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STUDY OF HYDROLOGICAL CHARACTERS OF THE GROUNDWATER IN AN ARSENIC CONTAMINATED ZONE IN WEST BENGAL, INDIA

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ABSTRACT

Arsenic occurs widely in groundwater of the alluvial aquifers of the southern part of the Bengal Basin in West Bengal and Bangladesh. Groundwater is regularly used for agricultural and household purposes in these areas. The Nadia district of the Bengal delta plain, situated in West Bengal, India has been selected for studying the hydrological parameters of the groundwater in the pre monsoon and post monsoon periods. The area is mostly groundwater dependent for irrigation purpose, and the inhabitants use hand pumped tube wells for daily water requirements. The water samples were collected from the study area (Kalinarayanpur, Ranaghat Block, Nadia; 23°22’ N, 88°56' E) by hand pumping from the shallow tube wells of average 70 feet depth. The concentrations of Lead (Pb), Cadmium (Cd) and Copper (Cu) didn’t vary in the water samples in two different sampling seasons, while pH, Arsenic (As), Iron (Fe) and Fluoride (F) varied with two different seasons. The water samples were generally neutral to slightly alkaline in nature, and most of the samples contained fluoride, iron, copper, cadmium under permissible limit. Arsenic contents of most of the samples of the zone were 10-15 times higher than the permissible limit recommended by WHO. Additionally, most of the water samples were found to be highly contaminated with lead. The study overall revealed that arsenic and fluoride are the two significant hydrological threats in that area and need to be mitigated urgently.

1. INTRODUCTION

Bengal delta is one of the largest deltas of the world and accommodates an enormous volume of sediments deposited during the Tertiary and Quaternary periods.[1] It was formed by the sedimentation of the river *Ganga, Brahmaputra* and *Meghna*, along with their tributaries and distributaries.[2] During the late Holocene period, marshy or swampy lowlands developed in several parts of the Bengal Delta Plain and formed the peat and other sediments rich in organic matter.[3] The Bengal basin is regarded to be the most acutely arsenic affected geological province in the world.[2]

The densely populated areas of Bangladesh and India, although traversed by two of the world's largest river systems and recipient of several meters of rainfall yearly, faces unparalleled water-supply problems.[4] As rainwater is insufficient to support the water demand of the increasing population and intensive agricultural system of West Bengal, thousands of shallow tube-wells were installed for irrigation in last 40-45 years.[4] A vast majority of these tube wells have been installed privately with locally available expertise, without any check of the quality and yield of the water that originates from them. Heavy withdrawal of groundwater, especially during that lean period, resulted in oxygenated decomposition of pyrites forming Fe^{2+} and Fe^{3+} sulphates and sulphuric acid, which in turn are responsible for arsenic mobilization.[1] Due to different hydro-chemical behaviors of aquifers in the Bengal delta, the redox potential, pH, temperature, Ca-HCO_3 or Ca-Mg-HCO_3 water type vary substantially which control the arsenic dynamics in the area.[1] In groundwater, inorganic arsenic commonly exists as As(V) (arsenate) and As(III) (arsenite), among which the trivalent state is considered to be more mobile and toxic for living organisms[1]. Arsenate can be efficiently adsorbed in sediments and the high arsenic concentrations are mostly correlated with high HCO_3 concentrations.[5] The mobility of arsenic is mainly determined by the adsorption capacity on the mineral surfaces, which is controlled by geochemical parameters such as pH, Eh, ionic composition, and mineral type.[6] However, redox processes in the aquifers trigger the mobility through dissolution of the Fe oxides that transfer substantial amounts of arsenic into the aqueous phases.[1]

The Bengal arsenic disaster is possibly one of the worst environmental catastrophes in the history of human civilization. In Bangladesh, 118849 km^2 area and over 30 million people are affected with arsenic poisoning,[7] whereas in West Bengal, 38865 km^2 area and approximately 6 million people are affected; of which nearly 3 million people have arsenic skin lesions.[8] The figures are more prominent than the other arsenic affected areas of the world and are increasing day by day. More than 100 million people are living in the arsenic affected districts of India and Bangladesh. The objective of the study is to identify the extent of arsenic contamination in the groundwater along with other water parameters and their pre monsoon (April-June) and post monsoonal (October-December) variations. The study was performed in and around Kalinarayanpur (23°22' N, 88°56' E), Nadia, West Bengal, India. The region, while being among the maximally affected zones of the country due to arsenic pollution, is greatly involved in agriculture.[7] The agricultural system in this region is mostly dependent on irrigation with groundwater obtained from a depth ranging from 70 ft. to 600 ft. through tube-wells. Huge amount of groundwater is used for agricultural irrigation. Much of this groundwater is contaminated with arsenic, which is deposited in the soil in contact with the irrigation water throughout the year.

2. MATERIALS AND METHODS

2.1. Collection of water samples: The sampling bottles were pre-conditioned with 5% nitric acid and later rinsed thoroughly with distilled de-ionized water. Groundwater samples were collected from forty randomly selected tube wells, which were generally used by the local farmers for irrigation purpose. These tube wells are generally used for drinking, cooking and other household purposes by the villagers and shallow large-diameter tube wells are used for agricultural irrigation. At each sampling site, the polyethylene sampling bottles were rinsed at least three times before sampling was done. Groundwater samples were collected from four distinctly isolated spots in the study area. The tube wells were pumped individually for 10 minutes to expel the water remaining in the tube well column, and then water samples were collected in the polyethylene bottles.[9] About 500 ml. of the water samples were taken at each sampling site. Samples were acidified with 10% HNO_3, placed in an ice bath and brought to the laboratory. The samples were filtered through a 0.45 μm micropore membrane filter and kept at 4 °C until analysis. Samples were collected from the respective tube wells three times: at pre-monsoon, monsoon and post-monsoon seasons and the same procedure of sample collection were followed every time. Sampling were done for three consecutive pre monsoon (April to June) and post monsson period (October to December) during the period 2008-2011 and the samples were analyzed accordingly.

2.2. Measurement of pH: pH was measured in the field condition without any kind of processing of the water samples by using portable pH meter.

2.3. Test for As, Pb, Cd and Cu in groundwater. Levels of As, Pb, Cd and Cu in groundwater was estimated by HG-AAS using an AAnalyst 200 atomic absorption spectrometer (Perkin Elmer, MA, USA) fitted with a FIAS-100 (Perkin Elmer, MA, USA) flow injection system.[10,11] Levels of arsenic were also measured by spectrophotometric method using silver dithiodiethylcarbamate (SDDC) for further verification.[11]

2.3. Test for Iron in groundwater: In a 100 ml volumetric flask, a definite measured volume of water sample (iron content 0.01-0.05 mg) was mixed with 10 ml buffer solution followed by 5 ml hydroxyl amine hydrochloride and 4 ml o-phenanthroline and made up the volume. After 15 minutes, absorbance was measured using spectrophotometer at 510 nm, and then the concentration was estimated from calibration curve.[11]

2.4. Test for Flouride in groundwater: For estimation of fluoride content in the water samples, 50 ml of a water sample (F^- content < 1.4 $\mu g.L^{-1}$) was taken in a 100 ml volumetric flask. 10 ml mixed reagent (5 ml SPADNS solution and 5 ml zirconyl acid reagent) was added and mixed well. The spectrophotometer was adjusted to zero absorbance with the reference solution (reference solution: 10 ml SPADNS solution was added to 100 ml distilled water. 7 ml conc. HCl diluted to 10 ml was then added to the diluted SPADNS solution. Resulting solution was used for zero absorbance) and absorbance was measured at 570 nm. Fresh reference was used for every set of measurement. Fluoride concentration was estimated from the calibration curve.[11]

3. RESULTS AND DISCUSSIONS

For the estimation of the collected water samples, data were collected for two seasons (Pre-monsoon and Post-monsoon) to study the change in the groundwater parameters. All the concentrations are expressed as ppm. or mg./lt. The concentrations of Lead (Pb), Cadmium (Cd) and Copper (Cu) didn't vary in the water samples in two different sampling seasons, while pH, Arsenic (As), Iron (Fe) and Fluoride (F) varied with two different seasons. Most of the groundwater samples were found to be highly contaminated with arsenic and some of them showed severely high arsenic concentration compared to the recommended permissible limit of WHO[12] (Figure 2). Maximum contamination level found was 0.17 ppm., whereas the permissible limit of arsenic in drinking water is only 0.01 ppm[12]. This evidently confirmed that the site of the study was highly contaminated with arsenic; in congruency with a previous report by Chakraborti *et al.*[7] Most of the water samples were neutral to slightly alkaline in nature (Figure 1). Fluoride and iron levels of the groundwater samples were found to be well under permissible limit (Figure 3,4). Interestingly, most of the water samples were found to be contaminated with lead, with a highest contamination level of 1.198 ppm. (Figure 5). Cadmium and copper concentrations were also well under permissible limit, except in one sample, where both the element were found to be quite above the permissible limit (3.186 ppm. of Cadmium and 2.436 ppm. of Copper) (Figure 6,7). Mean and standard deviation of the water parameters data was shown in Table 1.

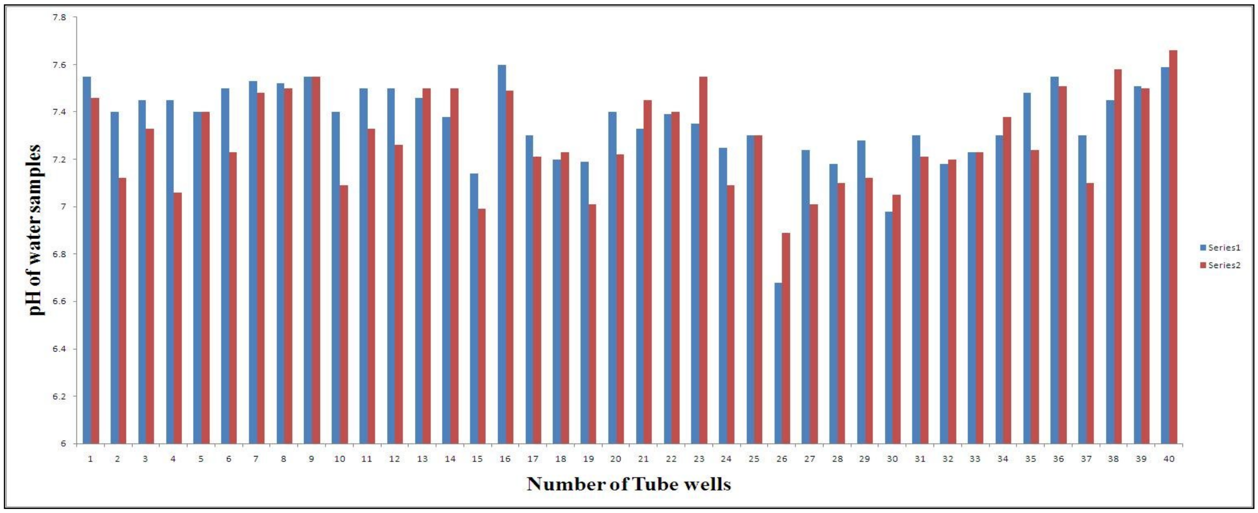

Figure 1. Variations of pH in the tube well water samples in the pre-monsoon and post monsoon season, Series 1 (in blue colour) indicates the pre-monsoon pH value and series 2 (in red colour) indicates the post-monsoon pH value.

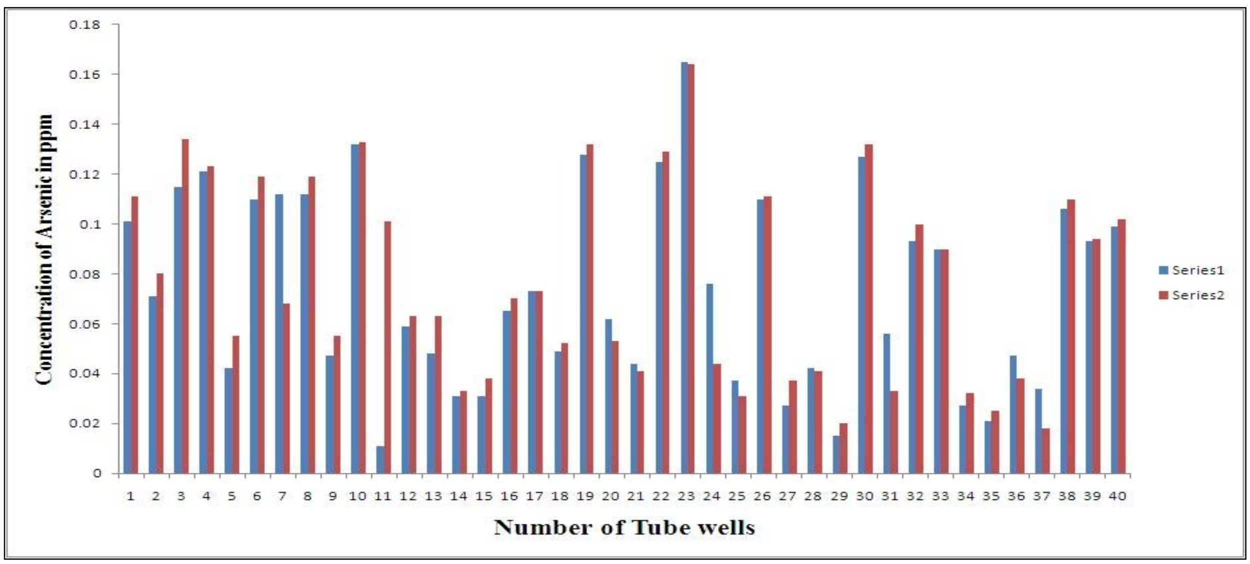

Figure 2. Variations of arsenic content in the tube well water samples in the pre-monsoon (Series 1 in blue colour) and post monsoon season (Series 2 in red colour). In both season the level of arsenic is above the permissible limit in most of the water samples.

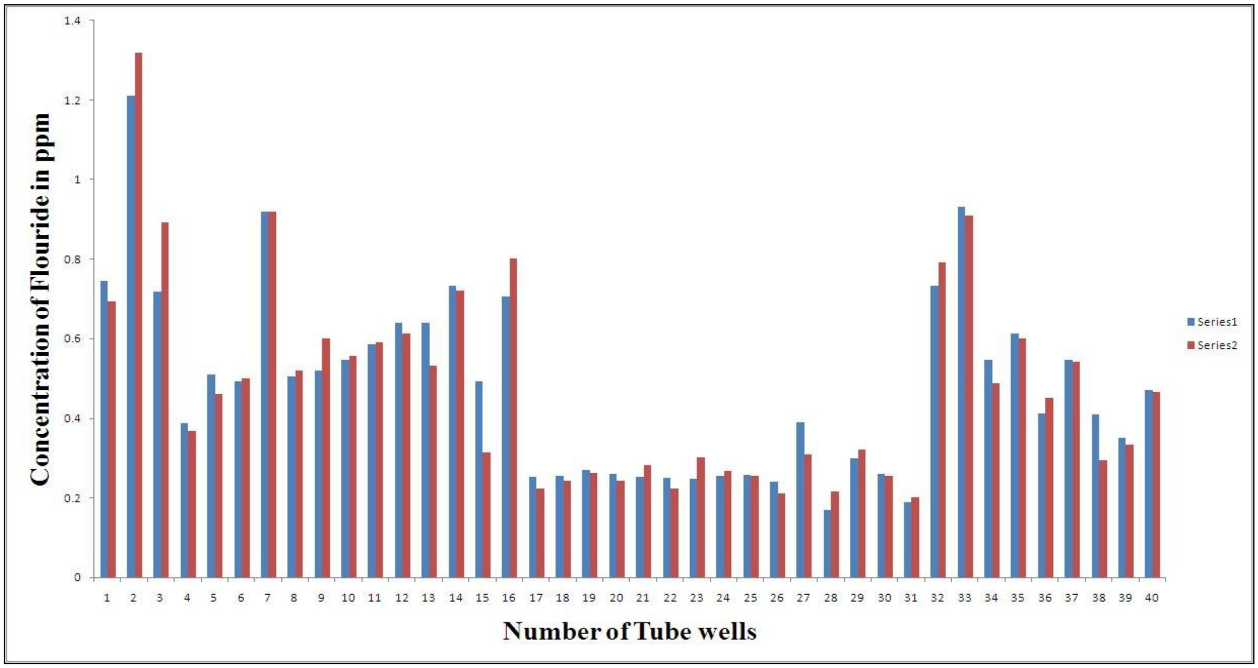

Figure 3. Variations of fluoride content in the tube well water samples in the pre-monsoon and post monsoon season. Series 1 (in blue colour) indicates the pre-monsoon concentration and series 2 (in red colour) indicates the post-monsoon concentrations.

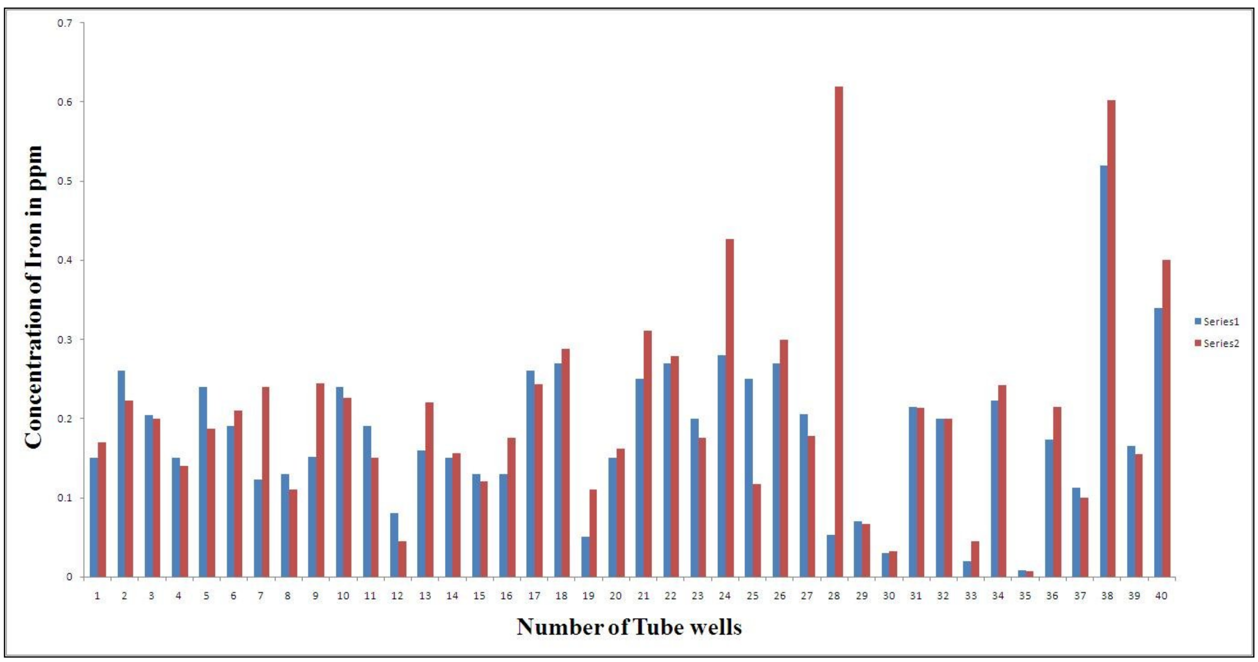

Figure 4. Variations of iron content in the tube well water samples in the pre-monsoon and post monsoon season. Series 1 (in blue colour) indicates the pre-monsoon concentration and series 2 (in red colour) indicates the post-monsoon concentrations.

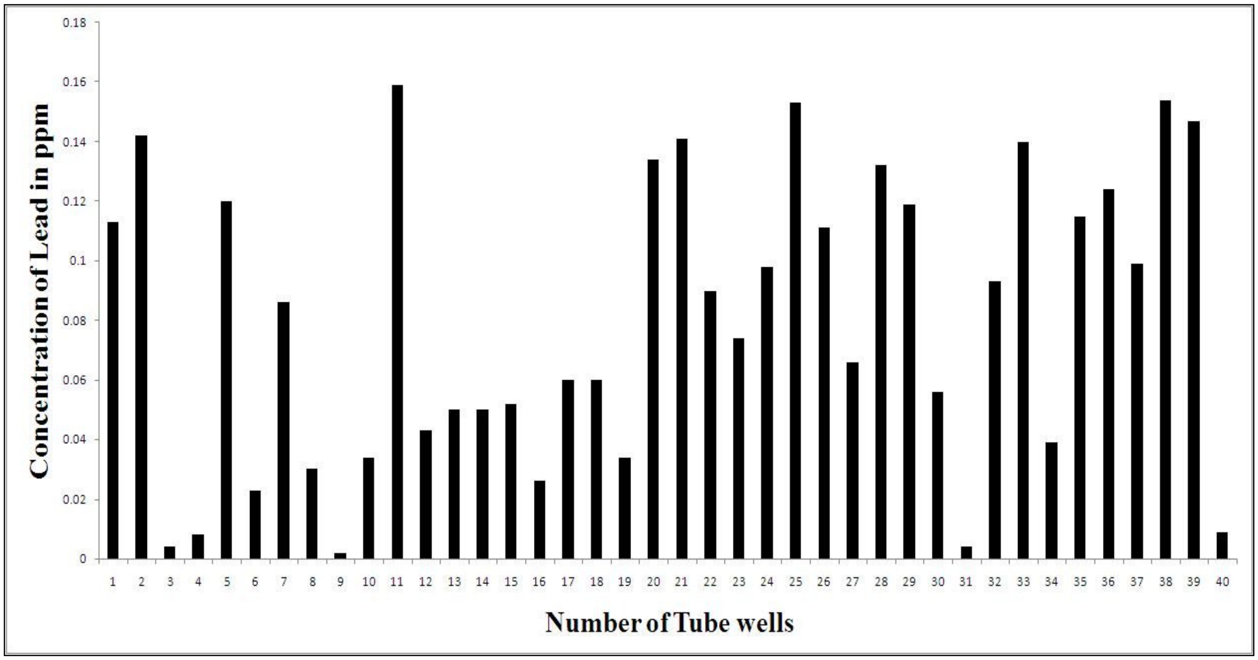

Figure 5. Concentrations of lead in the tube well water samples. Most of the samples contained lead over permissible limit recommended by WHO.

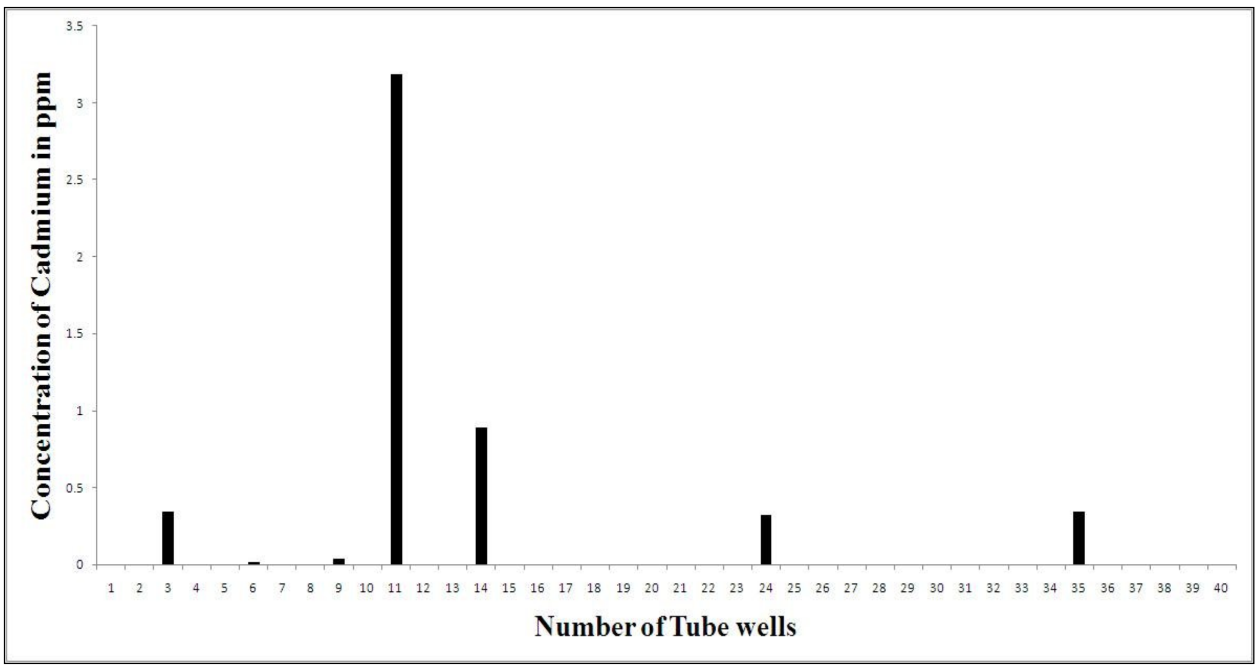

Figure 6. Concentrations of Cadmium in the tube well water samples. Most of the samples had no cadmium; however in five samples shown above, the levels were higher than permissible limit of WHO.

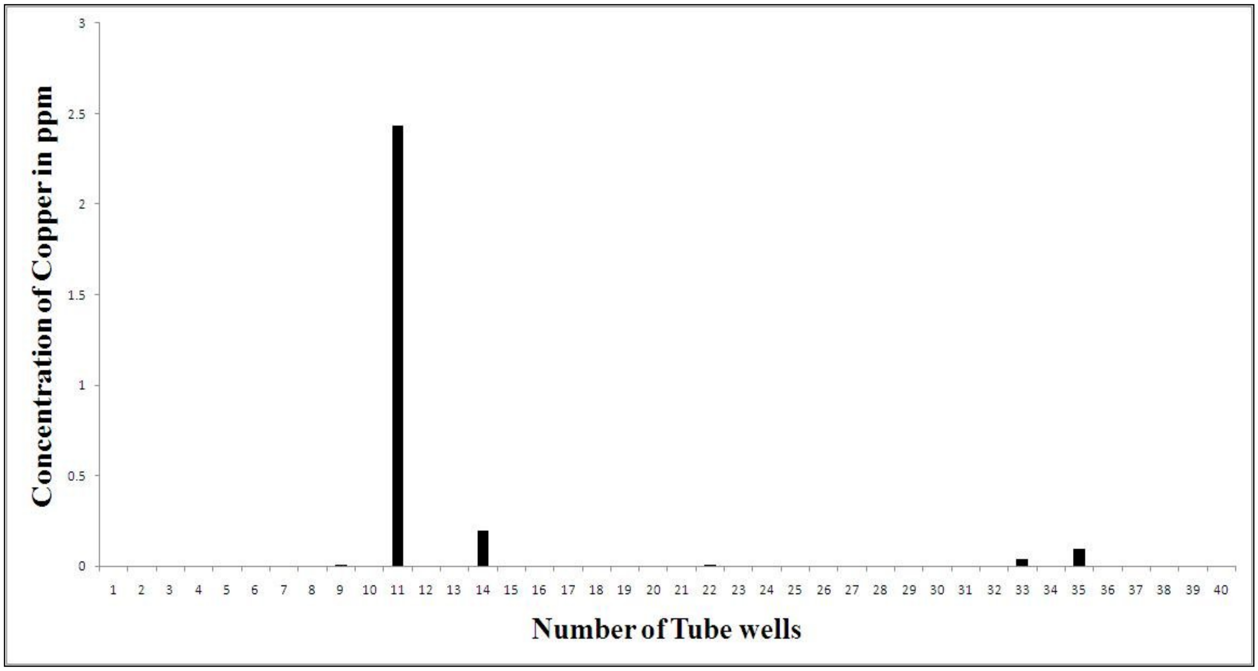

Figure 7. Concentrations of Copper in the tube well water samples. Only in one sample, the concentration exceeded the permissible limit of WHO.

Table 1: Descriptive statistics of the water samples data.

	Mean	Standard Deviation	Number of samples (N)
pH pre monsoon	7.3573	.17931	40
pH post monsoon	7.2882	.19705	40
Arsenic in ppm. pre monsoon	.07532	.03805	40
Arsenic in ppm. post monsoon	.07671	.04004	40
Flouride in ppm. pre monsoon	.4803	.23480	40
Flouride in ppm. post monsoon	.4772	.25386	40
Iron in ppm. pre monsoon	.1816	.09655	40
Iron in ppm. post monsoon	.2077	.12990	40
Lead in ppm.	.0799	.04952	40
Cadmium in ppm	.1288	.52212	40
Copper in ppm.	.0698	.38525	40

4. CONCLUSION

As the local agricultural system is highly dependent on groundwater irrigation in Bengal Delta, the arsenic contaminated groundwater can pose threat to the locally growing crops and edible plants. Soil arsenic levels are strongly related to local well water arsenic concentrations, which indicate that the source of soil contamination is the irrigation water (Bhattacharya et al. 2007). In

Bangladesh, where irrigation is carried out with arsenic contaminated groundwater, soil arsenic level can reach up to 83 mg/kg.[13] Except for the rainy season, the agricultural land is exposed to irrigated groundwater round the year. Sometimes the farmers used to run the shallow tube wells in the rainy season due to insufficient rain. Rice is the main cultivable crop of our study area and several researchers already showed that rice is a very efficient accumulator of arsenic because of the formation of iron plaque in the rhizosphere zone of the plant and the submerged condition of the soil during cultivation, because of which arsenic generally remain in bioavailable form in the rice root zones.[14] It is evident from our study that the study zone was highly contaminated with arsenic, which, in turn, can affect the human health. Intensive investigation on a complete food chain is urgently needed in the zone, which should be one of the priorities in future researches. Besides, lead contamination which was found in some of the tested samples indicates that thorough environmental monitoring is required for the area for detecting the source of lead pollution. There is no industry found in that area from which lead contamination can be occurred. However, there is a possibility of lead contamination from pesticides and fertilizers used for agricultural purpose in that area. Arsenic contamination is already affecting the inhabitants of that area; cumulative toxicity of lead and arsenic will be detrimental for the local population.

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