Investigation of Some Physicochemical Parameters and Heavy Metals for Monitoring the Groundwater Quality of Savar Upazila of Dhaka, Bangladesh

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ABSTRACT

Safe and clean water is an indispensable component for all kinds of living beings. An attempt was taken to examine the drinking water, particularly the groundwater quality of Savar Upazila under the Dhaka District of Bangladesh by assessing some physicochemical parameters such as pH, total dissolved solids (TDS), electrical conductivity (EC), and temperature and the levels of different heavy metals (Cu, Cd, Cr, Fe, Mn, and Zn). To measure the concentration of the six selected metals from the groundwater samples collected from 38 different locations of Savar Upazila, Atomic Absorption Spectrophotometry (AAS) was used. Our results showed that the pH, TDS, EC, and temperature ranged from (6.56-7.72), (73-437 mg/L), (117-654 µS/cm), and (27.7-30.5ºC), respectively which were found within the limit of water standards recommended by national and global regulatory authorities. The mean concentration of different studied metals in the reported water samples of Savar Upazila followed the order of Fe > Zn > Mn > Cr > Cu > Cd. The average concentration was 0.136±0.188 mg/L, 0.121±0.289 mg/L, 0.033±0.060 mg/L, 0.015±0.0096 mg/L, 0.0104±0.005 mg/L, and 0.0022±0.0019 mg/L for Fe, Zn, Mn, Cr, Cu, and Cd, respectively. In this study, Water quality index (WQI) was also calculated for the studied samples and it was observed that the groundwater of Savar Upazila belonged in the good to excellent categories and can be recommended as suitable for drinking purposes.

1. INTRODUCTION

Water plays a pivotal role in the existence of all known forms of life on the earth's surface. A large number of sources of drinking water like rivers, ponds, lakes, wells, and tube wells are present in our environment and it is highly desirable to keep these sources safe and secure from any kind of pollution. If these resources of essential drinking water become contaminated, they may pose the greatest risk to human health. The random and misuse of agricultural, industrial, and various natural activities throughout Bangladesh have led to the degradation of the quality of groundwater resources over the past few decades (Bhuiyan et al., 2015; Bodrud-Doza et al., 2016; Islam et al., 2017; Islam et al., 2018). This deterioration of groundwater quality is highly threatening as it is very difficult to control the severity of groundwater contamination which causes environmental as well as human health hazards (Gupta et al., 2008). In recent days, industrial growth is occurring rapidly which expedites the discharge of chemical toxins along with heavy metals into the environment (Saha et al., 2017). The waste from the industries and factories is usually discharged into the ponds, rivers, lakes, and into the ocean if the industry is located near seaside zones with or without proper treatment and causes surface water as well as groundwater contamination (Bakis and Tuncan, 2011; Lu et al., 2016).

Heavy metals are defined as metallic elements which are found in the nature and have a very high

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density which is greater than 5 g/cm^3 (Singh et al., 2018). Heavy metals in water are toxic to the human body even in trace levels which are related to several health problems such as nutritional deformities, immunological disfigurement, deficient intrauterine growth, imperfect psycho-social behavior, and many more (Nweke and Sanders, 2009; Khan et al., 2011). Generally, these metals are not degradable with any kind of environmental chemicals or microbial attack and remain in the environment for a very long time. They are often transported from soil and water sources and deposited into various tissues of plants and animals causing long-term deleterious effects on recipient species. Various human organs such as the liver, kidneys, lungs, bones, and brain can be highly affected due to chronic exposure to heavy metals (Tchounwou et al., 2012). Both essential and toxic elements if excessively present are of concern in groundwater investigations. Long-time exposure to copper (Cu) in potable water can lead to copper toxicities which results in liver and kidney damage, anemia, hepatic cirrhosis, and corrosion of the basal ganglia (Harris and Gitlin, 1996). High levels of zinc (Zn) in the drinking water can lead to stomach cramps, neurological problems, vomiting (Hooper et al., 1980). Manganese (Mn) is an essential element for human body which is a significant cofactor for a variety of enzymes in the brain (Hurley and Keen, 1987). In a study of the rural area Araihazar in Bangladesh, it was found that elevated levels of Mn exposure in drinking water may hinder learning mathematics in elementary school children (Khan et al., 2012). An extreme level of iron (Fe) accumulation is associated with Parkinson disease, hyperkeratosis, cardiovascular disease, Huntington disease, diabetes mellitus, pigmentation changes, Alzheimer disease, kidney, liver, respiratory, and neurological disorders (Powers et al., 2003; Kell, 2010; Farina et al., 2013). Over consumption of chromium (Cr) in the body may create health risks including the damage of liver, kidney, nose, lungs, and possible asthma attacks (Kleefstra et al., 2004). Cadmium toxicity is linked with the damage to the cardiovascular system, kidneys, and bones (Fang et al., 2014). The types of the bedrock and the pH value also play important roles for the presence of such elements (Gore et al., 2010). According to WHO, 80% of diseases arise due to contaminated groundwater (Smith et al., 2000). Therefore, it is necessary to protect the quality of water particularly groundwater as this is mostly used for drinking purposes.

The UN Agenda 2030 and the Sustainable Development Goals (SDGs) have given fair significance to the goals that are “by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally” (UN, 2017). Population growth led to a demand for resources for industrialization and urbanization worldwide (Boojhawon and Surroop, 2021). In a developing country like Bangladesh, groundwater pollution by heavy metals causes environmental risk which may have a negative impact on the environment, and the effects may be irreparable. Savar is a rapidly growing industrial area of Bangladesh which is located near the capital city of Dhaka and many industries like garments, textile mills, electronic equipment, leather materials, chemicals, paper, fertilizers, metals, and miscellaneous manufactures have been established in the area. Industrial development causes pollution in both surface and groundwater in many areas of Bangladesh (Rahman et al., 2020). As an economic zone of Bangladesh, Savar Upazila is expanding its industrial area very quickly which may pose a great threat to the groundwater due to untreated and contaminated industrial wastes and debris. This necessitates the investigation of the quality of the groundwater used for drinking purposes by the inhabitants of Savar Upazila. The aim of the present study was to monitor the physicochemical properties and the levels of different elements (Cu, Cd, Cr, Fe, Mn, and Zn) for assessing the groundwater quality of Savar Upazila of Dhaka of Bangladesh.

2. METHODOLOGY

2.1 Description of the study area and water sampling

Our study sites were in the Savar Upazila which has an area of about 280 km^2 and is the second largest Upazila of Dhaka District located on the northern side of the district. The geographical position of the studied area lies between 23°44'N and 24°12'N latitude and between 90°11'E and 128 90°22'E longitude. This is one of the most densely populated areas in the country which consists of a total population of about 1.39 million people. The northern side of the Upazila is bounded by Kaliakair and Gazipur Sadar Upazilas, Keraniganj Upazila is on the south side, Dhamrai and Singair Upazilas are found on the West and on the eastern side, Mirpur, Mohammadpur, Pallabi, and Uttara thanas are found. This studied region is a rapidly growing industrial and urbanized area of the country and surrounded by the Bangshi, Dhaleswari, Karnatali, and Turag Rivers.

2.2 Sample collection and preservation

A total of 38 groundwater samples (S1-S38) from different places of Savar Upazila adjacent to Dhaka City of Bangladesh were collected in the month of July, 2022 (Figure 1). The geographical positions of the selected sampling points were determined by Global Positioning System (GPS). To get fresh groundwater samples free from any kind of unwanted debris, the tap was run for 10 min before sampling and then the representative water samples (500 mL) were taken in acid-washed, cleaned plastic bottles which were rinsed three times with sampled water. The collected samples were shifted immediately to the Laboratory. The pH of the studied samples was measured by Hanna Instrument and some other physicochemical parameters such as total dissolved solids (TDS), electrical conductivity (EC), and temperature were analyzed by using a multiparameter analyzer EZDO 7200. For the analysis of six selected heavy metals (Cu, Cd, Cr, Fe, Mn, and Zn), the collected samples were then filtered using Whatman filter paper (number 42), acidified with 2 mL of 65% nitric acid (Merck, Germany) per litre of water for the removal of microbial growth, chemical absorption and precipitation (Singare et al., 2013), and then preserved in a refrigerator at 4ºC until final analysis.

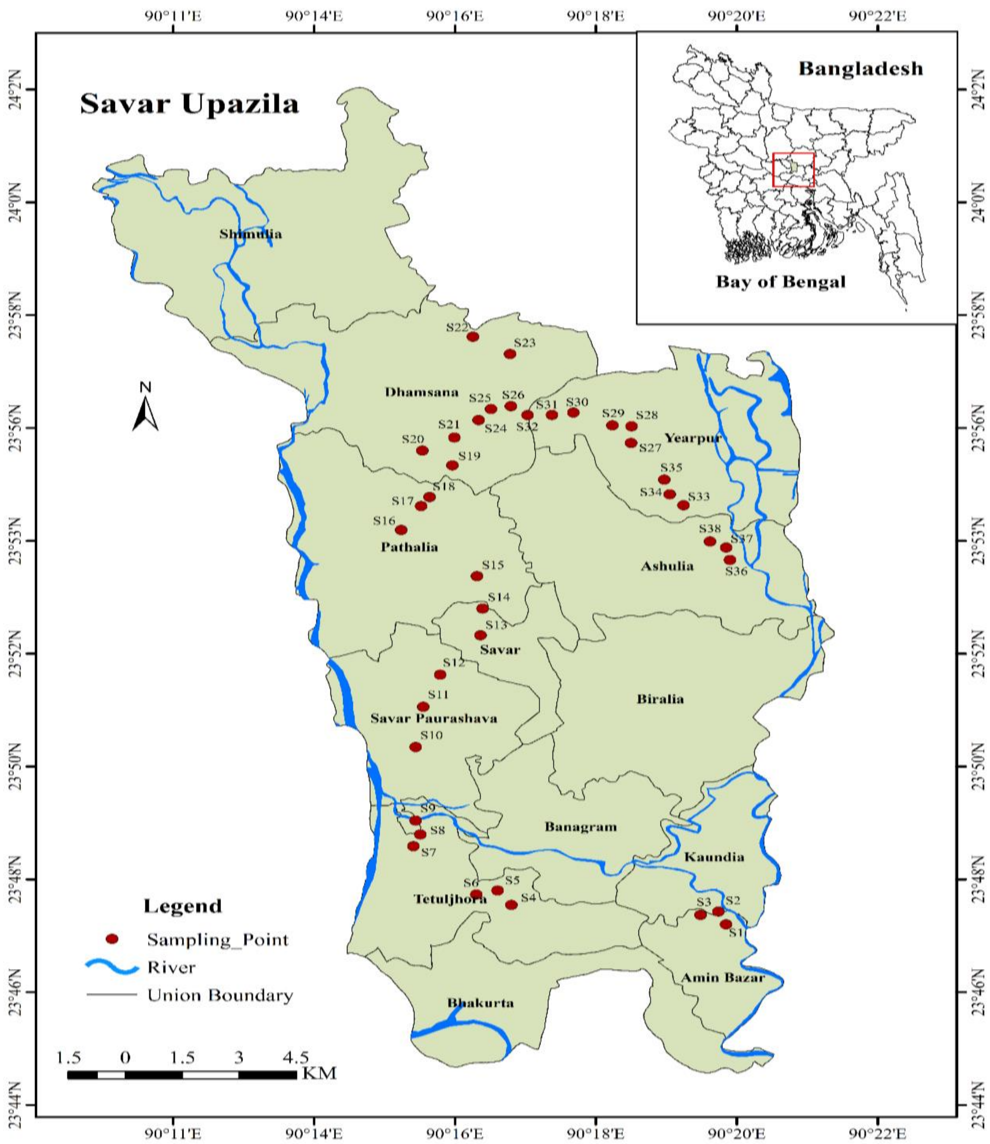

Figure 1. Map of the sampling points of the Savar Upazila, Dhaka, Bangladesh

2.3 Reagents and standards

Analytical grade reagents and calibration standards without any further treatment were used throughout the study. The six different metal standards of Fe, Zn, Mn, Cr, Cu, and Cd with a concentration of 1,000 mg/L were obtained from inorganic ventures, USA. Reference standards with different concentrations and the reagent blank solution for escaping the risk of contamination during sample preparation and analysis were prepared with deionized distilled water.

2.4 Analysis of metals

The selected groundwater samples were analyzed by flame atomic absorption spectroscopy (AAS) (Model: AA-7000, Shimadzu Corporation, Japan) for this study. Background correction of the machine was done using the deuterium-arc lamp. An aliquot of the samples was injected into the air acetylene flame for six chosen metals (Fe, Zn, Mn, Cr, Cu, and Cd) using a Shimadzu auto sampler ASC-7000. The operating conditions (shown in Table 1) for the Flame AAS were followed by the instrument manufacturer's specifications. A blank reading was taken to allow background correction and necessary corrections were made during the calculation of concentration of our desired elements. The value of the blank sample was deducted from the studied groundwater samples to make sure that the equipment read only the particular values of heavy metals.

Table 1. The instrumental settings of AAS for metal analysis of groundwater samples of Savar Upazila

Elements	Wavelength	Lamp current	Slit width	Gas flow rate
Cd	228.8 nm	8 mA	0.7 nm	1.8 L/min
Cr	357.9 nm	10 mA	0.7 nm	2.8 L/min
Mn	279.5 nm	10 mA	0.2 nm	2.0 L/min
Cu	324.8 nm	6 mA	0.7 nm	1.8 L/min
Fe	248.3 nm	12 mA	0.2 nm	2.2 L/min
Zn	213.9 nm	8 mA	0.7 nm	2.0 L/min

2.5 Groundwater quality index (WQI) analysis

The Department of Environment's (DoE) standard for Bangladesh groundwater quality was used to determine the WQI using four steps (Rahaman et al., 2020). Firstly, the weight (w_i) was assigned on a scale of 1 to 5 based on the likelihood that each parameter (pH, TDS, EC, Fe, Mn, Cu, Zn, Cd, and Cr) would have an adverse effect on human health (Tabrez et al., 2022). Secondly, the following equation was used to obtain the relative weight (W_i).

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

Where; w_i=each parameter's weight and n=total number of parameters.

Thirdly, the quality rating scale (q_i) was derived by using the formula:

$$q_i = \frac{C_i}{S_i} \times 100$$

Where; C_i=each parameter's concentration in mg/L and S_i=groundwater standard value for a specific parameter as set by the DoE in mg/L. Finally, after calculating the sub index (SI) for each parameter, the WQI was computed by summing the SIs. The equations are:

$$SI_i = W_i \times q_i \quad (2)$$

$$WQI = \sum SI_i \quad (3)$$

Where; SI_i=subindex for i^{th} parameter, q_i=quality rating scale for i^{th} parameter, and W_i=relative weight of i^{th} parameter. Each parameter's relative weights (W_i) have been calculated and given in Table 2.

2.6 Statistical analysis

Data for different physicochemical parameters and heavy metals of groundwater samples of the studied region of Dhaka were analyzed statistically using the Microsoft Excel 2016 software and the analyzed data were presented as mean±standard deviation (SD).

Table 2. Relative weight of drinking water quality parameters

Chemical parameters	DoE standard	Weight (w_i)	Relative weight (W_i)	Reference
pH	8.5	4	0.1176	Tabrez et al. (2022)
TDS	1,000	4	0.1176	Tabrez et al. (2022)
EC	1,000	4	0.1176	Tabrez et al. (2022)
Fe	1	4	0.1176	Tabrez et al. (2022)
Mn	0.1	4	0.1176	Tabrez et al. (2022)
Cu	1	3	0.0882	Tabrez et al. (2022)
Zn	5	1	0.0294	Tabrez et al. (2022)
Cd	0.005	5	0.1471	Tabrez et al. (2022)
Cr	0.05	5	0.1471	Tabrez et al. (2022)

3. RESULTS AND DISCUSSION

3.1 Physicochemical characteristics of groundwater of Savar Upazila

Different physicochemical parameters (pH, TDS, EC, and temperature) of the studied groundwater samples of Savar Upazila were analyzed and the obtained results were presented in Table 3. In our present study, the pH of the water samples from different regions of Savar Upazila ranged from 6.99-7.62. The value of pH is a traditional measuring parameter for water that affects biological and chemical reactions. The solubility and toxicity of chemicals and heavy metals in the water can be highly affected based on the level of pH in the water (EPA, 2012). Low level of pH in drinking water has a profound effect on pipes which may be degraded and may increase the level of toxic metals in the water supply, causing health issues if consumed. Besides, water containing high pH provides an unpleasant taste and has certain concerns such as skin and eye irritations (Fink, 2005). The average (±SD) pH value of groundwater samples of Savar was obtained at 7.24 (±0.28) which is slightly alkaline in nature. According to the water quality standards of WHO (2011) and DPHE, Bangladesh (2019), the pH of drinking water should be between 6.5 and 8.5 and the measured pH of the water of the studied region is within the allowable limit. A similar study in Savar Upazila documented the mean pH value of 6.90 which also followed the standard range of WHO (2011) and DPHE, Bangladesh (2019) (Hasan et al., 2022). The level of pH in the water of Dhaka metropolitan city was obtained (6.54±0.42) which was found slightly acidic in nature (Sharmin et al., 2020) while the mean pH was characterized as alkaline (8.07±0.51) in an industrial area of Narayanganj City (Rahman et al., 2020).

One of the most important parameters for drinking water quality assessment is TDS which is comprised of dissolved substances and organic matter in water. The mean±SD of TDS value in this study was reported 181.63±82.69 mg/L which was under the permissible limit proposed by different national and international authorities. The highest TDS was obtained in the S1 site and the value was 437 mg/L, while the lowest TDS value was 73 mg/L obtained in the S24 site. The mean TDS was reported at 270.80 mg/L in groundwater samples of Savar Upazilla in another study done by Hasan et al. (2022). In other recent studies, the mean TDS value was reported 321.30 mg/L, 242.25 mg/L, 237.5 mg/L, and 162.2 mg/L in Dhaka Metropolitan City, Rangpur, Gazipur, and Jamalpur area of Bangladesh, respectively (Bakali et al., 2014; Zakir et al., 2018; Saha et al., 2019; Sharmin et al., 2020). Another essential water quality assessment parameter is EC which was measured in the collected water samples of our studied region and it was observed that the EC varies from 117-654 µS/cm which was within the standard limit set by WHO (2011) and USEPA (2009). EC has a strong relationship with TDS. The mean value of EC in the studied area was 265.47 µS/cm which was lower than the studies performed in Chittagong, Rajshahi, and Sylhet (Ahmed et al., 2010; Mostafa et al., 2017; Ahmed et al., 2019). As TDS and EC values are interdependent, high values are a sign of salt in the groundwater (Hasan et al., 2022). According to Bangladesh standards, the water temperature (ºC) should be ranged between 28 and 30, and in our study done in Savar Upazila, it varies from 27.7-30.5ºC with a mean of 29.40±0.70ºC which was within the safe limit of DPHE, Bangladesh (2019) standard.

Table 3. The physicochemical properties of studied groundwater samples of Savar Upazila

Sampling station	Longitude	Latitude	pH	TDS (mg/L)	EC (µS/cm)	Temperature (ºC)
S1	90.3277	23.7876	6.94	437	654	28.9
S2	90.3268	23.7881	7.01	247	361	29.6
S3	90.3259	23.7887	7.04	312	470	29.6
S4	90.2802	23.7951	7.25	204	308	29.6
S5	90.2798	23.7942	7.00	215	327	29.7
S6	90.2713	23.7933	7.22	227	342	29.8
S7	90.2573	23.8116	7.15	222	334	29.6
S8	90.2575	23.8140	7.52	213	317	29.5
S9	90.2569	23.8165	7.68	250	376	29.5
S10	90.2574	23.8391	7.30	182	274	29.8
S11	90.2592	23.8510	6.92	257	385	29.7
S12	90.2632	23.8605	6.80	212	315	29.5
S13	90.2727	23.8721	7.02	137	203	29.6
S14	90.2732	23.8800	7.62	105	164	29.5
S15	90.2719	23.8896	6.85	103	160	29.1
S16	90.2539	23.9032	7.72	87	131	29.8
S17	90.2592	23.9115	7.29	177	263	29.7
S18	90.2603	23.9128	6.56	97	147	30.5
S19	90.2661	23.9223	7.51	106	157	28.5
S20	90.2589	23.9267	7.40	112	165	27.7
S21	90.2665	23.9305	7.55	104	156	27.8
S22	90.2709	23.9603	7.66	78	117	28.2
S23	90.2797	23.9551	7.58	86	132	27.7
S24	90.2723	23.9368	7.36	73	119	30.0
S25	90.2757	23.9362	7.30	107	163	29.8
S26	90.2768	23.9364	7.00	236	393	29.6
S27	90.2927	23.9367	7.30	252	376	29.7
S28	90.2896	23.9372	7.30	170	255	29.7
S29	90.2838	23.93715	7.20	171	256	29.9
S30	90.3080	23.9308	7.10	157	236	29.7
S31	90.3074	23.9321	7.02	158	238	29.6
S32	90.3039	23.9341	7.02	158	237	29.6
S33	90.3207	23.9105	7.69	396	265	28.7
S34	90.31874	23.9131	7.10	184	274	28.7
S35	90.3187	23.9136	7.20	205	312	28.6
S36	90.3309	23.8972	7.60	183	282	28.6
S37	90.3308	23.8980	7.40	192	291	28.8
S38	90.3296	23.8989	7.05	90	133	30.0
Mean			7.24	181.63	265.47	29.4
SD			0.28	82.69	112.07	0.71
DPHE, Bangladesh (2019)			6.5-8.5	1,000	-	20-30
BIS (2012)			6.5-8.5	500-2,000	-	20-30
WHO (2011)			6.5-8.5	500	1,500	-
USEPA (2009)			6.5-8.5	500	750	-

3.2 Concentration of different heavy metals in groundwater of Savar Upazila

The concentrations of the six selected heavy metals (Cu, Cd, Cr, Fe, Mn, and Zn) in the studied groundwater of 38 different locations of Savar Upazila of Dhaka are shown in Table 4. Figure 2 illustrates the average concentration of the studied heavy metals found in collected groundwater samples of the Savar

Area of Dhaka, Bangladesh. The obtained results for heavy metals concentration showed the decreasing order of Fe > Zn > Mn > Cr > Cu > Cd and the Fe was detected in the highest amount with an average (±SD) of 0.136 (±0.188) mg/L. The value of Fe in the selected locations of the Upazila ranged from Below the Detection Limit (BDL) to 0.756 mg/L, where the maximum Fe was detected in the S9 site of the Upazila. The maximum acceptable limit of Fe in drinking water is 1 mg/L according to the drinking water standard set by the DPHE, Bangladesh (2019) and all the samples showed lower levels of Fe than the DPHE, Bangladesh (2019) standard, though groundwater from four different locations, S7, S9, S11, and S12, of Savar crossed the international regulations which is 0.3 mg/L set by Health Canada (2001), USEPA (2009), BIS (2012), and WHO (2011). The obtained concentration of Fe in studied groundwater ties well with the previous study done in the Savar Upazila wherein the content of Fe in groundwater was 0.18 mg/L which was also lower than the standard water quality guideline values (Hasan et al., 2022). The reported Fe level was compared with other studies done in different cities of Bangladesh and it was observed that the level of Fe in the groundwater of the Savar Area was comparatively lower than Sylhet, Rajshahi, Chittagong, Lakshipur, which exceeded the standard limits, while studies from Dhaka Metropolitan City, Gazipur which are near to our studied region also maintained drinking water standards (Table 5). From the study of Sharmin et al. (2020) and Bodrud-Doza et al. (2020), it was clearly seen that the Fe level in Dhaka City was 0.0896 mg/L, and 0.208 mg/L, respectively, which was also within the safe limit of drinking water quality.

Table 4. Concentration (mg/L) of heavy metals and estimated WQI value with the classification of studied groundwater of Savar Upazila

Sampling station	Zn	Fe	Mn	Cr	Cd	Cu	WQI	Classification
S1	0.4891	0.0078	0.0126	0.0358	BDL	0.0077	34.90	Excellent
S2	0.0524	0.0563	0.0108	0.0358	BDL	0.0115	29.45	Excellent
S3	0.0460	BDL	0.0042	0.0393	BDL	0.0045	31.06	Excellent
S4	0.0588	0.0089	0.3213	0.0184	BDL	0.0071	59.47	Good
S5	0.0615	BDL	0.0135	0.0271	BDL	0.0071	25.72	Excellent
S6	0.0830	0.0606	0.0130	0.0289	BDL	0.0090	27.56	Excellent
S7	0.0654	0.4020	0.0387	0.0098	0.0017	0.0052	33.69	Excellent
S8	0.1368	0.2448	0.0515	0.0150	0.0037	0.0083	41.03	Excellent
S9	0.0691	0.7564	0.2320	0.0202	0.0012	0.0052	63.74	Excellent
S10	0.0190	0.0002	0.0343	0.0011	0.0019	0.0102	25.52	Excellent
S11	0.1407	0.6681	0.0232	0.0098	0.0019	0.0127	36.39	Excellent
S12	0.0668	0.5862	0.0179	0.0115	0.0030	0.0096	36.94	Excellent
S13	0.1107	0.2943	0.0303	BDL	0.0015	0.0285	25.47	Excellent
S14	0.0185	BDL	0.0011	0.0011	0.0019	0.0096	19.85	Excellent
S15	0.1272	0.1015	0.0090	0.0011	0.0012	0.0228	18.96	Excellent
S16	0.5229	0.0218	0.0128	0.0092	0.0039	0.0228	29.70	Excellent
S17	0.0194	BDL	0.0076	0.0116	0.0026	0.0071	27.29	Excellent
S18	0.0493	0.0175	0.0053	0.0092	0.0027	0.0064	23.51	Excellent
S19	0.0119	BDL	0.0222	0.0116	0.0031	0.0071	28.70	Excellent
S20	0.0133	BDL	0.0121	0.0139	0.0032	0.0083	28.51	Excellent
S21	0.0119	BDL	0.0083	0.0116	0.0029	0.0071	26.50	Excellent
S22	0.2928	0.0724	0.0098	0.0185	0.0031	0.0127	29.74	Excellent
S23	1.7110	0.2071	0.0290	0.0162	0.0038	0.0096	35.94	Excellent
S24	0.0488	0.1723	0.0152	0.0140	0.0075	0.0117	42.57	Excellent
S25	BDL	0.1845	0.0167	0.0089	0.0060	0.0103	37.77	Excellent
S26	BDL	0.1740	0.0203	0.0073	0.0052	0.0075	39.03	Excellent
S27	BDL	0.1671	0.0191	0.0174	0.0013	0.0167	27.75	Excellent
S28	0.0303	0.0017	0.0195	0.0089	0.0037	0.0110	30.30	Excellent
S29	BDL	0.1340	0.0235	0.0073	0.0009	0.0117	23.60	Excellent
S30	0.1066	0.0313	0.0215	0.0089	BDL	0.0096	23.15	Excellent

Table 4. Concentration (mg/L) of heavy metals and estimated WQI value with the classification of studied groundwater of Savar Upazila (cont.)

Sampling station	Zn	Fe	Mn	Cr	Cd	Cu	WQI	Classification
S31	BDL	0.0278	0.0211	0.0106	BDL	0.0089	21.11	Excellent
S32	0.0550	0.0174	0.0215	0.0140	BDL	0.0082	21.95	Excellent
S33	0.0677	0.1793	0.0627	0.0056	0.0045	0.0103	42.92	Excellent
S34	BDL	0.1462	0.0199	0.0123	0.0037	0.0082	33.85	Excellent
S35	0.0303	0.2558	0.0223	0.0157	0.0039	0.0103	37.88	Excellent
S36	0.0860	0.0609	0.0215	0.0292	0.0005	0.0110	29.44	Excellent
S37	BDL	0.0696	0.0255	0.0190	0.0037	0.0110	36.31	Excellent
S38	0.0147	0.0296	0.0203	0.0174	BDL	0.0103	20.33	Excellent
Mean	0.1210	0.1360	0.0335	0.0146	0.0022	0.0104	31.78	
S.D.	0.2890	0.1880	0.0600	0.0096	0.0019	0.0049	9.644	

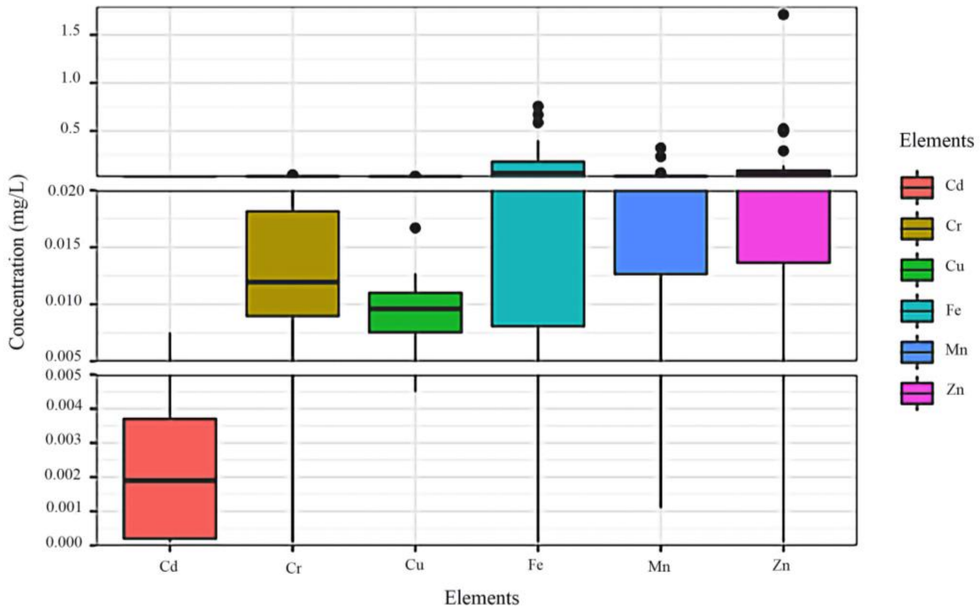

Figure 2. Comparison of the mean concentration (mg/L) of heavy metals in groundwater of Savar

The level of Zn was also analyzed in studied groundwater samples and it was detected in the highest amount followed by Fe. The mean concentration of Zn in the Upazila was documented as 0.121±0.289 mg/L which was far below the tolerable limit provided by both national and international regulatory bodies. The range for Zn in the groundwater of our study area in Upazila was BDL-1.711 mg/L. The location S23 contained the maximum level of Zn (1.711 mg/L) in the present study. Our study clearly showed that there is no risk in the consumption of water on the basis of the concentration of Zn. A similar study in a coastal area in Bangladesh showed the mean concentration of Zn (0.17333±0.12146) mg/L that followed the standard range of Health Canada (2001), USEPA (2009), BIS (2012), and WHO (2011) (Deeba et al., 2021). Another study showed the average concentration of Zn (0.010383±0.010199) mg/L that was absolutely fine according to drinking water quality standards and consistency with our study (Bodrud-Doza et al., 2016). Previous studies from Rakib et al. (2020), Bhuiyan et al. (2016), and Sharmin et al. (2020) detected the concentration of Zn in different cities in Bangladesh and the value was 0.420, 0.02164, and 0.0053 mg/L, respectively, which were all within the water quality guidelines.

The concentration of Mn in the groundwater of the Savar area varied from 0.0011-0.3213 mg/L, reaching an average of 0.0335 mg/L. The maximum allowed limit of Mn in drinking water is 0.4 mg/L and 0.1 mg/L set by WHO (2011) and DPHE, Bangladesh (2019) respectively. In addition, Health Canada (2001) and USEPA (2009) determined a maximum limit of 0.05 mg/L for Mn. Though the samples from S4

(0.3213 mg/L) and S9 (0.232 mg/L) sites exceeded the limit of DPHE, Bangladesh (2019), Health Canada (2001), and USEPA (2009), the level of Mn was still within the permissible limit of WHO (2011). The Mn content from the present investigation was compared with recent past findings. Our data are consistent with other studies done on the groundwater samples of Dhaka city nearby Savar Upazila. The mean concentration of Mn was determined to be 0.057 mg/L, and 0.058 mg/L in Dhaka city groundwater samples studied by Bodrud-Doza et al. (2020) and Sharmin et al. (2020), respectively. Another study described the mean Mn value as 0.22693 mg/L which was under the permissible limit of WHO (2011), but exceeded the DPHE, Bangladesh (2019) standard (Deeba et al., 2021) (Figure 3).

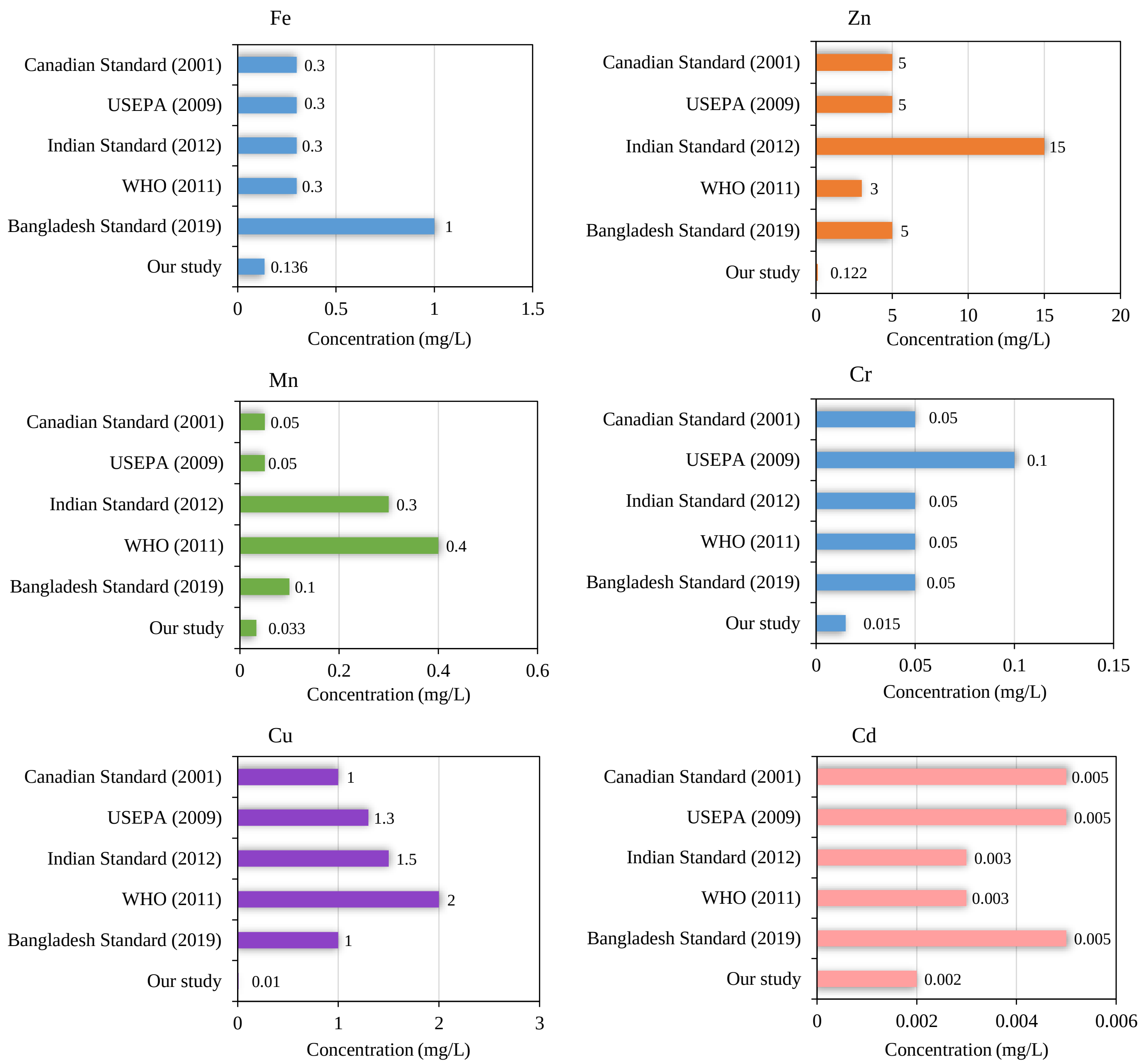

Figure 3. Maximum permitted limits of heavy metals (mg/L) for drinking water quality

The concentrations of Cr and Cu in the groundwater of the Savar Upazila of Dhaka varied among the sampling locations (S1-S38) and the mean±SD of the metals were 0.0146±0.0096 and 0.010±0.0049 mg/L, respectively. Hasan et al. (2022) found a similar amount of Cr from the groundwater samples of Savar Upazila and it was reported as 0.01152 mg/L. Cr is a vital ingredient for the human metabolism of sugar and fat, but excessive amounts from eating, inhalation, or skin contact may be harmful to one's health (Rahman et al., 2020). Both the Cr and Cu levels in the studied Upazila were found

Table 5. Comparison of measured parameters of studied groundwater of Savar Upazila with other different locations of Bangladesh

Locations	Physicochemical parameters				Mean concentration (mg/L) of heavy metals						Ref
	pH	TDS (mg/L)	EC (µS/cm)	Temperature (ºC)	Fe	Zn	Mn	Cr	Cu	Cd	
Present Study	7.24	181.63	265.47	29.4	0.136	0.121	0.0335	0.015	0.0104	0.002	
Savar	6.90	270.80	-	20.1-22.7	0.18	-	0.24	0.01152	-	-	Hasan et al. (2022)
Dhaka City	6.54	321.30	459	-	0.0896	0.0053	0.0588	0.0015	0.0096	-	Sharmin et al. (2020)
Dhaka City	7.32	72.22	120.64	-	0.208	0.021	0.057	-	-	-	Bodrud-Doza et al. (2020)
Gazipur	6.70	237.5	38.25	-	0.08	0.20	0.29	-	0.08	-	Bakali et al. (2014)
Narayangonj	8.068	554.5	1350	-	-	-	-	0.0709		0.0067	Rahman et al. (2020)
Chuadanga	6.47	-	686.10	-	1.303	0.0801	0.284		0.3347	0.03316	Bodrud-Doza et al. (2019)
Kushtia	-	-	-	-	5.072	1.501	1.614	0.031	1.078	0.0019	Islam and Mostafa (2021)
Faridpur	6.9122	-	788.7667	-	5.952	0.0103	0.00064	-	-	-	Bodrud-Doza et al. (2016)
Joypurhat	6.74	222.0	336.1	-	0.42	-	-	3.10	0.76	-	Kumar et al. (2017)
Tangail	6.6	243.66	-	-	2.7265	-	0.97	-	-	-	Uddin et al. (2013)
Gopalganj	7.53	1,635.04	3,206.95	27.41	5.12	-	0.20	-	-	-	Rahman et al. (2018)
Lakshmipur	7.0369	1,135.086	-	-	3.235	0.02164	0.652	-	-	-	Bhuiyan et al. (2016)
Rajshahi	7.0	241.65	454.98	-	2.23	0.18	2.2	-	0.39	0.016	Mostafa et al. (2017)
Sylhet	6.64	-	302.47	25.53	5.91	-	0.30	-	-	-	Ahmed et al. (2019)
Chittagong	7.38	787.0	2,822.1	-	1.67	0.015	0.19	0.005	0.010	-	Ahmed et al. (2010)
Khulna	7.8	1,043	1,777	-	1.21	-	-	-	-	-	Adhikary et al. (2012)
Cox's Bazar	7.69	522.61	804	27.95	1.255	0.173	0.227	0.068	0.057	0.017	Deeba et al. (2021)
Rangpur	6.63	361.58	242.25	28.32	-	-	-	-	-	-	Saha et al. (2019)
Sathkhira	6.03	3,691	7,135.67	-	4.9	0.42	-	-	-	-	Rakib et al. (2020)
Jamalpur	6.87	162.2	270.5	-	0.363	0.020	1.075	0.006	0.008	-	Zakir et al. (2018)

under the permissible limit of drinking water quality. The observed data, therefore, indicated that the groundwater samples of Savar Upazila were not contaminated with Cr and Cu. A minor quantity of Cu is required for maintaining sound health and if exposed to excess concentration, these may cause various health complications such as gastrointestinal distress, anemia, and disrupt liver and kidney functions. A similar kind of research on Dhaka City detected almost the same amount of Cu (0.0096 mg/L) in groundwater (Sharmin et al., 2020). Deeba et al. (2021) reported a high level of Cu (0.05680±0.01522 mg/L) at the South Eastern Coastal Area, Cox Bazar District which was beyond the limit of both WHO (2011) and DPHE, Bangladesh (2019). Most of the cities of Bangladesh showed a higher level of Cu than the present report, while in the Jamalpur Area of Bangladesh, the amount of Cu was detected at a low level in groundwater (Table 5). In a study of the Chittagong area, the level of Cu (0.010 mg/L) was found in a similar amount that was obtained in our present study. Except for Kushtia, the concentration of Cd (0.0022 mg/L) in our study was lower than the other cities of Bangladesh (Table 5). In the studied location of S24, the maximum amount (0.0075 mg/L) of Cd was detected and the level exceeded the maximum allowable limit of drinking water which is a great concern. Among all the samples of groundwater, only two samples (S24 and S25) were beyond the limit of DPHE, Bangladesh (2019) as the standard determined the maximum level as 0.005 mg/L.

3.3 Water quality index (WQI)

The suitability for human consumption of our studied groundwater was assessed by measuring the Water quality index (WQI) value. The results indicated that the range varied from location to location of Savar Upazila of Dhaka of Bangladesh. Following the standard equations, the obtained result was presented in Table 4 and the result revealed that the WQI for the selected samples ranged between 18.96 and 63.74 with a mean value of 31.78. WQI is usually categorized into five different classes from excellent to unsuitable for drinking (Table 6). The method used for WQI indicated that the permissible WQI value for drinking is considered 100 and the water quality will be categorized as poor and hence unsuitable for drinking if the value surpassed this tolerable limit. Our study reported that almost all the studied groundwater quality was excellent while a sample from the site S4 was categorized as good (59.47) and hereafter, it can be inferred that the groundwater is safe and suitable for drinking purposes by the dwellers of the Savar Upazila of Dhaka, Bangladesh.

Table 6. Drinking water categories based on WQI values (Ramakrishnaiah et al., 2009; Tabrez et al., 2022).

WQI range	Category of water	Number of location	Percentage of groundwater samples
<50	Excellent water	37	97.44
50-100	Good water	1	2.56
100-200	Poor water	-	-
200-300	Very poor water	-	-
>300	Unsuitable for drinking	-	-

4. CONCLUSION

The major focus of the present investigation was to monitor the groundwater quality of Savar Upazila of Dhaka for evaluating its suitability for drinking purposes. Safe drinking water is obligatory for human health which will save us from many water-borne diseases. The residents of the Upazila almost entirely rely on groundwater for their daily activities such as drinking, bathing, washing, and other household activities. The obtained physicochemical parameters (pH, TDS, EC, and temperature) and the level of six different metals (Cu, Cd, Cr, Fe, Mn, and Zn) in almost all the studied water were within the guideline values proposed by different regulatory authorities. The level of Mn in two different sites of Savar exceeded the desirable standard limit of Bangladesh while the limit was within the maximum allowed level of WHO (2011). Though the concentration of Cd in two different locations was beyond the maximum residue limit, the measured WQI values of the groundwater samples of Savar area revealed that all the water samples were in the good to excellent category and recommended as suitable for drinking and may be considered as safe reserves of water for future use. Therefore, it can be concluded that our studied groundwater quality is considered suitable for drinking on the basis of the level of our studied physicochemical parameters and WQI analysis. This study can help the national authorities of Bangladesh to know the current status of the drinking water quality of the Savar Upazila and may aide taking appropriate measures for maintaining the standard quality of drinking water for safe consumption in the future. It is recommended that seasonal variation should be measured in the regions and periodic monitoring should be carried out to retain the standards of the water and, thus, to maintain functional human health.

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