Variation of arsenic content in groundwater with depth and river distance: GIS mapping[1]

Harun-Ar-Rashid[2], Deb Kumar Nath[2], Mobarok Hossain[2], Muhammad Ullah Khan[2], Dr.Abdul Latif Shah[3], Dr.M.A. Saleque[3], Dr. M. Shamsur Rahman[3] and Dr.M.A. Ghani[4]

Abstract

Ground water is the most important source of water supply for drinking and irrigation in Bangladesh. But arsenic contamination in groundwater is one of the most serious natural calamities to befall Bangladesh. This study was aimed to find out the variation of arsenic content in groundwater according to well depth, age of and distance between wells (HTWs, STWs and DTWs) and distance from rivers in Rajshahi (Charghat and Bagha upazilas) and Chapai Nawabganj (Sadar, Shibganj) districts using GIS mapping to fix the database and plot the various indicators. Among the three types of wells, As contamination was found to be the highest with HTWs (27%), followed by STWs (21%) and the least with DTWs (7%). The middle layers (i.e., those between 40 -160 feet) reflected the highest levels of arsenic contamination in groundwater. The shallower layers up to 35 feet and the deeper layers below 160 feet below the surface showed uniformly low (safe) levels of arsenic. As for age; the 3 types of tubewells tested were found to have no relationship with As contamination. In case of lateral zoning with a 4 km assigned distance, most of the unsafe wells were within the 1st zone and gradually decreased with the increase of distance from the rivers.

---

[1] Paper presented in the Workshop on Arsenic in the Food Chain: Assessment of Water Soil-Crop Systems at Hotel Eastern Residence, Banani, Dhaka-1213, Bangladesh on 22 July 2004.

[2] Agricultural Advisory Society (AAS), House-8/7, Block-B, Lalmatia, Dhaka-1207
[3] Bangladesh Rice Research Institute (BRRI), Gazipur
[4] PETRRA/IRRI, House-39, Road-23, Block-J, Banani, Dhaka-1213

Could be contacted at: E-mail: aas@bdcom.com

Introduction

Arsenic is a metalloid widely distributed in the earth's crust and present at an average concentration of 2 mg/kg. It occurs in trace quantities in all rock, soil, water and air. Inorganic arsenic of geological origin is found in ground water used as drinking water in several parts of the world, for example Bangladesh (WHO, 2001). Excessive concentrations of arsenic in water (i.e., concentrations above 0.05 ppm) are certified to be toxic and, hence, very dangerous to human health. In recent years, Bangladesh has become aware that much of its ground water aquifer is dangerously contaminated with naturally occurring arsenic. This represents a serious turn of events because, in recent years, Bangladesh has become heavily dependent on its ground water supplies as the main source of both drinking and irrigation water.

Thousands of years ago, rocks rich in arsenic were eroded from the Rajmahal Hills, foothills of the Himalayas range and a few other high-lying source areas. The alluvium form these was deposited millions of years ago along with sands, gravels, silts and clays in low-lying areas which now make up West Bengal in India, and Bangladesh. These arsenic-bearing sediments became buried over thousands of years and now form an important part of the aquifers we are tapping into for our water resources (Unicef Bangladesh, 2000).

Contamination of ground water by arsenic in the deltaic region, particularly in the Gangetic alluvium of Bangladesh has become one of the world's most publicized natural calamities. Ground water in 60 out of 64 districts has been reported to be contaminated at various degrees and about eighty five million people may be at some health risk due to the ingestion of this contaminated water (Haq and Naidu, 2003, Ghani *et.al.*, 2004). Since it is believed that there are a total of some 6-11 million tubewells in Bangladesh, mostly exploiting the depth range 10-50 m, some 1.5-2.5 million wells are estimated to be variously contaminated with arsenic according to the Bangladesh standard (BGS/GOB/LGRD/DPHE, 2001).

There is a distinct regional pattern of arsenic contamination with the greatest contamination in the south and south-east of the country and the least contamination in the north-west and in the uplifted areas of north-central Bangladesh. However, there are occasional arsenic 'hot spots' in the generally low-arsenic regions of northern Bangladesh. In arsenic contaminated areas, the large degree of well-to-well variation within a village means that it is difficult to predict whether a given well will be contaminated from tests carried out on neighboring wells.

Concentrations are uniform in the south-east of Bangladesh. There are also marked spatial and depth variations in the As concentration patterns. The distributions are controlled by geology and hydrogeochemical processes active in the aquifers. Of the major aquifers, only the Holocene alluvial aquifers are contaminated. In general, the maximum As concentration are found between 20-

40 m below the surface. Very shallow wells (~10 m) and deep wells (>150 m) are mostly As safe (Haq and Naidu, 2003).

The young (Holocene) alluvial and deltaic deposits are most affected whereas the older alluvial sediments in the north-west and the Pleistocene sediments of the uplifted Madhupur and Barind Tracts normally provide low-arsenic water (Abdullah, 2002). However, Groundwater drawn from alluvial aquifers located within Quaternary deposit of Bangladesh used for drinking water is polluted with naturally occurring arsenic.

Aquifers beneath the elevated alluvial terraces (Dupi Tial Formation) are almost free of arsenic pollution. In aquifers beneath the Holocene floodplains, within the alluvial and deltaic plains of the Ganges, Meghna, and Brahmaputra (in Bangladesh, Jamuna) rivers, concentrations of arsenic commonly exceed the Bangladesh drinking-water standard (0.05 ppm). Limited data show that highest arsenic concentrations occur at depths of around 30 m (McArthur *et.al.,* 2002). Below 45 m, a reduction occurs in the percentage of wells that are contaminated, but risk remains significant until well-depth exceeds 150 m.

It has been proved beyond doubt that the origin of arsenic in ground water in the country is geogenic. Therefore, the arsenic is of natural origin and is believed to be released to ground water as result of a number of mechanisms which are poorly understood.

However, a study (BGS/MML/GOB, 1999) has found that the arsenic sediment has released into the ground water in Bangladesh by a natural process called “oxyhyroxide reduction”. In this process, arsenic is released into the surrounding water when fine-grained iron or manganese oxyhydroxides dissolve due to natural conditions that lead to a decrease in oxygen levels (Unicef Bangladesh, 2002). The release appears to be associated with the burial of fresh sediment and the generation of anaerobic (oxygen-deficient) groundwater conditions.

In recent study shower that anaerobic metal-reducing bacteria can play a key role in mobilization of arsenic in sediments collected from a contaminated aquifer (Farhana *et. al.*, 2004). The anaerobic bacteria are a special group of bacteria gain energy by respiring (breathing) using the metal iron and arsenic containing minerals in the earth sediments. The bacteria cause changes in the mineral structure of the sediments, leading to release of arsenic into groundwater. Thus, the study found that maximum amount of arsenic is released from contaminated sediment into groundwater in the absence of Oxygen (The daily Star, 14 August 2004).

Understanding of the hydrological situation of arsenic contamination in groundwater is essential for both short-term avoidance and long-term remediation programme (Rahman and Hossain, 1999). Within the arsenic contaminated areas, some aquifers also contain acceptable concentrations. Unfortunately, the concentrations are highly variable over relatively small distances, which make restriction on locating regional or sub-regional safe aquifer at this stage.

But the actual source of arsenic contamination, its release and mobilization mechanism in groundwater is yet to be definitively investigated. An integrated hydrogeological study is very much needed to better understand the dynamic of aquifer contamination as well as the environmental impact, assessment and management of the Arsenic contamination problem.

Objective of the study

To find out the variation of arsenic content in groundwater with respect to depth, age and distance of wells (HTWs, STWs and DTWs) from the rivers in four upazilas of Rajshahi and Chapai Nawabganj districts and to undertake the whole process using GIS mapping tools and techniques.

Methodology

A bench-mark survey was conducted during 2002-2003 and 2003-2004 boro seasons to monitor the Arsenic status in groundwater in Rajshahi (Charghat and Bagha Upazilas) and Chapai Nawabganj (Sadar and Shibganj upazilas) districts. At the beginning of the survey tubewells (HTWs, STWs and DTWs) were selected randomly (see Fig.1). Water samples were collected from randomly selected tubewells in four upazilas of Rajshahi and Chapai-nawabganj districts. A list of the selected tubewells in Rajshahi and Chapai Nawabganj districts is provided in the following table 1:

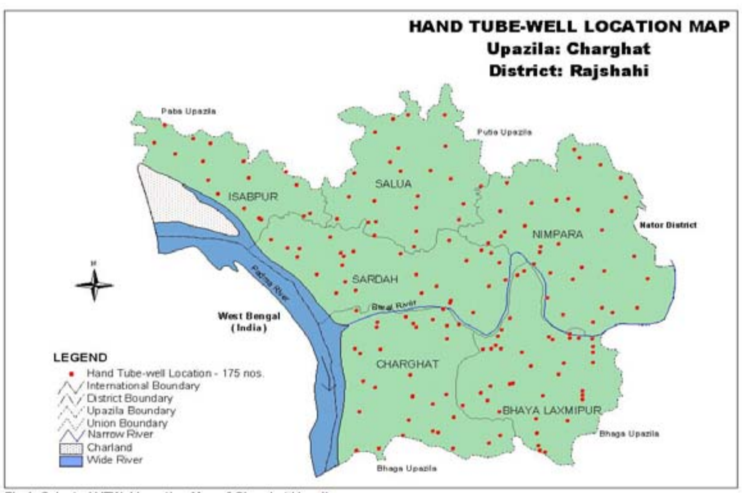

Fig.1: Selected HTWs' Location Map of Charghat Upazila

Table 1. List of the selected tubewells

District	Upazila	HTW	STW	DTW
Rajshahi	Charghat	175	257	25
	Bagha	190	204	23*
Chapai Nawabganj	Sadar	158	100	66
	Shibganj	182	126	86
Total		**705**	**687**	**200**

*water samples were collected but analytical data were not available

Water samples for analysis of arsenic contamination level were collected 30 minutes after starting the deep and shallow tubewells and for hand tubewells after 100 strokes. Water samples were collected from selected tubewells (HTWs, STWs and DTWs) in 100 ml plastic bottles. Before sampling, bottles were washed with distilled water and rinsed 2-3 times with respective tubewell's water. In each bottle 90 ml water sample was collected and 10 ml 2N HCl solution was added. Assigned Irrigation Engineers tested the water samples of each selected tubewell (HTWs, STWs, DTWs) during it's collection by Merck/Nipsom field kit. All samples were pre-reduced with KI and ascorbic acid prior to hydride generation. In a 10 ml volumetric flask 1 ml sample of water was transferred. Later 1 ml of HCl (32 %, m/v) and 1 ml of mixture of 5 % of KI and 5% ascorbic acid were added to the flask. The solution was mixed well and was kept for 1 hr at room temperature to complete the pre-reduction. Finally, the sample was diluted to 10 ml with de-ionized water. The sample was then analyzed for arsenic content by a Perkin-Elmer A Analyst 100 atomic absorption spectrophotometer (AAS) equipped with a FISA-100 flow injection system at arsenic laboratory of soil science division, BRRI, Gazipur.

The following steps were followed for the GIS mapping study:

- ✓ Base Map preparation on the basis of site selection (Source: DLRS Thana Map and Soil & Land Map of SRDI)
- ✓ Geo-referencing well locations using GPS receiver
- ✓ Downloading well locations from GPS receiver into PC
- ✓ Converting well locations records as a Arc-view shape file
- ✓ Developing database (using well attribute ablate)
- ✓ Preparing well location maps using Base Map and well location shape file
- ✓ Arsenic distribution map preparation showing Arsenic contamination wells and Arsenic free wells
- ✓ Spatial analysis using Base map and well attributes showing arsenic concentration, depth of wells and age of wells
- ✓ Arsenic contaminated and Arsenic free Zones Map preparation for contaminated area detection and future planning
- ✓ Spatial relational chart preparation showing Arsenic concentration, depth and age
- ✓ Lateral Zoning with a 4 km assigned distance from river(s) on the basis of sedimentation and Arsenic contamination in groundwater.

Results and Discussions

The benchmark survey study was conducted to find out the arsenic contamination in groundwater at 4 highly contaminated upazilas in Rajshahi region. The water samples of HTWs, STWs and DTWs were collected from the study area and tested at BRRI, Gazipur and presented by using GIS mapping tools. The findings of the study are as follows:

Unsafe wells:

Within the four upazilas of Rajshahi and Chapai Nawabganj districts, out of 705 HTWs, 191 (27%), out of 687 STWs, 146 (21%) and out of 177 DTWs, 13 (7%) were found to be unsafe (As contamination exceeded 0.05 ppm or 50 ppb). Percentage of unsafe wells of four upazilas of Rajshahi and Chapai Nawabganj districts are given in the following table 2:

Table 2. Percent unsafe wells in four upazilas of Rajshahi and Chapai Nawabganj districts

District	Upazila	HTW		STW		DTW	
		Total	% unsafe*	Total	%unsafe*	Total	%unsafe*
Rajshahi	Charghat	175	25	257	8	25	0
	Bagha	190	19	204	14	23**	NA
Chapai - Nawabganj	Sadar	158	34	100	54	66	11
	Shibganj	182	32	126	33	86	7

* % unsafe= Arsenic concentration exceeding 0.05 ppm or 50 ppb.
** Water samples were collected but analytical data were not available.

In Charghat upazila, out of the 175 HTWs tested, 43 (25%) tubewells, out of the 257 STWs tested, 21(8%) tubewells and out of the 25 DTWs tested, no tubewells, were found to be unsafe. In Bagha upazila, out o f 190 HTWs tested, 36 (19%) tubewells and out of the 204 STWs tested, 29 (14%) tubewells were found to be unsafe. In Chapai Nawabganj Sadar, out of the 158 HTWs tested, 54 (34%) tubewells, out of the 100 STWs tested 54 (54%) tubewells and out of 66 DTWs tested, 7(11%) tubewells were found to be unsafe. In Shibganj upazila, out of the 182 HTWs tested, 58 (32%) tubewells, out of the 126 STWs tested, 42 (33%) tubewells and out of the 86 DTWs tested, 6 (7%) were found to be unsafe.

It is noteworthy that among the three types of wells, HTWs and STWs were highly contaminated and DTWs were the least contaminated tubewells. In some cases it is contradicting that though HTWs, STWs and DTWs started extracting water from the same layers, DTWs were the least contaminated. In case of DTWs it might happens that due to its wide range of water extracting aquifers and lots of discharge comparing with HTWs and STWs, arsenic concentrations of extracting water coming from different layers mixes and becomes homogenous and thus the water pumped out reflects a certain diluted concentration.

Unsafe wells' water extracting layers:

The middle layers between 40-160 feet reflected the highest probability of unsafe levels of arsenic contamination in groundwater. The shallower layers up to 35 feet and the deeper layers below 160 feet from the ground surface showed uniformly safe concentrations of arsenic in groundwater. Haq and Naidu, 2003, reported that in general, the maximum As concentration are found between 65-131 feet below the ground surface and in our study this range with a little bit expansion shows the similarity with their study. The layers which are unsafe for extracting water by three types of wells in four upazilas of Rajshahi and Chapai Nawabganj districts are provided in the following table 3:

Table 3. Unsafe wells' water extracting layers in four upazilas of Rajshahi and Chapai Nawabganj districts

District	Upazila	Range of unsafe wells' water extracting layers (feet)		
		HTW	STW	DTW
Rajshahi	Charghat	85-135	110-125	all safe
	Bagha	50-160	60-130	NA
Chapai-Nawabganj	Sadar	40-130	60-110	110-134
	Shibganj	40-145	50-120	115-160

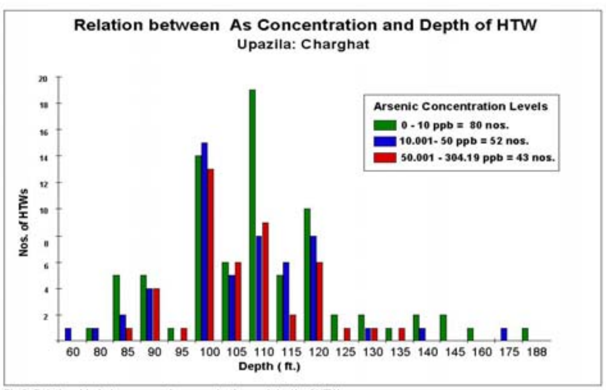

Fig.2: Relationship between arsenic concentration and depth of HTWs

In Charghat, the maximum numbers of unsafe HTWs were extracting water from water layers between 85 and 135 feet (see Fig.2). The majority of seriously contaminated STWs were found to be in water layers in the 110-125 feet depth range. There was no unsafe DTW among the tested wells (see Fig.4). In Bagha, unsafe HTWs and STWs were extracting water from water layers in 50-160 feet and in 60-130 feet depth range respectively. In Chapai Nawabganj Sadar, the maximum numbers of unsafe HTWs, STWs and DTWs were extracting water from water layers in 40-130 feet, 60-110 feet and 110-134 feet depth range respectively (see Fig.3).

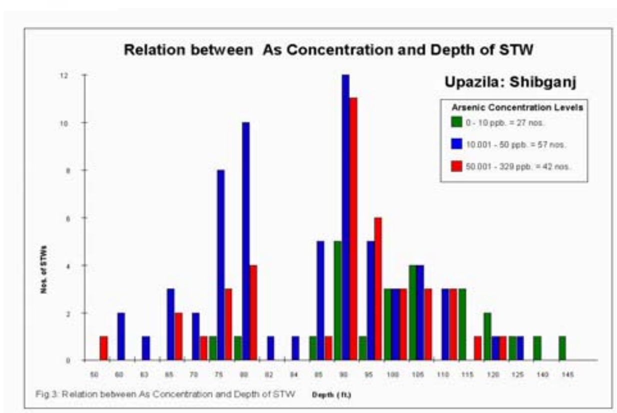

Fig.3: Relation between As Concentration and Depth of STW

In Shibganj the maximum numbers of unsafe HTWs, STWs and DTWs were extracting water from water layers in 40 -145 feet, 50-120 feet and 115-160 feet depth range respectively.

Arsenic concentrations of safe wells at 2 levels:

In Bangladesh standard, 0.05 ppm As concentration in drinking water is acceptable. However, some countries have declared that concentrations above 0.01 ppm are not acceptable. Therefore, attempts were made to divide the safe category in two levels. Please see the details in the following table 4:

Table 4. Percent of As contaminations of safe wells at 2 levels in four upazilas of Rajshahi and Chapai Nawabganj districts

District	Upazila	% As concentration of safe wells					
		HTW		STW		DTW	
		10-50 ppb	<=10 ppb	10-50 ppb	<=10 ppb	10-50 ppb	<=10 ppb
Rajshahi	Charghat	30	45	14	78	12	88
	Bagha	16	65	41	45	NA	NA
Chapai-Nawabganj	Sadar	22	44	46	0	4	85
	Shibganj	24	44	45	22	30	63

Note: 1 ppm=1000 ppb

In Charghat, the remaining 132 (75%) HTWs showed arsenic concentrations 0.05 ppm (50.00 ppb) or below and were deemed, by prevailing Bangladesh standards, to be safe for drinking. The safe HTWs were extracting water from 60 to 80 feet and there were some extracting deeper than 135 feet (see Fig.2). The remaining 92% of STWs tested were found to be safe. The safe STWs were generally found to be extracting water from the 60-105 feet level or below 155 feet from the ground surface. Out of the 25 DTWs tested, all 25 were found to be within the safe range of 0.01-0.05 ppm (10.00-50.00 ppb). All of the DTWs were found to be extracting water from layers at the 180 ft. level or below (see Fig.4). In Bagha, the remaining 154 (81%) HTWs' showed As concentrations 0.05 ppm (50 ppb) or below, which are safe for drinking in Bangladesh standard and the remaining 86% of STWs tested were found to be safe. In Chapai Nawabganj Sadar the remaining 104 (66%) HTWs' water showed arsenic concentrations 0.05 ppm (50 ppb) or below. The remaining 46% of STWs tested were found to be safe and their As concentrations were within 0.01-0.05 ppm (10-50 ppb). The safe STWs were generally found to be extracting water below 120 feet of the ground surface. Nevertheless, a few of them were found to have extracting water within 60 feet depth. The remaining 59 (89%) DTWs tested were found to be safe. The safe

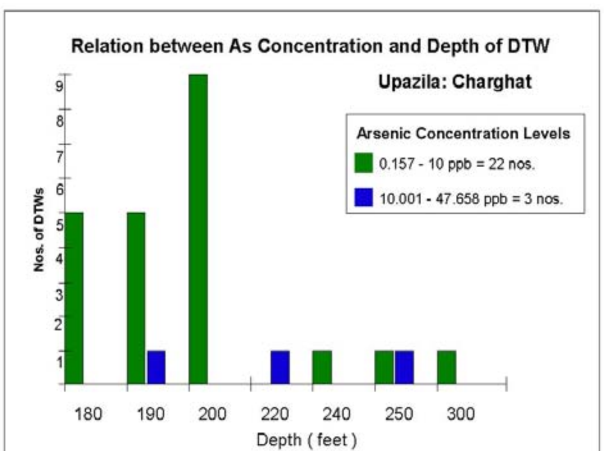

Fig.4: Relation between As Concentration and Depth of DTW

DTWs were generally found to be extracting water from the water layer 90 -100 feet range and some below 135 feet from the ground surface.

In Shibganj, the remaining 124 HTWs' water showed arsenic concentrations 0.05ppm and less than that, which is considered safe for drinking in the context of Bangladesh.The remaining 67% STWs and 80 (93%) DTWs tested were found to be safe for drinking. The safe DTWs were generally found to be extracting water from 60 to114 feet depth or below 160 feet from the ground surface.

Age of tubewells and Arsenic contamination:

The age of tubewells tested (whether 1 years or 47 years) seemed to have no bearing on the overall level of tubewell contamination (see Fig.5 and Fig.6). The age of the 3 types of tubewells tested in any site was found to have no relationship with As concentration.

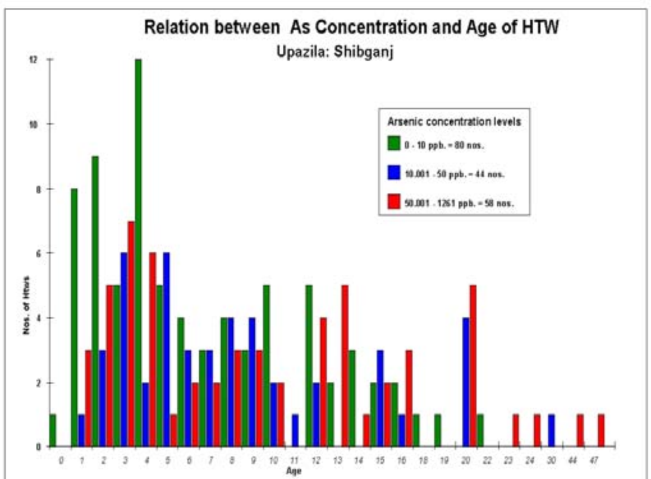

Fig.5: Relationship between arsenic concentration and age of HTWs

Since Thousands of years ago, rocks rich in arsenic were eroded from the Himalayas and other high-lying source areas, and deposited along with sands, gravels, silts and clays in low-lying areas and formed Bangladesh. These arsenic-bearing sediments became buried over thousands of years, forming Recent or Holocene aquifers (An epoch of the Geological Time Scale, approximately 10,000 years ago to the present time). Water mostly from the aquifers of Recent or Holocene sediments is mostly contaminated with higher than permissible amount of arsenic. So, tubewell age, whether 25 years or 47 years is a very short period comparing with the age of Holocene aquifers. On the other hand, in case of Chapai Nawabganj Sadar, most of the safe DTWs are located in High Barind Tract and contaminated DTWs are located in Active Ganges River Flood Plain and High Ganges River Flood Plain. As we found that all the tubewells in Barind Tract are arsenic safe and draw water from the aquifer below the red clay beds. In geological terms these beds

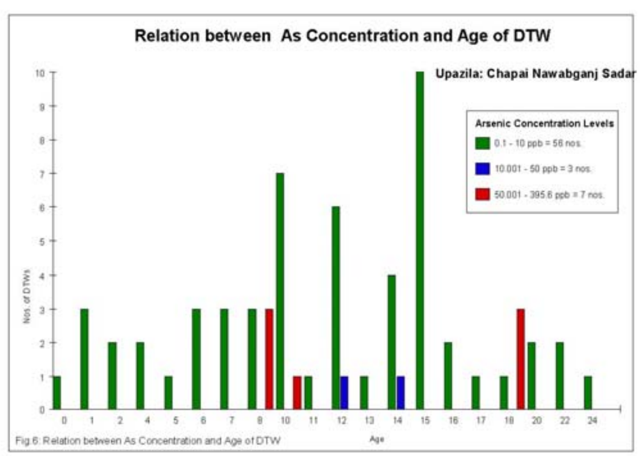

Fig.6: Relation between As Concentration and Age of DTW

belong to the Pleistocene age (An epoch in the geological time scale that started about 1.8 million years ago and lasted until the start of Holocene some 10,000 years ago). Similarly, it must be mentioned that Dhaka city withdraws about 102 crores (1.2 billion) liters of water every day by 327 tubewells from the aquifer below the red clay beds which is safe (Abdullah, 2002).

That's why the sole determining factor seemed to be the depth of the water layers and the type of the aquifers from which water was being extracted, not to be the age of the tubewells.

River sedimentation and Arsenic concentration:

The river Padma is the prominent river for all four upazilas. Besides, for Chapai Nawabganj Sadar and Shibganj upazila the river Mahananda and Pagla have great effects to the sedimentation process. All contaminated wells were in 'Active Ganges Flood Plain' and in 'High Ganges Flood Plain' but the wells of Barind Tract were safe from As contamination. Actually these Flood Plains are Holocene sediments and providing As contamination in groundwater but in case of lateral zoning with a 4 km assigned distance, it was found that most of the contaminated wells were within the first four kilometer from river or river systems (two or three rivers' combined system) and the contamination rate gradually decreases with the increase of the distance. It shows that older sediments in holocene aquifer has less contamination comparing with the new sediments of that holocene aquifer. Zone wise the percent of unsafe wells were given in the following table 5:

Table 5. Percent unsafe wells (HTWs, STWs and DTWs combined) in four upazilas of Rajshahi and Chapai Nawabganj districts

District	Upazila	% unsafe wells			
		1st zone (0-4 km)	2nd zone (4-8 km)	3rd zone (12-16km)	4th zone (16-20 km)
Rajshahi	Charghat	31	9	5	0
	Bagha	24	18	7	6
Chapaina-wabganj	Sadar	38	0	0	0
	Shibganj	29	21	0	NA

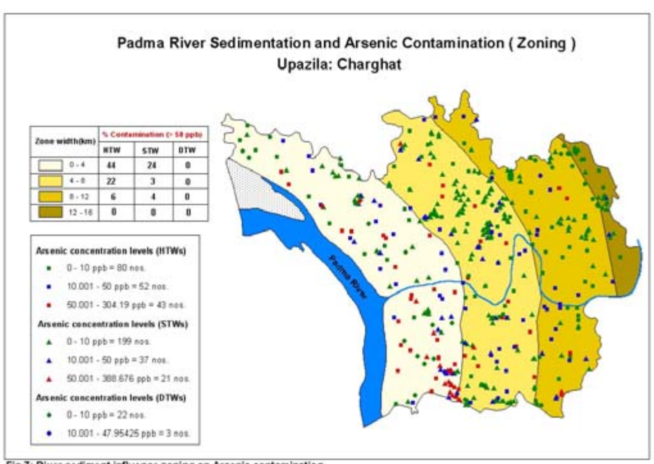

Fig.7: River sediment influence zoning on Arsenic contamination

In Charghat, within the 1st zone (0-4 km from the Padma), out of 135 wells (HTWs, STWs and DTWs), 42 wells (31%) were found to be unsafe (above Bangladesh standard of As concentration>0.05ppm). In 2nd zone (4-8 km from the Padma), out of 195 wells (HTWs, STWs and DTWs), 17 wells (9%) were found to be unsafe. In 3rd zone (8-12 km from the Padma), out of 105 wells (HTWs, STWs and

DTWs), 5 wells (5%) were found to be unsafe. In 4th zone (12-16 km from the Padma), there were 22 wells and all were found to be safe. It is revealed that higher number of unsafe wells is found to be in closer distance from the Padma River. The number, however, declines with the distance increasing from the river (see Fig. 7).

In Bagha, within 1st zone (0-4 km from the Padma), out of 161 wells (HTWs and STWs), 38 wells (24%) were found to be unsafe (As concentration > 0.05 ppm or 50 ppb).In 2nd zone (4-8 km from the Padma), out of 108 wells (HTWs and STWs), 19 wells (18%) were found to be unsafe.In 3rd zone (8-12 km from the Padma), out of 92 wells (HTWs and STWs), 6 wells (7%) were found to be unsafe. In 4th zone (12-16 km from the Padma), out of 33 wells (HTWs and STWs), 2 wells (5%) were found to be unsafe. Number of unsafe wells is also found higher in closer proximity of the river while their number decreases with the increase of the distance from the river (see Fig.8).

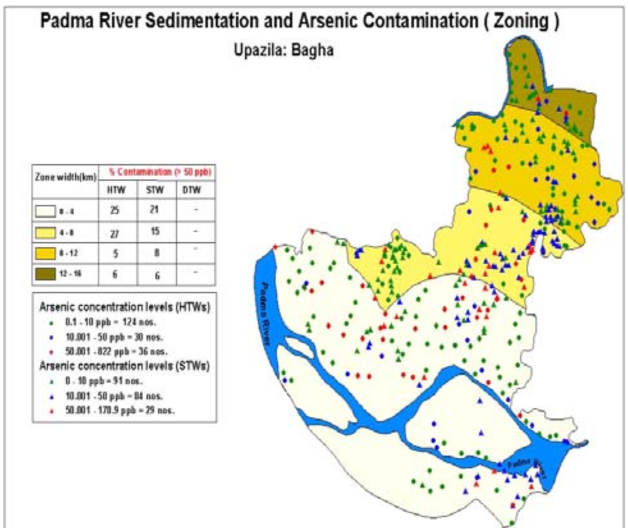

Fig.8: River sediment influence zoning on Arsenic contamination

In Chapai Nawabganj Sadar within the 1st zone (0-4 km from river system of the Padma and the Mahananda), out of 304 wells (HTWs, STWs and DTWs), 115 wells (38%) were found to be unsafe (As concentration > 0.05 ppm or 50 ppb). In 2nd, 3rd and 4th zones (4-8, 8-12 and 12-16 km from river system respectively), there were no unsafe wells. In this upazila number of unsafe tubewells is found to be 38%, which are within 4 km distance of the Padma and the Mahananda river system and those that were found safe are located beyond such distance from the rivers (see Fig.9).

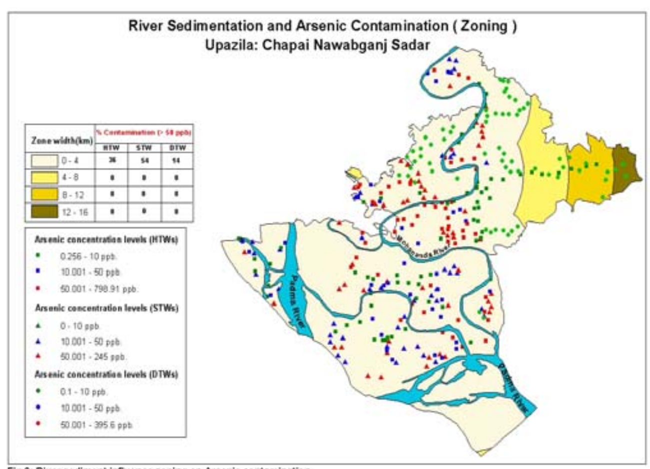

Fig.9: River sediment influence zoning on Arsenic contamination

In Shibganj, within the 1st zone (0-4 km from river system), out of 322 wells (HTWs,STWs and DTWs), 92 wells (29%) were found to be unsafe (As concentration > 0.05 ppm or 50 ppb).In 2nd zone (4-8 km from river system), out of 67 wells (HTWs, STWs and DTWs), 14 wells (21%) were found to be unsafe.

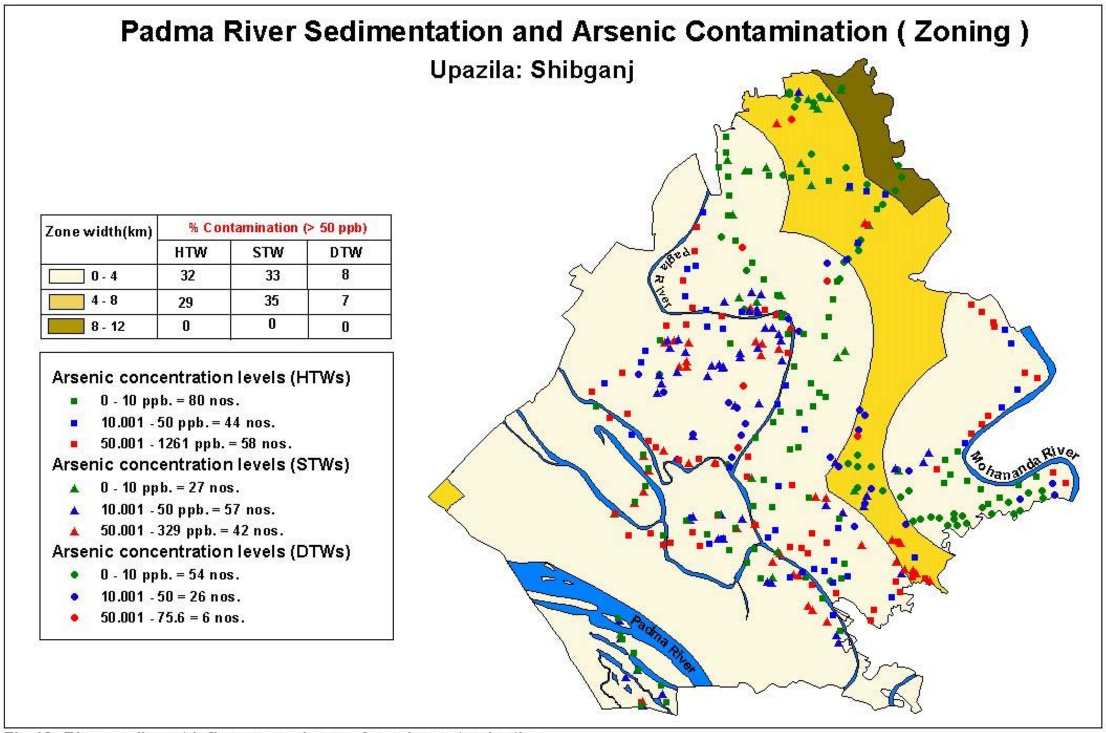

Fig.10: River sediment influence zoning on Arsenic contamination

In 3rd zone (8-12 km from river system), all wells were found to be safe. The concentration of As also gradually decreases with the increase of distance of the wells from the river systems of the Padma, the Mahananda and the Pagla (see Fig.10). Number of unsafe wells is also found higher in closer distance (0-8 km).

Conclusion and Recommendations

Conclusion:

Three types of tubewells i.e. Hand tubewells (HTWs), Shallow tubewells (STWs) and Deep tubewells (DTWs) have been studied in 4 upazilas of Rajshahi and Chapai Nawabganj districts. Among the three types of wells, arsenic concentration was found to be the highest with HTWs (27%), followed by STWs (21%) and the least with DTWs (7%). HTWs and STWs were highly contaminated as extracting water from the middle layers and DTWs were the least contaminated as extracting water from the deepest layers. It might happens that due to the wide range of water extracting aquifers and lots of discharge of DTW, As concentrations of extracting water coming from different layers mix and the water pumped out contained a distinctly diluted concentration. However, the middle layers, 40-160 feet below from the ground surface, reflected the highest level of arsenic contamination. The shallower layers up to 35 feet and the deeper layers below 160 feet from the ground surface showed safe concentrations of arsenic in groundwater. Arsenic concentration has no relationship with the age of the 3 types of tubewells tested in any site of the study areas. It was found that the river sedimentation process has impact on As concentrations in ground water. The river Padma is the prominent river for all four upazilas. Besides, for Chapai Nawabganj Sadar and Shibganj upazila the river Mahananda and Pagla have great effects to the sedimentation process. All contaminated wells were in 'Active Ganges Flood Plain' and in 'High Ganges Flood Plain' but the wells of Barind Tract were safe from As contamination. That is why Flood plains contain more As contamination. In case of lateral zoning with a 4 km assigned distance, it was found that most of the contaminated wells were within the first four kilometer from rivers or river systems (two or three rivers' combined system) and the contamination rate gradually decreases with the increase of the distance.

Recommendations:

- ✓ Additional, similar mapping needs to be done using GIS techologies in highly As contaminated upazilas across the country specially in South-West and North-West regions (i.e, greater Khulna, Jessore, Faridpur, Pabna and Rajshahi districts).

- ✓ Water testing is needed not only from certain middle layers but also from very deep layers as well and from the upper layer through installation of observation wells randomly in different depths in the highly As contaminated spots in each upazila.

- ✓ Impact of river sedimentation process on Arsenic concentration in ground water should be further studied.

References

Abdullah, S.K.M., (2002): Arsenic problem in the groundwater in Bangladesh. Proceedings on International workshop on Arsenic mitigation, Dhaka, 14-16 January 2002. LGD, Ministry of local government, rural development and co-operatives, GOB.

BGS/GOB/LGRD/DPHE, (2001): Arsenic contamination of groundwater in Bangladesh. Vol 1: Summary. BGS technical report WC/00/19. Volume 1.

BGS/MML/GOB (1999): Groundwater studies for Arsenic contamination in Bangladesh. Phase I. Rapiid Investigation Phase. Main Report.

Farhana S. Islam, Andrew G.Gault,Christopher Boothman, David A. Polya, John M. Charnock, Debashis Chatterjee and Jonathan R.Lioyd (2004): Role of metal-reducing bacteria in arsenic release from Bengal delta sediments. Nature, Vol.430:68-71 pp

Ghani M.A.; Rashid.,M.A. and Shah, A.L, (2004):Arsenic contamination and its impact on food production and environment. Paper presented in Third South Asia Water Forum (SAWAF-iii) in Dhaka, Bangladesh during July 13-15, 2004.

Huq, S.M.I, Department of Soil and Environmental Science, University of Dhaka and Ravi Naidu, CSIRO, Adelaide Laboratory, Australia (2003): Project Reports on Arsenic in groundwater of Bangladesh: Contamination in the Food chain.

McArthur J.M., Ravenscroft. P., Safiullah S. and Thirlwall M.F, (2000): Arsenic in groundwater: testing pollution mechanisms for sedimentary aquifers in Bangladesh. This paper is produced courtesy of AGU, the American Geophysical Union, the Copyright holders, from Water Resources Research, 37(1),109-117.

Rahman M. and Hossain, K.S (1999): Study Report on Source detection of Arsenic contamination in Bangladesh Ground water and Mitigation measures. Main Report, Volume 1: Water Supply, Paper No.557

The Daily Star (14 August 2004): Bacteria solution to groundwater arsenic.

Unicef-Bangladesh, 2000: Arsenic Mitigation in Bangladesh. Media Brief

WHO, 2001. Environmental Health Criteria 224. Arsenic and arsenic compounds (Second edition).