Suitability assessment of groundwater around Tangratilla gas blowout affected area, NE Bangladesh

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Abstract- Ground water quality determination is vital to ensure sustainable safe use of water. In the present paper, an attempt has been made, for the first time in this region, to identify the factors which govern the groundwater quality. To this purpose, collected water samples were investigated with respect to P^H, Electrical conductivity (EC), Turbidity, Total Alkalinity (TA), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Manganese (Mn^{2+}), Iron(Fe^{2+}), Suspended solids(SS), Dissolved solids(DS), Total Solids(TS), Total Hardness(TH), Chloride(Cl^-) and sodium (Na^+). The physicochemical results obtained were interpreted using statistical analysis (correlation matrix). This statistical analysis of data exhibits good and interesting correlation values lead to interpretation of the results. Evaluation of the samples for different uses such as drinking, domestic and irrigation purposes were obtained according to WHO standards and sodium adsorption ratio (SAR). Results of this study show that groundwater samples characterize by good quality for different uses.

Kew words: Correlation matrix, Groundwater, Sodium adsorption ratio, Water quality parameters.

I. INTRODUCTION

Safe drinking water is very much essential ingredient for good public health and the socio-economic development of human [1]. Ground water is considered as the main source of drinking water in both rural and urban areas. Human society cannot be imagined without safe groundwater availability. Groundwater is being used not only for the safe drinking purposes but also for the agricultural and industrial sector. Now a days, it had been reported a sustainable source of uncontaminated water. Both surface and subsurface water sources are getting polluted due to development activities. Ground water resources are dynamic in nature and affected by such factors as the expansion of irrigation activities, industrialization and urbanization, hence monitoring and covering this important resources is essential [2]. The major sources of pollution in streams, rivers and underground water arises from anthropogenic activities largely caused by the poor and uncultured living habit of people as well as the unhealthy practices of factories, industries and corporate bodies, resulting in the discharge of effluents and untreated wastes [3]. The quality of groundwater is the resultant of all processes and reaction that act on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring and varies from place to place and with the depth of water table [4]. Groundwater is particularly important as it accounts for about 88% safe drinking water in rural areas, where pollution is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist [5]. The natural water analyses for physical and chemical properties including trace elements contents are very important for public health studies. These studies are also a main part of pollution studies in the environment [6].

Therefore, the main objective of the present study is to assess the quality of under groundwater around Tangratilla gas blowout affected area, NE Bangladesh using twelve boreholes water samples of this region. This area is poor infrastructure and facing many severe problems like gas seepage due gas blowout and adverse health effect due to the lack of nutrition. The social relevance of the problem has encouraged me in carrying out this work. For this regard, the physical and chemical properties of these groundwater samples were analysed and compared each parameter with the standard desirable limit of respective one's and finally evaluate the groundwater samples to illustrates its suitability for different uses.

II. MATERIALS AND METHODS

A. The study area

The Tangratilla gas blow out affected area is located in Sunamgonj district, Northern-Eastern (NE) part of Bangladesh. It is also known as the Chattak-2 gas field zone. It is 30 km away from the Sylhet metropolitan area. Being located between 91º32´ and 91º33´ longitudes and 25º04.335´ and 25º04.750´ latitudes, the study area with an average area of 1 km^2 is located in northern side of the gas blowout affected area.

From a geologic standpoint, the main geologic features of this study area-

a) The Chattak-2 gas field (known as Tangratllla gas field) is located under Sylhet Trough and this is housed in structural traps i.e. folded anticline and the folded trap is in north-south direction [7].

b) The pattern of the fold structure as well as its vertical and areal closures varies considerably. The fold is affected by several faults. Seismic data indicate that the Sylhet Trough contain huge amount of elastic sediment [8].

c) The sequence of the rocks encountered in the Sylhet Trough is Eocene to recent age where the Dupitila formation is the water bearing formation [8]. But the Alluvium formation also contains some water.

The location of the study area and sampling sites are shown in Fig.1.

B. Sampling sites and Sample collection

Groundwater samples were collected from twelve wells. The collected water samples were designated as S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11}, S_{12}. Among them sample no. S_1 to S_6 were collected from close to the blowout affected area and the remaining samples were collected from 1 km away from the blowout affected area. The location of the sampling points is shown in Fig.1 (approximately). The depth of the wells ranged from 90-170 feet in all the sample collection sites. All the sampling source and corresponding habitats are bore wells and populated villages respectively.

The sampling has been carried out in the month of July'2011. Clean polyethylene bottles were used for collecting groundwater samples. These bottles were previously soaked in 10% nitric acid solution and thoroughly rinsed several times with doubled-distilled water and finally with a portion of the water sample. All samples were tightly sealed after collection and labeled in the field and immediately taken to the laboratory for analysis. All samples were stored in a dark and cool environment (4ºC) before analysis to minimize physicochemical changes [9, 10].

C. Measurements and Analysis

The present study was performed in the Laboratory of Water Supply and Sewerage Engineering under the Department of Civil and Environmental Engineering of Shah Jalal University of Science and Technology, Sylhet, Bangladesh. Analytical reagent-grade chemical were used for the preparation of all solutions and for conducting all chemical analysis. All chemicals used were purchased from Merck, Germany (A.R. 99%). The various parameters were determined using standard procedures [11].

The water samples were analysed for 14 parameters, which include P^H, Electrical conductivity (EC), Turbidity, Total Alkalinity (TA), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Manganese (Mn^{2+}), Iron(Fe^{2+}), Suspended solids(SS), Dissolved solids(DS), Total Solids(TS), Total Hardness(TH), Chloride(cl^-) and sodium (Na^+). All the water quality parameters are expressed in mg/l, except P^H, EC and turbidity.

P^H and Electrical conductivity (EC) of each water sample were measured at the sampling points by a digital P^H and EC meter (HANNA P^H and EC instrument). For Turbidity measurement, Microprocessor Turbidity meter HI 93703 by HANNA instruments was used. Total alkalinity and Total hardness were measured by titrimetric method using standard sulfuric acid and standard EDTA solutions, respectively. Samples for Dissolved solids (DS) was determined by evaporating 1L of filtered water sample at 100ºC. The residue was dried at 180ºC for two hours [11]. The parameter Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by EDTA titration method and volumetric method respectively. Both Iron (Fe^{2+}) and Manganese (Mn^{2+}) were measured using UV-VIS spectrophotometer (Hach, Australia, 4000U). Total solids (TS) and Suspended solids (SS) were measured based on standard procedure [11]. Chloride (Cl^-) ion is measured according to Mohr's method. The parameter Sodium (Na^+) is determined by maintaining standard procedure. All the experiments were carried out in triplicate from the sample and including a blank in each batch.

D. Statistical Analysis

The statistical analysis of the physico-chemical parameters was conducted using SPSS statistical software. The application of correlation analysis (Bivariate correlation analysis) is based on examination of relationship between pairs of variables [12]. The numerical level of relationship represented by the coefficient of correlation varies between -1 to +1 according to the statistical significance of the estimated correlations. In general, coefficient greater than 0.5 is statistically significant at a 95% confidence level.

III. RESULTS AND DISCUSSION

A. Physical- Chemical Parameters

Drinking water samples were collected from twelve boreholes around Tangratilla gas blow out affected area in the period of July'2011. The major physical and chemical properties of the drinking water samples include P^H, Electrical conductivity (EC), Turbidity, Total Alkalinity (TA), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Manganese (Mn^{2+}), Iron(Fe^{2+}), Suspended solids(SS), Dissolved solids(DS), Total Solids(TS), Total Hardness(TH), Chloride(cl^-) and sodium (Na^+). All findings and their comparison with WHO health based drinking water guidelines (2008) [13] and EQS (Bangladesh Standard guidelines) [14] are presented in Table 1.

Hydrochemical results and discussion were categorized based upon the studied water quality parameters.

A (a) P^H – The P^H values fluctuated between 7.5 to 8.1. Therefore, most of the groundwater samples were slightly alkaline due to presence of carbonates and bicarbonates. The P^H values of groundwater samples were found within the limit of WHO and EQS. The graphical representation of the variation of P^H values in groundwater samples are shown in Fig.2.

A (b) Electrical conductivity (EC) in micro-ohm/cm

Electrical conductivity (EC) is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts [15]. The measured value of EC ranged from70 μs/cm to 250 μs/cm for all the samples of S_1 to S_{12}. Although, this measured ranged were positioned within WHO and EQS acceptable limit but sample S_{10} and $_{12}$ show elevated result than that of other samples. The variation of EC results are shown in Fig.3.

A (c) Turbidity in NTU

In most water, Turbidity or the reduction in transparency in water is due to colloidal and extremely fine dispersions. The Turbidity values varied between 4.60 NTU to 6.71 NTU for all samples and found above the limits prescribed by WHO for the samples S_1, S_2, S_5, S_6, S_{11}, S_{12}. Fig. 4 shows the variation of Turbidity in water samples.

A (d) Total Alkalinity (TA) in mg/l

Alkalinity of water shows its capacity to react with a strong acid to a designated P^H. Highly alkaline water is usually unpalatable. The standard desirable limit of alkalinity in potable water is 120 mg/l. The measured alkalinity values ranged between 53 mg/l to 81 mg/l which is within acceptable limit presented by WHO.

A (e) Total solids (TS), Dissolved solids (DS) and Suspended solids (SS) in mg/l

Total dissolved solids or Total solids (TS) indicate the salinity behavior of groundwater. Water containing more than 500 mg/l of TDS or TS is not considered desirable for drinking water supply. The measured values of TDS or TS ranged between 37.5 mg/l to 61 mg/l where DS and SS values varied between 28.3 mg/l to 50.2 mg/l and 2 mg/l to 15.5 mg/l respectively. All solids content in groundwater samples show the acceptable limit prescribed by WHO and EQS. Fig. 5 shows the variation of TDS or TS, DS and SS graphically in collected water samples.

A (f) Chloride (Cl^-) in mg/l

Chlorides are important in detecting the contamination of groundwater by waste water. There is no known evidence that Chlorides constitute any human health hazard. For this reason, the permissible limit of Chloride in drinking water is 250 mg/l. The measured values of Chloride ranged between 8.1 mg/l to 25.4 mg/l shows the acceptance by WHO. Fig.6 depicts the variation of Chloride in collected groundwater sample.

A (g) Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) in mg/l

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) are directly related to hardness. The analysed groundwater samples contain Calcium (Ca^{2+}) in the range of 9.6 mg/l to 31.6 mg/l and Magnesium (Mg^{2+}) in the range of 2.6 mg/l to 7.2 mg/l. Both results are in within acceptable limit prescribed by WHO. The variation of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) are shown in Fig.7.

A (h) Iron (Fe^{2+}) in mg/l

Elevated values than WHO acceptable limits were observed for iron concentration in all collected groundwater samples except S_5, S_8, S_9, S_{10}. S_2 shows the more elevated values in Iron (Fe^{2+}) concentration than that of other samples. Fig.8 demonstrates the variation of iron concentration in water sample.

A (i) Manganese (Mn^{2+}) in mg/l

Manganese may causes discoloration of water. The values of Manganese varied between the ranges of 0.01 mg/l to 0.135 mg/l. These values are within the acceptable limit by WHO. Fig.9 shows the variation of Mn^{2+} in groundwater samples.

A (j) Total hardness (TH) in mg/l

Hardness is the property of water which prevents the lather formation with soap and increases the boiling points of water [16]. Hardness of water mainly depends upon the amount of calcium or magnesium or both. The hardness values shown range from 55 mg/l to 165 mg/l which are within the acceptable limit prescribed by WHO and EQS. Fig.10 shows the variation of total hardness in water samples graphically. Based on total hardness the classification of the water samples were in moderately hard type.

A (k) Sodium (Na^{+}) in mg/l

Sodium concentrations were found in between 3.1 mg/l to 5.5 mg/l for all samples S_1 to S_{12}. This limit of sodium concentrations is quite acceptable according to WHO prescription.

B. Statistical analysis (Correlation matrix)

To find out the relationship between different samples of groundwater, a correlation matrix of 14 variables was calculated (Table-2). This correlation matrix allows me to distinguish several relevant hydrochemical relationships. Using test of significance of the observed correlation coefficient, found that a total of 19 correlations coefficient within at significant level. Among them 15 were found to have significant at 5% level and the remaining 4 were found to have significant at 1% level. Mn^{2+}, SS and TS were found in negatively correlated with total alkalinity (TA) comprising r = -0.604,-0.587and -0.622 respectively. Calcium (Ca^{2+}) were found in positively correlated with Mn^{2+} (r = 0.647) and Fe^{2+} (r = 0.600) and negatively correlated with Na^{+} (r = -0.853, 1% significant level). Manganese (Mn^{2+}) were found in positively correlated with Fe^{2+} (r = 0.870, significant at 1% level). DS and TS were found in positively correlated with Mn^{2+} comprising r = 0.652 and 0.607 respectively. Mn^{2+} were found in negatively correlated with Na^{+} (r = -0.679). Turbidity were found in positively correlated with iron (r = 0.620). Electrical conductivity (EC) shows positive correlation with TA (r = 0.705) and Mg^{2+} (r = 0.765) and negative correlated with DS (r = -0.592). Suspended solids (SS) were found in positively correlated with Total solid (TS) (r = 0.651) and negatively correlated with Total hardness (TH) (r = -0.682). Iron shows positively correlation with DS (r = 0.596) at 5% significant level.

C. General discussion about gas blow out and contamination of surrounding groundwater

A blow out is a high pressure uncontrolled release of reservoir fluids (hydrocarbon) into the wellbore, which may or may not ignite, that occurs when a high pressure oil or gas accumulation is unexpectedly met while drilling and the mud columns fails to contain the formation fluid that is expelled through the wellhead bore. Two blow out occurred in Tangratilla (8 January and 17 June 2005) where the raging flames were visible from 30 km away at this gas field. Gas broke through to the surface close by and is still venting out today from fissure in the well side and near-by agricultural land and in the villages. Gas blow out has a negative effect on surrounding environment and on the surrounding surface and subsurface water. In most of the cases, the contamination of groundwater is due to anthropogenic activities and this type of contamination rate may be enhanced due to gas blow out. Fractures formation owing to gas blowout and created channel in the crust due to gas seepage may leads to the contamination of groundwater from polluted surface water.

D. Evaluation of the groundwater samples

D (a) Suitability of the samples for drinking and domestic purposes

According to WHO [13] and EQS (Bangladesh guideline standard) [14], results of the samples analyses indicate that the samples are suitable for drinking and domestic uses (Table1)

D (b) Suitability of the samples for irrigation purposes

Sodium adsorption ratio (SAR) is used as index refers to suitability of water for irrigation as follows:

$$\text{SAR} = \frac{Na+}{\sqrt{[(Ca2+)+(Mg2+)]}}$$

The ionic symbols indicate concentrations of the ions in the irrigation water in mmol/l [17]. Calculation of the SAR for given water provides a useful index of the sodium hazard of the water for soils and crops. Applying this index on the samples show excellent result of SAR values ranged 0.32 to 1.32 on an average and these results recommended that these samples may be used for irrigation purposes at any soil types.

IV. SCOPE AND LIMITATIONS OF THIS RESEARCH WORK

This study has been carried out in a well equipped laboratory where all respective instruments were calibrated. There were no greater time gap between the sample collection and analysis of the sample in the laboratory. All experiments were done in a triplicate manner for the precision of data and showing the good results of reproducibility of data.

In the present study, Carbonate, Bicarbonate, Nitrate, Phosphate, Sulfate, Potassium were not determined due to constraint of lab facilities during analysis period.

V. CONCLUSION

The groundwater samples from twelve boreholes around Tangratilla gas blowout affected area were collected and investigated for various physicochemical parameters to assess the groundwater quality. From the results it is clear that all parameters except turbidity and iron were found in below the guidelines for drinking water given by the World Health Organization (WHO). In case of Turbidity, samples S_1, S_2, S_5, S_6, S_{11}, S_{12} demonstrate elevated results above WHO prescribed limit. This may be arises due to the over flooded and low land study area. For iron (Fe^{2+}), the samples S_1, S_2, S_3, S_4, S_6, S_7, S_{11}, S_{12} show the slightly elevated result above WHO acceptable limit and need minor treatment prior to use as a drinking water. Statistical analysis of data confirms results of chemical analyses and show good correlation with significant level.

VI. RECOMMENDATION

It may be recommended for further work based on this study are-

a) Although this study show the acceptable results for good public health, despite the fact, further study may be carried out for both surface and subsurface water quality assessment in this region in greater extent.

b) Hydrocarbon contamination in water in this study area may be evaluated as further work.

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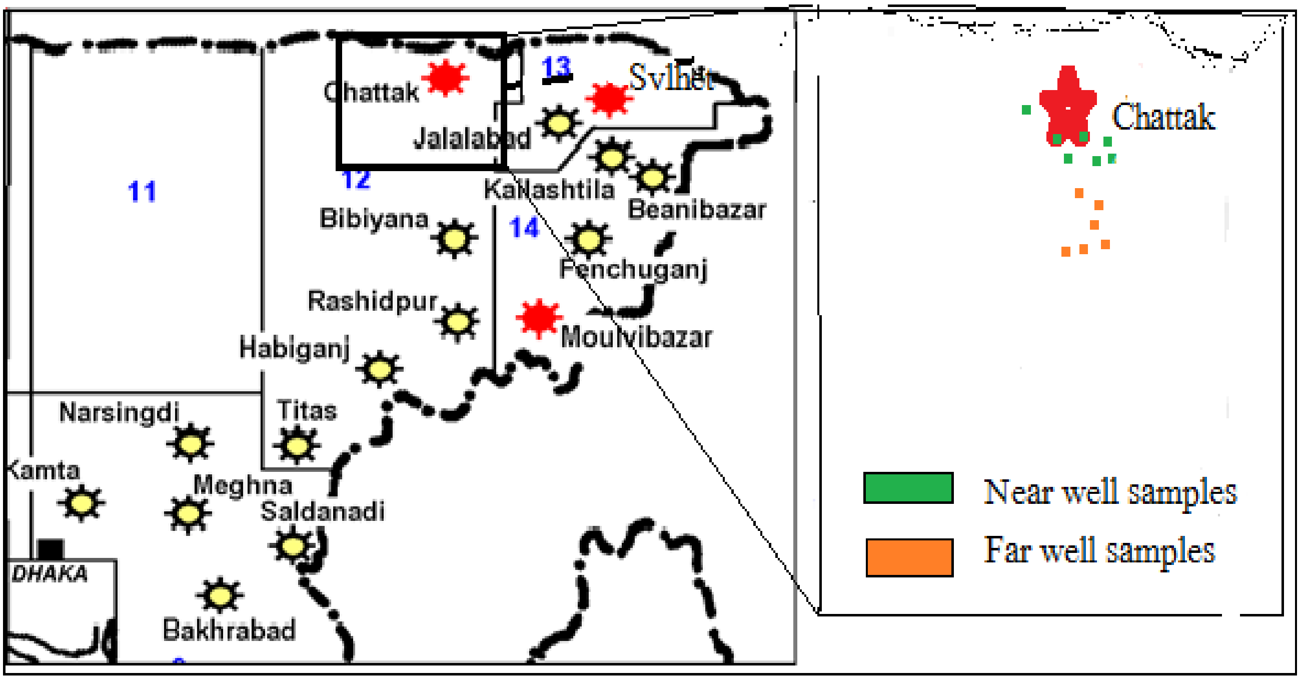

Fig. 1 Location of Tangratila (Chattak-2)gas field [18] and location of samples (Approximately)

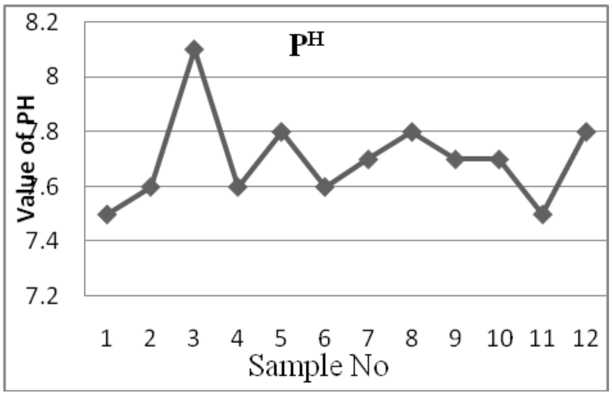

Fig. 2: A two dimensional (2-D) line chart of of pH variation.

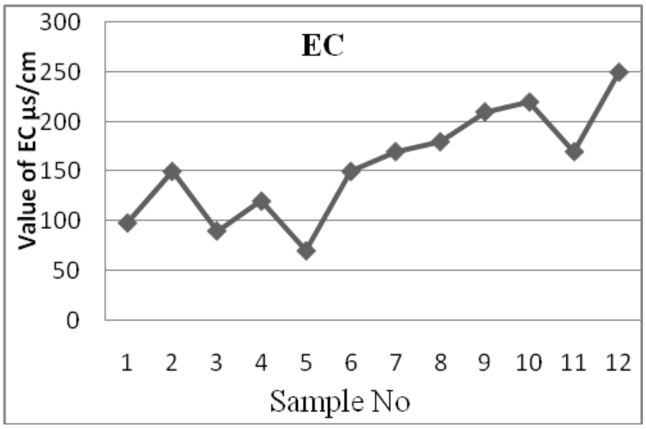

Fig.3: A two dimensional (2-D) line chart of EC variation

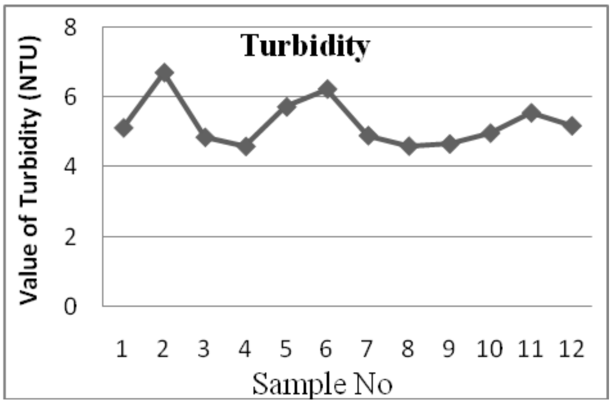

Fig.4: A two dimensional (2-D) line chart of turbidity variation

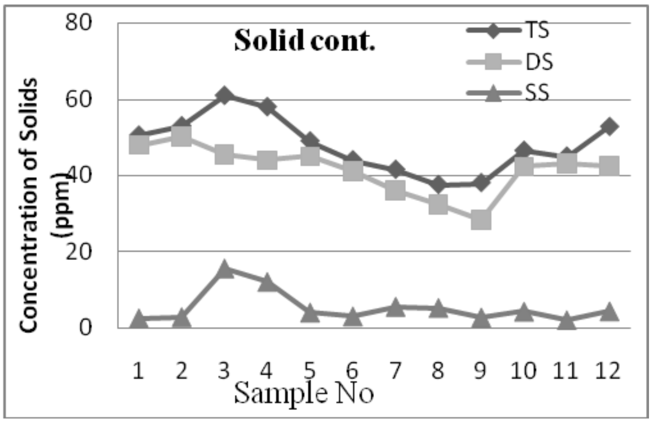

Fig.5: A two dimensional (2-D) line chart of various solids deviation

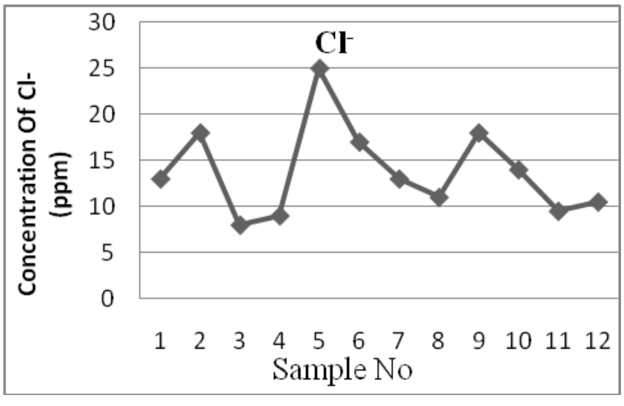

Fig.6: A two dimensional (2-D) line chart of Chloride variation

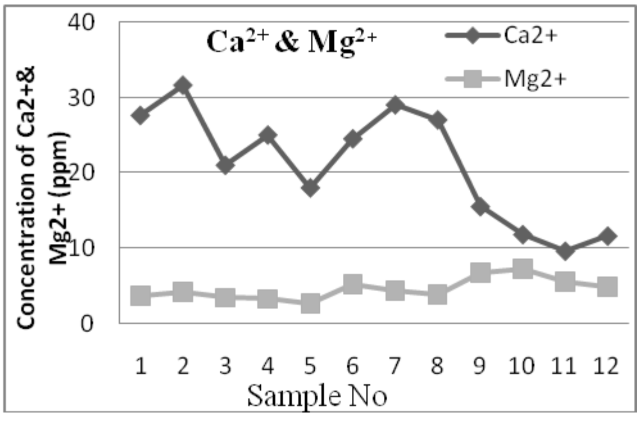

Fig.7: A two dimensional (2-D) line chart of Ca^{2+} & Mg^{2+}concentration inequality

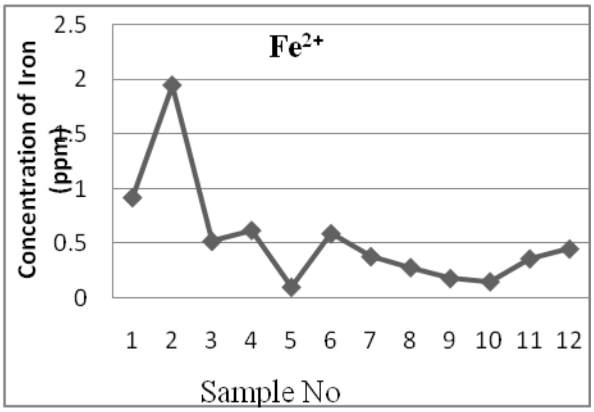

Fig. 8: A two dimensional (2-D) line chart of Fe^{2+} concentration disparity

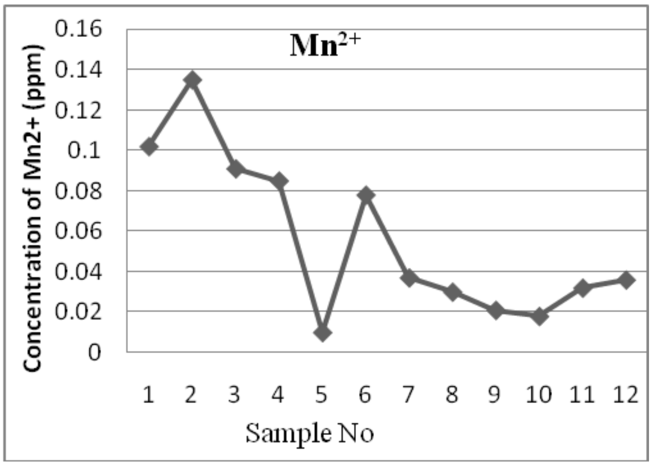

Fig.9: A two dimensional (2-D) line chart of Mn^{2+} deviation

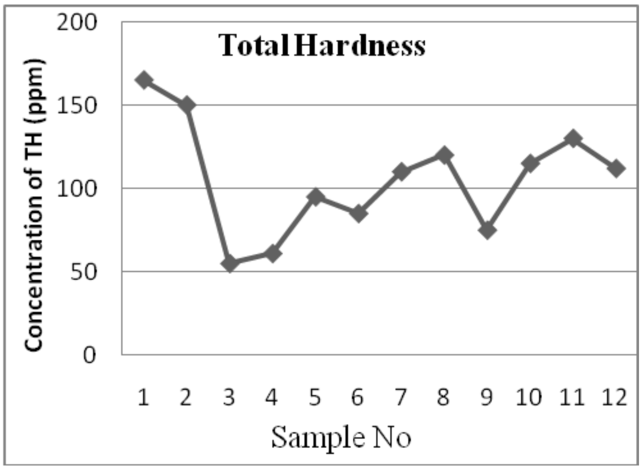

Fig. 10: A two dimensional (2-D) line chart of Total Hardness deviation.

Table 1: Physical and Chemical (mg/l) parameters of ground water samples around Tangratilla gas blowout affected area, NE Bangladesh

S No.	Parameter	WHO	EQS	Sampling points around Tangratilla gas blowout affected area											
				S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
1	P^H	7-8.5	6.5-8.5	7.5	7.6	8.1	7.6	7.8	7.6	7.7	7.8	7.7	7.7	7.5	7.8
2	EC	250	-	98	150	90	120	70	150	170	180	210	220	170	250
3	TS or TDS	500	-	50.5	53	61	58	49	44	41.5	37.5	38	46.5	45	52.8
4	Turbidity	<5	-	5.13	6.71	4.86	4.60	5.73	6.24	4.91	4.61	4.67	4.98	5.56	5.19
5	TA	120	-	62	58	53	55	61	67	71	73	70	65	81	80
6	TH	500	40-180	165	150	55	61	95	85	110	120	75	115	130	112
7	Ca^{2+}	75-200	-	27.6	31.6	21	25	18	24.5	29	27	15.5	11.8	9.6	11.6
8	Mg^{2+}	150	30-50	3.6	4.2	3.4	3.2	2.6	5.1	4.3	3.8	6.7	7.2	5.5	4.8
9	Mn^{2+}	0.5	-	0.102	0.135	0.091	0.085	0.010	0.078	0.037	0.030	0.021	0.018	0.032	0.036
10	Cl^-	250	250	13	18	08	09	25	17	13	11	18	14	9.5	10.5
11	Na^+	200	-	3.2	3.1	3.3	3.6	5.5	3.5	3.1	3.4	4.2	4.5	5.1	5.3
12	Fe^{2+}	<0.3	0.3-1	0.92	1.95	0.52	0.62	0.10	0.59	0.38	0.28	0.18	0.15	0.36	0.45
13	SS	500	-	2.5	2.8	15.5	12	4	3	5.5	5.2	2.7	4.2	2	4.3
14	DS	1000	-	48	50.2	45.5	44	45	41	36	32.3	28.3	42.3	43	38.5

- EC unit is µs/cm
- Turbidity unit is NTU

Table 2: Correlation coefficient values of physicochemical parameters of groundwater samples around Tangratilla gas blowout affected area, NE Bangladesh (Correlation matrix)

	P^H	EC	Turbidity	TA	Ca^{2+}	Mg^{2+}	Mn^{2+}	Fe^{2+}	SS	DS	TS or TDS	TH	Cl^-	Na^+
P^H	1	-.096	-.325	-.243	-.109	-.232	-.142	-.309	.645*	-.167	.277	-.554	-.118	.037
EC		1	-.172	.705*	-.444	.765**	-.423	-.193	-.383	-.592*	-.452	.126	-.207	.256
Turbidity			1	-.073	.184	-.056	.391	.620*	-.447	.545	.107	.372	.511	.037
TA				1	-.491	.458	-.604*	-.377	-.587*	-.557	-.622*	.307	-.148	.469
Ca^{2+}					1	-.547	.647*	.600*	.145	.207	.057	.182	.072	-.853**
Mg^{2+}						1	-.383	-.237	-.436	-.422	-.477	.054	-.009	.217
Mn^{2+}							1	.870**	.284	.652*	.607*	.174	-.197	-.679*
Fe^{2+}								1	-.077	.596*	.392	.454	.034	-.515
SS									1	.155	.651*	-.682*	-.512	-.297
DS										1	.740**	.297	.035	-.085
TS or TDS											1	-.216	-.291	-.051
TH												1	.091	-.056
Cl^-													1	.253
Na^+														1

***. Correlation is significant at the 0.05 level**

****. Correlation is significant at the 0.01 level**