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Quality Analysis Based on Water Quality Criteria of BMDA's Drinking Water Supply System in Barind Area.

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Abstract

An investigation was carried out to assess the water qualities of drinking water supply system and its extents of impurities in groundwater abstracted from BMDA deep tube wells in Barind area. Water samples from a total of 275 deep tube wells were collected and tested in BMDA laboratory. Samples collected from different sites (deep tube wells) were analyzed for physic-chemical, biological and hydrological parameters with standard methods and after chemical analysis of the collected samples, different physic-chemical, biological and hydrological properties were found. Among all considered parameters of ground water, concentrations of arsenic, iron, chloride, pH, total hardness and total E. coli bacteria were found within the permissible limits for potable water. Other parameters like calcium, magnesium, electrical conductivity, dissolved oxygen, total dissolved solid etc. were also determined and found within permissible limits. In a very few cases like, electrical conductivity**,** calcium, magnesium etc. were slightly without permissible limits. Except those, the quality of drinking water supply system from BMDA's deep tube wells in the study area is safe for drinking purpose and other domestic uses. It is recommended as more suitable and sustainable drinking water source for this study area.

Keywords: **Deep Tube well, BMDA, Ground Water, Drinking Water, Water Quality Parameters**

Introduction

Water is probably the only natural resource to touch all aspects of human civilization-from agricultural and industrial development to cultural and religious values embedded in society. It covers 75% of the earth's surface. Fresh or drinking water is found as groundwater in underground aquifers and on the surface in ponds, lakes and rivers. Seas and Oceans account for 97% of all water on earth. But this water contains dissolved salts and other elements, and is therefore unfit to drink. The remaining water is found in various forms in this earth, keeping about only 1% for drinking and other safe uses.

All available water is not suitable for all purposes; by adding or subtracting some amount of ingredients make the water suitable for a particular use. The uses of water are of various types like agricultural, industrial, geological, sanitary, domestic and drinking etc. Water when used for any purposes, depends on the source of supply and its degree of mineralization. The presence and degree of impurities can easily be determined by chemical analysis. Water is used for various purposes and the nature of chemical analysis of water depends on the purpose where it is used for.

Drinking water supply and irrigation are the major utilization of water for the benefit of human being. Ground water and surface water used by man are of different characters. Ground water contains dissolved minerals from the soil layers through which it process. In the process of seepage through ground water gets depilated of most of the microorganism originally present in the surface water.

Surface water contains a lot of organic and mineral nutrients which feed algae and large bacteria population. But the surface water sources continue to be contaminated with runoff water from agricultural fields containing pesticides, fertilizers, soil particles, waste chemicals from industries and sewerage from cities and rural areas.

A large number of elements present in water may be toxic to plants, animals or human beings. Presently the water resources of Bangladesh are being polluted due to uncontrolled discharge of wastes into the natural environment and the effect of fertilizers and insecticides application on agricultural land. In addition to these, the ground water of several parts of Bangladesh has been contaminated with arsenic and other elements to the extent beyond drinking and irrigation limits. So it is important to monitor water quality for mitigation of water pollutants including arsenic for safe drinking and irrigation in Bangladesh.

Water quality is very crucial for domestic use, especially for drinking purpose, and therefore, water needs to be properly handled. It was reported that about 80 million people in Bangladesh used improved drinking water sources that meet the GoB (Government of Bangladesh) standards for arsenic and *Escherichia coli (E. coli)* and 73.3 million people used improved drinking water sources that do not meet the GoB (Government of Bangladesh) standards for arsenic and *E. coli,* out of 173.3 million people. They had access to improved water sources in Bangladesh (BBS and UNICEF, 2018).

Water quality at the source often differs from water quality at the point of use. Recent studies and trends in ground water development for irrigation have proven the suitability of the alluvial aquifers in Bangladesh among the most productive in the world. Deep tube wells (DTWs) are included for construction of irrigation water distribution system. For confirmation about the quality of water for human consumption, laboratory test of the same is necessary. Feeling such necessity, provision of water quality test is incorporated in Barind Multipurpose Development Authority (BMDA) profile. In this background water samples are collected from the aforesaid deep tube wells and tested in different laboratories for inter comparison of the result.

The aim of the present study was to assess the quality of drinking water lifted from BMDA's deep tube wells and to ensure safe drinking water for the people in the study area. Present study also aimed to assess and compare the ground water quality.

A Review on Water Quality

About 97% water is exists in oceans that is not suitable for drinking and only 3% is fresh water wherein 2.97% is comprised by glaciers and ice caps and remaining little portion of 0.3% is available as a surface and ground water for human use (Miller, 1997). Safe drinking water is a basic need for good health and it is also a basic right of humans. Fresh water is already a limiting resource in many parts of the world.

Drinking water has been the main focus of attention since the early 1990's when widespread contamination of groundwater by Arsenic (As) was discovered in shallow aquifers of Bangladesh (BGS-DPHE 2001). However, As (Arsenic) contamination in groundwater has implications for agricultural as well as potable water supplies. In Bangladesh, nearly 35 million people are at risk from As, as concentrations in drinking water exceeding 50 μg l^{-1}, the current maximum contamination level (MCL) used in Bangladesh, are common (Nordstrom, 2002).

Considering the World Health Organization (WHO) MCL of 0.01 mg l^{-1} As, some 70 million people, would be considered at risk. According to WHO surveys, an estimated 35–77 million people have been chronically exposed to As via drinking water in what has been described as the "*largest mass poisoning in history*" (Flanagan et al., 2012).

A survey of 3534 tube wells in 61 Districts found that the water in 25% of the wells exceeds the Bangladesh standard. High As concentration was mainly limited to groundwater from shallow aquifers with depths less than 100 m. A total of 77 million people of Bangladesh are exposed to toxic levels of As (WHO Standard of (10 μg/l) in their drinking water (Argos et al., 2010) that primarily comes from shallow ground water.

In Asia and the Pacific, on average, about 32% of the population uses groundwater as a drinking water source (Morris et al., 2003). However, there are regions where dependence on groundwater for drinking purposes is much larger. For example, 60% of the rural population in Cambodia relies on groundwater (ADB 2007a) and 76% of people who do not have access to piped system depend on tube wells in Bangladesh (ADB 2007b; ADB 2007c). The safe drinking water plays an important role for the development of good health condition of a nation.

The World Health Organization (WHO) states that water containing many types of impurities from various sources causes different types of water borne diseases and each year millions of people suffer from such diseases due to unsafe drinking water supplies (Ahmed and Rahman, 2000). The Arsenic contamination in groundwater is increasing at an alarming rate. Today, in Bangladesh, an estimated 35–77 million people have been chronically exposed to Arsenic via drinking water. An estimated 25% of the wells exceed Arsenic levels according to the Bangladesh standard (Qureshi et al, 2014). Nearly 14% samples collected from shallow tube wells exceed As concentrations of 50 μg/L (BBS and UNICEF, 2011).

Microbial contamination of drinking water quality is the second leading risk factor for diarrheal diseases. The majority of rural Bangladeshis consume drinking water from groundwater aquifers using shallow tube wells rather than surface water. These shallow tube wells, with depths less than 140 feet, are relatively inexpensive to install, require little labor and maintenance, and provide access to drinking water that is much less contaminated with microbial pathogens than surface water (Van Geen et al., 2003).

More generally, fecal contamination of shallow groundwater is one reason for the persistence of diarrheal disease in Bangladesh (Howard et al., 2006; Luby et al., 2008; Van Geen et al., 2011; Wu et al., 2011b). Exposure to either high arsenic concentrations or high fecal microbe concentrations in shallow wells indicates the need for an alternative drinking water source.

Common arsenic mitigation strategy is consuming drinking water from deep tube wells that tap into an aquifer usually greater than 500 feet deep and mostly free of arsenic (Ravenscroft et al., 2013; van Geen et al., 2003; Van Geen et al., 2007). As of 2010, approximately 165,000 deep tube wells had been installed throughout the country and have become a cornerstone of efforts to reduce arsenic exposure (DPHE, 2010).

The low arsenic concentrations in deep tube wells have been shown to be stable over time, except when poorly constructed (Fendorf et al., 2010; Radloff et al., 2011; Van Geen et al., 2007).

Deep tube wells have also demonstrated better microbial quality at source compared to shallow tube wells as E. coli and fecal coliform levels decrease with increased depth (Islam et al., 2001; Luby et al., 2008). *E. coli* concentration is a measure of water quality on both continuous and categorical scales based on a priori risk categories. As per WHO guidelines, the ranges of *E. coli* concentration are - <1/100 ml (safe), 1–10 /100 ml (intermediate risk), 11–100 /100 ml (high risk) and >100/100 ml (very high risk) (Brown et al., 2008).

Hence, it is possible that deep tube wells may provide added health benefits through better microbial quality in drinking water in addition to reduced arsenic exposure, resulting in lower incidence of diarrheal diseases, as compared to shallow tube wells (Escamilla et al., 2011; Winston et al., 2013). From the above discussion in the references it is clear that quality test of drinking water is a must.

Location, Soil and Crops and Climatic Conditions of Study Area

Rajshahi division is in the North-West part of Bangladesh and an agro-based area of the country. Among 8 districts of this division, Rajshahi, Naogaon and Chapai Nawabganj districts are in scarce of water in dry season (normally November to May). The study area comprises of these three districts. This area is located in between 24°23' to 25°15' north latitude and 88°02' to 88°57' east longitude covering an area of 756350 ha.

Total cultivable land is 5.75 lac hectares, out of which 5.11 lac hectares of land has brought under controlled irrigation. Irrigated area through BMDA's DTW is 2.85 lac hectares (BADC, 2019). There are three types of land in respect to topography-high land (47%), medium land (38%) and low lying area (15%) (BMDA, 2005). High Barind and Level Barind tracts (Agro-ecological Zone, 26 and 25) exist in the study area.

In high Barind area, there are about 80% lands terraced or undulated. Boro (rice) crops are being the major cereals in where irrigation demand is very high. Paddy, wheat, maize, potato, mustard, pulses, sugarcane etc. are the major crops grown in this area. A map of the study area is given bellow **(Figure 1).**

The climate of Rajshahi Barind is extreme in both summer and winter. A typical dry climate with comparatively high temperature prevails in Barind area except for the wet season beginning from mid-June to October. The rainfall in this area is from about 1100 mm to 1400 mm which is less than the average rainfall of the country (2000 mm to 2400 mm). Temperature ranges from 4° Celsius to 44° Celsius and relative humidity is about 78%.

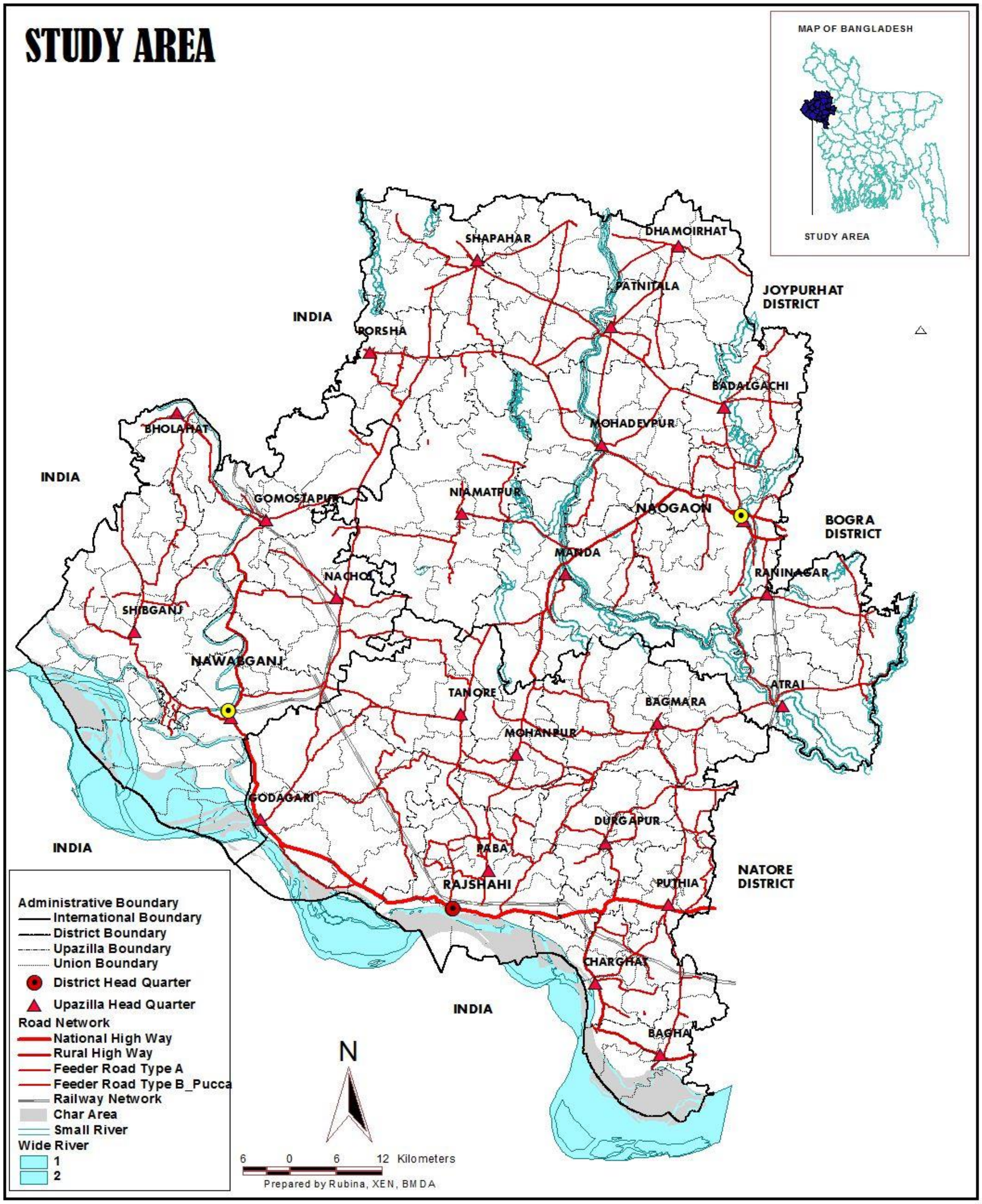

Figure 1: Map of the Study Area

Out of total cultivable land, 34% is loamy, 10% is sandy, 49% is clayey soil and the rest of 7% is other types of soil according to the soil classification as reported by BBS (Bangladesh Bureau of Statistics). The elevation above MSL (Mean Sea Level) ranges from 12 m to 46 m (Gomostapur of Chapai Nawabganj district) (BMDA, 2005).

Methodological Approach for Water Quality Tests

Water lifted from underground through deep tube wells are commonly used for irrigation, drinking purpose and other domestic uses. One should know the quality of water before its use. In case of water being used for drinking and other domestic purposes water quality test is a must. Because any element contained in water which is beyond its acceptable limit may cause harm to the user either for drinking or for irrigation.

To overcome such hazards water quality test is essential. Considering the above importance, BDMA has established a Laboratory for testing of water quality **(Figure 2).** It is only used for the test of water supply schemes, specially for the supply of drinking water in BMDA. Authority has taken up steps for test of water quality of deep tube wells particularly where the pipe water system being established.

Figure 2: BMDA Water Testing Laboratory.

After confirmation of the quality of the water identifying several parameters like Arsenic (As), Iron (Fe), Chloride (Cl), pH, Total Dissolved Solid (TDS), Dissolved Oxygen (DO), E. coli etc. for drinking purposes, the piped water distribution systems are installed. During operation/use, some periodic water quality tests, particularly for Arsenic and bacterial coliform, are conducted time to time to know the present situation.

Tested Parameters and Results

Normally in surface and ground water some elements and characters are found like Arsenic(As), Iron(Fe), Calcium(Ca), Chloride(Cl), Magnesium(Mg), Total Hardness, Phosphorus(P), Temperature, Electrical Conductivity(EC), Total Dissolved Solid(TDS), Hydrogen Ion Concentration(pH), Zinc(Zn), Boron(B), Alkalinity, Turbidity, Nitrate(NO_3), Nitrogen(N), Sulfate (SO_4), Dissolved Oxygen(DO), etc. To know the quality of water many parameters need to be tested. Country basis the acceptance limits of water for drinking purpose may vary. In Bangladesh the parameters have separate ranges, whereas the WHO declared ranges are different from that. A comparative picture of Bangladesh and WHO standard is given bellow **(table 1).**

Table 1: Some allowable limits of water quality parameters according to ECR, 1997 (Bangladesh) and WHO standard

Allowable limits			
Parameters	Unit	Bangladesh Standard (according to Bangladesh Environment Conservation Rules, 1997)	WHO Standard
Arsenic(As)	ppm	≤ 0.05	≤ 0.01
Chloride(cl)	ppm	150 to 600	≤ 250
Iron(Fe)	ppm	0.30 to 1.00	≤ 0.30
Turbidity	NTU	≤ 10	≤ 5

*NTU – Nephelometric Turbidity Units

Different water quality parameters like arsenic (**As**), iron (**Fe**), calcium (**Ca**), magnesium **(Mg**), total hardness (**TH**), hydrogen ion concentration(**pH)**, electrical conductivity (***E*c)**, chloride (**C**l), dissolved oxygen **(DO**), E. coliform bacteria, turbidity and total dissolved solids **(TDS**) were analyzed in the laboratory of BMDA with standard methods (Bangladesh standard according to ECR, 1997)**.** Tested parameters details are given bellow:

Water Quality Parameters

a) Arsenic (As): Arsenic is a metalloid element, which means it has both the property of metal and nonmetal. It occurs in the ground as a part of the soil and rocks. Arsenic cannot be seen, but tested as smell when it is in water. Many arsenic compounds are water soluble. Most of the arsenic found in water derived from geological formation (Igneous and sedimentary), industrial discharge, mining operation, arsenical insecticides and from the combustion of fossil fuels. It has toxic property. Carcinogenic property also has been imputed to arsenic. The gastrointestinal tract, nervous system, respiratory tract and skin can be severely affected. The concentration of allowable limit of arsenic in drinking water is ≤ 0.05 mg/l or ppm. A status of Arsenic concentration is shown in **Table 2.**

Table 2: Arsenic Concentration (ppm) in BMDA's drinking water supply schemes (total scheme = 275).

District	Nos. of tested samples from DTW	Ranges of Arsenic(As) in ppm			Maximum value(ppm)	Remarks
		0 to 0.009	0.01 to 0.05	> 0.05		
Rajshahi	90	79	10	1	0.24 (Location of site: Bagmara, modhyokonda,65 /2745, Rajshahi)	WhO Standard ≤ 0.01
Naogaon	135	131	4	0		
C.Nawabganj	50	47	3	0		
Total	275	257	17	1		

b) Iron (Fe)

Iron as well as manganese, creates serious problem in public water supplies. The problems are most critical for ground water from exists in soils and minerals as insoluble ferric oxide/hydroxide and iron sulfide. In some areas, it also occurs as ferrous carbonate, which is very slightly soluble such waters, when exposed to the air so that oxygen can enter, becomes turbid and highly unacceptable for the aesthetic view point.

According to Bangladesh Environment Conservation Rules (1997), drinking water standard for iron is 0.3 – 1.0 mg/l and for irrigation water it is 2 mg/l. But for some crops up to 5 mg/l is permissible. The Iron concentration of the study area is given bellow **(Table 3).**

Table 3: Iron concentration (ppm) in BMDA's drinking water supply schemes (Total scheme = 275).

District	Nos. of tested samples from DTW	Ranges of Iron(Fe) in ppm			Minimum value (ppm)	Maximum value (ppm)	Remarks
		0 to < 0.3	0.3 to 1.0	> 1.0			
Rajshahi	90	8	82	0	0.001 (Location of site: Nachole, Khojarpara, 194/20, C.Nawabganj)	1.725 (Location of site: Manda, Kalisofa, 215/100, Naogaon)	
Naogaon	135	13	121	1			
Chapai Nawabganj	50	5	45	0			
Total	275	26	248	1			

c) Chloride (Cl)

Chlorides occur in natural waters in varying concentration. The chloride contents normally increase as mineral content increases. Upland and mountain water are usually quite low in chlorides, whereas rivers and ground water usually have a considerable amount.

Chlorides in reasonable concentrations are not harmful to human. At concentrations above 250mg/l they give a salty taste to water, which is objectionable to many people. For public use, chlorides are limited to 250mg/l. In many areas where water supplies are scarce the limit is flexible.

According to Bangladesh standard (ECR, 1997), drinking water standard for chloride is 150-600 mg/l, but for coastal regions of Bangladesh, the limit has been relaxed to 1000mg/l. According to WHO standards concentration of chloride should not exceed 250 mg/l. The chloride concentration of the study area is given bellow **(Table 4).**

Table 4: Chloride concentration (ppm) in BMDA's drinking water supply schemes (Total scheme = 275).

District	Nos. of tested samples from DTW	Ranges of chloride (cl) in ppm			Minimum value (ppm)	Maximum value (ppm)	Remarks
		0 to <150	150 to 600	> 600.0			
Rajshahi	90	90	0	0	16.8 (Location of site: Porsha, Gopalganj, 80/134, Naogaon)	201 (Location of site: Manda, Satail, 209/1507, Naogaon)	WHO Standard ≤ 250
Naogaon	135	134	1	0			
Chapai Nawabganj	50	49	1	0			
Total	275	273	2	0			

d) Hydrogen Ion Concentration (pH)

pH is a measure of the acid or alkaline condition of water. It is a way of expressing the hydrogen ion concentration or more preciously the hydrogen ion activity. A controlled value of pH is desired in water supplies, sewage treatment and chemical process plants. In water supply, pH is important for coagulation, disinfection, water softening and corrosion control.

According to Bangladesh Environment Conservation Rules (1997), drinking water standard for pH is 6.5 - 8.5. The pH value of the study area is shown below **(Table 5).**

Table 5: pH in BMDA's drinking water supply schemes (Total scheme = 275).

District	Nos. of tested samples from DTW	Ranges of pH			Minimum value	Maximum value	Remark
		0 to 6.50	6.50 to 8.50	> 8.50			
Rajshahi	90	0	90	0	6.8 (Location of site: Naogaon Sadar, Chakrajbollov, 17/457,Naogaon)	7.9 (Location of site:Durgapur Polashbari, 59/3309, Rajshahi)	
Naogaon	135	0	135	0			
Chapai Nawabganj	50	0	50	0			
Total	275	0	275	0			

Table 6: Ranges of other parameters in BMDA's drinking water supply schemes (Total scheme = 275).

Parameters	Nos. of tested samples from DTW	Allowable Limits (ECR, 1997)	Nos. of sample in Allowable Limits	Minimum value	Maximum value	Remarks
Total Hardness (TH)	275	Allowable limit 200 – 500 mg/l Soft <50 mg/l as CaCO3 Moderately Soft 50-150 mg/l as CaCO3 Hard 150-300 mg/l as CaCO3 Very hard >300 mg/l as CaCO3	173 0 71 182 22	75	690	
Electrical Conductivity (EC)	275	600-1000 µs/cm	82	200	1176	Who Std. 2500µs/cm
Calcium(Ca)	275	71-75 mg/l	49	16.01	76.89	
Magnesium (Mg)	275	30-35 mg/l	0	0.98	20.76	
Dissolved Oxyzen(DO)	275	≤ 6 ppm	254	2.6	9.5	
Total Dissolved Solid(TDS)	275	≤1000 <300 mg/l excellent (but extremely low unacceptable) 300-600 mg/l good 600-900 mg/l fair 900-1200 mg/l poor	275 214 61 0 0	77	550	Who Std. ≤1000
Turbidity	275	≤10 FAU (Formation Attenuation Unit)	275	-	-	

Analysis of Results

In the study area, a total of 275 water samples collected from deep aquifer (40 – 64 m depth) were tested for physicochemical properties of groundwater. Here 3 districts have been identified for quality control purpose. Total of 275 drinking water supply schemes (DTW) have been selected to know the quality of water for drinking purpose in the study area. Analytical test reports of arsenic, iron, chloride, pH, calcium, magnesium, electrical conductivity, dissolved oxygen, total dissolved solid, total hardness etc. are given in table 2 - 6.

Out of 275 samples, 274 nos. of DTW were found to be safe for drinking purpose according to Bangladesh standard in respect to arsenic content. Arsenic content (0.24 ppm) in only 1 DTW (location: Bagmara, Modhyokonda, 65/2745, Rajshahi) was higher than the maximum permissible limit for drinking purpose. According to WHO standard

262 nos. of DTW were in safe limit in which no existence of Arsenic had been seen in 210 samples. i.e, out of 275 samples, 13 were found having arsenic levels above the value of ≤ 0.01mg/l according to WHO guideline, of which 1 exceeded (o.24 ppm) the Bangladesh drinking water standard (≤ 0.05 ppm). The trend of Arsenic content in Rajshahi district was slightly higher than the Arsenic content of other two districts in the study area.

Out of 275 samples, iron content of 274 samples was in safe limit as Bangladesh Standard for drinking purpose. But according to WHO standard, 235 samples were in safe limit. The maximum value of the samples (Iron) was 1.725 ppm and the minimum was 0.001 ppm. In respect to chloride concentration, most of the samples were beyond acceptable limit as Bangladesh standard except only 2 samples but all the samples were almost safe for drinking purpose.

Normally, pH of water ranges from 6.0 to 8.5. It is noticed that water with low pH will tend to be toxic and with higher degree of pH it is turned into bitter taste. According to Bangladesh standard, pH of water should be 6.5 to 8.5. In the study area, it was ranges from 6.8 to 7.9. Water of 24 samples was slightly acidic and 220 samples were slightly alkaline in nature. Out of the 275 samples, 31 samples were quietly neutral. Hence, in study area, the pH values were not exceeded the standard limit. In majority cases these were falling in alkaline range. The values of pH in the study area were quite safe for drinking purpose.

The bacterium *Escherichia coli O157 (E. coli)* is the most commonly recommended indicator of fecal contamination in water and food utensils. According to WHO recommendation there should be no *E. coli* in a 100 ml drinking water sample. In this study there was no *E. coli* found in the studied samples.

Only the case, *E. coli* may be formed in drinking water storage tank **(Figure 3)** in BMDA deep tube well due to inappropriate handling. So a routine check **(Figure 4)** has to be done by BMDA as regular basis. In this process, BMDA collect water sample from the scheme that stored in the header storage tank. An *e. coli* test is done in BMDA chemical laboratory.

Figure 3: Drinking water header tank with BMDA deep tube well.

Figure 4: Routine checkups in distribution line.

Figure 5: People taking drinking water from BMDA deep tube well.

Some of these samples were tested in another two laboratories (BCSIR laboratory, Rajshahi and DPHE laboratory, Rajshahi) as cross check. The testing results were almost same. There was no trace of Arsenic content in these water samples. Once it is ensured that the supply of drinking water has no contamination by any means, the villagers then collect pure and safe water from the deep tube wells for their drinking purpose and domestic uses **(Figure 5).**

Analysis of water from the samples described above, the results indicated that the other parameters were quietly safe for drinking purpose and domestic uses, except a few parameters like EC, calcium, magnesium etc. according to Bangladesh standard **(Table 6).**

Although the most of the physic-chemical, biological and hydrological parameters of groundwater are not at the alarming stage, but the condition of pathogenic bacteria may exclusively a threatening in future. It may be our concern. There was a slightly higher hardness in the ground water of the study area which contains different minerals, like iron, manganese, calcium and magnesium etc.

Findings from the result, it can clearly be mentioned that the quality of water from BMDA deep tube wells under Rajshahi, Naogaon and Chapai Nawabganj district is good. Allowable limits of the parameters are within the limit and in fact a very few exception, the average quality of deep tube well water in the study area are found to be safe for drinking purpose.

Conclusion

People in the study area largely depend on improved water sources developed from groundwater for drinking purpose and other domestic activities. The study was conducted to investigate the drinking water quality parameters from different DTW sources in BMDA study area and living and hygienic conditions of the people in Barind area. It was found that the levels of As, Fe, cl, DO, pH, EC, TDS from near about all deep tube well, except a few cases, were within or near to standard level (ECR, 1997) which are suitable for drinking purposes.

The Arsenic and Iron concentration of tube well water were within the standard level for drinking purpose in which maximum values (0.24 ppm and 1.725 ppm) were identified at Bagmara upazila of Rajshahi district and Manda upazila of Naogaon district respectively, and the minimum (0.0 ppm and 0.001 ppm) at Volahat and Nachole upazilas of Chapai Nawabganj district respectively . The pH was also within the standard level. It was also observed that about 82.5 % people had access to deep tube well water and 17.5% people had no access to deep tube well water for drinking. The hygienic condition of the study area was almost fair.

Hence in a word we can say that deep tube wells may provide safer and better drinking water as compared to shallow tube wells. Future research and policy efforts should target better allocation of deep tube wells in needed areas and minimize the time taken and distance traveled by rural Bangladeshis to ensure safe drinking water consumption as a part of arsenic mitigation efforts.

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