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ASSESSMENT OF GROUNDWATER QUALITY AT MEHERCHANDI AREA OF RAJSHAHI CITY, BANGLADESH

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ABSTRACT

The physicochemical characteristics of groundwater samples collected from Meherchandi area of Rajshahi City, Bangladesh have been studied for the assessment of its quality and suitability especially for drinking purposes. Twenty water samples were collected from randomly selected domestic water supply tube wells throughout the area. Several parameters including temperature, pH, electrical conductivity (EC), total hardness (TH), total dissolved salts (TDS), quantity of dissolved anions viz. HCO_3^-, Cl^-, SO_4^{2-}, and cations viz. Ca^{2+}, Mg^{2+}, Fe^{3+}, Cu^{2+}, Zn^{2+}, Mn^{2+} and As^{3+} are determined following standard procedures.

It is observed that the ground waters of the area are transparent, colourless, odourless and tasteless at the time of extraction. Descriptive statistics depending upon pH demonstrates that the waters are in general, alkaline in nature; considering TDS, all groundwater samples are rated as 'fresh water' and as regards to hardness, water samples of this area are categorized as 'very hard' in quality. According to drinking water standard, the concentrations of Ca, Mg, Fe, Cu, Zn, Cl and SO_4 in the groundwater samples are within the safe limit causing no ionic toxicity; however the abundance of As, Fe and Mn in few samples may pose potential threats to human health and environment.

KEYWORDS: Groundwater, Physicochemical Characteristics, Trace Metals, Toxicological Effects, Human Health.

INTRODUCTION

Ground water is still the most preferred potable water source in many developing countries including Bangladesh. A compilation of recent estimates suggests that over 100 million villagers of Bangladesh, West Bengal (India), Vietnam, China, and several other South Asian countries drink and cook with groundwater drawn from shallow wells. Once believed to be safe from contamination as groundwater resides many strata below the surface, has now been proved to be prone to pollution by several researchers across the globe [1-5]. The suitability of water for different uses depends on its physical, chemical and biological characteristics; thus total analysis of water of a particular place is highly essential in order to see whether it is safe towards human being and environment. Similar studies

[6-11] have also been reported from the various parts of the world. Taking the above discussion and citation into consideration, the present study aims to provide some information on the physicochemical properties and concentrations of trace metals of groundwater body occurring at different sites of

Meherchandi area of Rajshahi City, Bangladesh. The present piece of work is a continuation of our earlier communications [12-14] reported from this laboratory.

EXPERIMENTAL

The Study Area and Environs

Location, extent and accessability.- Rajshahi is one of the four big cities in Bangladesh, 270 km north west-ward away from Dhaka, the capital of Banladesh. The city is situated on the river Padma and occupying an area of 97 km^2; population is about 0.727 million [15]. The study area is located at Meherchandi of Motihar Thana under Rajshahi City Corporation adjacent to the University of Rajshahi. The area is well connected with Rajshahi Central and other districts by means of national highway and railway. Total extent of the study area is approximately 2.5 sq. km.

Water Sampling Technique

20 groundwater samples of 2 litres each throughout the area were collected in dry clean plastic containers through Hand Pump Tube Wells (HPTW) those were in constant use during the months of April-May, 2005. Before collecting the samples, the wells were pumped for 4/5 minutes to obtain the fresh groundwater and then after rinsing the containers with pumped fresh water, the containers were filled up.

Preservation of the Samples

From each tube well, two samples were collected in two separate containers. To prevent any unwanted reaction, one set of samples is acidified with 1 ml. conc. HCl per litre of the samples for determination of As, Fe and other metal ions. Aeration was avoided as far as possible during sampling. Samples collected from the study area were carefully transported to the laboratory and preserved at a cool place in the dark.

Experimental Measurement

There are certain environment sensitive index parameters which are closely related to the environment of the water and are likely to be altered by sampling and storage thereby a meaningful value can be obtained only in the field. The most important environment sensitive field parameters are electrical conductivity (EC), pH, and temperature. Water quality test kit, Model No. 5, supplied by Abico Scientific Co., Japan was employed to measure the values of pH in the field within 20 minutes after sampling. Temperature of the samples is measured at the spot by using a glass thermometer. Temperature measurements are important for thermodynamic calculation related to water chemistry. The conductivity of water samples was measured as soon as possible after collection. A digital EC meter model HI 9033, Hanna instruments (Italy) was used for the purpose.

Laboratory Analysis

After collecting, the samples were brought to the laboratory and the pH was again measured by a digital pH meter (Model: pH S-3c REX, Shanghai, China). The concentration of metals (Ca, Mg, Fe, Zn, Cu, Mn etc.) was determined directly by flame atomic absorption spectrophotometer (AAS) Model No. Perkin Elmer 3110 (USA) with an air acetylene flame and single hollow cathode lamp at their corresponding wavelength. Arsenic and iron were determined by silver diethyldithiocarbamate and thiocyanate method respectively with the help of UV-Vis spectrophotometer (Model ANA-75, England). Sulphate was determined by UV-Vis spectrophotometer (turbidity method) at the wavelength 420 nm. Alkalinity (as HCO_3^-) was determined by titration method using 0.02M HCl and methyl orange as indicator. Hardness of water was determined by complexometric titration using 0.01 M ethylenediamine tetraacetic acid (EDTA) disodium salt solutions and Eriochrome Black T as indicator. Chloride was determined by titrimetric method using 0.05M $AgNO_3$ solution in presence of potassium chromate (10%) indicator. The chemicals used were of analytical grade (AR) grade and double distilled water was used throughout the study. Due care was practiced in order to follow standard methods for the examination of water [16,17].

RESULTS AND DISCUSSIONS

A total of 20 groundwater samples, collected from different places of Meherchandi area of Rajshahi city, have been studied for their physicochemical parameters in order to determine their quality and suitability especially for drinking purpose. The samples were systematically analyzed using standard physical methods and analytical techniques. Results of colour, odour, pH, EC and total dissolved salt (TDS) are shown in Table 1. After a careful examination, it is observed that the ground waters of the area in general, are colourless, odourless, tasteless, and devoid of turbidity. The pH values of the water samples have been determined in the field as well as in the laboratory. pH is one of the most important parameters in water quality management. The pH range essential for the continuation of biological existence is somewhat sharp and crucial (typically 6.0 to 8.5) which is the recommended drinking water standard [18] from the Bangladesh Standards and Testing Institution (BSTI). However, world health organisation (WHO) [19] sets the maximum permissible pH range for drinking water from 6.5 to 9.2. From Table 1, it is evident that pH of the tube well waters in the area varies from 6.97 to 7.96 (laboratory value) which are within the recommended limit. Hence these pH values make the groundwater of the area suitable for drinking and irrigation purposes. Statistics of analytical results are summarized in Table 4. Regarding pH values, one can see from the table that the central tendency (mean and median values) is prone towards 7.4, which indicates that these water samples are slightly alkaline in nature. This may prove helpful in neutralizing excess hydrochloric acid produced in the stomach of the local people and reduce heartburn. Alkaline pH values are also recorded in other measurements [20-22]. pH values have been applied widely and successfully over many years to ensure the wholesomeness of water [21].

The conductivity measurements are generally used to indicate the concentration of salts in water. The concentration of salts depends on the environment, movement and source of groundwater. EC values of the collected samples varied from 611 to 1059 $\mu S\ cm^{-1}$ with a central tendency of 800 $\mu S\ cm^{-1}$ (cf. Table 4) indicate high mineralisation of the groundwater. Higher value of conductivity may be due to high concentration of ionic constituents present in water. The present value is under permissible limit of

1400 μS cm^{-1} and henceforth potable. Table 2 shows that 8 samples out of 20 are under 'medium' (250-750 μS cm^{-1}) salinity classes [21]. Also, values for salinity could be expressed as TDS in mgL^{-1}. In effect, the measured EC value is used as a surrogate measure of TDS concentration [23]. The concentrations of TDS in the study area are found to lie within the range of 428 to 741 mgL^{-1} (Table 2). Water samples containing TDS value less than 1000 mgL^{-1} are rated as 'fresh water'. United States Public Health (USPH) sets a secondary standard of 500 mgL^{-1} TDS in domestic water supplies for drinking [24] and the maximum permissible limit of TDS in drinking water is 1500 mgL^{-1}. According to this standard, the present results indicate that all groundwater samples are within the safe limit of TDS for drinking and other purposes. High levels of TDS are also reported in literature; for example, TDS value of groundwater samples of Central and South region of Kalol taluka (India) ranges from 628 to 1920 mg/L and 296 to 2320 mg/L, respectively [25]. Secondary standards are unenforceable but recommended guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water. High TDS concentrations can produce laxative effects and can give an unpleasant mineral taste to water.

The alkalinity of natural water is usually due to the presence of HCO_3^-, SiO_3^{2-}, $HSiO_3^-$ and sometimes of CO_3^-. Bicarbonate is usually the major anion present in groundwater. The total alkalinity is not only due to the presence of HCO_3^- and OH^- but also to other ions that react with acid. The alkalinity of water determines the suitability of water for drinking and irrigation purposes. A critical examination of data in Table 2 reveals that alkalinity (as HCO_3^-) of the groundwater of Meherchandi area varies from 338 to 539 mgL^{-1}. The mean and median values coincide around 445 mgL^{-1} (cf. Table 4). The concentration of bicarbonate in groundwater commonly remains less than 500 mgL^{-1} but the tube well waters of 1, 2 and 10 exceed this value and samples no. 8, 13, 14 and 18 tend to achieve this value. Comparing the above data with the standard value, it can be said that the groundwater of the area is suitable for irrigation and acceptable for drinking and industrial purposes with some reservations. Hardness results from the presence of divalent metallic cations, of which Ca^{2+} and Mg^{2+} are the most abundant ones in underground water. Other cations along with the most important anions with which they are associated are: Sr^{2+}, Fe^{2+}, Mn^{2+} and HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-, SiO_3^{2-}. The frequently used standard hardness scale as mgL^{-1} $CaCO_3$, classifies water supplies by soft (0-75 mgL^{-1}), moderately hard (75-150 mgL^{-1}), hard (150-300 mgL^{-1}) and very hard (>300 mgL^{-1}). Table 2 records high values of groundwater hardness that lie within the range from 262 to 460 as mgL^{-1} $CaCO_3$ and with a mean value of 363 mgL^{-1}. After the view of Sawyer and Mc Carty [26], the waters of all tube wells in the present study area are 'very hard' (H_T> 300 as $CaCO_3$) except tube well no. 16. Hence, the groundwater of the area is regarded excessively hard and associated with scale formation in boiler units, heating pipes etc. and needs to be softened if used for industrial purpose. However, the water is near about safe for drinking purpose since the desirable and maximum permissible limit (MPL) of hardness values are within 100 and 500 mgL^{-1} as $CaCO_3$ respectively. The hardness of water is not a pollution parameter but indicates water quality, primarily in terms of Ca^{2+} and Mg^{2+}, expressed as $CaCO_3$ [24].

Chloride in drinking water is relatively harmless, if present in amounts below 75 mgL^{-1} since permissible limit [24] is 250 mgL^{-1}. The principal source of Cl^- in groundwater is sedimentary rocks;

other sources include sewage, industrial wastewater and intruded sea water. Table 2 records the Cl^- content of the groundwater samples from 9.22 to 65.23 mgL^{-1}. Water containing less than 250 mgL^{-1} chloride ion is suitable for drinking, agricultural, and industrial purposes. In view of the above facts, the chloride content of all the ground waters are within the level recommended for drinking and household purposes. In potable water, the salty taste produced by Cl^- concentrations is variable and depends upon the chemical composition of water. If the major cation is Na, some waters containing about 250 mgL^{-1} Cl^- may taste salty whereas if the predominant cations are Ca and Mg, the typical salty taste may be absent [16] in waters containing Cl^- concentrations as much as 1000 mgL^{-1}. The SO_4^{2-} is one of the major anions occurring in natural waters. It has been of utmost importance in public water supplies because of its cathartic effect upon humans when it is present in excessive amounts. In the present investigation SO_4^{2-} concentrations are found in the range of 3.69 to 9.36 mgL^{-1} (cf. Table 2 and 4) which are far below the maximum permissible limit (MPL) recommended by WHO [19] for drinking and household purposes.

Of the cations found in natural water systems, Ca^{2+} is the most prevalent one. It is an essential element for the growth of human body. The MPL of Ca in drinking water is 100 mgL^{-1}. The Ca concentration in water samples of the study area ranges between 48 and 96 mgL^{-1}, which is within the MPL. The Mg concentration follows a similar trend like that of Ca. It ranges between 13.2 to 24 mgL^{-1}. The maximum allowable contaminant level of Mg^{2+} in drinking water is 150 mgL^{-1}. Hence groundwater of the studied area is quite safe for human consumption in terms of Ca and Mg concentration. The distribution of heavy metals in groundwater is an important aspect of this study. Fe is one of the most important metals. All kinds of water including groundwater have appreciable quantities of iron [27]. The Fe concentration in the study area ranges from 0.06 to 0.52 mgL^{-1} with a mean value of 0.18 mgL^{-1} (cf. Tables 3 and 4). Iron concentration in water more than 0.3 mgL^{-1} is not suitable for drinking purpose [13]. Present results reveal that most of the tube wells contain iron less than 0.3 mgL^{-1}. Sample no. 20 shows the highest Fe content (0.52 mgL^{-1}). So in the study area, Fe concentrations of 19 wells out of 20 are within the prescribed limit and suitable for drinking purpose.

Zn and Cu are well established as essential elements for the normal body growth and functioning. The interaction between the two elements is known to be mutually antagonistic and therefore, the study of one is usually associated with the study of the other. Zn salts render an unacceptable taste to water and at higher concentration it may cause toxic effects. The variations of Zn concentration range from 0.06 to 0.23 mgL^{-1} and that of Cu from 0.00 to 0.04 mgL^{-1} (Table 3). The MPLs of Zn and Cu in the drinking water are 5.0 mgL^{-1} and 1.0 mgL^{-1}, respectively [24]. Hence all water samples are free from Zn and Cu contamination. The MPL of Mn in potable water [24] is 0.05 mgL^{-1}. Present results show that Mn concentrations in the study area vary from 0.35 to 3.5 mgL^{-1} with a mean value of 1.04 mgL^{-1} that remains higher than the recommended limit. The lower Mn content is found in sample no. 13 while the highest value is recorded for sample no. 1. WHO specifies the desirable limit for Mn as 0.05 and highest permissible as 0.5 mgL^{-1}. Therefore, it is obvious that the concentrations of Mn in the studied ground waters exceed the recommended value and cannot be considered suitable for drinking purpose (in terms of Mn content). Fe, Cu, Zn and Mn are micronutrients and are essential for human body but toxicological effects are entangled with these trace metals concentration when exceeds MPL. Strong relationship exists between trace metals concentrations and human health [28].

The results in Tables 3 and 4 indicate that all of these water samples contain As ranging from trace to 0.065 mgL^{-1}. Arsenic contamination of groundwater at Meherchandi area can conveniently be discussed through different grading as follows: tolerance limit (0.00-0.05 mgL^{-1}), above tolerance limit (0.05-0.25 mgL^{-1}), unaccepted level (0.25-0.50 mgL^{-1}), dangerous (0.50-1.00 mgL^{-1}) and most dangerous (>1.00 mgL^{-1}) level. From the above breakup, it is clear that 95% of the tube well waters have concentrations within the tolerance limit. Only one tube well (Sample 5) water has concentration above the tolerance limit and may be considered unsafe. The study area has plenty of agricultural land and the majority of inhabitants are farmers. It is to be noted here that arsenic might be generated from fossil fuel burning. Fertilisers may contain elemental arsenic. Aqueous As in the form of arsenite, arsenate and organic arsenicals may result from the application of herbicides (arsenic trioxide, mono and disodium methane arsenate, Na and Ca arsenate and insecticides (lead arsenates). The ground waters of tube well no. 7, 10 and 18 contain respectively 0.04 mgL^{-1}, 0.046 mgL^{-1} and 0.05 mgL^{-1} arsenic, which are on the brink of tolerance limit and might be considered unsafe. The mean values recorded for descriptive statistics in Table 4 indicate that the ground waters in the studied area are in general within the permissible limit and hence potable. However, for countries like Bangladesh, which has a significant groundwater arsenic problem, identification of arsenic-contaminated wells is quite important and the situation [29-30] should be handled with due attention.

CONCLUSIONS

From the results of the present investigation, it is concluded that the quality of water in the area is in general, good for the utilization in agricultural, industrial or domestic purposes. However few water samples were found ‘unsuitable’ for drinking purpose, due to the presence of excess Fe, As and Mn. Though excess Mn content in the groundwater of Meherchandi area is not posing any immediate threat to the potability but the status should not let continue unconcerned for the situation may get critical in the near future. Besides, tube well waters that show high As content should be red marked at the earliest convenience and proper measures should be taken for the removal of As and Mn from the contaminated tube well waters. City Corporation Authority and Public Health Department may play a vital role in this context.

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Table: 1 Results of Colour, Odour, Ph, EC and TDS

Well Sl. No.	colour	odour	pH in fields	pH in lab	EC (µScm-1)	TDS (mgL^{-1})
1	nil	nil	6.70	6.97	713	499
2	nil	nil	6.75	7.20	649	454
3	nil	nil	6.90	7.15	687	481
4	nil	nil	6.95	7.45	618	433
5	light yellowish red	nil	7.30	7.80	738	517
6	nil	nil	7.10	7.51	895	627
7	nil	nil	7.50	7.96	611	428
8	nil	nil	7.30	7.90	725	508
9	nil	nil	6.90	7.25	851	596
10	nil	nil	6.95	7.20	997	698
11	nil	nil	7.00	7.35	1059	741
12	nil	nil	7.00	7.40	802	561
13	nil	nil	7.00	7.35	850	595
14	nil	nil	6.80	7.25	868	608
15	nil	nil	6.95	7.30	795	557
16	light yellowish red	nil	7.00	7.30	642	449
17	nil	nil	7.10	7.27	820	574
18	nil	nil	7.00	7.38	845	592
19	nil	nil	7.20	7.50	855	599
20	light yellowish red	nil	7.40	7.80	835	585
Recom. values	nil	nil	6.5 - 8.5		1400	500

Table: 2 Results of Permanent Hardness, Total Hardness, Alkalinity and Dissolved Anions (All Concentrations are Expressed in Mgl^{-1}).

Well No.	Permanent hardness	Total Hardness	HCO_3^-	Cl^-	$SO4^{2-}$
1	136	435	539	29.78	7.23
2	116	374	501	9.22	7.59
4	70	339	440	36.87	7.95
5	90	327	384	38.29	6.36
6	62	374	457	65.23	6.36
7	80	310	381	14.89	4.77
8	105	340	474	35.45	5.46
9	127	402	446	26.94	7.95
10	111	405	522	13.47	5.13
11	102	460	395	19.85	7.41
12	110	326	438	15.46	9.36
13	101	373	469	14.18	7.59
14	109	384	488	10.64	4.05
15	66	350	408	39	4.23
16	80	262	339	14.18	5.13
17	106	356	433	37.58	8.82
18	122	373	461	26.23	8.46
19	85	379	482	16.17	4.23
20	102	366	437	22.69	5.64
Recom. values	-	200	-	250	250

Table 3. Quantity of Dissolved Cations* in Groundwater of Meherchandi area,

Rajshai City (*All Concentrations are Expressed in Mgl^{-1}).

Well No.	Ca	Mg	Fe	Cu	Zn	Mn	As
1	90	24	0.205	0.02	0.06	3.5	0.012
2	80	20.4	0.257	0.02	0.06	1.7	0.021
3	74	18	0.095	0	0.09	1.5	0.028
4	72	16.8	0.105	0	0.1	1.51	nil
5	70	14.4	0.255	0.01	0.07	1.18	0.065
6	88	19.2	0.09	0.01	0.06	0.96	0.041
7	66	13.2	0.105	0	0.08	0.79	0.04
8	84	19.2	0.18	0.02	0.09	1.09	0.03
9	64	21.6	0.115	0.02	0.07	0.6	0.03
10	72	20.4	0.092	0.03	0.08	0.57	0.046
11	96	21	0.096	0.02	0.06	1.21	0.022
12	66	18	0.285	0.02	0.1	0.89	0.033
13	64	16.8	0.182	0.03	0.08	0.35	nil
14	78	20.4	0.175	0.02	0.07	0.54	0.01
15	60	14.4	0.21	0.04	0.09	0.75	0.013
16	48	13.2	0.315	0	0.06	0.38	0.018
17	66	18	0.145	0.02	0.06	0.6	0.017
18	74	22.8	0.095	0.02	0.07	1.08	0.05
19	76	20.4	0.06	0.02	0.1	0.79	0.02
20	80	19.2	0.52	0.03	0.23	0.84	0.015
Recom. values	100	30	0.3	1	5	0.5	0.05

Table 4 Descriptive Statistics for the Chemical Analyses of Groundwater Samples

Location	Statistics	pH	EC mgL^{-1}	TDS mgL^{-1}	H_T mgL^{-1}	HCO_3^- mgL^{-1}	SO42- mgL-1	Cl^- mgL^{-1}
	Min.	6.97	611	428	261	339	3.69	9.22
Meher-chandi,	Max.	7.96	1059	741	460	539	9.36	65.2
Rajshahi	Mean	7.41	793	555	363	447	6.37	25.4
n=20	Med.	7.35	811	567	369	443	6.36	22
	SD	0.26	120	84	44	49	1.74	13.7
Metals	→	Ca	Mg	Fe	Cu	Zn	Mn	As
Meher-chandi,	Min	48	13.2	0.06	0	0.06	0.35	0.1
Rajshahi	Max	96	24	0.52	0.04	0.23	3.5	0.07
n=20	Mean	74.4	18.5	0.18	0.02	0.08	1.04	0.03
	Med	74	19	0.16	0.02	0.075	0.87	0.02
	SD	11.3	3	0.109	0.01	0.04	0.69	0.02