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Determination of Arsenic (As) and Iron (Fe) Concentration in Ground Water and Associated Health Risk by Arsenic Contamination in Singair Upazila, Manikganj District, Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author AT designed the study, performed the statistical analysis, investigated and wrote the protocol and the first draft of the manuscript. Author TA managed the literature searches, reviewed and revised the manuscript. Author MKU supervised and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Contamination of drinking water by Arsenic (As) & Iron (Fe) is nowadays appeared as a big concern for public health and environment as well. Immoderate and continued revelation of inorganic arsenic along with drinking water is triggering arsenicosis. High Fe and As concentration found in the study area is also appeared as very challenging to those people who are consuming the water on regular basis and they may confront to a high health risk. This study is conducted to determine the concentration of Fe and As in ground tube-well containing possible health risk in Bangladesh which examines the ground water As and Fe scenario of Singair Upazila, Manikganj district. Total 40 samples were collected from the study area. As and Fe were analyzed using Atomic Absorption Spectrophotometer (AAS). The study found As concentration ranged from 0.0011 to 0.0858 mg/L

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with the mean concentration as 0.04186 mg/L. Concentration of Fe was found 0.175 to 13.865 mg/L with the mean concentration as 3.600 mg/L whereas WHO standard level is 0.01 mg/L for As and 0.3 mg/l for Fe. It was also noticed that As and Fe concentration in shallow tube-well was relatively high than that in deep tube-well and a strong correlation between As and Fe was marked in the ground water. Therefore, to cope with this challenge, people should look for other sources or relocate the tube-well or treat the water for drinking and other everyday purposes.

Keywords: Arsenic; iron; ground water; health risk; Bangladesh.

1. INTRODUCTION

Water is the foremost constituent of the fluids of livings and is decisive for all known forms of life. Groundwater acts as an important component of natural resources and plays a significant role to serve many purposes as drinking, irrigation, and other domestic usages [1]. A lot of people in different countries are exposed to excessive levels of As by ingestion of As-prone groundwater. Elevated level of As in groundwater has also been well documented in Bangladesh [2–6]. Groundwater contamination in Bangladesh is reported to be the biggest issue in the world nowadays [7]. As a developing country, Bangladesh is coping with great problems of water pollution caused by excessive use of pesticides, fertilizers, disposal of wastes etc. [8]. But contaminations by As and Fe have the most harmful upshot on human health, though these elements are very little in amount in groundwater [9]. In developing countries, about 80% of the diseases are related to contaminated water and the resulting death is 10 million per year [10]. In 1993, the Department of Public Health Engineering (DPHE) of Bangladesh first reported the existence of As poisoning in groundwater. According to World Health Organization (WHO), inorganic arsenic has assumed as a carcinogenic agent which have the potentiality to cause cancer [11,12]. The toxicological study indicates that trivalent inorganic arsenic is found more dangerous than pentavalent in human metabolism [13].

Besides, Fe contamination in groundwater is now a big concern in Bangladesh. Fe is most commonly found in nature in the form of its oxides [14]. In several areas of Bangladesh, groundwater withdrawals are causing a huge Fe contamination in groundwater during dry season [15].

This study aims (a) to examine the concentration of As and Fe in groundwater of Singair Upazila (b) to establish a correlation between the concentration of As and Fe and (c) to find out potential health risks of As.

2. MATERIALS AND METHODS

2.1 Location of the Study Area

The area of this study is Singair Upazila of Manikganj district which is located between $23^0 45'$ and $23^0 50'$ north latitudes and between $90^0 04'$ and $90^0 15'$ east longitudes. This area covers a total of 217.56 sq km and is bounded by Dhamrai and Manikganj Sadar upazila on the north, Nawabganj (Dhaka) upazila on the south, Savar and Keraniganj upazila on the east, Manikganj Sadar upazila on the west. Here, the main water bodies are the rivers of Dhaleshwari, Ghazikhali and Kaliganga.

2.2 Sample Collection Procedure

2.2.1 Quality control

In environmental impact assessment, sample collection procedure must have special importance in case of evaluating inorganic pollutants like As, Fe and other trace elements. As is known to be adsorbed by glass surfaces on prolonged standing. Depending on the presence of other redox species, As^{+3} rapidly converts to As^{+5}. Many water samples containing As, also carry fairly a large concentration of Fe, which in contact with air is transformed into ferric hydroxide [$Fe(OH)_3$]. $Fe(OH)_3$ thus precipitated can remove As from the water samples. As a result, there may be a change in the concentration of As during subsequent measurements. To circumvent this situation a few drops of 2M HNO_3 was added to suppress the precipitation of $Fe(OH)_3$.

2.2.2 Sampling

Ground water samples were collected at the GPS location of 23°48´21.874´´N and 90°8´59´´E of Singair Upazila.

Fig. 1. Map of the study area

Total 40 samples were collected from this locations on August 28 to August 31 in 2015 at day time between 9:00 am to 3:00 pm with an interval of 20-25 minutes. At each sampling site, the geographic location was recorded by a hand-held Global Positioning System (GPS) receiver and information of the depth of tube-wells were attained through personal communication with the tube well owners.

At each site, tube-well was purged for approximately 3–5 minutes to expel any standing water in the well pipes and water was pumped into a plastic beaker in which pH was measured using a portable pH meter. Then samples were collected in 250 ml plastic bottles and tightly screwed. All the samples were stored in dark and controlled temperature in the Water Research Centre of Jahangirnagar University, Savar, Dhaka before transporting to the laboratory where samples preparation and analysis were initiated. The entire study was carried out in Bangladesh Council of Scientific & Industrial Research (BCSIR).

2.3 Chemicals and Equipments

- De-ionized water (DI water),
- Concentrated Hydrochloric acid (HCl),
- Potassium Iodide (KI),
- Sodium Borohydrate ($NaBH_4$),
- Concentrated Nitric acid (HNO_3),
- Hot plate
- Beaker, pipette etc.

2.4 Methods of Sample Analysis

The parameters of As and Fe were measured by Atomic Absorption Spectroscopy (AAS), (Model No: AAS 240 FS).

2.5 Principle of AAS

The technique uses absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with investigated analyte content to form the relation between the measured absorbance and the analyte concentration and relies therefore on the Beer-Lambert Law. In brief, the electrons of the atoms within the atomizer can be upgraded to higher orbitals (excited state) for a short duration of time (nanoseconds) by absorbing a specified quantity of energy (radiation of a given wavelength). This volume of energy, i.e., wavelength, is specific to a certain electron transition in a particular element. As a whole, each wavelength corresponds to one element only and the width of an absorption line is merely of the order of a few picometers (pm), which provides the technique its elemental selectivity. The radiation flux with a sample and without a sample in the atomizer is measured with the application of a detector and the ratio between the two values (the absorbance) is converted in order to analyte concentration or mass using the Beer-Lambert Law [16].

Fig. 2. Atomic absorption spectroscopy

2.6 Sample Preparation for Arsenic (As)

The sampling procedure of Arsenic was accomplished as below-

- At first 2.5 ml sample water were taken into a 25 ml volumetric flask.
- Then 2.5 ml Conc. HCl were added to the sample.
- After that 2.5 ml KI were added to the sample and filled up the sample with DI water up to the mark of the volumetric flask.
- Finally, $NaBH_4$ was added before analyzing the sample by AAS at the temperature of 925°C with a wave length of 193.7 nm.

2.7 Sample Preparation for Iron (Fe)

The sample preparation of Iron was accomplished maintaining the steps as below-

- At first the 250 ml beakers were washed with distilled and DI water.
- Taken 50 ml sample water.
- Added 2 ml HNO_3.
- Filled up the beaker up to the mark by adding DI water & heated the solution at (216-230)°C on a hot plate.
- Stopped heating when the sample solution was almost 25 ml.
- Finally, collected the sample solution into a 50 ml volumetric flask and added DI water to the sample up to the mark and measured it by AAS with the wave length of 248.3 nm.

3. RESULTS AND DISCUSSION

3.1 pH of the Sample Water

The investigated pH value of the ground water of Singair Upazila varied from 6.5 to 7.55 with an average value of 7.09. This variation was found according to the depth of tube-wells. The observed average value indicated the neutral condition of ground water.

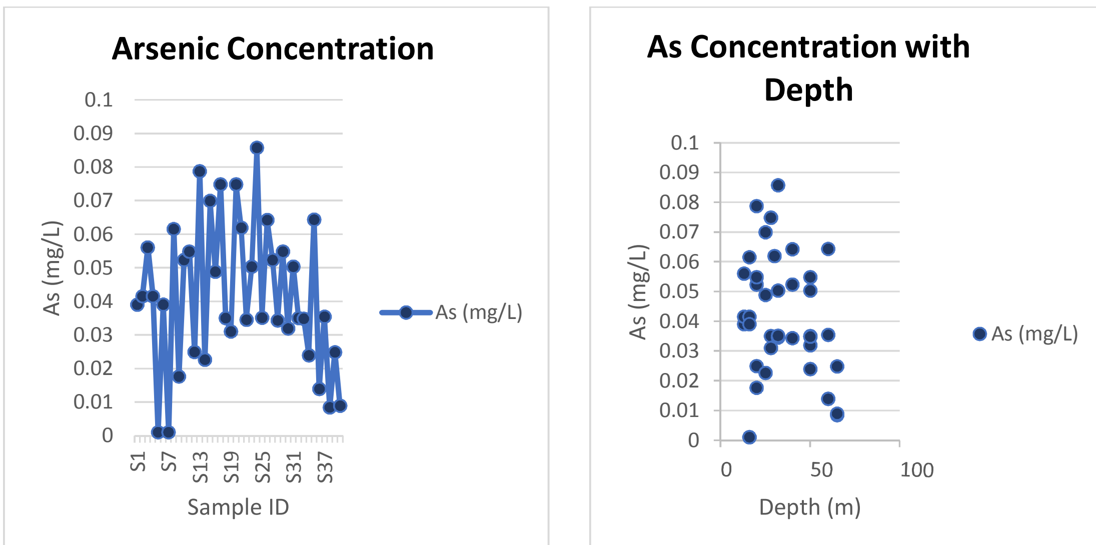
3.2 Arsenic (As) Concentration in Ground Water

Fig. 3a shows the graphical presentation of As concentration of the ground water of 40 samples which indicates that most of the areas had high As concentration than the permissible level (0.01 mg/L) recommended by WHO.

Concentration of As in Singair Upazila ground water varied from (0.0011 to 0.0858) mg/L with a mean concentration of 0.04186 mg/L. In shallow aquifer between (10-30) m, 21 samples were taken and found a mean of As concentration as 0.04423 mg/L which had focused that the shallow aquifer had a great portion of As minerals which release As at a reducing condition, but some displacements were also shown in the shallow tube-wells of Singair ground water, where the As concentration was relative low. In aquifer range between (31-50) m, 13 samples were taken and found a mean of As concentration as 0.0453 mg/L. In aquifer greater than 50 m, 6 samples were taken and found a mean of As concentration as 0.02605 mg/L, that focused the decreasing rate of As concentration with depth which was a common scenario of other As contaminated area. But all of these mean values were higher than WHO standard (0.01 mg/L) and the study area was very badly affected by arsenic. The concentration had predominantly varied for regional variation, which are shown in Fig. 3b.

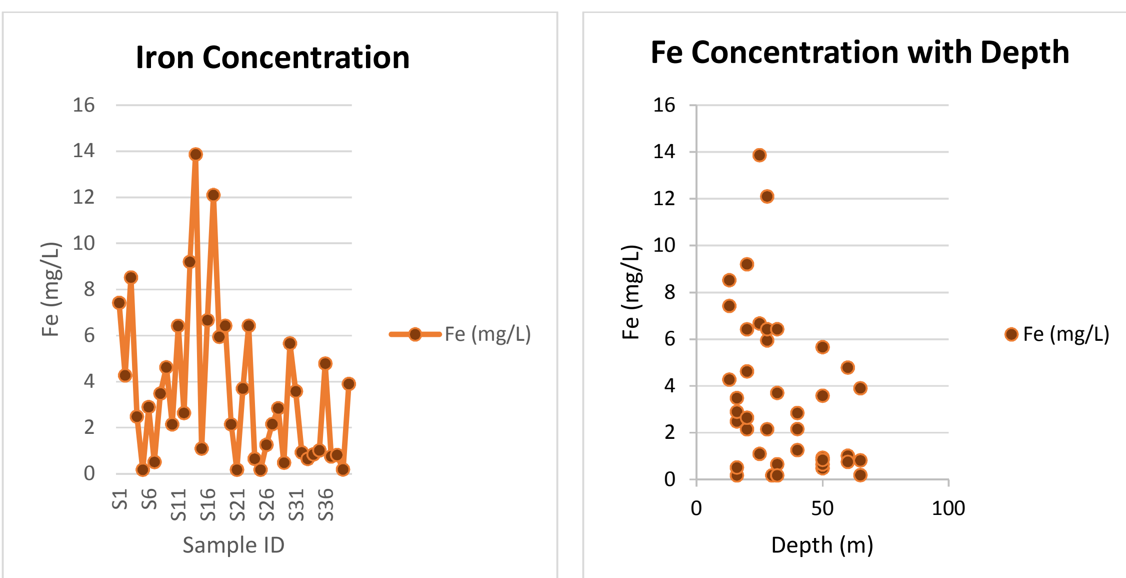
3.3 Iron (Fe) Concentration in Ground Water

Fig. 4a presents the graphical image of Fe concentration of the ground water of 40 samples which indicates that most of the areas of Singair Upazila had high Fe concentration than the



(a) As Concentration of Samples **(b) Concentration of As with depth**

Fig. 3(a&b). Concentration of arsenic in ground water



(a) Fe Concentration of Samples **(b) Concentration of As with depth**

Fig. 4(a&b). Concentration of iron in ground water

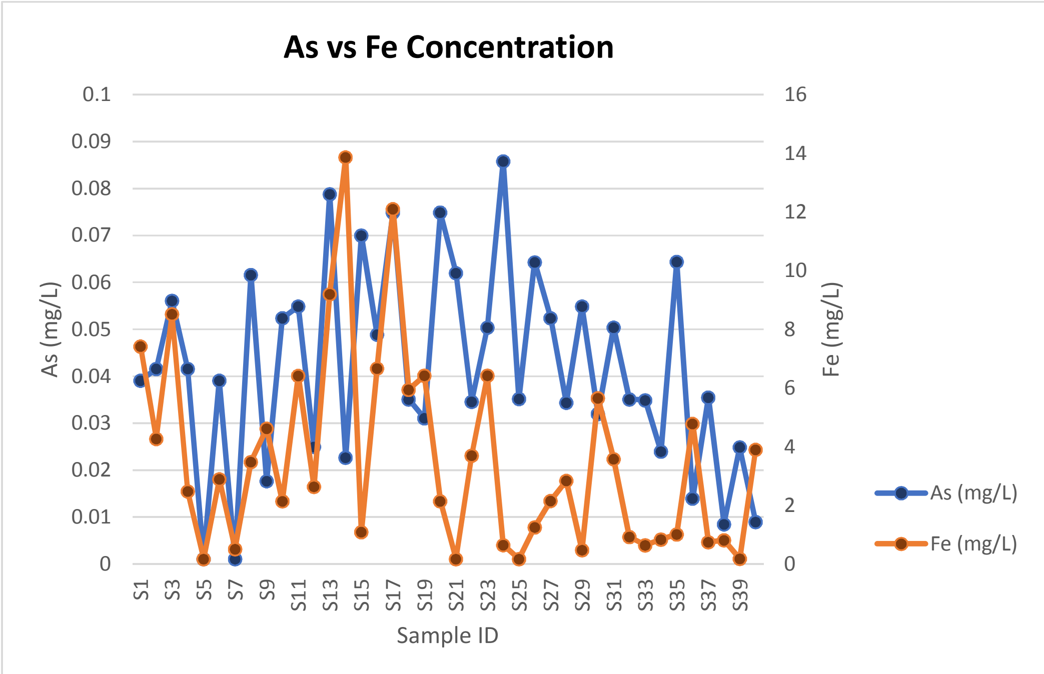


Fig. 5. Concentration of as with Fe in ground water

recommended level (0.3 mg/L) while on the contrary, only very few areas had low Fe concentration.

Concentration of Fe in ground water of Singair Upazila varied from (0.175 to 13.865) mg/L with a mean of Fe concentration as 3.600 mg/L. In shallow aquifer between (10 - 30) m, 21 samples were taken and found a mean of Fe concentration as 4.9145 mg/L. In aquifer range between (31-50) m, 13 samples were taken and found a mean of Fe concentration as 2.257 mg/L. In aquifer greater than 50 m, 6 samples were taken and found a mean of Fe concentration as 1.909 mg/L. Iron concentration was comparatively high in shallow aquifer but with the increasing of depth the concentration became reduced, which are shown in Fig. 4b.

3.4 Arsenic vs Iron Concentration in Ground Water

The graphical representation (Fig. 5) shows that As and Fe in Singair Upazila were stayed together with different concentrations. Concentration of As and Fe varied by depth and place. In some places, Fe portion was found very high where As portion was relatively low. Moreover, some places also showed similar or very near appearances in concentration of both the elements. Further, it was noticed that at high depth concentration of both As and Fe were relatively low [17].

The ground water sampling location and depth with arsenic and iron concentration are as below in Table 1.

3.5 Discussion

Inorganic arsenic is assumed as a carcinogenic agent according to the Department of Health and Human Services (DHHS), Environmental Protection Agency (EPA) and World Health Organization (WHO) which have the potentiality to cause cancer in humans [11,12]. Tube-well waters have been contaminated by arsenic (As) in 61 districts of Bangladesh [18]. About more than 20 million people are drinking water exceeding the national standard for arsenic levels in Bangladesh [19]. Arsenic concentration for most of the water samples in this study are also found comparatively higher than WHO recommended limit (0.01 mg/L). Arsenic concentration above WHO recommended guidelines are chemically unfit for human consumption in the study area. Intermittent incidents of arsenic contamination in groundwater also can arise both naturally and industrially. The natural occurrence of

Table 1. The ground water sampling location and depth with arsenic and iron concentration

Sample Id	Latitude	Longitude	Depth (m)	As (mg/L)	Fe (mg/L)
S1	23.80226	90.14957	13	0.0391	7.42
S2	23.79675	90.16607	13	0.0416	4.27
S3	23.7852	9.0985	13	0.0561	8.52
S4	23.80608	90.241529	16	0.0416	2.482
S5	23.80029	90.183719	16	0.0011	0.175
S6	23.79978	90.124567	16	0.0391	2.896
S7	23.79932	90.190935	16	0.0011	0.512
S8	23.80755	90.142536	16	0.0616	3.482
S9	23.79927	90.239476	20	0.0177	4.62
S10	23.80029	90.234987	20	0.0524	2.146
S11	23.79928	90.190345	20	0.0549	6.42
S12	23.7785	90.097105	20	0.025	2.64
S13	23.6852	90.2456	20	0.0788	9.2
S14	23.8061	90.190936	25	0.0227	13.865
S15	23.68925	90.257845	25	0.07	1.095
S16	23.8208	90.13102	25	0.0489	6.67
S17	23.75465	90.190936	28	0.0749	12.1
S18	23.79928	90.239478	28	0.0351	5.945
S19	23.80608	90.145268	28	0.0311	6.425
S20	23.75466	90.135687	28	0.0749	2.146
S21	23.77025	90.133793	30	0.062	0.175
S22	23.80086	90.133793	32	0.0346	3.7
S23	23.80303	90.239478	32	0.0504	6.425
S24	23.79952	90.204512	32	0.0858	0.651
S25	23.7806	90.0995	32	0.0352	0.175
S26	23.79571	90.266735	40	0.0643	1.256
S27	23.82412	90.125482	40	0.0524	2.156
S28	23.76356	90.10425	40	0.0344	2.842
S29	23.79928	90.1909	50	0.0549	0.481
S30	23.80284	90.198873	50	0.032	5.658
S31	23.79796	90.198873	50	0.0504	3.581
S32	23.79926	90.239478	50	0.0351	0.929
S33	23.78524	90.16548	50	0.0349	0.645
S34	23.754	90.095485	50	0.024	0.841
S35	23.80971	90.089738	60	0.0644	1.017
S36	23.75184	90.102873	60	0.014	4.783
S37	23.78921	90.145267	60	0.0355	0.752
S38	23.76548	90.14975	65	0.0085	0.816
S39	23.8027	90.101311	65	0.0249	0.186
S40	23.80752	90.103345	65	0.009	3.9

arsenic in groundwater is directly associated with the arsenic complexes present in soils. Arsenic can liberate from these complexes under some conditions. Since arsenic in soils is extremely mobile, once it is liberated, it results in possible groundwater contamination.

The yellowish color of water indicated the presence of iron (Fe) in the collected water samples. The highest amount of iron was found as (13.865 mg/L) while the lowest amount was also 0.175 mg/L in Singair Upazila, Manikganj district, Bangladesh. It was found from the study that most of the samples had exceeded the standard levels of iron concentration proposed by World Health Organization (WHO) as 0.3 mg/l, which indicated that the sources of water were not suitable for drinking purposes. These higher amounts of iron found in the study area might be very harmful to health of the members of those families who had been using those water sources for their daily drinking and other domestic purposes. To overcome such health hazards, the inhabitants should avoid drinking these higher amount of iron containing groundwater immediately and should also find other sources of water or relocate the tube-well or bring the water under treatment for drinking and other daily usages. In Bangladesh, groundwater withdrawals are causing a large iron contamination in groundwater levels during the dry season [15]. Since, millions of people of Bangladesh rely on groundwater sources for their daily purposes, the determination of groundwater quality is one of the most needful tasks. Because, only the outcomes of such investigations can show the way to detect and minimize different health hazards and can ensure a healthy life for the inhabitants in safe drinking water issues.

3.6 Health Risk Associated with Arsenic

3.6.1 Population affected by arsenic contamination

The most commonly reported symptoms (often referred to as arsenicosis) of chronic exposure to arsenic are hyperpigmentation (dark spots on the skin), hypopigmentation (white spots on the skin) and keratosis (skin hardens and develops raised wart-like nodules). Sometimes, hyperpigmentation and hypopigmentation are commonly referred to as melanosis. Chronic exposure to arsenic can also cause skin cancer, internal cancers and a wide range of other health problems (e.g., abdominal pain, nausea, vomiting, diarrhea, anemia). The most commonly manifested disease in Bangladesh so far is skin lesions (melanosis and keratosis). It estimated that the prevalence of arsenicosis in Bangladesh annually could be up to two million cases if consumption of contaminated water continues [20]. For skin cancer, it could be up to one million cases and the incidence of death from arsenic-induced cancer could be 3,000 cases. In a survey conducted in 270 villages of Bangladesh, more than 7,000 arsenicosis patients were identified [21].

3.6.2 Toxicity of Arsenic (As)

As toxicity in humans and animals have been recognized by different review articles. It is a potent carcinogen, leading to skin, bladder, liver and lung cancers [22]. It induces epidemiological toxicity and is also known to cause cytotoxicity [23] and genotoxicity [24]. Moreover, the ingrained fact is that the continuing exposure to arsenic can direct to arsenicosis including different dermal diseases and cancers. Several studies also have signified elevated level of As to be the sole reason for arsenicosis [25].

The upshot of the current study have pointed out the average As concentration (0.04186 mg/L), which have surpassed the standard value (0.01 mg/L) set by WHO and indicated the above health risks for the inhabitants of Singair Upazila as well as the inhabitants of 61 As-prone districts of Bangladesh.

4. CONCLUSION

It is to be concluded that arsenic and iron concentration found in most of the tube-wells water was significantly higher than the permissible limits proposed by WHO, though the concentration of both the elements varied regarding place and depth of tube-wells. The findings of this study clearly articulate that drinking such tube-well water contaminated especially by As concentration surely poses great health risks to the inhabitants who uses those water for drinking and other daily purposes. Simultaneously, the study draws attention of the people of Bangladesh to be aware of this vulnerability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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