrial areas are very less [**8**]. There are mainly rubber based unit, thermal power plants, Steel rolling plant, distillery, food processing, stone crusher, brick kiln, dairy, automobile, pharmaceuticals, rubber wood treatment, spices, tyre & tube, hot mix plant, latex processing, cattle feed etc. industries are found in selected industrial area of study and have high water pollution potential. The present study is focused on assessment of ground water quality of selected industrial sites of the study area by examining the various physico-chemical parameters during pre-monsoon and post-monsoon seasons of the year 2016. The details of sampling locations are illustrated in Table 1 & 2.

Table 1. Bodhjungnagar Industrial Estate

Location No.	Source	Location	Latitude	Longitude
GW-1	Tube Well	Khash Noa Gaon	N $23^0$51’665’’	E $91^0$20’797’’
GW-2	Tube Well	Kisog Chowmuhani	N $23^0$53’362’’	E $91^0$22’959’’
GW-3	Tube Well	Debram Thakur Para	N $23^0$52’486’’	E $91^0$19’648’’
GW-4	Tube Well	Beltali	N $23^0$52’782’’	E $91^0$19’572’’
GW-5	Tube Well	Rajarban	N $23^0$52’695’’	E $91^0$20’950’’
GW-6	Tube Well	Administratve Block, Budhjungnagar Industrial Estate	N $23^0$52’845’’	E $91^0$21’880’’
GW-7	Tube Well	Banikya Chowmuhani	N $23^0$51’862’’	E $91^0$20’660’’
GW-8	Tube Well	Debendra Choudhury Para	N $23^0$51’917’’	E $91^0$20’116’’
GW-9	Tube Well	Birbal Para	N $23^0$53’524’’	E $91^0$22’731’’
GW-10	Tube Well	Laxmipur	N $23^0$51’742’’	E $91^0$20’585’’
GW-11	Tube Well	Amtali	N $23^0$51’765’’	E $91^0$19’434’’
GW-12	Tube Well	Nandannagar	N 23.52078	E 91.18960

Table 2. A.D. Nagar, Dukli and Badharghat Industrial Cluster

Location No.	Source	Location	Latitude	Longitude
GW-13	Tube Well	Bordowali	N $23^0$49’07’’	E $91^0$16’38’’
GW-14	Tube Well	Unnayan Sangha	N $23^0$49’09’’	E $91^0$16’01’’
GW-15	Tube Well	Camper Bazar	N $23^0$48’97’’	E $91^0$15’22’’
GW-16	Tube Well	Charipara	N $23^0$47’938’’	E $91^0$15’14’’
GW-17	Tube Well	Shantinagar	N $23^0$47’97’’	E $91^0$16’11’’
GW-18	Tube Well	Milan Chakra	N $23^0$47’25’’	E $91^0$15’79’’
GW-19	Tube Well	Hapania	N $23^0$47’02’’	E $91^0$15’16’’
GW-20	Tube Well	Amtali Ramthakur Ashram	N $23^0$46’69’’	E $91^0$16’18’’
GW-21	Tube Well	Ranirkhamar	N $23^0$46’86’’	E $91^0$17’77’’
GW-22	Tube Well	Dukli Industrial Estate premises	N $23^0$46’90’’	E $91^0$17’506’’
GW-23	Tube Well	Kathaltali Madhuban	N $23^0$47’18’’	E $91^0$17’208’’
GW-24	Tube Well	Badharghat Industrial Estate premises	N $23^0$48’162’’	E $91^0$16’672’’
GW-25	Tube Well	A D Nagar Industrial Estate premises	N $23^0$48’81’’	E $91^0$16’26’’

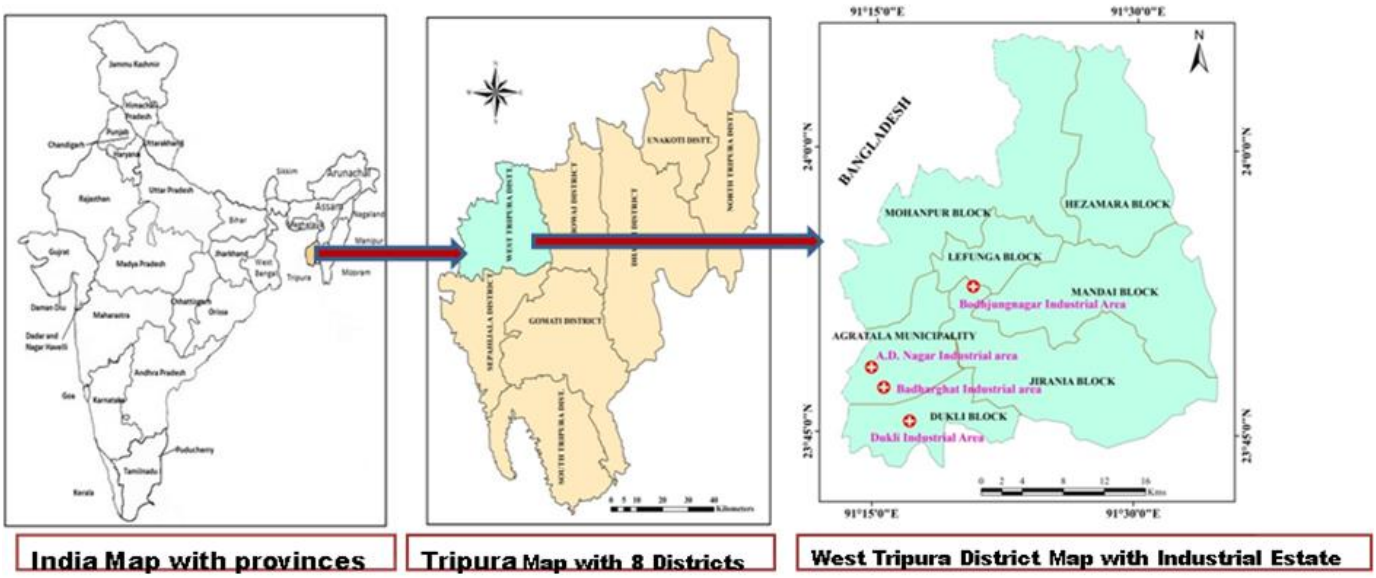

Figure 1. Map showing the selected four industrial area in Tripura West district, Tripura, India.

III. MATERIALS AND METHODS

To assess the impact of industrial pollution on ground water quality, the ground water samples have been collected from 12-different locations in and around Budhjungnagar Industrial estate and from 13-different locations in and around the industrial cluster consisting of three industrial area (A.D. Nagar, Dukli and Badharghat) in the month April-May 2016 (pre-monsoon) and October–November, 2016 (post-monsoon). The ground water samples were collected from hand pumps having the water table at depth of 75 to 200 feet. The water Samples were collected after running the well for about 10 minutes which removes water in contact with the metal-well casing from the well-bore and adjacent aquifers [**9**]. The water samples were collected in hard plastic bottles of 1.5 litre capacity with stopper as per the standard methods prescribed for sampling. Each bottle was washed with 2% nitric acid and then rinsed three times with distilled water [1]. The parameters like pH, electrical conductivity (EC), total dissolved solids (TDS) were measured *in situ* using the potable HI 98130 Combo pH/ EC/ TDS meter (Hanna Instruments). Total Hardness, calcium (Ca) and magnesium (Mg) were measured complexo-metrically, chloride (Cl^-) was measured following argento-metric analysis and sulphate (SO_4^{2-}) was measured by spectrophotometer (Thermo fisher: Evolution 201), fluoride (F^-) was measured colorimetrically, Iron (Fe) and Arsenic (As) were analysed using atomic absorption spectrophotometer (Perkin Elmer AAS 700). The quantitative analytical data have been presented in Tables 3-6. The concentrations were measured in mg/l. The other parameters were analysed by using standard methods as Prescribed by APHA [**10]**. To assess the drinking water quality, water quality indices have been calculated for every selected location of the study areas. The values and graphical representation have been presented in results and discussions.

Water Quality Index (WQI) represents the large number of water quality data to a single numerical value. It signifies the composite influence of various water quality parameters on the overall quality of water [11 & 12]. In this study, the water quality index has been calculated considering twelve important parameters. The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organisation (WHO) [13]. Three steps have been followed to calculate WQI. In the first step, twelve parameters have been assigned a weight (wi) according to its relative importance in assessment of drinking water quality. The weightage has been given to the parameters according to their importance in water quality assessment.

In the second step, the relative weight (Wi) is calculated with the help of following equation:

$$Wi = wi / \sum_{i=1}^{n} wi$$

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters.

In the third step, a quality rating scale (qi**)** for each parameter is calculated by the following equation:

$$qi = (Ci / Si) \times 100$$

Where, Ci is the concentration of each chemical parameter in each water sample in mg/l, and Si is the Indian drinking water standard for each chemical parameter in mg/l according to the guidelines of WHO.

Using the relative weight and quality rating scale values SI for each parameter is calculated. WQI is thus calculated using the equation mentioned below:

$$SI_i = Wi \cdot qi$$

$$WQI = \Sigma SI_i$$

The weights assigned and relative weights for each parameter have been given in Table 7, Water Quality Index values have been presented in Table 8 and Water Quality Index classification has been presented in Table 9. The graphical representation of Water Quality Index in Pre-Monsoon and Post-Monsoon seasons is shown in Figure 2.

IV. RESULTS AND DISCUSSION

The data obtained from the analysis of ground water samples from 25 different selected locations of our study areas during pre-monsoon and post-monsoon seasons are given in Tables 3-6. The results have been compared with drinking water standards [WHO].

Table 3. Physico-Chemical Parameters of Ground Water in and around Budhjungnagar Industrial Estate
*Units of all the parameter are in mg/l except pH, EC (μS cm^{-1}) and Turbidity (NTU).

Locations No.	pH		Turbidity		EC		TDS		TH		Ca		Mg	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
GW-1	5.47	3.69	1.45	1.33	100.9	296	52	148	40.20	40.40	12.08	8.09	2.44	4.90
GW-2	5.95	5.32	0.79	1.11	68.9	110.2	34	52	30.15	35.35	8.06	10.12	2.44	2.46
GW-3	5.72	5.18	5.22	2.04	103.1	36.80	52	22	30.15	40.40	8.06	8.09	2.44	4.90
GW-4	5.84	4.64	0.36	0.40	42.9	64.4	22	32	50.25	50.50	12.08	12.14	4.89	4.90
GW-5	5.51	5.22	0.47	0.60	50.1	74.0	26	34	50.25	60.60	12.08	14.16	4.88	6.13
GW-6	5.88	5.69	2.20	0.85	41.1	37.1	20	22	30.15	40.40	8.06	8.09	2.44	4.90
GW-7	5.06	5.25	0.19	1.24	164.9	122.0	82	24	50.25	60.60	12.08	10.12	4.88	8.59
GW-8	5.72	5.94	2.44	1.87	64.8	83.70	32	42	40.20	40.40	8.06	8.09	4.88	4.90
GW-9	5.29	5.52	2.22	0.74	46.0	49.5	24	26	37.38	50.50	7.49	12.14	4.54	4.90
GW-10	5.94	5.34	3.01	1.20	108.6	130.4	54	64	28.03	40.40	7.49	8.09	2.27	4.90
GW-11	6.54	6.66	1.46	2.60	137.1	168.4	68	88	46.72	66.66	11.23	14.16	4.54	7.60
GW-12	6.31	5.54	4.99	2.20	114.8	130.2	58	82	46.72	50.50	7.41	12.14	6.81	4.90

Table 4. Physico-Chemical Parameters of Ground Water in and around Budhjungnagar Industrial Estate
*Units of all the parameter are in mg/l.

Locations No.	Alkalinity		Cl		F		SO_4		PO_4		NO_3		Fe		As	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
GW-1	25.20	22.12	18.86	32.09	0.40	0.30	5.11	4.52	0.05	0.27	0.18	0.24	0.70	0.30	BDL	BDL
GW-2	45.36	26.64	14.16	24.04	0.28	0.30	4.22	4.00	0.05	0.10	0.29	0.35	0.33	0.23	BDL	BDL
GW-3	30.24	22.12	23.58	13.75	0.24	0.20	4.77	1.91	0.08	0.07	0.36	0.30	0.27	0.22	BDL	BDL
GW-4	80.64	90.24	14.16	24.22	0.38	0.42	3.88	4.60	0.04	0.05	0.25	0.34	0.46	0.39	0.01	BDL
GW-5	30.24	32.66	14.16	18.24	0.42	0.55	3.11	5.64	0.05	0.55	0.15	0.25	0.88	1.10	BDL	BDL
GW-6	35.28	26.54	14.16	13.75	0.54	0.50	3.77	1.41	0.04	0.09	0.09	0.11	0.40	0.32	BDL	BDL
GW-7	25.2	34.40	23.58	36.20	0.28	0.34	3.55	5.88	0.04	0.05	0.15	0.41	2.84	2.40	0.014	0.01
GW-8	45.36	30.94	23.58	13.75	0.47	0.40	3.33	1.45	0.03	0.08	0.08	0.10	1.18	1.14	BDL	BDL

Locati	Alkalinity		Cl		F		SO_4		PO_4		NO_3		Fe		As	
GW-9	20.16	26.54	14.14	18.34	0.40	0.48	BDL	2.66	0.10	0.07	0.89	0.92	3.50	3.10	BDL	BDL
GW-10	30.24	43.12	28.29	32.22	0.36	0.44	6.33	8.44	0.14	0.20	1.46	1.60	1.69	1.39	BDL	BDL
GW-11	25.20	38.40	28.29	32.22	0.45	0.50	7.77	10.32	0.18	0.22	1.69	2.12	1.60	1.21	BDL	BDL
GW-12	65.65	45.23	14.14	12.22	0.35	0.30	18.33	16.42	0.16	0.22	0.91	1.20	1.18	1.30	BDL	BDL

Table 5. Physico-chemical Parameters of Ground Water in and around AD Nagar, Dukli and Badharghat Industrial Cluster estate.

*Units of all the parameter are in mg/l except pH, EC (μS cm^{-1}) and Turbidity (NTU).

Locations No.	pH		Turbidity		EC		TDS		TH		Ca		Mg	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
GW-13	4.83	5.23	2.09	1.18	220	277	46	138	49.01	40.40	7.85	8.09	4.31	7.36
GW-14	5.12	4.95	16.9	12.0	330	346	62	78	68.62	75.75	19.94	10.12	4.76	12.27
GW-15	5.3	5.1	0.53	0.24	194.4	210.2	36	54	58.81	50.50	11.78	8.09	7.14	7.36
GW-16	5.82	5.24	5.55	3.44	280.4	310.2	52	64	49.01	50.50	7.85	6.07	4.31	8.59
GW-17	5.61	5.23	1.5	1.0	69.1	75.2	42	52	49.01	45.45	3.92	6.07	1.92	7.36
GW-18	5.05	4.85	0.52	0.56	209.1	235.5	38	46	49.01	35.35	7.85	10.12	4.31	2.45
GW-19	5.18	4.76	1.13	0.82	234.1	437	32	36	88.27	50.50	23.57	8.09	7.15	7.36
GW-20	4.45	4.23	0.78	6.92	434	161	28	80	78.42	50.50	19.64	8.09	7.14	9.81
GW-21	5.76	5.43	0.89	12.00	113.3	68.6	48	12	29.4	60.60	3.92	12.14	1.38	7.36
GW-22	5.23	4.89	1.31	1.0	35.5	54.32	38	42	29.4	39.21	3.92	7.85	2.03	4.76
GW-23	5.55	5.21	1.77	1.83	70.92	98.50	42	48	19.6	60.6	3.92	8.09	1.96	4.90
GW-24	4.8	5.2	0.42	0.20	145.4	162.2	64	72	29.4	25.25	3.92	6.07	1.96	2.45
GW-25	5.27	4.94	0.63	0.20	106.1	123.1	42	56	39.21	35.35	7.85	6.07	4.76	4.90

Table 6. Physico-chemical Parameters of Ground Water in and around AD Nagar, Dukli and Badharghat Industrial Cluster area.

*Units of all the parameter are in mg/l.

Locations No.	Alkalinity		Cl		F		SO_4		PO_4		NO_3		Fe		As	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
GW-13	25.02	26.54	42.43	55.01	0.48	0.40	12.32	8.40	0.10	0.14	0.22	0.26	0.80	0.74	BDL	0.016
GW-14	30.02	34.50	23.57	34.22	0.32	0.24	8.56	12.00	BDL	0.02	0.16	0.24	3.60	3.20	BDL	BDL
GW-15	35.02	25.34	47.57	50.32	0.40	0.26	20.34	16.56	0.08	0.04	0.30	0.34	0.17	0.44	0.01	0.01
GW-16	75.06	85.22	56.58	67.56	0.28	0.24	9.46	12.52	BDL	0.02	0.12	0.34	1.00	0.94	BDL	BDL
GW-17	35.02	47.23	42.43	37.62	0.12	0.10	6.32	10.12	0.06	0.04	0.56	0.68	1.20	0.80	BDL	BDL
GW-18	20.01	29.06	42.43	48.56	0.06	0.04	12.48	10.46	0.08	0.06	0.44	0.58	0.26	0.14	0.015	0.010
GW-19	30.02	22.12	47.15	59.60	0.54	0.60	22.68	20.12	0.05	0.05	1.22	1.20	0.74	1.51	BDL	0.016
GW-20	10.08	53.08	84.87	22.92	0.33	0.42	8.20	6.75	0.06	0.05	0.42	0.40	0.32	0.30	BDL	BDL
GW-21	20.01	22.12	14.14	13.75	0.40	0.44	10.56	8.44	0.16	0.05	0.38	0.30	0.48	0.37	BDL	0.003
GW-22	15.01	28.21	14.14	16.22	0.24	0.22	14.42	12.22	0.20	0.14	0.48	0.54	0.38	0.28	BDL	BDL
GW-23	60.04	22.12	23.57	18.34	0.42	0.44	8.66	6.88	0.04	0.09	0.26	0.28	2.62	2.45	BDL	BDL
GW-24	20.01	32.05	37.72	31.12	0.33	0.30	14.88	10.87	0.11	0.10	0.58	0.80	1.54	1.28	BDL	BDL
GW-25	35.02	30.34	14.14	8.05	0.36	0.26	6.33	8.54	0.14	0.10	1.46	1.60	0.45	0.38	BDL	BDL

The pH values of ground water samples of Budhjungnagar Industrial estate were not within standard limit of WHO (6.5-8.5) except one location (G-11) and varied between 5.06 to 6.31 and 3.69 to 5.54 during pre- monsoon and post-monsoon seasons respectively. The pH values of ground water samples of AD Nagar, Dukli & Badharghat Industrial Cluster were also not within standard limit and varied between 4.45 to 5.8 and 4.23 to 5.43 during pre- monsoon and post-monsoon seasons respectively. The lower pH of water may be due to dissolved carbon dioxide, organic acids and agricultural runoff as well as discharge of industrial wastes. Lower pH value of groundwater may cause gastrointestinal disorders especially hyperacidity, ulcers and burning sensation [14**].** The pH value is in decreasing trend from pre-monsoon to post-monsoon which may be due to the dissolution of various salts/minerals during rains [1].

The Turbidity values of samples collected in and around Budhjungnagar Industrial estate were found within the permissible limits (5 NTU) except GW-3 in pre-monsoon season. The Turbidity values of samples in and around AD Nagar, Dukli & Badharghat Industrial Cluster were within permissible limits except in GW-14 (pre-monsoon and post-monsoon), G-16 (pre-monsoon) and GW- 20 & 21 (post-monsoon). The turbid nature of water may arise from underground clay contamination in ground water [15].

Electrical Conductivity (EC) is an important parameter which affects the taste [1]. EC varied between 41.1 to 137.1 μmhos/cm and 36.80 to 296 μmhos/cm during pre-monsoon and post-monsoon seasons respectively in and around Budhjungnagar Industrial estate. EC varied between 35.5 to 434 μmhos/cm and 54.32 to 437 μmhos/cm during pre-monsoon and post-monsoon seasons in and around AD Nagar, Dukli & Badharghat Industrial Cluster. The increasing trend of EC from pre-monsoon to post-monsoon season may be due the presence of high amount of dissolved inorganic substances in ionized form [**16]**. The same trend was observed in the case of TDS of ground water sources in both industrial area. The increase of TDS in post-monsoon season may be due to dissolution of salt and industrial discharge by rain water [17].

The presence of iron in the aquifers is quite natural but its levels in ground water can be increased by dissolution of ferrous boreholes and hand pumps components. It dissolves in ground water is in the reduced iron (II) form [18]. The iron content in the Budhjungnagar Industrial estate varied from 0.23 to 3.5 mg/l and 0.22 to 3.10 mg/l during pre-monsoon and post-monsoon seasons respectively. The iron content in and around AD Nagar, Dukli & Badharghat Industrial Cluster varied from 0.14 to 3.60 mg/l and 0.26 to 3.20 mg/l during pre-monsoon and post-monsoon seasons respectively. Seasonal variation was observed in samples. The high iron content may be due to influence of rainfall infiltrating and dissolution of iron bearing mineral rocks and soils which are leached into ground water sources [19 & 20]. Higher values of iron content in maximum samples in both the study areas were recorded in pre-monsoon which may be due to decrease of water levels [18]. The remaining parameters were within the prescribed standard limit (WHO).

Table 7. Relative weight of measured parameters

Parameter	WHO Standard	Weight(wi)	Relative Weight (Wi)
pH	6.5	5	0.11627907
EC	2250	2	0.046511628
TDS	1000	4	0.093023256
Ca	200	2	0.046511628
Mg	100	2	0.046511628
TH	600	3	0.069767442
$HCOO_3^-$	732	3	0.069767442
Cl^-	1000	3	0.069767442
SO_4^{2-}	400	5	0.11627907
NO_3	100	4	0.093023256
F^-	1.5	5	0.11627907
Fe	0.3	5	0.11627907
		∑wi=43	∑Wi=1

Table 8. Water Quality Index Value

Budhjungnagar Industrial Estate	WQI		AD Nagar, Dukli & Badharghat Industrial Cluster	WQI	
	Pre-Monsoon	Post-Monsoon		Pre-Monsoon	Post-Monsoon
Khash Noa Gaon	36.91	18.22	Bordowali	39.64	38.03
Kisog Chowmuhani	23.43	18.43	Unnayan Sangha	148.69	132.9
Debram Thakur Para	20.69	17.79	Camper Bazar	16.07	26.17
Beltali	28.27	23.41	Charipara	49.17	45.8
Rajarban	43.96	51.97	Shantinagar	56.54	40.36
Administratve Block, Budhjungnagar Industrial Estate	26.02	22.58	Milan Chakra	19.11	14.1
Banikya Chowmuhani	119.12	102.41	Hapania	37.94	67.74
Debendra Choudhury Para	55.96	54.81	Amtali Ramthakur Ashram	20.36	19.19
Birbal Para	145.12	130.02	Ranirkhamar	28.9	24.05
Laxmipur	76.12	63.42	Dukli Industrial Estate premises	24.08	19.6
Amtali	73.28	58.81	Kathaltali Madhuban	111.47	104.3
Nandannagar	57.02	60.29	Badharghat Industrial Estate premises	68.27	58.91
			A D Nagar Industrial Estate premises	28.86	23.56

Table 9. WQI Classification and Results

WQI Value	Water Quality	Percentage of Samples			
		Pre-Monsoon		Post-Monsoon	
		Budhjungnagar Industrial estate	AD Nagar, Dukli & Badharghat Industrial Cluster	Budhjungnagar Industrial estate	AD Nagar, Dukli & Badharghat Industrial Cluster
<50	Excellent	41.66	69.23	41.66	69.23
50-100	Good	33.33	15.38	41.66	15.38
100-200	Poor	16.66	15.38	16.66	15.38
200-300	Very Poor	0	0	0	0
>300	Unsuitable	0	0	0	0

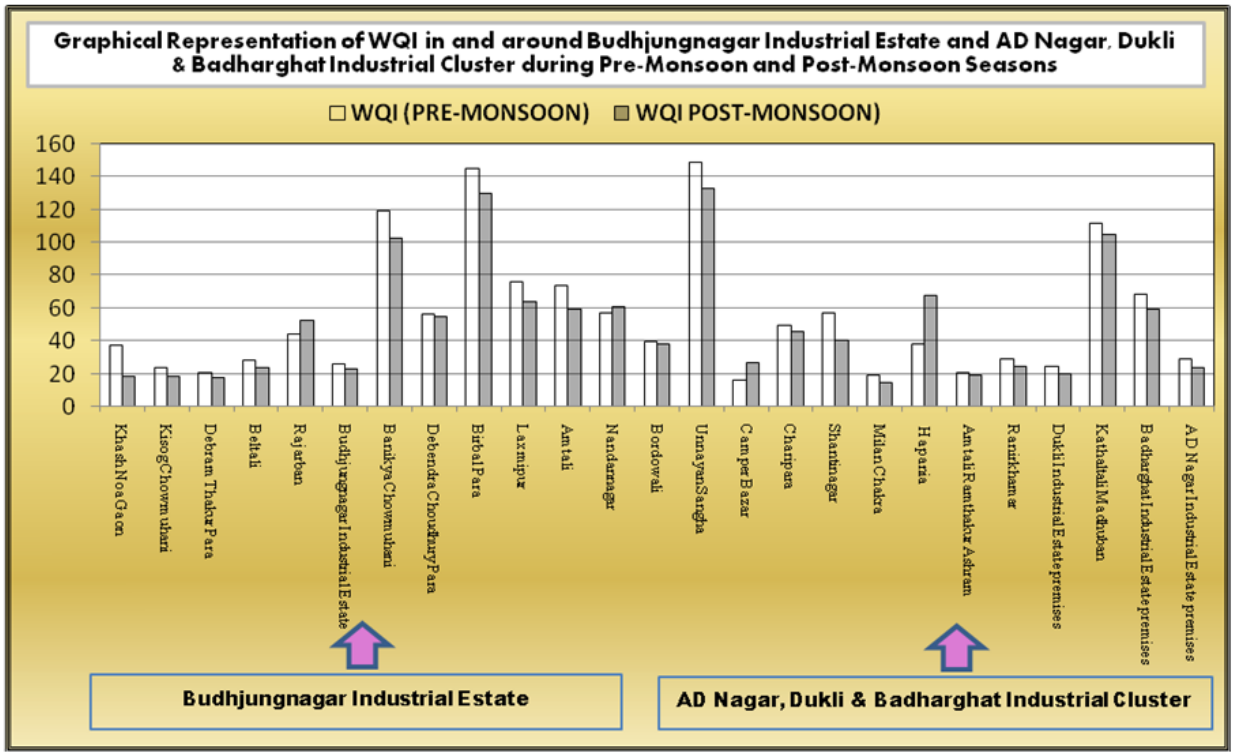

Figure 2. Graphical Representation of WQI during Pre-Monsoon and Post-Monsoon seasons.

The calculated Water Quality Index for ground water of Budhjungnagar Industrial Estate reflected that 41.66 % of the samples were excellent, 16.66% were poor quality in both seasons and 33.33% were good in pre-monsoon, 41.66% were good quality in post-monsoon season. The 69.23% of the samples were excellent, 15.38% were good and 15.38% were poor quality in AD Nagar, Dukli & Badharghat Industrial Cluster during pre-monsoon and post-monsoon seasons. On the basis of WQI, it is inferred that ground water quality of Budhjungnagar Industrial Estate is more affected due to industrialization with respect to that of AD Nagar, Dukli & Badharghat Industrial Cluster.

V. CONCLUSIONS

Analytical data of samples reveal that all the parameters show slight variations and no major changes have been observed in water quality during study period. It has been observed that the values of groundwater quality parameters of the study area are lower during post-monsoon period reflecting an improvement in quality due to fresh recharge and clearly indicated seasonal variation. The Water Quality Index value also reflects that water quality in four sampling sites (Banikya Chowmuhani, Birbal Para, Unnayan Sangha and Kathaltali Madhuban) are poor quality which may be due high iron content. Hence, the study of ground water quality to be carried out on regular interval to monitor further contamination. It is also need to promote awareness campaign among the end users to maintain ground water quality.

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