



# **Arsenic Contaminated Groundwater in Bangladesh: A Threat to Human Health and A Source of Drinking Water**

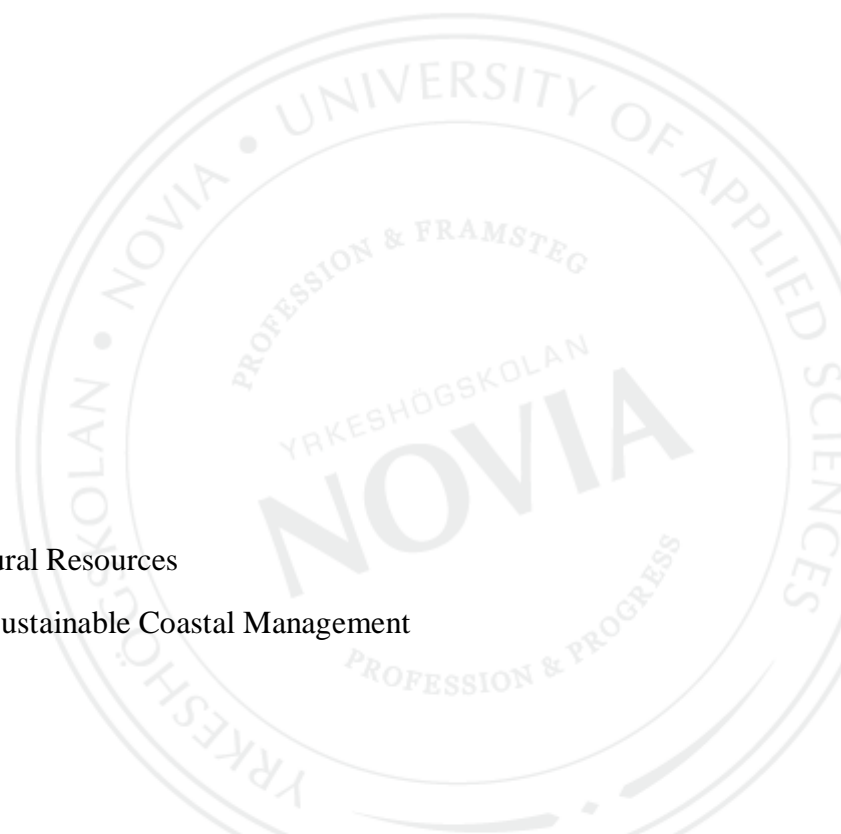
## **Case of Damurhuda Upazila**

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### Summary

The groundwater contamination by arsenic in Bangladesh has become a natural threat and people are suffering through drinking water. The scale and effect of this natural disaster is greater than anything seen before. In Bangladesh, people are using groundwater by pumping tube wells. Historically, tube wells were installed to prevent illness and death from gastrointestinal diseases.

The purpose of this paper is to discuss, the recent arsenic contamination status, the relation between arsenic contamination and over-exploitation of contamination and the age of the tube wells groundwater as well as that between arsenic contamination and the age of the tube wells. A survey of tube wells (n=2435) from three villages, selected by a NGO, under Damurhuda Upazila of Bangladesh, has shown that 22% of tube wells are arsenic contaminated. An analysis of the collected data indicates that arsenic contamination has relation with over-exploitation of ground water but not with the age of the tube wells. This unlikely relation with the age of the tube wells leads the area for further studies. Due to the contamination, it is an important issue for further studies, as a priority, towards sources of safe drinking water.

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Language: English    Key words: Arsenic, arsenic contamination, groundwater, water table, over-exploitation

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## **1 Introduction**

Arsenic, usually known as a notorious toxic, is being treated as one of the detrimental environmental pollutants, threatening the lives of millions people around the globe. Arsenic is not only a pollutant, but it is also used for murder, medicine and wallpaper. The history says that the accidental poisoning of Napoleon Bonaparte was due to the use of arsenical dyes in wallpaper during the time of his imprisonment on St Helena. Around 3000 BC, it was also known as the king of the poisons and it was used for strengthening the bronze which was to be given to the winners as a prize by the Egyptians, Greeks and Romans. So this toxic element was not unknown to the people (Mehrag 2005, 22). Now this poison has created a big problem by contaminating groundwater. About 80% of the total rural population of Bangladesh use tube wells for drinking water. But unfortunately this water is becoming arsenic contaminated and the people are suffering from arsenic related diseases. In this situation a lot of people are at risk. Approximately 5 million tube wells are arsenic contaminated and up to 70 million people have arsenic in their bodies for drinking this water. The permissible limit of arsenic in drinking water for Bangladeshi people is 50 µg/L but more than this permissible amount has been found in 61 districts among 64 (Rahman 1998, 11-15).

## **2 Objective of this study**

The objective of the study is to find out the recent contamination status of the study areas and the relation between arsenic contamination and over-exploitation of the ground water and that between arsenic contamination and the age of the tube wells.

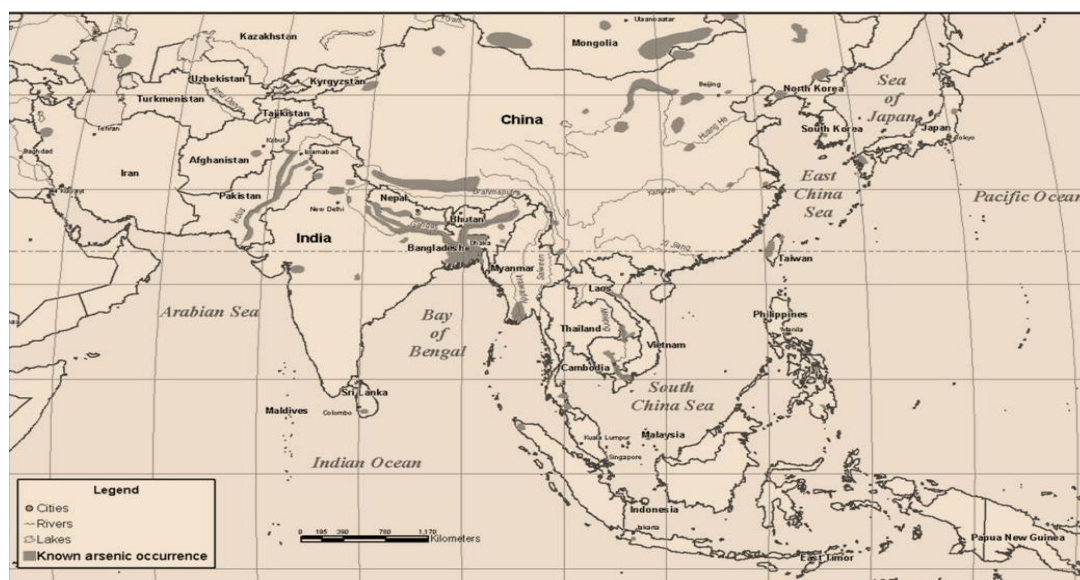
## **3 Review of the past studies**

With the collaboration of national and international universities and organizations, there has been a significant amount of research carried out to establish the relation between contamination status for over-exploitation of groundwater and the age of the tube wells. For the last two decades, researchers have been working with great interest on arsenic contamination worldwide. The review of the past studies shows that over-exploitation of ground water and the age of the tube wells are responsible for the arsenic contamination of the tube wells. Ravenscroft et al. (2009) found that the contamination threshold is being affected in respect to the age of the tube wells. The

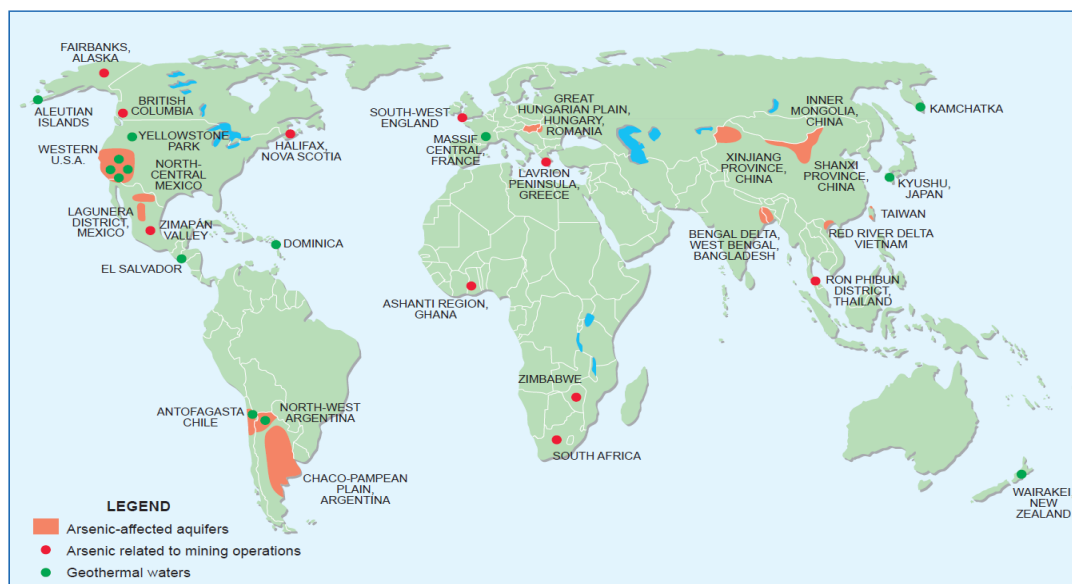
description was also presented by graph (figure 6) which shows the proportional relationship between contamination and the age of the tube wells. Most of the researches conducted in West Bengal, India, found that high-arsenic groundwater was not related to the areas of high arsenic concentration (Ghosh et al. 2008, 2-7). Some factors were being identified for the release of arsenic from those minerals in the shallow aquifer due to the oxidation. Over-exploitation of water for drinking and irrigation was one of the important causes for oxidation. In India, the origin of arsenic is natural but over-exploitation is spreading the contamination to the groundwater (Atanu2007, 1-12).

#### 4 Arsenic contamination in the world

Arsenic contamination has been treated as a major threat to the people around the world from developing to developed countries (figure 1). Among the developing countries Bangladesh, India, Nepal, Myanmar, Japan and Vietnam are the most affected countries in Asia as well as some parts of Africa, America and Europe (figure 2). Millions of people from South Asia and South-East Asia are suffering from arsenic contamination but among them Bangladesh is suffering at the highest level (Tutor et al. 2007, 1-17). About 24 million people are already affected by the arsenic contamination and about 75 million are at high risk (Safiuddin et al. 2001, 6).



**Figure 1. Ground water Arsenic contamination in south and south-east Asia (Hugh 2009, 647)**



**Figure 2. Documented cases of arsenic problems in groundwater related to natural contamination(Kinniburgh et al. 2001, 11).**

## 5 Bangladesh and Arsenic contamination

### 5.1 Geographical features of Bangladesh

Bangladesh is in South Asia, which is located beside the east of India. It is an agro based country where rice is the staple food. Geographically, it is a new land formation due to the sedimentation and most of the parts are less than 12 meters high above the sea level. It has been calculated that 10% of the land will be submerged if the sea level rises at least by one meter (Ali 1996, 171-179).

### 5.2 Arsenic pollution in Bangladesh

Arsenic pollution is an alarming topic in Bangladesh because some people are already infected by this through drinking groundwater. This came to the international attention in 1995 (David et al. 1995, 645–654). An overview of the arsenic pollution in Bangladesh is presented in table 1.

**Table 1. Statistics of Arsenic Calamity in Bangladesh (Karimw.y., 3)**

Total number of districts in Bangladesh	64
Total Area of Bangladesh	148,393 km <sup>2</sup>
Total Population of Bangladesh	125 million
GDP Per Capita (1998)	US\$260.00
WHO Arsenic Drinking Water Standard	0.01 mg/l
Bangladesh Arsenic Drinking Water Standard	0.05 mg/l
Number of Districts Surveyed for Arsenic Contamination	64
Number of Districts Having Arsenic above 0.05 mg/l in Groundwater	59
Area of Affected 61 Districts	126,134 km <sup>2</sup>
Population at Risk	75 million
Potentially Exposed Population	24 million
Number of Patients Suffering from Arsenicosis	8,500
Total Number of Tube wells in Bangladesh	8 million
Total Number of Affected Tube wells	5 million

## 6 Study Area

The study was carried out in the three villages Kapasdanga, Natipota and Juranpur (figure 3) under Damurhuda upazila (Figure 4), in the southern part of Bangladesh. Upazila is the local administrative area consisting of several villages and acts as a sub unit of a district. This research is conducted about 233 km far from the capital city Dhaka.



Figure 3. DamurhudaUpazila in Bangladesh map (Google map)

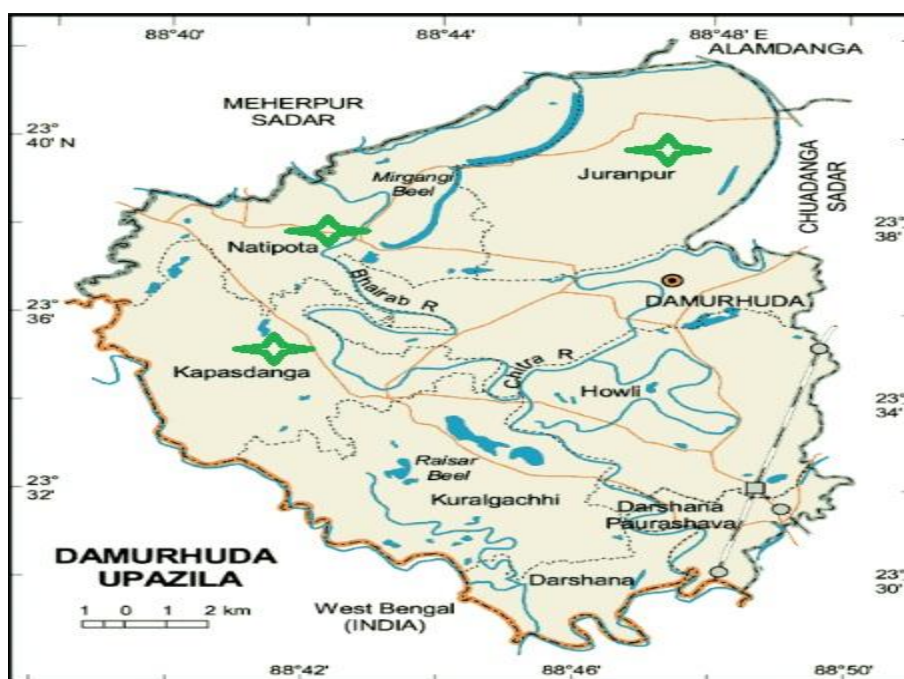


Figure 4. DamurhudaUpazila Map - three villages are indicated by a star sign(Google map)

## 7 Arsenic

### 7.1 The Nature of Arsenic

In Bangladesh, the impact and the presence of detrimental element was not found normally in drinking water because the water was not being tested at an interval of time. During the 1980s, there were some poisonous effects of an unknown element which became more toxic over a period of time. Since the element was colourless, tasteless, and odourless unknown element made it was tough to identify the element and its nature. Gradually the unknown element became more toxic in a low concentration. Finally the unknown element was recognized as arsenic. Arsenic occurrence varies from place to place depending on geographical location and the climate. In most of the cases, it has been found in the places of deposited sands by the large rivers and the worst presence has been observed in the tropical river basin of Asia, such as the Ganga-Brahmaputra river basin (Ghosh et al. 2008, 5). It has also been found in unconsolidated sediments and sedimentary igneous and metamorphic rocks of which are a few thousands to more than a billion years old. Arsenic is also present in various climates, from hot to tropics as well as from Arctic Alaska to hyper arid deserts. Along with the variation of geographical locations and climate changes, the contamination of groundwater has the particular connection to the layers of the earth surfaces and to certain depths of the wells (Ravenscroft et al. 2009, 2).

### 7.2 Arsenic Chemistry

Arsenic is a naturally occurring element in the earth's crust at a concentration of 1.8 ppm. On the basis of abundances element, it ranks 22<sup>th</sup> in nature and 12<sup>th</sup> in human body. It occurs in both organic and inorganic forms (Mason, 1966). Dimethylarsinic acid ( $C_2H_7AsO_2$ ) and monomethylarsonic acid ( $CH_5AsO_3$ ) are more common organic forms while arsenic trioxide ( $As_2O_3$ ) and sodium arsenate ( $NaH_2AsO_4$ ) are inorganic in the water (table 2). Arsenic has four oxidation states,  $As^0$ ,  $As^{3-}$ ,  $As^{3+}$ ,  $As^{5+}$  and among them  $As^{3+}$  and  $As^{5+}$  inorganic forms ( $As^{3+}$  is 60 times toxic than  $As^{5+}$ ) dominate in ground water (Dipankar et al. 1995, 917-925).

**Table 2. Features of Arsenic (Jones, 1903, 15)**

<b>Atomic number</b>	<b>33</b>
<b>Atomic symbol</b>	As
<b>Atomic weight</b>	74.92
<b>Classification</b>	Metalloids
<b>Electron Configuration</b>	[Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>3</sup>
<b>Phase</b>	Solid
<b>Density</b>	5.727 g/cm <sup>3</sup>
<b>Oxidation States</b>	5,3,2,1,-3
<b>Crystal Structure</b>	rhombohedral

### 7.3 Source of arsenic in groundwater

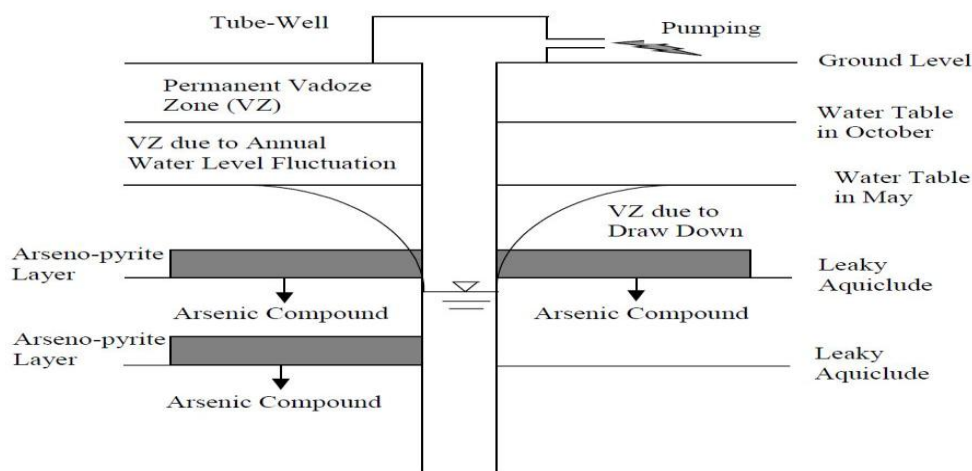
Arsenic sources in the environment can be both natural and anthropogenic but it mostly depends upon the geographical location, biological and industrial activities of the certain places. A high concentration of arsenic can be present in the oxidized environments (arid or semi-arid) and in intensely reduced aquifers (Nuñez et al. 2009, 9). The mining of geological materials, like coal and iron ores, is one of the most common anthropogenic ways for arsenic contamination (Fengxiang et al. 2003, 395-401). Improper disposal of sulfide-rich ores waste from mining may cause arsenic contamination as well (Abrahams & Thornton 1987, B1-B8; Williams 2001, 267-278). In the last decade arsenic containing chemicals, possible source of arsenic, were used but nowadays it has been controlled due to the environmental and health risks. Though the arsenic containing pesticides, agricultural products, textile chemicals, tanning agents of leather, anti-corrosive agents, glass and ceramic products and paints have been forbidden to use and produce their impact still the detrimental effect. In spite of the detrimental effects, arsenic (as arsenic pentoxide, a by-product of sulfuric acid production) is still being used in wood preservation and plastic industries as an antimicrobial additive (Parviainen et al. 2006, 6). In Bangladesh and West- Bengal of India, the source of arsenic in the groundwater is natural (Ahmed

1999, 22). Some of the studies (Dhar et al. 1997, 48-49) have showed that the electric poles which are being used for the electrification are treated with arsenic and these are also another source of arsenic. The groundwater in the river delta and Bengal basin is also naturally responsible for this contamination (Luziet al. 2004, 12).

## 7.4 Arsenic contamination of groundwater

### 7.4.1 The mechanism of arsenic contamination in groundwater

Arsenic is not a rare element in the nature but it is unusual when it is found in the water (Cheng et al. 2005, 475). There are two well-known theories established to explain the mechanism of arsenic movement from the earth crust to groundwater. Possible theories are oxidation and oxy-hydroxide reduction theory but of these two theories oxidation theory is more accepted (Safiullah 2001, 109–17). According to the oxidation theory, the arsenic is released from sulfide minerals (Arsenopyrite) due to the reaction with oxygen in shallow aquifers. When the water exploitation rate for drinking and irrigation is more than the recharge rate then the water table goes down, and this movement of water table causes the diffusion of oxygen within the pore spaces of the sediments (figure 5). The diffused oxygen is being accumulated on the upper part of the water table as a hydrated iron arsenate compound which is known as pitticite. This compound is soft and water soluble, so the light pressure of tube wells break it and convert it to a powdery substance which ultimately is being soluble in water (Mallick&Rajagopal 1996,956-958; Mandal et al. 1998, 201-235).

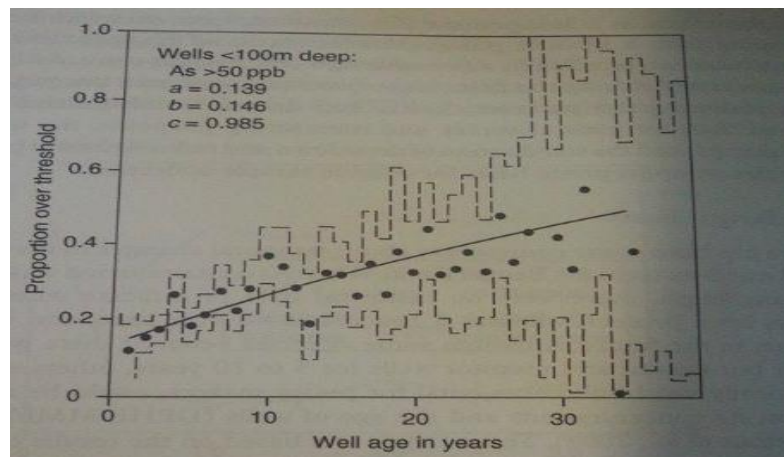


**Figure 5. Aerobic Condition in Groundwater around a Heavy-Duty Tube well (Karim et al. 1997, 783-792)**

Nowadays the oxy-hydroxide reduction theory, proposed by Nickson et al. (200, 402-413), is also being accepted by some scientists and researchers for the mobilization of arsenic. According to this theory, arsenic is derived by desorption from ferric hydroxide minerals in reducing conditions and the ferric hydroxide minerals are coating the aquifers sediments (Bhattacharya et al. 1997, 79-92).

## 8 Age of tube wells and arsenic contamination

During the discovering time of arsenic contamination in Bangladesh, it was challenging to assume that whether it has always been present and was increasing over time or not. Due to having no historical data, it was unpredictable to assume the future status and the consequences. Some of the government and non-government organizations believed that the arsenic contaminated tube wells should be monitored for 5 to 10 years (McArthur et al. 2004, 1255-1293). After the time being, a significant number of studies have been done in several places of Bangladesh but the results showed that arsenic content is related with the age of tube wells. It has been found that less than 25% of new tube wells have exceeded the permissible level (50 ppb) for human while 40% for 10 years old tube wells. (Sengupta et al. 2006, 1823-1829). Ravenscroft et al. (2009, 96) revealed the correlation between contamination and age of the wells (figure 6).



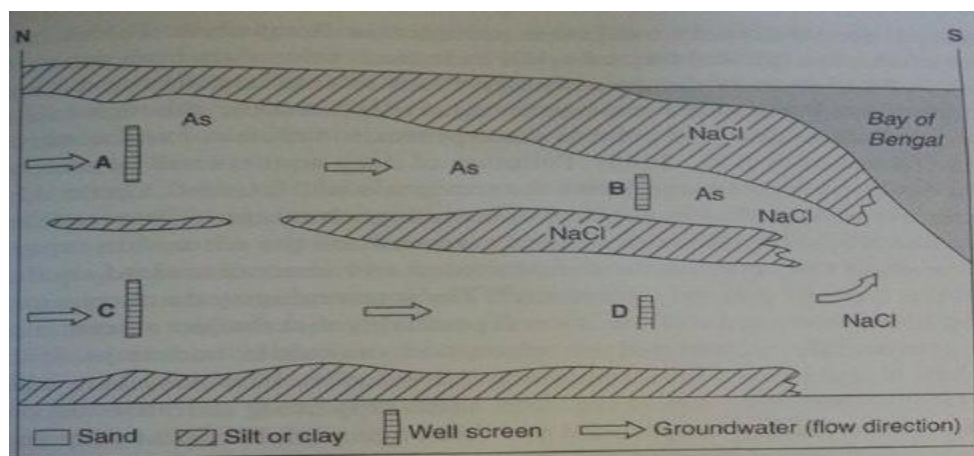
**Figure 6: Temporal trends of arsenic in groundwater in Bangladesh (Ravenscroft et al. 2009, 96)**



**Figure 7.** A pump painted in red indicates that the water is contaminated with arsenic (International Atomic Energy Agency)

## 9 Over-exploitation changes contamination

Bangladesh is situated in the Bengal basin and the people are basically pumping water from this basin. This pumping either for drinking water and irrigation is causing the arsenic pollution. People are usually pilling into deeper aquifer in those areas where the arsenic is present in the upper aquifer. In most of the cases, pilling is destroying the Arsenic layers as a result the Arsenic becoming soluble into the water. Most of the places in Bangladesh, ground water tables are going down due to the large consumption of water because the consumption rate is higher than the recharge rate. That is why the water becoming unreachable for pumping. At the same time, arsenic is being released due to the oxidation of arsenic containing minerals. The mechanism has been shown in the figure 5.



**Figure 8.** Schematic hydro-geological section through the lower Bengal basin (Ravenscroft 2009, 113)

In the Bengal basin, aquifers are around Holocene and Pleistocene strata. An ideal hydrological section (Fig. 8), consisted of four imaginary wells, through the Bengal basin has been described below.

**Well A** – This is the shallow aquifer and worst in condition due to the migration of arsenic. Arsenic contaminated water can come out during pumping for drinking water and irrigation.

**Well B** – This is similar to well A but here is the abundance of salinity due to the coastal section. Withdrawal water can be partially replaced by the horizontal inflow from the coast, but the inflow and replacement rate is so slow because this aquifer is not open to the coast.

**Well C** – The water of well C is arsenic free but it becomes risky when the water of upper wells is arsenic contaminated, because either the pumping mixes the arsenic or the recharge water comes from well A. This well is recharged through horizontal inflow or vertical leakage.

**Well D** – According to the geographical principle, the well D is similar to well C. If the pumping is not sustainable then this well becomes salinized long before the arsenic contamination (Ravenscroft et al. 2009, 112-113).

## **10 Effects of Arsenic Contamination**

### **10.1 Human Health**

Arsenic contaminated groundwater acts as a slow poison by affecting the people in chronic and acute diseases. The effects of acute disease is worse than the chronic effect because the symptoms of acute can be noticed immediately after drinking the water, whereas the chronic exposes the symptoms after a few years of drinking (figure 9&10). The exposure of a chronic effect as hypo pigmentation and hyper pigmentation can be seen on the skin while the acute can lead to coma and death (Hurd 2001, 15). A large number of populations in Bangladesh are suffering from melanosis, leuco-melanosis, keratosis, hyperkeratosis, dorsum, non-petting oedema, gangrene and skin cancer due to arsenic contamination (Karim 2000, 12). An arsenic related disease depends on the ingestion and excretion of arsenic from the human body and it has been reported that 40% to 60% arsenic can be retained into the human body. The people who are working hard such as day

laborare more likely to be arsenic infected due to high consumption of water (5 liters / day) (Farmer 1990, 342-348).



**Figure 9: Skin Lesions on Palm due to Arsenic Intake in Drinking Water (Mandal 1998, 185-201)**



**Figure 10: Skin Lesions in Soles due to Arsenic Intake in Drinking Water (Smith et al. 2000, 1093-1103)**

## 10.2 Social Life

Arsenic poisoning is causing big social problems in many parts of the world along with the health issues. In Bangladesh, if we see back to the last couple of decades when the arsenic problem was discovered, the people became more conscious to keep distance from the affected ones. Some schools, colleges, and public places were restricted for them and they even had to live a miserable life. Husband had the social and mental pressure to live with affected wife and sometimes it separated them from the conjugal life. The worst scenario was that the unmarried people were to remain unmarried due to the arsenic problem. It was thought that arsenic is a contagious disease. Currently, due to the role of media and technology, people have got the actual picture of the arsenic poisoning and they are much more conscious about the propaganda. Still now, the affected people are very shy to let others know about their contamination though it is not a contagious disease. In some rural areas, severe criticism among children and women is causing social problems (Hasan et al. 2005, 2201-11).

## 11 Methodology

Qualitative method was used to carry out this research. This chapter describes the research procedure that was used in the collection and analysis of the data. It includes the data source, research design, data collection and method of data analysis and presentation.

### 11.1 Data source

Primary data was collected by conducting a survey on 2435 tube wells and health condition of those tube wells users. In this survey, eight questions were determined to ask from the respondents.

### 11.2 Research design

At the very beginning of the survey a study has been designed for the well-managed field work which was evaluated by a group of local people. The key steps of this study design have been shown in a tabular presentation.

<b>Well-Designed Survey</b>	<p><b>Design of the questionnaire</b></p> <ul style="list-style-type: none"> <li>- A ‘meaningful, realistic and plausible’ questionnaire was designed to capture the real condition of drinking water and health issues</li> <li>- Biases were minimized through the awareness</li> <li>- The draft questionnaire was reviewed externally</li> </ul>
<b>Carried out by</b>	<p><b>Trail and training</b></p> <ul style="list-style-type: none"> <li>- Draft questionnaire was pre-tested in three hydro-geological representative locations</li> <li>- About 20 enumerators were specially trained to carry out the survey</li> </ul>
<b>Representative sampling</b>	<p><b>Field work (Actual survey)</b></p> <ul style="list-style-type: none"> <li>- The survey was carried out in three villages which had arsenic problems</li> </ul> <p>Random sampling methodology was used to survey 2435 tube wells among</p>

	the villages
<b>Data analysis</b>	<p><b>Data Analysis</b></p> <ul style="list-style-type: none"> <li>- Extra care was taken to reduce the personal error for data interpretation</li> <li>- Modification of data was prohibited</li> <li>- Preliminary result of analysis was presented and discussed before preparing 1st draft</li> </ul>

### 11.3 Data collection

A questionnaire was used to interview from door to door. A male family member, who is the head of the household, was interviewed per tube well. All of the tube wells in these villages were tested by the government of Bangladesh to check the presence of arsenic.

### 11.4 Data analysis and presentation

The collected data has been analyzed throughout Microsoft Excel and statistical software PSPP. In this data set, the contamination status in respect to over-exploitation and age of the tube wells has been tested by using Pearson's chi-squared test ( $\chi^2$ ). This test has been used as two-sided version tests against the alternative. In this case the true variance is either less than or greater than the specified value(0.50).According to the Pearson's chi-squared test ( $\chi^2$ ), we have two hypotheses; hypothesis – I for user range and contaminated tube wells and hypothesis –II for age of the tube wells and contaminated tube wells.

Hypothesis –I, Null Hypothesis ( $H_0$ ): There is a relation between the over-exploitation of water and the contamination percentage.

Alternative Hypothesis ( $H_1$ ): There is no relation between over-exploitation of water and the contamination percentage.

Hypothesis – II, Null Hypothesis ( $H_0$ ): There is a relation between the age of the tube wells and the contamination percentage.

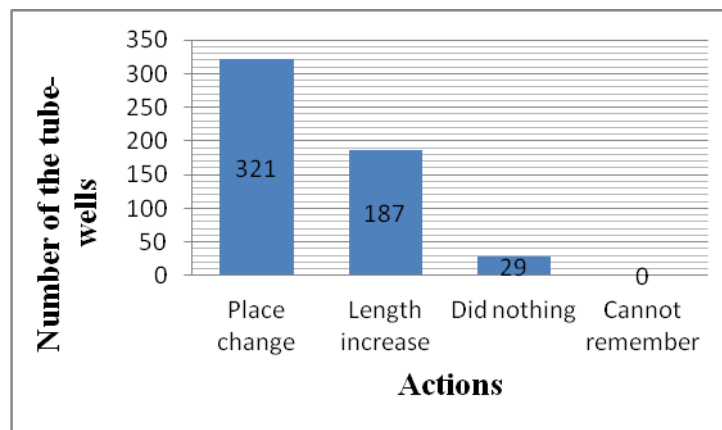
Alternative Hypothesis ( $H_1$ ): There is no relation between the age of tube wells and the contamination percentage.

**Table 3: The questions about arsenic and arsenic contamination**

Have you heard about Arsenic?		
	Yes	No
	2435	0
Have you experienced Arsenic contamination in your tube well water?		
	Yes	No
Respondents	2435	537
		1898

The information about the devastating arsenic contamination has been reached to the people of the survey areas. From the collected data (table 3), it has been observed that 100% respondents have the information about arsenic and 22% have arsenic contamination problem in their tube wells.

**Table 4: If the tube well is contaminated, how do you solve the Arsenic contamination?**



**Figure 11: Actions taken towards arsenic free tube well**

According to the collected data (table 4), 537 tube wells were contaminated by arsenic whereas 1898 tube wells were not infected. In the case of contamination, different actions were taken to get arsenic free drinking water. Among the total 537 contaminated tube wells, 321 were replaced, the length of the tube was increased for 187 tube wells and 29 tube wells were left unchanged.

**Table 5: If the tube well is contaminated, nowadays what is the main source of drinking water of your family?**

Sources	Respondents
Same tube well	8
Replaced tube well	524
Dug well	0
Rain water	2
Surface water (river, pond, lake, canal, irrigation channel)	3
<b>Total Respondents 537</b>	

According to the data analysis (table 5), it has been found that 524 tube wells were modified by changing places or increasing tube length. We have also been noticed that five people have stopped tube wells' water and started using rain and surface water. Eight people have been found using the same contaminated tube wells instead of taking any initiative to change the water source or tube wells.

**Table 6: The questions about arsenic related diseases.**

<b>Do your family members have arsenic disease? (only for contaminated tube wells)</b>		
<b>Number of respondents</b>	<b>Contaminated tube wells</b>	
Yes	513	513
No	1649	10
Do not know	27314	
<b>Did your family members have arsenic disease? (If the answer is No and Do not know)</b>		
Yes	No	I cannot remember
132	1790	0

From the survey data of (table 6), 513 respondents of the contaminated tube wells reported about the arsenic disease of their family members whereas 1649 respondents informed about their family members as non-infected. On the other hand, 273 respondents did not have any information whether they were infected or not. Among the 1922 respondents, who

replied as 'No' and 'Do not know' to arsenic disease, 132 replied that their family members had diseases before the survey conducted.

**Table 7: How old is your tube well?**

Range of age	Number of tube wells	Contaminated tube wells (contamination %)
Less than 5 years	832	75 (9%)
6 to 10 years	1158	187 (16%)
11 to 15 years	393	265 (67%)
16 to 20 years	47	9 (19%)
More than 20 years	5	1 (20%)
	Respondents	2435

**Table 8: Pearson's chi-squared test between age of the tube wells and contamination percentage**

		Contaminated	Group
<b>Contaminated</b>	PearsonCorrelation	1.00	.17
	Sig. (2-tailed)		.784
	N	5	5
<b>Group</b>	PearsonCorrelation	.17	1.00
	Sig. (2-tailed)	.784	
	N	5	5

From the correlation  $p = 0.784$ ,  $r = 0.17$  and  $N = 5$ . Null hypothesis ( $H_0$ ) is rejected.

**Table 9: How many people are using your tube well?**

User Range	Number of tube wells	Contaminated tube wells (contamination %)
1 to 5	836	148 (17%)
6 to 10	1404	251 (18%)
11 to 15	179	126 (70%)

16 to 20	12	9 (75%)
More than 20	4	3 (75%)
Respondents	2435	

**Table 10: From the Pearson's chi-squared test between over-exploitation (user range) and contamination percentage**

		Contaminated	Group
<b>Contaminated</b>	PearsonCorrelation	1.00	.89
	Sig. (2-tailed)		.042
	N	5	5
<b>Group</b>	PearsonCorrelation	.89	1.00
	Sig. (2-tailed)	.042	
	N	5	5

From the correlation  $p = 0.042$ ,  $r = 0.89$  and  $N = 5$ . Null hypothesis ( $H_0$ ) is accepted.

## 12 Results

From the data analysis, it has been found that over-exploitation of water from tube wells cause arsenic contamination. On the other hand, age of the tube wells does not have any influence on contamination.

## 13 Discussion

There are many initiatives have been taken by the Bangladesh government, local and international non-governmental organizations (NGOs) and some of the Bangladeshi universities and who are working on different projects to combat this contamination. This was one of the main ways to make the people aware of arsenic. The most effective way was the painting of contaminated tube wells as red and safe as green. Through these initiatives, arsenic contamination is well known to most of the people. It has been found that some people have not taken any initiative concerning the replacement of contaminated tube wells. Due to the different reasons, the owners did not take any initiatives but the reasons behind this were not a part of this survey. They were asked to not drink water from these tube wells but due to the lack of alternative sources, they were bound to use the

same tube wells. During the data collection, it was found that some people were drinking from the red painted (arsenic contaminated). People have been using those red colored tube wells for every purpose in spite of their awareness. Because arsenic is colorless, odorless and gives no acute symptoms like fever and pain immediately. Though some people have been using surface and rain water for their daily necessities, but it was not permanent solution for arsenic free water. According to the different research articles, the contamination has relation with age of the tube wells and over-exploitation of water. On the other hand, from the interpretation of collected data, it was found that the relation was only between contamination and over-exploitation of water. This unlikely relation between contamination and the age of the tube wells brought out several possibilities behind this result, such as different depth of the tube wells, insufficient number of tube wells which are older, geographical properties of the places. The further experiments should be carried out to identify the actual cause behind this relation.

## **14 Recommendation and suggestion**

The following recommendations were raised in mind during the survey. These have been recommended in respect to the reality what we have been experienced along with the opinions from the affected people.

1. Regular basis water testing programs should be carried out by the health workers of the local government so that people can be benefited in two ways; a) in arsenic contamination tube wells determination and b) awareness increase due to the programs initiation. If the workload is huge for them, local youth organizations can also join to continue the program effectively. Therefore, the youth organization and health workers should have integration, proper plan, education and training. In the field level, they should advise the people about the arsenic contamination, sources of arsenic free water, and the treatment programs including the nutrition.
2. The government and non-governmental organizations (NGOs) should provide free treatment and medicines, such as skin creams for keratosis, basic tablets for fungal infections. Pregnant women should be under special care so that they can be examined to measure the impact of arsenic exposure on children not born yet. In case of severe contamination, patients should be forwarded to nearest hospital.

3. Being an agricultural based country, most of the people are using groundwater irrigation system, so the presence of arsenic in irrigation water should be measured like tube wells water measurement.
4. Children should be observed carefully so that they cannot drink water from unsealed red painted tube wells. If it is possible to get arsenic free water, the red painted tube wells should be sealed.
5. A team of social workers, chemists, geologist, health workers, politicians, and local people should be formed to assess the current situation of the arsenic contamination, and the people should be warned according to the assessment.
6. Social workers should inform people about this non-contagious arsenic disease and monitor carefully so that infected people cannot be deprived and neglected from proper attention.
7. The use of fertilizers and pesticides should be minimized or stopped in the area of severe contamination. The same importance should be given to irrigation pumps.
8. The municipality should list the arsenic containing waste for secure management, so that arsenic cannot be infiltrated into the groundwater.
9. The government should have a separate financial sector in the annual budget for arsenic contaminated areas to ensure adequate drinking water, investigate arsenic contamination level, installing remediation plants and replacing mostly used tube wells.

## **15 Conclusion**

Arsenic contaminated ground water is being treated as an alarming issue in Bangladesh, but if this issue cannot be treated with sustainable mitigation efforts then this phenomenon might spread out as an epidemic in the country. The history of water consumption behavior was switching from surface water to groundwater in order to reduce water-borne diseases. The presence of arsenic in groundwater was detected after a long period of time, so it is better to test the water in regular basis to ensure that there is no other toxic element in the water. Although arsenic contamination has been declared as a national disaster by the Bangladesh government, but along with all initiatives towards arsenic free drinking

water, government should find out long term alternative source. Nowadays, it is necessary to focus on arsenic free water supply, alternative sources, water quality improvement and surveillance activities in order to keep the nation away from arsenic-attributable diseases.

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## Appendices

### Survey Questionnaire

#### Arsenic Contaminated Tube wells

**Serial Number:**

1. Have you heard about Arsenic?

- a) Yes            b) No

2. Have you experienced Arsenic contamination in your tube well waste

- a) Yes            b) No            c) Not sure

3. If yes, what did you do?

- a) changed the place    b) increased the length of tube    c) did not do anything  
d) I can't remember

4. If As contaminated, what is the main source of drinking water for your family members?

- a) Same Tube well    b) Replaced tube well    c) Dug well    d) Rain water    e)  
Surface water ( river, pond, lake, canal, irrigation channel)

5. If Tube well, how old your tube well is?

- a) Less than 5 years    b) 6 to 10 year    c) 11 to 15 years    d) 16 to 20 years  
e) More than 20 years

6. How many people are using your tube well?

a) 1 to 5   b) 6 to 10   c) 11 to 15   d) 16 to 20   e) More than 20

7. Do your family members have arsenic disease?

a) Yes                      b) No                      c) Do not know

8. In case of No and Do not know, was any member infected?

b)      Yes                      b) No                      c) Do not know