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Groundwater Arsenic Variations: the Role of Depth, Seasons and Age of Tube Wells

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Abstract: Groundwater arsenic contamination is now one of the most significant problems in Bangladesh. Role of depth, seasons and age of tube well for groundwater arsenic variation of Bangladesh was studied. Results indicate that arsenic concentration levels are about 41.31% under WHO guideline (0.01 mg/l), 29.69% is within the permissible level (0.05 mg/l) and 29% exceeds the permissible level (> 0.05 mg/l). Depth bellow 15 m, 92.68% of tube wells was arsenic level under WHO guideline (0.01 mg/l), 4.88% within permissible limit (0.05 mg/l) and 2.44% exceeding permissible limit (>0.05 mg/l). Depth between 15 to 30 m, 40.43% of tube wells were arsenic levels under WHO guideline, 34.04% within the permissible limit and 25.53% exceeding the permissible limit. Depths between 31 to 46 m, 25.49% of tube wells were arsenic levels under WHO guideline, 39.22% within the permissible limit and 35.29% exceeding the permissible limit. Depth between 46 to 76 m, 0% of tube wells were arsenic level under WHO guideline, 40% within permissible limit and 60% exceeding permissible limit. But, there were many significant changes observed in each depth from below 30m depths to above 70m depths. Less arsenic concentration were observed in the dry season as compared to the wet season. Result showed that from less than 15 m to 76 m depth arsenic concentration trend is higher in each tube wells that was installing from eighty decades.

Key words: Merck Test Kit • Aquifer and Tube well

INTRODUCTION

Arsenic enrichment in Bangladesh groundwater is considered to be one of the greatest current environmental disasters in the world. Out of 64 districts, 61 have arsenic concentration above the maximum permissible limit of 0.05 mg/l [1]. Source of As in groundwater is naturally occurring geological deposits at shallower depths (usually 12-46m). The Department of Public Health Engineering (DPHE) first detected arsenic in groundwater in 1993 and the issue came in limelight at the beginning of 1995. Population exposed to a As poisoning through drinking water is about 36 millions. It is suspected that over 0.2 million people are suffering from arsenic related diseases ranging from melanosis to skin cancer and gangrene. So far, about 38000 As-patients are clearly identified and predicted that 0.2 to 0.27 million people will die of cancer from drinking As contaminated drinking water and foods in Bangladesh alone [2].

In the present paper, the author present the distribution of arsenic level in groundwater, to detect the arsenic level in some tube wells for identifying the sources of high, medium and low arsenic content, depth wise distribution of arsenic in tube wells, amount of arsenic content in groundwater, arsenic concentration variations in different depth during dry and wet season and arsenic concentration variations with age of tube wells.

MATERIALS AND METHODS

Sampling Procedure for Drinking Water: Data was collected from four southern district of Bangladesh like as Faridpur, Madaripur, Magura and Kustia. Arsenic concentrations were tested from those Tube well of the area in which arsenic concentration was not tested as before. This information was gathered from local people, Union Council and Department of Public Health Engineering. Each sample was collected in plastic containers that were labeled separately with a unique identification number. It also included the information on the collection date, depth of the tube well and previously arsenic test was done or not. This was done to prevent possible contamination with other samples in the laboratory. The relationship between arsenic contamination and depths of tube well were also analyzed from collected data.

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Procedure of Tube Well Age Determination: Tube well ages were determined in two ways. One was from the secondary source of Department of Public Health Engineering. Other was through asking questions of tube well owners as well as surrounding neighbors' when tube well was installed. Maximum people informed that based on war of independence (1971) as a basis of response. Such as after three years of independence and so on. At the end tube well age were verified through DPHE, Union Council and number of respondent opinion.

Procedure of tube well water depth measurement: Tube well water depths were measured with the help of avometer, measuring tap and plastic insulated wire. A small heavy weight of rod piece was bonded tightly one end of the wire and other end of the wire was kept open to connect with avometer. Before measurement of water depth, tube well was opened at the top of the pipe. During depth measurement, tube well was opened and then rod end of the wire entered in the pipe of the tube well up to when avometer showed indication. It means rod end touch water level. After that with the help of measuring tap water depth was measured.

Role of Test Kits in Measuring Arsenic: Test kits are relatively inexpensive, portable and generally operate on measuring/observing an immediate chemical reaction. However, in practical terms, field test kits have inherent limitations to their use in isolated village situations. They require replenishment of chemical reagents so incur maintenance costs and their results can be easily validated unless the chemical protocols that eliminate cross-contamination are adhered to strictly.

Test kits may be very good for demonstrating the presence of particular chemicals or pathogens, but currently they are not always sufficiently sensitive, or accurate for quantitative assessments. Test kit results should be regarded as initial indicators. Their main limitation is that in raw water samples many chemical reactions may be masked by others occurring in the same solution. The range of technical accuracy of test kits varies generally with their price, but none currently on the market is sufficiently sensitive to provide the data needed to ensure particular quality standards are reached.

Arsenic's propensity to switch valency states means that As^{3+} is more likely to be indicated by test results, while the presence of As^{3+} may not be identified because its reacts more slowly. Test kits therefore commonly under-evaluate total arsenic presence. The most effective use for portable test kits is to indicate the presence of arsenic. As a general principle, these guidelines recommend that, if the test kit demonstrates the presence of arsenic, alternative safe drinking water sources need to be identified.

Testing Through Merck Arsenic Kit: Collected water samples were tested using MERCK Arsenic Test Kit No.1.17926.0001. Zinc and sulfuric acid were added to compounds of arsenic (iii) and arsenic (v), arsenic hydride is liberated, which in turn reacts with mercury (ii) bromide contained in the reaction zone of the analytical test strip to form yellow- brown mixed arsenic mercury halogenides. The concentration of arsenic (iii) and arsenic (v) were measured by visual comparison of the reaction zone of the analytical test strip with the field of a color scale. Measuring range/color scale graduation were 0.00-0.01- 0.025-0.05 - 0.1 - 0.5 mg / l $As^{3+/5+}$.

Removed 1 analytical test strip and immediately reclosed the tube. With the reaction zone first inserted the test strip about half way through the slot in the stopper of the reaction vessel. By means of the syringe, transferred 10 ml of the solution to be tested to the reaction vessel and added 2 measuring spoonfuls of reagent As•[1](zinc). Rapidly added 10 drops of reagent As•[2] (sulfuric acid) immediately closed the reaction vessel with the stopper and swirled gently. The sample solution was not come in to contact with the test strip. Leave to stand for 30 minute, gently swirled two or three times. Removed the test strip, briefly dip into water, shaked off excess liquid and determined with which colour field on the label the colour of the reaction zone coincides most exactly. Read off the corresponding concentration value in mg / l $As^{3+/5+}$. If an exact colour match could not be achieved estimated an intermediate value. If the colour of the reaction zone is equal to or more intense than the colour field for 0.5 mg/l $As^{3+/5+}$, use the Merckoquant Arsenic Test cat. No. 1.10026.0001 (measuring range 0.1-3 mg / l $As^{3+/5+}$). But in our observation any sample could not exceed 0.5 mg / l $As^{3+/5+}$.

The Merck kit, which is manufactured in Germany and has the major drawback that it can only measure down to 0.10 mg/l, that is, double the regional arsenic standard of 0.05 mg/l. However, it is widely acknowledged that none of the test kits are very accurate at low concentrations and that Merck reagents are of very high quality.

The Merck field test kit is extremely simple, with emphasis on ensuring replicable and reliable results. The kit and all the individual reagents results. The kit and all the individual reagents (Zinc powder, hydrochloric acid, mercury bromide papers) carry expiry dates and the well-packaged reagents ensure that users normally achieve about 100 tests per kit. Despite not having additional reducing reagents, or a method of removing sulfide interface, evaluations have found the Merck kit to be at least as accurate and reliable as other more complex field kits.

RESULTS AND DISCUSSIONS

Distribution of Arsenic Level in Groundwater: Arsenic contaminated aquifers have no regular pattern, varies both horizontally and vertically within short distances. Data on arsenic concentration in the southern region of Bangladesh were relatively scarce. The data on arsenic concentration of 305 groundwater TWs provided a solid basis for evaluating arsenic contamination in the southern region of Bangladesh. These data were particularly useful because arsenic testing in this study was done using standard testing method, which provide reliable results. Figure 1 represents the distribution of arsenic in the tube wells located in the southern region of Bangladesh. It indicates that the arsenic concentration level is about 41.31% under WHO guideline (0.01 mg/l), 29.69% is within permissible level (0.05 mg/l) and 29% exceeds the permissible level (> 0.05 mg/l). Out of the total 305 tube wells from southern region, arsenic concentrations in 174 were found to be below 0.01 mg/l, 140 were found in the range of 0.01 to 0.05 mg/l and 91 were found to be above 0.05 mg/l. More tube wells need to be tested for identifying the pattern of arsenic contamination in the southern regin of Bangladesh.

A survey of well waters (n= 3534) from throughout Bangladesh, excluding the Chittagong Hill tracts, have shown that water from 27% of the 'shallow' tube wells, that is well less than 150 m deep, exceeded the Bangladesh standard for arsenic in drinking water (0.05 mg/l), 46% exceeded the WHO guideline value of 0.01 mg/l. Figures for 'deep' wells (greater than 150 m deep) were 1% and 5%, respectively. Since it is believed that there are a total of some 6-11 million-tube wells in Bangladesh, mostly exploiting the depth range 10-50 m, some 1.5-2.5 million wells are estimated to be contaminated with arsenic according to the Bangladesh standard, 35 million people are believed to be exposed to an arsenic concentration in drinking water exceeding 0.05 mg/l and 57 million people are exposed to a concentration exceeding 0.01 mg/l [3]. However, according to [4], the distribution of arsenic in the groundwater is related to the geology of the country rather than just the depth of the water table. According to them, the division of the aquifer system from the geological point of view - like the Upper Holocene aquifer, Middle Holocene aquifer, Upper Pleistocene-Early Holocene aquifer, Pilo-Pleistocene aquifer and older aquifers-is more logical when applied to the depth of the tube well pumping system as is customarily adopted in Bangladesh. They conclude that most of the arsenic-contaminated tube wells are drawing water from the Middle and Upper Holocene sediments.

Depth-Wise Distribution of Arsenic in Tube Wells: Arsenic contamination is commonly associated with fluctuating water tables and flooding cycles particularly in acid sulfide/sulfate soils or where iron and/or manganese-enriched layers or saline-layered aquifers occur. Under these conditions the complex chemistry of arsenic will result in changes depending on exposure

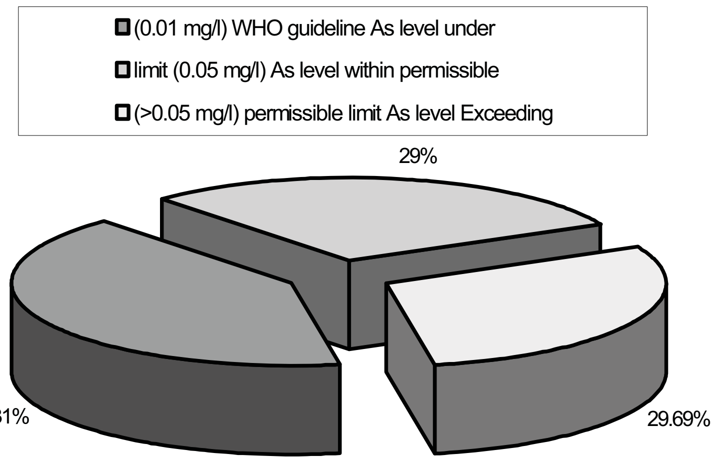

Fig. 1: Distribution of arsenic level in ground water

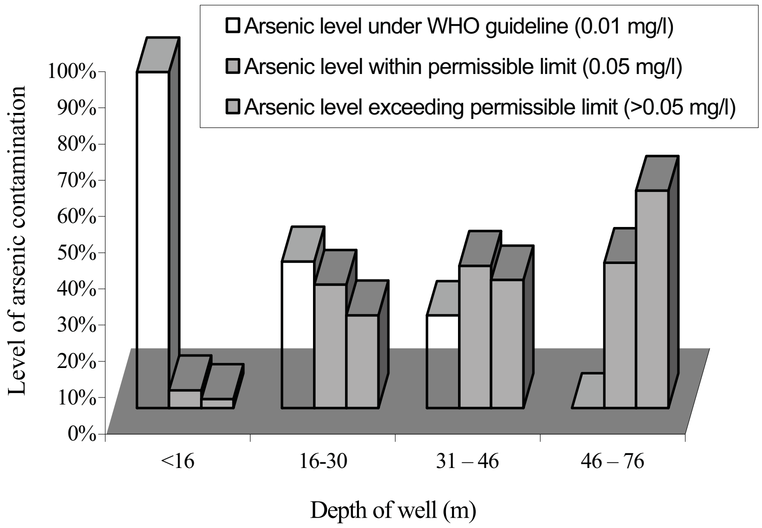

Fig. 2: Depth-wise distribution of arsenic in tubewells

either to air or saturated soils. Levels of arsenic contamination in water supplies can vary through a year adding to the difficulties of identification and monitoring. A depth-wise variation of arsenic concentration in the wells is shown in Figure 2. It indicates that the arsenic contamination increase with the increase of depth. Depth bellow 15 m total 49 numbers of tube well samples were tested. Out of the tested samples 92.68% of tube wells were arsenic level under WHO guideline (0.01 mg/l), 4.88% within the permissible limit (0.05 mg/l) and 2.44% exceeding the permissible limit (>0.05 mg/l). Depth between 15 to 30 m total 94 tube well samples was tested. Out of the tested samples 40.43% arsenic levels under WHO guideline (0.01 mg/l), 34.04% within the permissible limit (0.05 mg/l) and 25.53% exceeding the permissible limit (>0.05 mg/l). Depths between 31 to 46 m total 51 numbers of tube well samples were tested. Out of tested samples 25.49% of tube wells were arsenic levels under WHO guideline (0.01 mg/l), 39.22% within the permissible limit (0.05 mg/l) and 35.29% exceeding the permissible limit (>0.05 mg/l). Depth between 46 to 76 m total 51 numbers of tube well samples was tested. Out of tested samples 0% of tube wells had arsenic levels under WHO guidelines (0.01 mg/l), 40% within permissible limit (0.05 mg/l) and 60% exceeded the permissible limit (>0.05 mg/l). The rest of the tube wells were not considered due to the lacking of data of water table depth.

Arsenic Concentration Variations in Different Seasons and Depths: During the course of the study, hand tube wells were monitored for arsenic, water levels and seasonal variations of arsenic contamination. No clear or consistent changes in arsenic were detected during the monitoring period. However, longer-term monitoring of the wells is required to establish whether there will be significant seasonal and long-term trends in water chemistry. The relatively small variations in arsenic concentrations observed in many of the wells emphasize the need for very careful sampling and high precision analysis if seasonal or long-terms trends are to be detected reliably.

Arsenic concentrations in monitored wells were largely constant during the monitoring period. None of the shallow wells showed any seasonal response in As to rainfall. Concentrations were a little more variable during the early stages of sampling but this may due to temporary disturbances in the groundwater chemistry following drilling. Table 1 shows the mean arsenic concentration at different season. Significant difference was observed between dry and wet season. Less arsenic concentration was observed in dry season as compared to wet season. No difference was observed within each season.

The Table 2 displays the mean arsenic concentration at different depth. Significant variation was observed among different depth with arsenic concentration. Lower arsenic concentrations were observed up to 39m depths and more arsenic concentration were observed above 39m depths. Within each depth arsenic concentration varied more significantly. Also, there were many significant changes observed in each depth from below 30m depths to above 70m depths.

Table 1: Mean arsenic concentration (mg/l) at different seasons

Seasons	Arsenic concentration (mg/l)
Dry seasons	0.04
Wet seasons	0.56
SED	0.021
LSD	0.056
Level of significance	*

SED denotes standard errors of differences of means; LSD denotes least significant differences of means; * denotes P<0.01

Table 2: Mean arsenic concentration (mg/l) at different depths

Depths	Arsenic concentration (mg/l)
> 30 m	0.03
30 - 39 m	0.08
40 - 49 m	0.44
50 - 59 m	0.34
60 - 69 m	0.41
< 70 m	0.51
SED	0.037
LSD	0.096
Level of significance	*

SED denotes standard errors of differences of means; LSD denotes least significant differences of means; * denotes P<0.01

The depth distributions show to be fallacious, the belief that drilling deeper than 100 m provides arsenic free water, it will do so in some parts of Bangladesh, but not, for example, in the region of the Sylhet Basin. A sharp upper limit to high concentrations of arsenic appears to occur at about 10-15 m depth; few data are available for wells in the depth range 0-10 m, so this may be an artefact of data distribution. That it is not is suggested by the fact that dug wells, which are mostly much less than 10 m deep, are rarely polluted with arsenic [5]. Below 200 m, arsenic concentrations rarely exceed a few milligrams per liter [6].

Arsenic Concentration Variation with Age of Tube Wells: One of the questions which was of concern to many was whether the tube wells currently safe will remain so in the future or the concentration of arsenic will change with time in the aquifers for worse due to stress imposed by abstractions. In order to obtain answers to such questions data have to be collected over extended period of time. Delay for such observation was not possible, as answers were needed immediately. It was found suitable proxy parameters that can reasonably replace the time parameter. One such proxy could be the age of the tube wells. As tube wells were sunk without specifically taking into consideration the aquifer properties, the average concentration of arsenic in tube wells sunk at any given period should be statistically the same as any other period. So, any change in the concentration of arsenic with tube well age should represent its abstraction-induced effect.

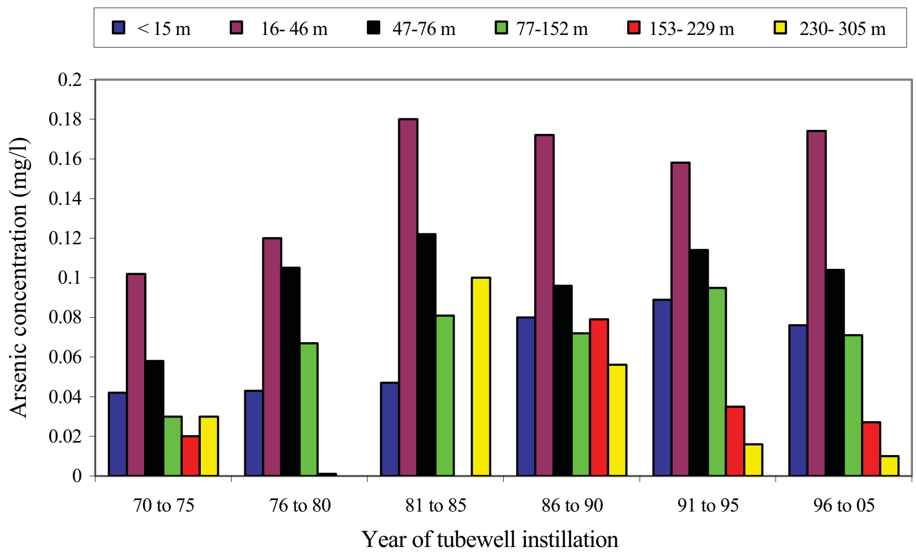

Fig. 3: Arsenic concentration variation with depth and age of tubewel

Average concentrations for arsenic in tube wells grouped by age were calculated for all the tube wells and also for the depth segregated groups. The results were shown in Figure 3.

It can be seen that for all the groups except >305m, the concentrations do not appreciably change with tube well age. There appears to a slight decrease with time but this may not be very significant as these mostly relate to tube wells dating back to seventies. As pointed out earlier data for these tube wells may not be all that accurate. In the case of tube wells of depth greater than 305m, there may be even greater problem with data and it may be probably reflected in the increase in the arsenic concentration for the tube wells between the periods 1970-80. Also, in eighteen-decade trends of mean arsenic concentration was higher in all categories of depth.

CONCLUSIONS

Groundwater with high arsenic concentrations from naturally occurring sources is the primary source of drinking water for millions of people in Bangladesh resulting in major public health crises of recent times. Arsenic concentration levels are 41.31% under the WHO guideline (0.01 mg/l), 29.69% is within permissible limit (0.01- 0.05 mg/l) and 29% exceeds the permissible limit (>0.05 mg/l) in southern Bangladesh. In case of depth-wise variation, 92.68% under WHO guideline, 4.88% within permissible limit, 2.44% exceeding permissible limit for depth below 15 m. Depth between 15 to 30 m, 40.31% under WHO guideline, 34.04% within permissible limit and 25.53% exceeding permissible limit. For 31-46 m and 46-76 m depth, 25.49% and 0% under WHO guideline, 39.22% and 40% within permissible limit and 35.29% and 60% exceeding permissible limit was observed in southern Bangladesh. Mean arsenic concentrations are less up to 39 m depth and after that concentration tends to be higher. Arsenic concentration increase with the increase of well depth. Depth between 46 to 76 m, 60% of tube wells were exceeding permissible limit (>0.05 mg/l). Significant difference was observed between dry and wet season. Less arsenic concentration was observed in the dry season as compared to wet season. No difference was observed within each season. More arsenic concentration was observed in dry season as compared to wet season. Relationship among arsenic concentration, depth and age of tube well provides evidence that arsenic concentrations are always higher in 16-46 m depth from 1970 to 2005 years of tube well instillation. Data on age of tube well indicate arsenic concentrations have been increasing from eighty decade in which tube wells were installed.

These studies demonstrate groundwater arsenic varies with some factors like as depth, seasons and age of tube wells. However, the extent of these factors varies considerably and is influenced by several biogeochemical processes during sediment water interactions in the Helocene aquifers within the country.

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