

## Monitoring of Groundwater Quality in Arsenic and Salinity Prone Areas of Jashore, Bangladesh

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**Abstract:** The groundwater contamination by arsenic is a large-scale pollution in drinking water history. Safe water supply is a big challenge due to critical hydrogeological situation and water quality problems in this area. The analytical results show that a range of pH, TDS, chloride, total alkalinity, total hardness, sodium, potassium, calcium, magnesium, manganese, iron and arsenic were found between 7.50-7.23, 504.00-201.00 mg/L, 90.30-31.43 mg/L, 410.81-174.31mg/L, 616.47-202.97 mg/L, 52.59-13.28 mg/L, 17.13-2.87 mg/L, 108.57-44.53 mg/L, 83.87-22.29 mg/L, 1.78-0.01 mg/L, 11.78-1.45 mg/L, 0.42-0.02 mg/L, respectively. This study will help making a future plan for groundwater quality monitoring and its hydrogeological application for safe water source identification.

**Keywords:** Arsenic, groundwater contamination, arsenic mitigation; salinity, water quality.

### Introduction

Worldwide groundwater is a very common source used for domestic, agricultural and industrial purposes due to its availability, quality and low cost of extraction (Carrard et al., 2019). Groundwater seems to be chemical and pathogenic contaminants free water which is considered as a valuable safe water source for its quality and quantity (Sarma, 2020). However, rapid urbanization, industrialization, advance economic growth, modern agriculture for food security, huge growth of population and climate change issues are changing the groundwater consumption pattern and create unparallel pressure on groundwater source (Assembly, 2012). Multipurpose use of groundwater is common for a developing country due to absence of alternate source, lack of motivation, loose regulations and very poor institutional power to manage groundwater (Mechlem, 2016). For the purpose of domestic, agricultural and industrial water supply around the world, it is the main source. One-third of the world's population depends on groundwater for drinking and cooking purposes (Nickson et al., 2005). It is reported that arsenic contamination in groundwater has been detected in 70 countries in six continents of the world (Bhattacharya et al., 2002). Groundwater pollution of arsenic poses a risk to the health of millions of people; especially in densely populated river deltas of south Asia and south-east Asia (Edition, 2011; Ravenscroft et al., 2009). Bangladesh is one of the arsenic contaminated country where large scale pollution occurred in groundwater (Smith et al., 2000). People are changing their habits of drinking water, where the sources are groundwater instead of surface water for reducing waterborne diseases (Diarrhea, dysentery, typhoid and cholera

(Hussain et al., 2001). In Bangladesh about 8000 community people in 61 districts are facing a serious health threat due to consuming arsenic-contaminated water for drinking and cooking (Survey et al., 1999). Since 1970 more than 97% of people in Bangladesh are using groundwater for drinking and cooking purposes (Organization, 2000). However, the number of users are decreasing about 70% due to the arsenic poisoning in groundwater (Water and Organization, 2004). Arsenic occurs in groundwater in several forms depending on pH and redox potential (ORP). Arsenate (As-V) and arsenite (As-III) are the primary forms of arsenic found in natural waters (Naujokas et al., 2013). The thermodynamically stable form is arsenate (As-V) in the presence of oxygenated environment and arsenite (As-III) is a stable format in reducing environment in ground water. Several studies reported that low concentration of arsenic ingestion for over a long-term period can cause arsenicosis disease and different types of cancer like melanosis, leukokeratosis, keratosis, edema, skin cancer and bladder cancer are common (Islam et al., 2007). According to DGHS data, 38412 arsenic patients have been suspected through consuming arsenic-contaminated water for drinking and cooking purposes (Mukherjee and Wisniwski, 2012). World Health Organization (WHO) in 1993 and the Department of Environment (DoE, Bangladesh) in 1997 established drinking water standard for arsenic is of 0.01mg/L and 0.05mg/L (Edition, 2011). According to WHO and DoE standard for drinking water, all the water quality parameters are reported in literature (Tanjil et al., 2019; Monir et al., 2011; Monir et al., 2012). Groundwater quality is influenced by the quality of recharged water, rainfall, inland surface water and hydrogeological structure (Bhattacharjee et al., 2019).

Its quality in the coastal area depends on precipitation, seawater intrusion, rising deep aquifer and anthropogenic sources (Chandrajith et al., 2016). Coastal aquifers acting as a source of freshwater supply, but it can affect the groundwater quality due to salinity contamination by seawater intrusion which is caused by huge extraction of groundwater for domestic, irrigation and industrial purposes (Khan et al., 2019; Richards et al., 2019). It is assumed that arsenic is naturally present in minerals and released to groundwater, either through the oxidation of pyrite or released from iron oxides (Roychowdhury, 2010). The As release from iron oxides is mostly associated with increasing pH and/or reduction due to oxygen shortage when groundwater levels increase (Roychowdhury, 2010). The water quality is the key to all the roles that water plays in human life and the natural environment. For the coastal population of Bangladesh, surface and groundwater are the main aquatic resources for drinking, bathing, irrigation and household purposes (Ahmed et al., 2019; Ahmed et al., 2019; Monir et al., 2012). However, safe water sources are not available for drinking and cooking in rural areas of Sagardari union in Jashore district (Ahmed et al., 2019). Therefore, this study investigated the arsenic and salinity contamination in groundwater including the monitoring of groundwater movement and seasonal effect on groundwater quality.

## Materials and Methods

Jashore district is more arsenic prone area in Bangladesh. This study area comprises Marua, Samta, Bishnupur and Sagardari villages in Jashore district with areas of same number of arsenic patients and the cases of arsenic contamination (Table 1, 2; Fig. 1). About 126, 312, 18 and 3 arsenic patients have been suspected in Jashore district. Marua, Samta, Bishnupur and Sagardari villagers are suffering from arsenic ingested diseases by consuming arsenic-contaminated water from groundwater sources, moved to other areas of Jashore district (Ahmed et al., 2015).

The household survey was conducted in four villages for selecting water sample collection points. This survey measured the water level at each test tube well by using measurement tape. The water samples were collected from 18 tubewells in the study area, which were installed by RGAG and AAN-Rotary projects. This study was conducted on groundwater quality monitoring at 18 sampling points in the summer season. The water samples were collected in April 2017 from four villages in Jashore district. All of the samples were collected in 500ml and 100ml plastic bottles for physiochemical and metal analyses. A 100 ml sample was preserved by 2ml of 6N nitric acid for metal analysis but another 50ml sample was preserved in the refrigerator at 4°C. The concentration of pH, TDS, total alkalinity, total hardness, sodium, potassium, calcium and magnesium were measured by membrane electrode, conductivity, Mohr's titration, acid-base titration, EDTA complex metric and flame-AAS method, respectively (Khan et al., 2016; Pandey and Bhatt, 2015).

## Results and Discussion

This study monitored 12 water quality parameters of groundwater at 5 villages of Jessore district in Bangladesh (Table 2, 3). This study mainly focused on the arsenic and salinity contamination in groundwater, used for drinking and cooking purposes.

## Physical Characteristics

The average concentration of pH was detected  $7.34 \pm 0.07$ , which is an acceptable range of DoE standard for drinking water [Do ESTD]. The highest and lowest concentrations of pH were found  $7.50 \pm 0.17$  and  $7.23 \pm 0.15$  at Marua (S-18) and Bishnupur (S-2) villages, respectively. In this study, pH was matched in all samples with DoE standard. Concentrations of sodium and chloride ion may increase the TDS value which is caused by salinity problems. Average concentrations of TDS were measured  $355.28 \pm 87.97$  mg/L and this value was lower than DoE standard ( $<1000$ mg/L) for drinking water [Do Estd.]. The highest and lowest concentrations of TDS were found  $504.00 \pm 6.56$  mg/L and  $201.00 \pm 4.58$  mg/L at Marua (S-18, S-14) village. In all the samples, TDS content remained below the DoE standard. Data indicated that salinity intrusion did not affect the groundwater

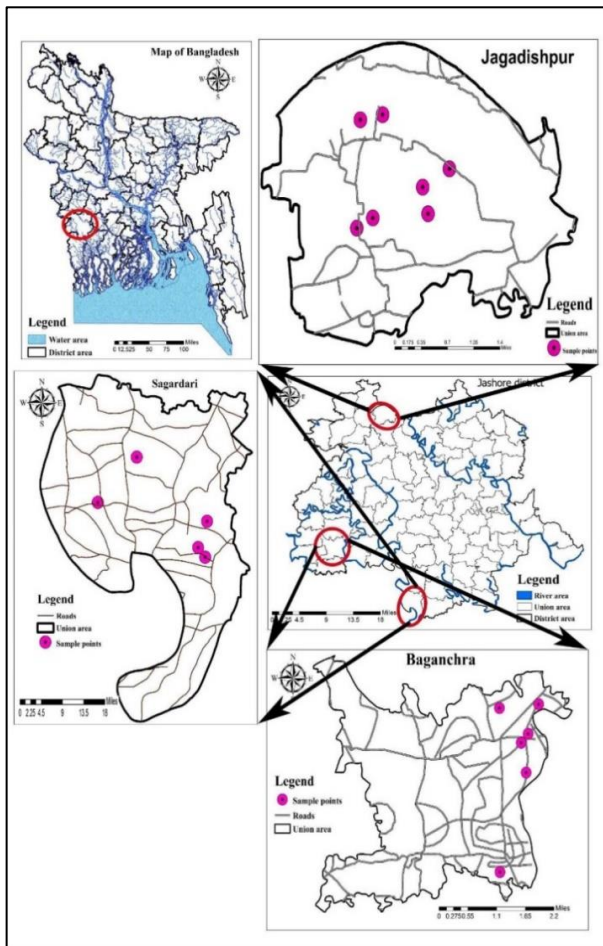


Fig. 1 Location of sampling points in the study area.

Table 1 General information of the study area.

Sample ID No.	Village	Union	Upazila	Depth (ft)	Water level (ft)	GPS	
						N	E
S-1	Bishnupur	Sagardari	Keshabpur	50	18.01	22°49.987	089°08.328
S-2	Bishnupur	Sagardari	Keshabpur	50	16.09	22°50.113	089°08.055
S-3	Sagardari	Sagardari	Keshabpur	50	18.1	22°49.945	089°08.479
S-4	Samta	Baganchra	Sharsha	50	25.06		
S-5	Samta	Baganchra	Sharsha	50	23.04	22°59.457	088°59.118
S-6	Samta	Baganchra	Sharsha	50	22.03	22°59.598	088°59.184
S-7	Sagardari	Sagardari	Keshabpur	50	15.08	22°48.933	089°09.879
S-8	Samta	Baganchra	Sharsha	50	27.01	22°59.812	088°59.262
S-9	Samta	Baganchra	Sharsha	50	27.01	22°59.541	088°59.944
S-10	Bishnupur	Sagardari	Keshabpur	150	18.5	22°50.118	089°08.389
S-11	Samta	Baganchra	Sharsha	50	27.01	23°16.054	089°04.055
S-12	Marua	Jagadishpur	Chowgachha	150	12.04	-	-
S-13	Marua	Jagadishpur	Chowgachha	50	12.01	-	-
S-14	Marua	Jagadishpur	Chowgachha	150	21.01	23°16.028	089°04.494
S-15	Marua	Jagadishpur	Chowgachha	50	20	23°16.587	089°05.199
S-16	Marua	Jagadishpur	Chowgachha	150	21.01	23°16.747	089°04.692
S-17	Marua	Jagadishpur	Chowgachha	50	13.08	23°16.747	089°04.692
S-18	Marua	Jagadishpur	Chowgachha	150	22.07	23°16.477	089°04.610

(shallow aquifers) in the study area. The average concentration of total alkalinity was measured  $289.53 \pm 61.94$  mg/L and the value was lower than DoE standard ( $<400$  mg/L) for drinking water [DoE std.]. Highest and lowest concentrations of total alkalinity were reported  $410.81 \pm 1.96$  mg/L and  $174.31 \pm 3.32$  mg/L at Bishnupur (S-1, S-2) village (Table 3). The concentration of total alkalinity exceeded the DoE standard for drinking water at Bishnupur (S-1) and Marua (S-18) villages.

Average concentration of total hardness was found (Table 3). The highest and lowest concentrations of total hardness were found  $616.47 \pm 4.78$  mg/L and  $202.97 \pm 0.54$  mg/L at Samta (S-8) and Marua (S-16) villages, respectively. In this work, the total hardness did not exceed the DoE average. The concentration of total hardness exceeds the DoE limit for drinking water

at Bishnupur (S-1), Samta (S-8) and Marua (S-15) villages.

### Chemical Characteristics

Average concentration of total chloride was found  $58.95 \pm 12.35$  mg/L which was lower than DoE standard ( $<500$  mg/L) for drinking water [DoE std.]. Highest and lowest concentrations of total chloride were obtained  $90.30 \pm 1.61$  mg/L and  $31.43 \pm 0.76$  mg/L at Sagardari  $400.35 \pm 107.08$  mg/L which value was lower than DoE standard ( $<500$  mg/L) for drinking water [DoE std.] (S-7) and Marua (S-18) villages, respectively. In all the samples total chloride did not exceed the DoE limit. Average concentration of total sodium was found  $25.54 \pm 9.63$  mg/L which was lower than DoE guideline ( $<200$  mg/L) for drinking water [DoE std.] (Table 3). The highest and lowest

Table 2 Concentration of pH, TDS, chloride, total alkalinity and total hardness in ground water.

ID.	Village	Conc. of pH	Conc. of TDS (mg/L)	Conc. of Chloride (mg/L)	Conc. of Total Alkalinity (mg/L)	Conc. of Total Hardness (mg/L)
S-1	Bishnupur	7.34	500.00	60.13	410.81	548.72
S-2	Bishnupur	7.23	395.33	60.53	174.31	380.83
S-3	Sagardari	7.40	331.67	61.10	293.74	385.68
S-4	Samta	7.33	410.00	55.13	290.26	434.87
S-5	Samta	7.33	384.00	59.13	290.84	296.30
S-6	Samta	7.33	411.67	60.33	293.27	335.77
S-7	Sagardari	7.33	344.67	90.30	293.34	326.41
S-8	Samta	7.23	405.67	65.03	287.98	616.47
S-9	Samta	7.37	471.33	60.47	293.19	471.43
S-10	Bishnupur	7.33	239.33	60.40	295.17	355.09
S-11	Samta	7.40	363.00	63.07	288.31	406.02
S-12	Marua	7.33	255.33	58.86	239.73	299.91
S-13	Marua	7.27	314.67	60.40	234.97	446.89
S-14	Marua	7.37	201.00	61.63	175.24	354.14
S-15	Marua	7.33	274.67	31.53	294.11	592.24
S-16	Marua	7.43	281.33	61.67	352.34	202.97
S-17	Marua	7.23	307.33	59.97	293.37	428.68
S-18	Marua	7.50	504.00	31.43	410.51	323.95
Maximum		7.50	504.00	90.30	410.81	616.47
Minimum		7.23	201.00	31.43	174.31	202.97
Average		7.34	355.28	58.95	289.53	400.35
Standard Deviation		0.07	87.97	12.35	61.94	107.08
DoE standard for drinking water (mg/L)		6.50-8.50	1000.00	600.00	400.00	500.00
WHO standard for drinking water (mg/L)		6.50-8.50	1000.00	600.00	400.00	500.00

concentrations of total sodium were found as at Samta (S-8) and Marua (S-12) villages, respectively. All the samples total sodium did not exceed the maximum DoE average for drinking water in Bangladesh. Average concentration of total potassium was found  $6.08 \pm 3.59$  mg/L which was lower than DoE standard

not safe for use. The average concentration of iron was found  $5.60 \pm 3.28$ mg/L which value was higher than DoE standard ( $<1.00$ mg/L) for drinking water [DoE std.]. The highest and lowest concentrations of iron were found  $11.78 \pm 0.07$  mg/L and  $1.45 \pm 0.02$ mg/L at Sagardari (S-7) and Samta (S-8) villages, respectively.

Table 3 The concentration of minerals and metals in groundwater.

ID.	Village	Conc. of Sodium (mg/L)	Conc. of Potassium (mg/L)	Conc. of Calcium (mg/L)	Conc. of Magnesium (mg/L)	Conc. of Arsenic (mg/L)	Conc. of Iron (mg/L)	Conc. of Manganese (mg/L)
S-1	Bishnupur	31.37	6.20	108.06	67.72	0.34	9.10	1.77
S-2	Bishnupur	29.28	5.38	74.64	47.22	0.13	6.69	0.84
S-3	Sagardari	21.10	6.29	76.30	47.39	0.14	8.65	0.8
S-4	Samta	29.04	3.47	80.62	56.72	0.42	6.26	0.02
S-5	Samta	33.97	13.54	70.32	29.31	0.03	10.22	0.17
S-6	Samta	22.64	5.79	65.62	41.75	0.03	10.60	0.17
S-7	Sagardari	18.30	17.31	73.12	34.93	0.03	11.78	0.95
S-8	Samta	52.59	5.36	108.57	83.87	0.02	1.45	0.21
S-9	Samta	38.63	5.48	95.10	56.81	0.12	4.20	0.01
S-10	Bishnupur	17.53	4.65	81.63	36.73	0.14	5.29	1.78
S-11	Samta	29.37	3.66	72.23	54.80	0.42	6.28	0.02
S-12	Marua	13.28	3.97	56.60	38.51	0.13	3.70	0.77
S-13	Marua	18.53	2.87	69.89	66.14	0.06	2.74	0.01
S-14	Marua	22.82	4.86	71.34	42.74	0.02	2.05	0.01
S-15	Marua	18.46	6.19	99.55	83.46	0.02	2.75	0.73
S-16	Marua	15.44	4.74	44.53	22.29	0.05	2.27	0.01
S-17	Marua	20.80	5.17	87.73	50.90	0.05	2.34	0.12
S-18	Marua	26.53	4.44	50.88	47.81	0.19	4.37	0.04
Maximum		52.59	17.31	108.57	83.87	0.42	11.78	1.78
Minimum		13.28	2.87	44.53	22.29	0.02	1.45	0.01
Average		25.54	6.08	77.04	50.51	0.13	5.60	0.47
Standard Deviation		9.63	3.59	17.82	16.84	0.13	3.28	0.59
DoE standard for drinking water (mg/L)		200.00	12.00	75.00	30.00	0.05	0.30-1.00	0.10
WHO standard for drinking water (mg/L)		200.00	12.00	75.00	30.00	0.01	0.30	0.10

(<200 mg/L) for drinking water [DoE std.]. The highest and lowest concentrations of total potassium were found as  $17.31 \pm 0.12$  mg/L and  $2.87 \pm 0.01$  mg/L at Sagardari (S-7) and Marua (S-13) village.

The potassium concentration did not exceed the DoE standard. Average concentration of total calcium was found  $77.04 \pm 17.82$  mg/L which lower than DoE standard (< 200 mg/L) for drinking water [DoE std.]. The highest and lowest concentrations of total calcium were found as  $108.57 \pm 0.96$  mg/L and  $44.53 \pm 0.22$  mg/L at Samta (S-8) and Marua (S-16) villages, respectfully. In all samples, total calcium did not exceed the DoE standard. The average concentration of total magnesium was found  $50.51 \pm 16.84$  mg/L which was higher than DoE standard (<30 mg/L) for drinking water [DoE std.]. The highest and lowest concentrations of total magnesium were found  $83.87 \pm 0.58$  mg/L and  $22.29 \pm 0.04$  mg/L at Samta (S-8) and Marua (S-16) villages, respectfully. In all samples, the total calcium did not exceed the DoE standard. The arsenic concentration was found as  $0.13 \pm 0.05$ mg/L which was higher than DoE standard (< $0.05$ mg/L) for drinking water [DoE std.]. The highest and lowest concentrations of arsenic were detected  $0.43 \pm 0.01$ mg/L and  $0.02 \pm 0.00$ mg/L at Samta (S-11) and Marua (S-15) villages, respectfully. In S-5, 6, 7,8,14 and 15 number tube well, the arsenic concentration did not exceed DoE standard for drinking water, but in other tubewells, the water was

Absorption of iron in tubewell water did not match with DoE standard for drinking water at all of the samples.

The absorption of manganese was found  $0.47 \pm 0.59$ mg/L which was maximum as compared to DoE standard (< $0.10$ mg/L) for drinking water [DoE std.] (Table 3). The highest and lowest concentrations of manganese were found  $1.78 \pm 0.02$ mg/L and  $0.01 \pm 0.00$ mg/L at Sagardari (S-7) and Marua (S-16) villages, respectfully. The concentrations of manganese in S-4, 9, 11, 13, 14, 16, 18 tubewells, the value did not exceed the DoE standard for drinking water (Fig. 2).

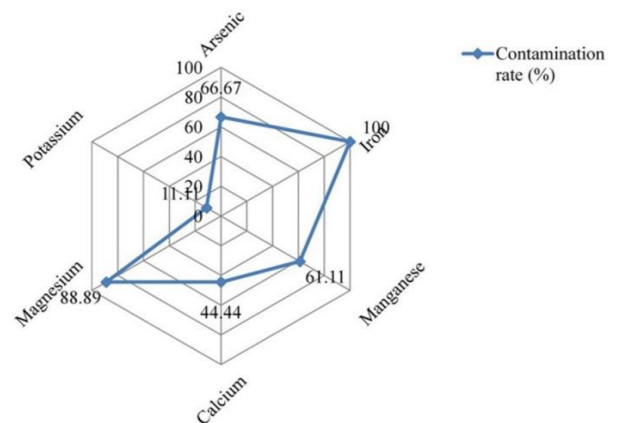


Fig. 2 Groundwater contamination graph in the study area.

Due to arsenic in groundwater, peoples have suffered environmental health risks such as cancer, skin diseases, diabetes and cardiovascular diseases. The over concentrations of iron in groundwater has also caused metabolic syndrome, cancer and micro vascular damage in the study area. In this area it is also found that nerve cells and brain diseases have been caused by the presence of manganese in groundwater. When hydrochemical concentrations (calcium and magnesium) exceed the DoE limit, people of these areas have been affected by the cardiovascular diseases. Moreover, hydrochemical parameter of potassium has directly affected the blood plasma. Therefore, the surface water and groundwater treatment system are necessary for these areas, by using low cost and sustainable technology.

## Conclusion

It is concluded that the order of metal contamination rate was iron (100%) > magnesium (88.89%) > arsenic (66.67%) > manganese (61.11%) > calcium (44.44%) > potassium (11.11%), respectively. The data reveal that the arsenic, iron, manganese, calcium, magnesium and potassium contamination in groundwater is alarming for human health safety. Before installing any safe water device in the study area, existing groundwater sources water quality data will be helped to find safe water. NGOs, GOs and other organizations should be promoted to use safe water and motivate community people about contaminated drinking water and health safety.

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