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Assessment of arsenic and iron contamination of groundwater in four development blocks of Lakhimpur District, Assam, India

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ABSTRACT

The increasing recognition of the wide geographic spread of arsenic contamination of groundwater has provided the motivation to carry out this study at a regional scale. The focus of the study is on rural rather than urban areas, due to the particular difficulties associated with applying mitigation measures in scattered rural communities. Forty eight groundwater samples were collected from tubewells and ringwells at different sites from four development blocks of North Lakhimpur sub-division during dry season. Arsenic and iron were analysed by using an atomic absorption spectrometer (Perkin Elmer AAnalyst 200) and uv-visible spectrophometer (Shimadzu 1240) respectively. The implications presented are based on statistical analyses of the raw data. Normal distribution analysis (NDA), t-test and correlation analysis are used for interpretation of data. Comparing the groundwater content of arsenic and iron with the recommended maximum values for drinking purposes, it is found that a good number of samples contain arsenic and iron at an alert and toxic level in the study area. Significant differences among mean, median and mode along with moment coefficients of skewness and kurtosis obtained for the studied parameter in the area show that sample frequency distribution curves differ from ideal Gaussian (normal). This study reinforced the extensive nature of arsenic and iron contamination of groundwater in the area under study and that, with continuous testing, more contaminated groundwater aquifers are bound to be identified.

Key Words: Arsenic, Iron, Skewness, Correlation, ANNOVA.

INTRODUCTION

The extent of the arsenic contamination of groundwater worldwide is as yet unknown. Presumably, there are areas where this problem still remains to be recognized in India. Before arsenic was identified as the unambiguous cause of wide-scale health problems in Bangladesh, such occurrences were considered relatively isolated. However, since the 1990s, efforts by governments, external support agencies, and academic institutions to identify other potential contamination areas have dramatically increased [1]. Although it is far too early to outline definitively the extent of the problem globally, it is clear that there are many countries in the world where arsenic in drinking water has been detected at concentrations greater than the WHO guideline value (10 μg/L) or the prevailing national standard [2]. Arsenic contamination of groundwater in India was first reported in 1976 from Chandigarh and different villages of Punjab, Haryana and Himachal Pradesh. The first cases of arsenicosis in India were identified in 16 patients from one village of a district in July 1983 [3, 4]. Arsenic and iron contamination of water is also reported from North Eastern India [5, 6]. During a survey in January-February 2004, for the first time, it detected arsenic contamination in groundwater of the Upper Brahmaputra plain [7] and with continuous testing, more contaminated groundwater aquifers are bound to be identified. Available literature shows that groundwater in Assam are highly contaminated with iron [8, 9]. The high concentration of iron is also of concern as large amount of ground water is abstracted by drilling water-wells both in rural and urban areas for drinking and irrigation purposes [10]. The increasing recognition of the wide geographic spread of arsenic contamination of groundwater has provided the motivation to carry out this study at a regional scale in North Lakhimpur sub-division of Assam.

MATERIALS AND METHODS

The study area Lakhimpur district is situated in the remote corner of north east India. Geographically, the district is situated between $26^{0}48^{/}$ and $27^{0}53^{/}$ northern latitude and $93^{0}42^{/}$ and $94^{0}20^{/}$ eastern longitude and covers an area of 2,977 km^2, out of which 2,957 km^2 is rural and 20 km^2 is urban. After careful study of the topography and other aspects of North Lakhimpur sub-division, forty eight groundwater samples were collected from tubewells and ringwells at different sites from four development blocks, *viz.* Nowboicha, Karunabari, Bihpuria and Narayanpur of North Lakhimpur sub-division during dry season (January, 2010 – May, 2010). Samples were collected once in a week by random selection and combined together in clean and sterile one-litre polythene cans to obtain a composite sample and stored in an ice box [11]. All probable safety measures were taken at every stage, starting from sample collection, storage, transportation and final analysis of the samples to avoid or minimize contamination. pH of the samples were measured quickly after collection by using a digital pH meter (ELICO, LI-127). Arsenic was analysed by using an atomic absorption spectrometer (Perkin Elmer AAnalyst 200) with flow injection analyze mercury hydride generation system (Model FIAS-100) at 189 nm analytical wavelengths as per the standard procedures [12]. The spectrometer has minimum detection limit of 0.002 μg/L for arsenic. Iron is measured by 1, 10 Phenanthroline method using a uv-visible spectrophometer (Shimadzu 1240) at 510 nm. Sample data were also subjected to statistical treatment using normal distribution statistic and reliability analysis (correlation matrix). We used a one population t-test and also ran one-way ANOVA to compare the concentrations of iron and arsenic among the sampling sites. We used an alpha level of 0.05 and considered differences to be significant if $P \leq 0.05$.

RESULTS

The experimental data are presented block wise in Table 1-4.

Table 1: Water test values at Nowboicha Development Block

Sample No	Location	Source	Depth in feet	pH	As (ppm)	Fe (ppm)
D-1	Gendhali	Deep Well	80	6.7	0.0235	0.56
D-2	Billotia	Deep Well	85	6.8	0.0096	5.95
D-3	Khalihamari	Deep Well	85	7.2	0.0067	4.01
D-4	Ranabari	Deep Well	75	7.1	0.0213	3.09
D-5	Kuwadunga	Deep Well	65	7.5	0.0137	8.64
D-6	Khankanbori	Tube Well	45	7.1	0.0246	3.09
D-7	Pohumara	Tube Well	50	7.1	0.0135	0.53
D-8	Phulbari	Tube Well	40	7.2	0.0073	0.61
D-9	2 No.Phulbari	Tube Well	60	7.5	0.0145	0.47
D-10	Dolapa	Deep Well	75	6.7	0.0212	0.51
D-11	Rangapathar	Tube Well	70	6.8	0.0861	5.95
D-12	Bishnuopur	Tube Well	65	6.9	0.0432	2.98

Table 2: Water test values at Karunabari Development Block

Sample No	Location	Source	Depth in feet	pH	As (ppm)	Fe (ppm)
E-1	Laluk	Deep Well	85	7.0	0.0211	2.11
E-2	Pachim Laluk	Tube Well	40	6.8	0.0156	1.51
E-3	Nij Laluk	Tube Well	45	7.1	0.0158	1.37
E-4	Karunabari	Tube Well	60	7.1	0.0413	1.61
E-5	Gosai Pukhuri	Deep Well	65	6.9	0.0462	1.31
E-6	Bangalmara Centre	Deep Well	90	7.2	0.0321	0.51
E-7	Bangalmara East	Tube Well	85	7.1	0.0431	0.65
E-8	Bangalmara West	Deep Well	75	7.9	0.0389	5.95
E-9	Doulatpur	Deep Well	85	6.8	0.0189	4.31
E-10	Kahipara	Tube Well	58	7.7	0.0056	3.97
E-11	Islampur	Deep Well	60	6.6	0.1421	3.20
E-12	Islampur West	Tube Well	65	7.7	0.1110	8.64

Table 3: Water test values at Bihpuria Development Block

Sample No	Location	Source	Depth in feet	pH	As (ppm)	Fe (ppm)
F-1	Rajabari No. 2	M-II	100	6.6	0.1851	3.09
F-2	Bamun Gaon	Deep Well	95	7.1	0.1921	13.16
F-3	Kachikata	M-II	90	7.5	0.0895	4.05
F-4	Bihpuria centre	Deep Well	85	7.2	0.0862	2.11
F-5	Gosai Pathar	M-II	90	7.0	0.0567	2.02
F-6	2 No. Dahgharia	Tube Well	40	6.8	0.0056	5.95
F-7	1 No. Dahgharia	Deep Well	45	7.9	0.0068	2.98
F-8	Koloni Bottumchuk	Hand Tube well	65	6.9	0.0922	3.05
F-9	Badati	Deep Well	70	7.0	0.0970	4.05
F-10	Kuluwani N. C.	Tara Pump	80	7.4	0.0853	5.01
F-11	Badati Jamuguri	Deep Well	70	7.7	0.0890	13.17
F-12	Badati (Kenduguri)	Tara Pump	70	7.2	0.0861	2.0

Table 4: Water test values at Narayanpur Development Block

Sample No	Location	Source	Depth in feet	pH	As (ppm)	Fe (ppm)
G-1	Harmati	Tube Well	75	7.5	0.0112	2.01
G-2	Banderdewa (Centre)	Tube Well	70	8.0	0.0152	3.47
G-3	Borpathar	Tube Well	80	7.4	0.0182	8.64
G-4	Jarabari	Tube Well	90	8.2	0.0241	5.72
G-5	Rongati	Deep Well	60	7.1	0.0085	2.09
G-6	Narayanpur Centre	Deep Well	55	7.2	0.0311	5.95
G-7	Mermukh	Tube Well	80	6.9	0.0122	1.35
G-8	Panbari	Tube Well	90	6.7	0.0222	0.97
G-9	Bholabori	Deep Well	85	7.6	0.0173	1.26
G-10	Madhupur	Deep Well	90	7.3	0.0245	3.97
G-11	Dholpur Centre	Tube Well	45	6.9	BDL	0.52
G-12	Dholpur Tiniali	Deep Well	70	7.8	0.0110	4.05

A conventional descriptive statistics based on normal distribution has been shown in Table 5. Only those samples were considered for statistical treatment in which arsenic could be detected and determined.

Table 5: Descriptive Statistics of Experimental Data

Descriptive Statistics		pH	As	Fe
No of parameter		48	48	48
Mean		7.20	0.0434	3.587
Std. Error of Mean		0.06	0.0066	0.433
Median		7.10	0.0229	3.070
Mode		7.10	0.0056	5.950
Std. Deviation		0.39	0.0457	2.997
Variance		0.15	0.0021	8.980
Skewness		0.65	1.7210	1.565
Std. Error of Skewness		0.34	0.3430	0.343
Kurtosis		-0.24	2.7300	2.768
Std. Error of Kurtosis		0.67	0.6740	0.674
Range		1.60	0.1921	12.700
Minimum		6.60	BDL	0.470
Maximum		8.20	0.1921	13.170
Sum		345.40	2.0840	172.180
Confidence Limit	Lower Bound	7.08	0.0302	2.717
	Upper Bound	7.31	0.0567	4.457
Percentiles	25	6.90	0.0136	1.355
	50	7.10	0.0229	3.070
	75	7.50	0.0782	4.835
Inter Quartile Range		0.60	0.0646	3.480

BDL below detection limit

DISCUSSION

To look into the trend and distribution patterns of studied parameters data are exposed to several statistical treatments and the implications presented are based on statistical analyses of the raw data.

Natural waters usually have pH values in the range of 4 to 9 and most are slightly basic because of the presence of bicarbonates and carbonates. In all the sampling stations studied pH are within the WHO guide lines values for safe drinking water. [13]

Comparing the groundwater content of arsenic with the recommended maximum values for drinking purposes, it is found that almost all the tubewell water samples of all the four development blocks of Lakhimpur district contain arsenic at an elevated level and a sizeable number of samples contain arsenic at toxic level. Analytical data also clearly reveals that groundwater in Bihpuria block of Lakhimpur district is alarmingly contaminated with arsenic. Large difference between mean and median in each case, high standard deviation and positive kurtosis indicate that the distribution is widely off normal. Wide data range in each case indicates the presence of extreme values, which are likely to bias the normal distribution statistic. Table 6 shows the extreme values (Outliers) of water test values for arsenic in the study area.

Table 6: Extreme values (outliers) of water test values for arsenic in the study area

Sl No	Sample Number	Value
1	F-2	0.1921
2	F-1	0.1851
3	E-11	0.1421
4	E-12	0.1110
5	F-9	0.0970

t-test is also performed under null hypothesis (H_0) by taking the assumption that the experimental arsenic content of groundwater are consistent with the maximum permissible limit given by WHO. One population t-test on analytical data at the 0.05 level indicates that the mean value of arsenic in the study area is significant (t = 5.06756, p = 6.69175E-6). This also implies that samples are at alert level, and are not completely safe, which can reach toxic level if not managed properly. One way ANOVA analysis presented in Table 7 for four development blocks in the study area also shows that at the 0.05 level, the means are significantly different (F = 10.23455, p = 2.95013E-5).

Table 7: One-way ANOVA data for arsenic in four development block

Name of Block	Mean	Variance
Nowboicha	0.0238	4.8475
Karunabari	0.0443	0.0017
Bihpuria	0.0891	0.0029
Narayanpur	0.0163	7.1381

In most of the samples under investigation, the iron contents were much above the guideline value of 0.3 ppm as set by WHO. A broad third quartile and positive skewness in case of iron represents a long asymmetric tail on the right of the median. Heaviness of the tail for iron distribution in the area is evident from very high positive kurtosis value. The iron contamination of groundwater in the area should be accorded maximum attention. The results of one population t-Test on analytical data for iron at the 0.05 level indicate that the mean value of iron in the study area is significant (t = 7.59985, p = 1.01357E-9).

The Pearson's product moment correlation is presented in Table 8. Since the directions of association of the measured variables are unknown in advance, two-tailed test of significance was carried out.

Table 8: Pearson Correlation Matrix among pH, As and Fe in the Study Area

		pH	As	Fe
Pearson Correlation	**pH**	1	-0.187	0.065
Significance Test. (2-tailed)		.	0.202	0.661
Pearson Correlation	**As**	-0.187	1	0.010
Significance Test. (2-tailed)		0.202	.	0.947
Pearson Correlation	**Fe**	0.065	0.010	1
Significance Test. (2-tailed)		0.661	0.947	.

From the correlation of the studied parameters as shown in Table 8, significant correlation was found among pH, arsenic and iron. Arsenic shares a clear negative correlation with pH at the 0.05 level in the area.

CONCLUSION

This study established the extensive nature of arsenic and iron contamination of groundwater in four development blocks of North Lakhimpur sub-division of Lakhimpur district, Assam, India. This study has also shown that naturally occurring arsenic and iron in groundwater is more widespread in the area than is generally recognized and that, with continuous testing, more contaminated groundwater sources are bound to be identified. It may be seen from our results that most of the tube well and deep well water samples of the study area were found unsafe with regard to arsenic. Statistical observations show arsenic and iron content of groundwater exhibit an asymmetric distribution with a long asymmetric tail on the right of the median in the area. Sporadic occurrence of arsenic in groundwater has been observed in the study area. One development block, namely, Bihpuria is likely place where future arsenic outbreaks may take place. Tube well waters of this place must be regularly monitored to detect any arsenic occurrence at the onset. Populations in the study area are likely to be affected through drinking arsenic contaminated water for a long time. However, study of other aspects like bioavailability of arsenic and their risks to human health is necessary for a comprehensive risk assessment and elucidation of arsenic distribution and mobilization mechanism in the area.

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