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Abstract

In order to assess the arsenic concentration change over time, water from a total of 246 tubewells Jhikargachha upazila of Jessore district were tested using atomic absorption spectrophotometer in two different periods of time. The main objective of the study was to develop a sustainable and affordable arsenic testing protocol for the arsenic affected communities of the country. While measuring groundwater arsenic concentration change over time, local hydrogeology and geostatistical relationship with arsenic were also analysed. It has been observed that movement of groundwater, according to elevation contour maps of dry and wet seasons of 1996, is from the central part of the study area towards the peripheral rivers. A relationship between arsenic distribution patterns and groundwater movement, though not obvious, could be established. Geostatistical analyses have been performed to investigate relationships between arsenic in groundwater with different well and aquifer parameters. A positive co-relation was observed between well depth vs. percentage of arsenic contaminated wells i.e. a general increasing trend of contaminated wells from 30 to 60m (r^2=0.81). This increasing trend changes at depth greater than 60m. The arsenic concentration results reveal that the highest number of tubewell water showed change in concentration level in either case (i.e. increased or decreased). The highest increase was 91 μg/L and lowest decrease was 128.20 μg/L. This trend indicates that arsenic concentration in tubewell water can change in both directions but the tendency to reduce concentration levels of arsenic in the analysed water was comparatively high. However, the findings of the study did not show any strong indication about changing the concentration level of arsenic in tubewell water.

Key words: Arsenic, Bangladesh, drinking water, mitigation, hydrogeology, geo-statistical, contour

Introduction

Arsenic contamination in groundwater has aroused widespread concern in Bangladesh as more and more information has been gathered by a large number of studies (BGS/DPHE, 2001; Chakraborti et al., 2002). Although there are difference in the numbers, at least one third of the countries domestic hand tubewells yield water at concentrations above the Bangladesh limit of 50 μg/L and more than 60% of the wells exceed the WHO provisional guideline value of 10 μg/L. Arsenic contamination, in fact, has become a global issue is public health as it has been encountered in many countries and regions under varying conditions (Smedely and Kinniburgh, 2002; Mandal & Suzuki, 2002).

Since the detection of the contamination in 1993, various studies have provided useful information regarding origin, occurrence, distribution and the factors controlling these (BGS/DPHE, 2001; Nickson et al., 2001; Bhattacharya et al, 2001). Studies have been undertaken to find sustainable mitigation of the arsenic problem. However, there is no single solution to the problem and mitigation strategies would differ from area to area based on local conditions. In the process, new concerns such as change of arsenic concentrations with time and transfer of arsenic through irrigation needs proper attention. It has already been reported that irrigation with arsenic contaminated water may create yet another pathway of arsenic intake (Imam et al., 2001; Chowdhury at al., 2002). At the same time there are substantial evidences of arsenic increase in the wells with time (DPHE/BGS/MMI, 2000; Burgess et al., 2002a; Burgess et al., 2002b; Van Geen et al., in press). The public health issues remain there as matters of great concern for those who have been already exposed to high arsenic (Smith & Rahman, 2000).

The current study synthesizes the data generated from the BRAC's *community-based arsenic mitigation* pilot study in Jhikargachha taken in collaboration with UNICEF and the Department of Public Health Engineering (DPHE) of the Government of Bangladesh (BRAC, 2001). Further addition to the study has been made by a M.Sc. thesis of the Department of Geology, Dhaka University (Nahar, 2001). We try to draw conclusions regarding the occurrence and distribution and time trends of arsenic in Jhikargachha based on limited data.

Material and Methods

Jhikorgachha Upazila of Jessore district with an area of 529.3 km^2, is located in the southwestern part of Bangladesh and lies between 89^{0}00' to 89 ^{0}07' E longitude and 22^{0}55'55" to 23^{0}12'34"N latitude (Figure 1). Under the action research pilot project all the wells have been screened for arsenic using Merck Field Kit. At the same time information on the wells and users were collected in a questionnaire. Further information on subsurface geology and hydrogeology has been collected from concerned organizations. In order to assess the arsenic concentration change over time, a total of 246 randomly selected tubewell water were tested using atomic absorption spectrophotometer in two different periods of time (first phase in June 2000 and the second phase in July 2001). Acidified (3 drops of nitric acid) bottles were used to collect water samples for laboratory analysis by atomic absorption spectrophotometer (AAS). Before pouring water in the provided bottles, tubewells were pumped for at least five minutes to flush the water stored in the well and thus to get the concentration of arsenic in aquifer water.

Arsenic occurrence and distribution in Jokorgacha

Distribution Pattern

Groundwater of the recent alluvium aquifer at Jhikorgacha Upazila contains variable concentration of arsenic ranging from less than 0.001 mg/l up to 0.5 mg/l. Few arsenic hotspots (zone of high arsenic concentration) were found to be random over the area. Most part of the area shows arsenic concentration greater than acceptable limit of Bangladesh standard. Field test data of 25,974 tubewells of the upazila shows that 57% wells are unsafe and 43% are found to be safe for human consumption. Union wise distribution of arsenic (Figure 2) shows that the southern part of study area is mostly affected where the percentage contaminated wells is in the range of 45-81. The northern part is moderately affected with 46-65% contaminated wells whereas the unions in the central part are less affected with 30-40% contaminated wells.

Geostatistical Relationship

Geostatistical analyses have been performed to investigate the relationship between arsenic in groundwater with different well and aquifer parameters. The relationship between arsenic and depth of wells is shown in 3.a (Arsenic vs Depth). The figure shows that percentage of arsenic contaminated wells are less than 60% in the wells within depth range of 30m whereas more than 60% wells are contaminated in the depth range of 30m-76m. The wells with depth >45m are most contaminated (80%). The figure also shows a general increasing trend of contaminated wells from 30 to 60 m. The diagram of well depth vs. percentage of arsenic contaminated wells shows a positive correlation. The correlation co-efficient (r^2) is 0.81, which is a significant correlation. The increasing trend changes at depth greater than 60 m. However, this decreasing trend cannot be ascertained because of lack of information below 76 m. Other studies carried out in different parts of Bangladesh reported that the aquifers at greater depth (>100 m) are less contaminated or free of arsenic (BGS/DHPE, 2001). The depth distribution is a factor of local geology (Ahmed et al. 2002).

Figure 3b (Arsenic vs well age) shows the relationship between well age and percentage of contaminated wells. It is evident from the figure that there is no definite correlation between the well age and percentage of contaminated wells. There is slight increase in percentage of contaminated wells for 0-5 to 10-15 years age. However percentage falls sharply for the wells of 15-20 years and increases again for wells >20 years. The diagram does not show any significant correlation where the r^2 value is 0.15.

The lithological relationships of arsenic contaminated wells are shown in Figure 3c. The figure shows that percentage of arsenic contaminated wells increases with increasing grain size and the medium sand aquifer has the higher percentage of arsenic contaminated wells (91%). The diagram of lithology vs. percentage of arsenic contaminated wells shows a positive correlation. The correlation co-efficient (r^2) is 0.86, which reveals a significant correlation.

The geostatistical relationships contradict some of the earlier relationships reported by other studies. It has been reported that high arsenic is generally associated with the finer sediments (Imam et al., 1999), but present study demonstrates that higher arsenic is related to coarser sediments. The contradiction in the relation between grain size and arsenic contamination may result from lack of exact grain size data of the screened depth of the wells. In some previous studies (BGS/ DPHE, 1999; Melanie, 1999) it has also been reported that older wells have higher probability of being contaminated. This study does not find any such trend.

Hydrogeology and Arsenic Relationship

Elevation contour maps of dry and wet seasons of 1996 (Figure 4a,b) show that the groundwater movement is from the central part of the study area towards the peripheral rivers. An area of restricted groundwater movement also occurs in the northern part. A relationship between arsenic distribution pattern and groundwater movement, though not very obvious, could be established. The unionwise arsenic distribution map (Fig 2) shows <40% arsenic contaminated wells lie in the central part whereas >60% contaminated wells are in the northern and southern part. Active flushing of groundwater in the central part may have diluted the arsenic concentration but restricted groundwater movement hindered flushing in the northern part. However, the relation of higher concentration in the southern part could not be inferred from the figures, as regional groundwater flow pattern is not completely established in the mapped area.

For the period of 1989-99, hydrographs of water level data from two BWDB observation wells within Jhikorgachha (JES006) have been constructed. The hydrographs of the water table elevation for the observation well (Figure 5) depict the pattern of water level movements for the last 25 years in the study area. From these figure, it can be inferred that within the study area there are no long-term water level variation, and it only fluctuates due to seasonal cyclicity of dry and wet season. However, seasonal fluctuations in the water level have been accentuated in recent years, due to the large amount of groundwater withdrawn from aquifers.

Changes with time

As shown in table 1, a total of 246 randomly selected water samples were analyzed using AAS method. Changes in arsenic concentration of the two sets of laboratory results were obtained by calculating the difference between the two analysis results. The calculated values have been categorized into three different groups: no change in concentration, increases in concentration, and decrease in concentration.

It can be seen from the Table 1 that arsenic concentration change in the tubewell water does not have any definite pattern but there is a tendency to reduce concentration over time, as the concentration decrease was more prominent than concentration increase: arsenic concentration decreased in almost 50% and increased in almost 46% of the tubewell water while, concentration remained unchanged (i.e. 0) in almost 4% of the tubewell water.

It is also evident from the table1 that a highest number of tubewell water showed change in arsenic concentration in either case (i.e. increased or decreased). The highest concentration increase in the analysed tubewell water was 91μg/L with a mean increase of 15.69μg/L and the lowest decrease was 128.20 μg/L with a mean decrease of 18.71μg/L.

Therefore, it can be said from the findings of the present study that arsenic concentration in tubewell water might change in both directions (i.e. increased or decreased) but the tendency to reduce arsenic concentration levels was found to be higher.

Conclusions

Jhikorgacha is one of the upazilla in the southwest Bangladesh where all the unions are affected by high arsenic in the groundwater. Almost 60% of the tubewells in the shallow alluvial aquifers are yielding arsenic contaminated water above Bangladesh limit (>0.05mg/L). A huge effort is needed to provide safe drinking water for the rural people of Bangladesh. To face this new threat, a number of alternative safe water options are proposed. Among the available options, existing arsenic-safe tubewells are considered as a good alternative source. Therefore, it is of utmost important to develop appropriate plans for this apparently safe tubewells to make them sustainable sources of drinking water. Exploitation of deeper aquifer, use of surface water and rainwater could be other options, particularly in the areas where most of the tubewells are yielding contaminated water. Since the present study could not find any definite pattern of changing arsenic concentration over time but there is an indication that concentration of the majority of the tubewell water decrease over time. Taking this indication into consideration, a detailed study involving the geology, soil, and other properties can be developed in order to find a definite pattern of arsenic concentration change in tubewell water for the benefit of millions of exposed population of the rural areas of Bangladesh. Therefore, all arsenic-related problems must be addressed in an integrated, comprehensive approach to mitigate the sufferings of the affected population.

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Figure 1: Location map of the study area.

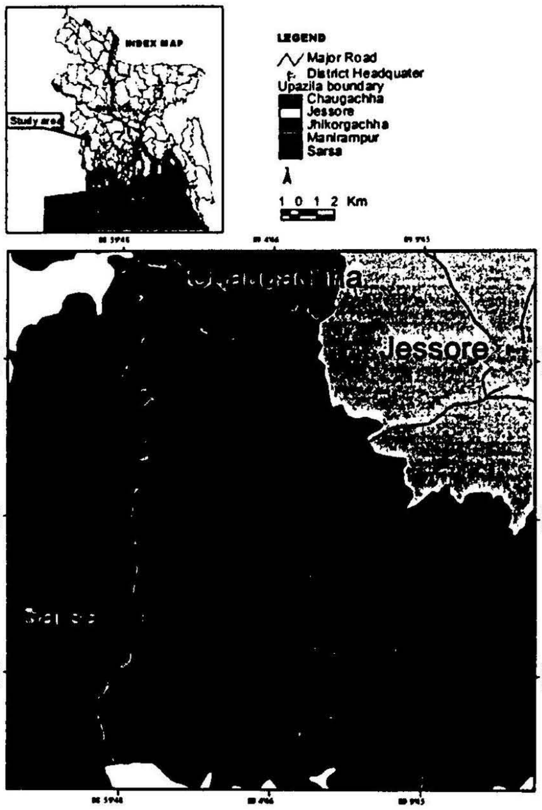

Figure 2: Unionwise distribution of arsenic contaminated wells.

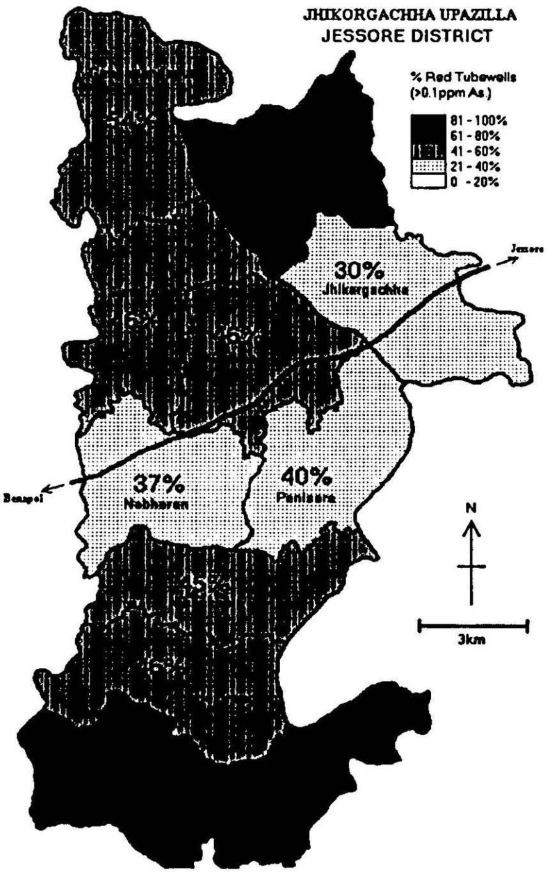

Figure 3: a) Correlation between percentage of contaminated wells and well depth; b) Correlation between percentage of contaminated wells and well age; c) Correlation between percentage of contaminated wells and lithology of the well screen section.

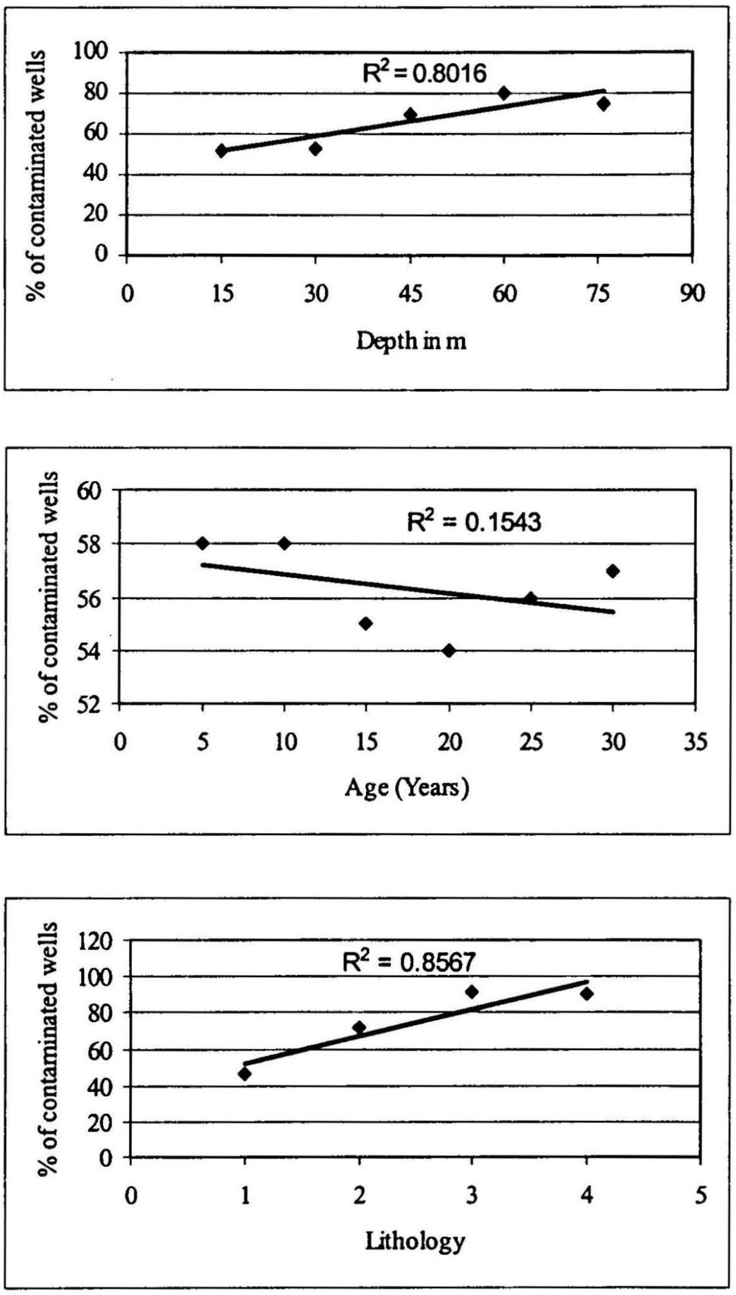

Figure 4: Water level elevation contour map of the study area and surroundings: a) dry season b) wet season.

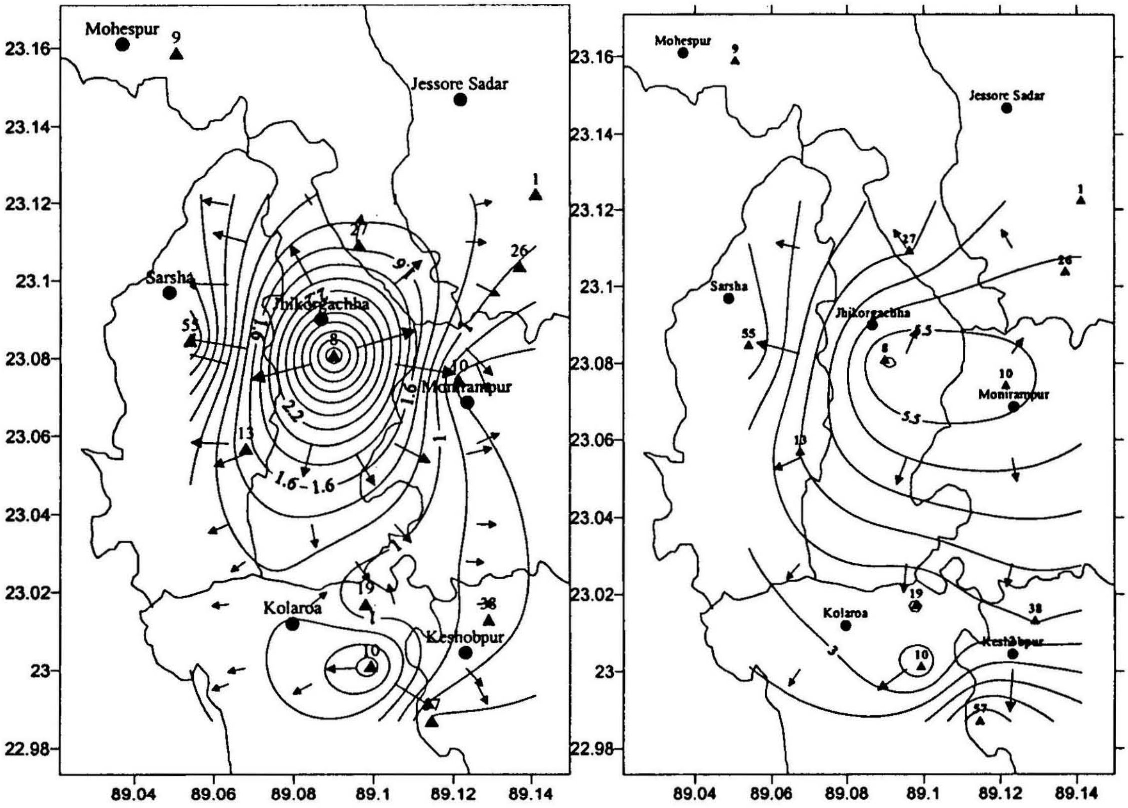

Figure 5: Long term water level hydrograph of Jhikargacha.

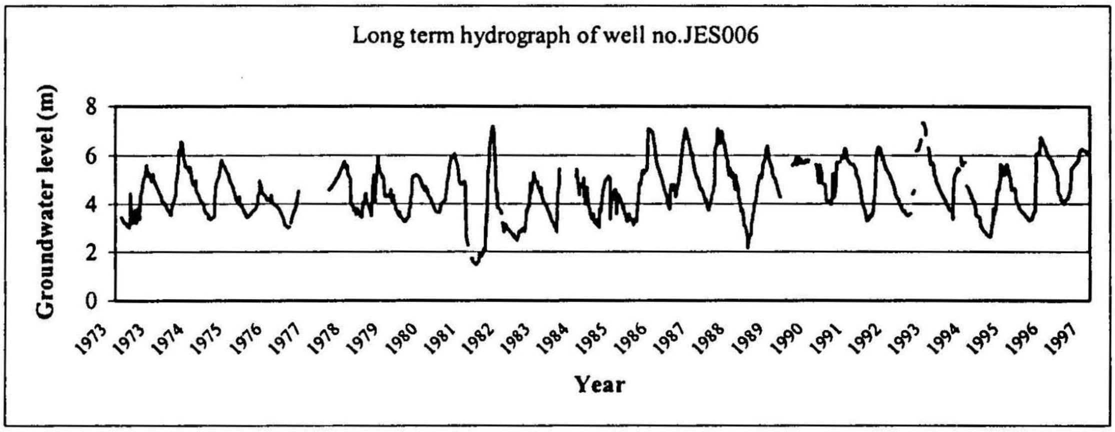

Table 1: Laboratory analysis of water samples

Category	Frequency	As concentration (ppb)			St. Deviation
		Minimum	Maximum	Mean	
No change	9(3)	0	0	0	0
Concentration increased	115 (47)	0.20	91.00	15.69	15.75
Concentration decreased	122 (50)	0.40	128.20	18.71	18.84
Total	246				

Figures within parenthesis indicate percentage