A Study on Arsenic and Iron Contamination of Groundwater in Three Development Blocks of Lakhimpur District, Assam, India

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Abstract: A study on arsenic and iron contamination of groundwater in Lakhimpur district of Assam, India has been presented. Thirty six groundwater samples were collected from tubewells and ringwells at different sites from three development blocks, *viz.* Telahi, Lakhimpur and Boginadi, 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 spectrophotometer (Shimadzu 1240) respectively as per the standard procedures. It is observed that the groundwater of the area is contaminated with iron. A sizeable number of groundwater samples contain arsenic at a toxic level. Statistical observations on pH, arsenic, and iron in groundwater also show that they exhibit an asymmetric distribution with a long tail on the right or left of the median. The present study has shown that naturally occurring arsenic and iron in groundwater is more widespread in the study area than is generally recognized. Hence, the present study accentuates the necessity of regular surveillance of groundwater quality with reference to arsenic, and iron contamination to protect the groundwater resources from the pollution for sustaining life. [Report and Opinion 2010;2(6):82-87]. (ISSN: 1553-9873).

Key words: arsenic; iron; groundwater; contamination

1. Introduction

The harmful health effect of drinking arsenic contaminated water has become increasingly clear in the last few years. Although it is not always possible to predict arsenic concentration of groundwater in a given area or aquifer, knowledge of its occurrence and distribution has improved greatly over the last few years. There have been a few review works covering the groundwater arsenic contamination scenario around the world (Bhattacharya et. al., 2002; Mandal and Suzuki, 2002). Approximately 20 incidents of groundwater arsenic contamination have been reported from all over the world (Mukherjee et. al, 2006, Twarakavi and Kaluarachchi, 2006). Widespread groundwater pollution by arsenic contamination in different parts of India is also well publicized (Bhattacharjee et al. 1997; Bhattacharjee et al. 2005; Sing, 2006). In India, the occurrence of arsenic in groundwater was first reported in 1980. The first case of arsenicosis in India was identified in July 1983 (Garai et. al., 1984; Chakraborti et. al., 2002). There are also reports of detecting arsenic in groundwater in north eastern India although no arsenocosis patients have been reported until now (Chakraborti et. al., 2004, NERIOWLM, 2004; Sing, 2004). Presumably, there are areas where this problem still remains to be recognized in India. Despite the advances made in recent years in understanding where high arsenic in groundwater are likely to exist on a global scale, predictability on a local scale is still poor and probably will always be so. A comprehensive analytical and statistical analysis of distribution of pH, arsenic and iron in groundwater in three development blocks of North Lakhimpur sub-division of Lakhimpur district, Assam has been presented in this study. The water sources, selected for this study, have been in use for a long time for meeting drinking water needs and other domestic purposes. No detailed analysis of these sources with respect to arsenic and iron had been undertaken before. The focus of the study is on the rural areas rather than urban areas, due to the particular difficulties associated with applying mitigation measures in scattered rural communities.

2. Materials and Methodology

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, thirty six groundwater samples were collected from tubewells and ringwells at different sites from three development blocks, *viz.* Telahi, Lakhimpur and Boginadi, 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 (Laxen and Harrison 1981). 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 (APHA 1998). 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 $P \leq 0.05$.

3. Results

The experimental data are presented block wise in Table 1-3. Descriptive statistics based on normal distribution has been shown in Table 4. The Pearson's product moment correlation is presented in Table 5.

Table 1 Water Test Data of Telahi Development Block.

Sample No	Sampling Station	Source	pH	As (in ppm)	Fe (in ppm)
A-1	Da Kati	Tube well	6.5	0.002	2.1
A-2	Dhenudharia	Tube well	6.5	0.005	1.6
A-3	Phukanar Hat	Tube well	6.8	BDL*	0.2
A-4	Bapakhat	Ring well	6.4	0.003	0.4
A-5	Solal gaon	Ring well	6.6	0.017	1.8
A-6	Telahi Banto	Tube well	6.0	0.011	14.2
A-7	Modar Guri	Tube well	6.5	0.001	10.7
A-8	Huka Chapari	Tube well	6.5	BDL	22.5
A-9	Madhupur	Tube well	6.5	BDL	0.9
A-10	Azad	Tube well	6.3	0.006	31.2
A-11	Borcharia	Tube well	6.5	BDL	0.4
A-12	Khaga	Tube well	6.5	0.002	17.7

Table 2 Water Test Data of Lakhimpur Development Block.

Sample No	Sampling Station	Source	pH	As (in ppm)	Fe (in ppm)
B-1	Rajgarh	Tube well	6.5	BDL	1.0
B-2	Rongpuria	Ring well	6.8	BDL	1.6
B-3	Napaam	Tube well	6.5	0.017	21.4
B-4	Lilabari	Tube well	6.5	0.005	20.8
B-5	Jahing	Tube well	6.7	BDL	0.31
B-6	Bogalijan	Tube well	6.4	BDL	6.9
B-7	Saboti	Tube well	6.5	0.006	47.2
B-8	Rangajan	Tube well	6.5	0.014	27.8
B-9	Chinatolia	Tube well	6.2	0.001	18.8
B-10	Nakari	Tube well	6.6	BDL	0.48
B-11	Gharmara	Tube well	6.7	BDL	11.9
B-12	Mahhara	Ring well	6.5	BDL	1.5

Table 3 Water Test Data of Boginadi Development Block.

Sample No	Sampling Station	Source	pH	As (in ppm)	Fe (in ppm)
C-1	Lamu gaon	Tube well	7.1	0.025	43.9
C-2	Kadam	Tube well	7.0	0.026	32.8
C-3	Kachari gaon	Ring well	7.1	0.026	20.8
C-4	Siyajuli	Tube well	6.7	0.027	49.6
C-5	Tenga Bosti	Ring well	6.6	0.006	5.2
C-6	Buka Nala	Tube well	6.9	0.018	28.1
C-7	Kulabali	Tube well	6.6	0.023	52.4
C-8	Lal pani	Tube well	6.4	0.024	16.5
C-9	Boginadi	Ring well	6.6	0.003	1.3
C-10	Baramile	Tube well	6.4	0.018	37
C-11	Tarioni	Tube well	7.1	0.003	4.6
C-12	Padumoni	Tube well	6.7	BDL	18.6

*BDL: Below Detection Limit

Table: 4 Descriptive Statistics of Experimental Data

Descriptive Statistics		pH	As	Fe
No of parameter		36	36	36
Mean		6.589	0.008	15.950
Std. Error of Mean		0.040	0.002	2.653
Median		6.500	0.003	13.050
Mode		6.500	0.000	0.400
Std. Deviation		0.240	0.010	15.920
Variance		0.058	0.000	253.449
Skewness		0.441	0.909	0.853
Std. Error of Skewness		0.393	0.393	0.393
Kurtosis		0.849	-0.764	-0.279
Std. Error of Kurtosis		0.768	0.768	0.768
Range		1.100	0.027	52.200
Minimum		6.000	BDL	0.200
Maximum		7.100	0.027	52.400
Sum		237.200	0.289	574.190
Confidence Limit	Lower Bound	6.51	0.0048	10.56
	Upper Bound	6.67	0.0113	21.34
Percentiles	25	6.50	0.000	1.525
	50	6.50	0.003	13.050
	75	6.70	0.017	26.475
Inter Quartile Range		0.2	0.017	24.95

Table 5. Pearson Correlation Matrix among pH, As and Fe in the Study Area

		pH	As	Fe
Pearson Correlation	**pH**	1	0.319	0.119
Significance Test. (2-tailed)		-	0.058	0.491
Pearson Correlation	**As**	0.319	1	0.679**
Significance Test. (2-tailed)		0.058	-	0.000
Pearson Correlation	**Fe**	0.119	0.679**	1
Significance Test. (2-tailed)		0.491	0.000	-

** Correlation is significant at the 0.01 level (2-tailed).

4. Discussions

Physiographically, the Lakhimpur district is largely plain with some hills. The district is in a strategic location between mighty Brahmaputra River and Himalayan foothills of Arunachal Pradesh. The area bordering the north of the district is hilly terrain. Groundwater in the area occurs under phreatic condition in the shallow aquifer zone and under semi-confined condition in the deeper aquifer. Rainfall is the main source of ground water recharge although seepage from canal, return flow from applied irrigation, seepage from surface water body etc. takes place.

pH is a numerical expression that indicates the degree to which a water is acidic or alkaline and is an operational parameter. 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. Corrosion effects may become significant at a pH below 6.5 and scaling may become a problem at a pH above 8.5. For this reason an acceptable range for drinking water pH is from 6.5 to 8.5 (WHO, 2004). High pH levels are undesirable since they may impart a bitter taste to water and also depress the effectiveness of disinfection by chlorination. However, pH alone does not provide a full picture of the characteristics or limitations with the water supply. In all the sampling stations studied pH are within the WHO guide lines values for safe drinking water. In the study area, the variation of pH is narrow and the mean pH value is 6.6, which is slightly acidic. Significant positive skewness value for pH indicates an asymmetric tail extending towards higher values. A positive kurtosis value is also indicative of sharp distribution of pH in the area. Analysis of variance (ANOVA) at the 0.05 level suggests that the means for pH in the three development blocks are significantly different ($F = 6.92019$, $p = 0.00309$). One population t-test at the 0.05 level also suggests that the values obtained for pH are significant ($t = 2.22247$, $p = 0.03281$). However, as far as pH values are concerned no serious problems are likely to be encountered by using water from the different sources of North Lakhimpur sub-division of Lakhimpur district.

The WHO guideline value (recommended limit) for arsenic in drinking water is 10 ppb and the national standard in most countries, including India, is 50 ppb. Comparing the groundwater content of arsenic with the recommended maximum values for drinking purposes, it is found that a good number of samples contain arsenic at an alert and toxic level in the study area. Arsenic in the study area can enter the water supply from natural deposits in the earth or from agricultural pollution. It is widely believed that naturally occurring arsenic dissolves out of certain rock formations when ground water levels drop significantly. High arsenic levels are often used to indicate improper well construction, or the location or overuse of chemical fertilizers or herbicides. Experimental data clearly reveals that Boginadi block of Lakhimpur district is alarmingly contaminated with arsenic. Significant differences among mean, median and mode along with moment coefficients of skewness and kurtosis obtained for arsenic in the area show that sample frequency distribution curves differ from ideal Gaussian (normal). We have taken only those samples for statistical treatment in which arsenic could be detected and determined. Wide data range and significant standard deviation of the data are likely to bias the normal distribution statistic. It seems that arsenic distribution in the area is sharp with a long asymmetric right tail. One population t-test at the 0.05 level suggests that the concentrations of arsenic in the whole study area (t = -1.232, p = 0.22616) are not significant. However, ANOVA analysis at the 0.05 level for arsenic suggests that the means in the three development blocks are significantly different (F = 11.38331, p = 1.73901E-4). Thus, groundwater of the study area should be regularly monitored to detect any possible outbreak of arsenic hazards.

Iron is a non-hazardous element that can be a nuisance in a water supply. Iron is the more frequent contaminants in water supplies. The iron contents of the tube wells and the ring wells were found to be very high in the study area. This may be due to soil origin and age old iron pipes used in the area. The data exceeds WHO guide line value of 0.3 mg/L in all cases. The groundwater concentration of iron in the area is not suitable for food processing, dyeing, bleaching and many activities. The iron content of the area may also promote the growth of iron bacteria, leaving a slimy coating in piping. The presence of these iron bacteria can also cause a rotten egg odour in the water and sheen on the water surface. Appreciable di erence in iron contents in ring well and tubewell waters indicated a depth correlation with iron content. Positive skewness value for iron in the area indicates an asymmetric tail extending to the right of the median. A negative kurtosis value is also indicative of its flat distribution in the area. Asymmetric nature of iron distribution in the study area is also evident from the width of the third quartile, which is much greater than the first and second quartile. ANOVA analysis for iron at the 0.05 level suggests that the means in the three development blocks are significantly different (F = 4.53591, p = 0.01818). Analysis of one population t-test at the 0.05 level also suggests that the values for iron (t = 5.89811, p = 1.05175E-6) are significant.

Correlation analysis measures the closeness of the relationship between chosen independent and dependent variables. Pearson's correlation coefficient is a measure of linear association among different variables. Correlation coefficient ranges between -1 (a perfect negative relationship) and +1 (a perfect positive relationship). A value of 0 indicates no linear relationship. If the correlation coefficient is nearer to +1 or -1, it shows the probability of linear relationship between the variables. Since the directions of association of the measured variables are unknown in advance, two-tailed test of significance was carried out and found that some correlations are significant at the 0.01 level (Table 5).

5. Conclusions

A comprehensive statistical analysis of arsenic and iron contents in groundwater of three development blocks of Lakhimpur district has been carried out. Results of the groundwater samples collected from tubewells and ringwells at different sites in North Lakhimpur sub-division reveal varying levels of arsenic and iron contamination. The contamination of groundwater by arsenic and iron are attributed to geogenic origin. Concentrations of iron are found to be significantly elevated as compared to WHO recommended levels in the study area. One interesting observation noticed that the sampling sites which were not considered to be arsenic affected earlier simply because the ground water samples were not analysed, have come under the arsenic belt with high degree of surveillance undertaken during this study. Boginadi development block is the likely place where future arsenic contagion may take place. Tubewell waters of this block should be regularly monitored to detect any arsenic occurrence at the inception. The present study has shown that naturally occurring arsenic and iron in groundwater is more widespread in the study area than is generally recognized. The key recommendations of this study are to take a more strategic approach to arsenic and iron contamination in the study area at project, regional and national levels.

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