Resolution of Trace Elements in Groundwater of Municipal Area at Kushtia and Jhenaidah District of Bangladesh

ABSTRACT

Groundwater samples from the municipal residential areas of the Pearatola, Kushtia and the DPHE, Jhenaidah districts were analyzed for trace elements determination of Iron (Fe), Manganese (Mn), Lead (Pb), Cadmium (Cd) and Zinc (Zn) evaluating the health effect of these trace elements is the prime object of this investigation. Fe, Mn, Pb, Cd and Znin groundwater water were determined by atomic absorption spectroscopy (AAS) on direct flame methods. The examined concentrations of Fe, Mn, Pb, Cd and Zn are respectively 0.74 mg/L, 0.37 mg/L, 0.04 mg/L, 0.004 mg/L and 0.057 mg/L (ppm) which were present in the groundwater sample of Kushtia. The absolute concentrations of Fe, Mn, Pb, Cd and Znare respectively 0.49 mg/L, 0.22 mg/L, 0.03 mg/L, 0.003 mg/L and 0.031 mg/L (ppm) which were present in the groundwater sample of Jhenaidah. Fe contamination of examined areas samples in 0.740 ppm and 0.490 ppm of cases exceeded the WHO criteria and 0.30 ppm exceeded BD standards which is a very scary risk factor for human health. The investigated data should be useful and helpful for general public awareness intake of groundwater.

Keywords: AAS, Groundwater, Health effect, Kushtia and Jhenaidah, Trace element.

1.0 Introduction

Many countries use groundwater as the prime source of drinkable water which also serves the purpose of agriculture and industry [1-2]. Groundwater is extensively used and becoming more important due to cases including climate change, global warming, the rise in ambient temperature and evaporation, dramatic population growth and excessive utilization of fresh water in agricultural and industrial activities [3-4]. Groundwater is presently essential to both social and economic development. All over the world, about 2.50 billion people depend on groundwater for drinking purposes [5]. Organic or inorganic contaminants have recently polluted water reservoirs by pollution, soil leaching, population growth and increased anthropogenic sources activity [6]. Among all contaminants, Arsenic is one of the most significant pollutants all over the world which affects approximately 70.0 million people [7].Some water-borne diseases like cholera, diarrhoea, dysentery, hepatitis A etc. are spreading out by unclean and contaminated water. It was studied that globally every year 842000 people die from diarrhoea [8]. Also, water scarcity has been a significant issue in recent days due to global warming which is created due to variations in rainfall and irregularity of rainfall [9]. Within 2025, 1.8 billion people will be under the scarcity of drinking water [10]. Bangladesh is a densely populated and agriculture-based country which extracts groundwater of nearly 32.0 km^3 (cubic kilometres) every year from this 90.0 % is used for irrigation and the remaining is used for domestic and industrial purposes. This quantity is about 4.0 % of the world's total groundwater withdrawals [11]. In Bangladesh, 11.0 million tube wells are used for the extraction of groundwater and about 98.0 % population uses it as drinking water [12-14].Several variables have an effect on water quality and quantity in Bangladesh whether directly or indirectly [12]. The contamination of groundwater by arsenic (As) in Bangladesh creates health issues [17]. Groundwater is a high threat of arsenic contamination that is very high in our nation. As a result, 35.0 to 77.0 million people were exposed to arsenic (As) in the first decades of this millennium [15]. Water-borne diseases are caused by water, sanitation and hygiene-related problems and for that reason about 8.50 % of deaths in Bangladesh [16].Twenty million humans consume groundwater with arsenic that is above the national acceptable limit [18] which was studied in 61.0 districts in Bangladesh. Apart from arsenic, other common metals such as Lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn) and zinc (Zn) are responsible for significant contamination of groundwater in Bangladesh [19]. Not only metal, bacteria and pesticides were also responsible for groundwater contamination [20-21]. The standard criteria of groundwater are presented in Table 1.

Table 1. Drinking water quality parameters prescribed by the US EPA [23], WHO [22, 25] and Bangladesh guidelines [24].

Constituent	US EPA	WHO Guideline	Bangladesh Guideline
Arsenic (mg/L)	0.05	0.01	0.05
Iron (mg/L)	0.30	0.30	0.30
Sodium (mg/L)	--	200.0	--
Calcium (mg/L)	--	--	75 (200)
Copper (mg/L)	1.30	1.0-2.0	1.50
Manganese (mg/L)	0.05	0.1-0.5	0.1 (0.5)
Zinc (mg/L)	5.00	3.00	5 (15)
Aluminum (mg/L)	0.05-0.20	0.20	0.1 (0.2)
Lead (mg/L)	0.015	0.01	0.10
Chromium (mg/L)	0.10	0.05	0.05
Cadmium (mg/L)	0.005	0.003	0.01
Barium (mg/L)	2.00	0.70	1.00
Antimony (mg/L)	0.006	0.005	--
Molybdenum (mg/L)	--	0.07	--
Nickel (mg/L)	0.10	0.02	--
Selenium (mg/L)	0.050	0.01	--

Silver (mg/L)	0.10	--	--
pH	6.50-8.50	6.50 - 8.50	6.5-8.5
Sulphate (mg/L)	250.0	--	100.0
Fluoride (mg/L)	4.00	--	1.00
Chloride (mg/L)	250.0	250.0	200 (600)
Bromide (mg/L)	--	--	--
Nitrate (mg/L)	10.0	--	10.0
Nitrite (mg/L)	1.00	--	--
Phosphate (mg/L)	--	--	6.0
Total Dissolved Solid (TDS)	500.0	1000.0	500 (1000)

From analysis, Fe, Mn, Pb, Cd and Zn contamination of examined samples, Fe in 0.74 ppm which exceeded the WHO criteria and Bangladeshi (BD) standard of 0.30 ppm [22, 24]. From this study, we have identified the quantitative analysis of trace amounts of groundwater in the Kushtia and Jhenaidah municipal regions as the prime focus of the study.

2. Materials and Methods

2.1. Study Location

The present study areas are in different places in different districts such as Kushtia and Jhenaidah municipal. In this present investigation, a total of two tube-well water samples were collected from the Pearatola residential area of Kushtia and the DPHE residential area of Jhenaidah municipal.

2.2. Sample Collection and Preservation

Groundwater (tube well water) samples were collected from two sampling points which are Kushtia and Jhenaidah municipal residential areas. All samples were collected in duplicate to analyze the trace elements. Tube well water samples were collected in acid-washed polyethylene (HDPE) bottles. The samples were then preserved with the addition of 5.0 – 6.0 ml ultrapure 1:1

HCl per litre of water sample to minimize the absorption of metals into the walls of the containers. The samples were then transferred to the analytical chemistry laboratory of the ACCE, Islamic University, Kushtia-7003. The analysis was performed accordingly to check repeatability.

3.0 Characterization

Analysis of trace elements by AAS. AAS is an analytical method for quantifying elements in solution or solid samples. AAS (Model: Varian Spectra AA220, Country of origin: Australia) determined the trace element concentrations in samples using an air-acetylene flame with a digital read-out system. The temperature formed in air-acetylene flame is around 2300.0 ^{O}C whereas acetylene-nitrous oxide (dinitrogen oxide) flame is around 3000.0 ^{O}C. Generally, with air-acetylene flame Cd, Pb and Zn can be determined. For analysis of trace elements in water samples, 2.50 ml of concentrated H_2SO_4 and 4.0 ml of concentrated HNO_3 were added. Samples taken in solution form or digested to be detected by FAAS. Typical detection units are around ppm range and sample analysis took 10.0 – 15.0 seconds per element. The Block diagram of FAAS and GFAAS is depicted in Fig. 1 (a) and (b). Generally, hollow cathode lamps as flame or graphite furnaces as an atomizer, grating as a wavelength selector and photomultiplier as a detector are used.

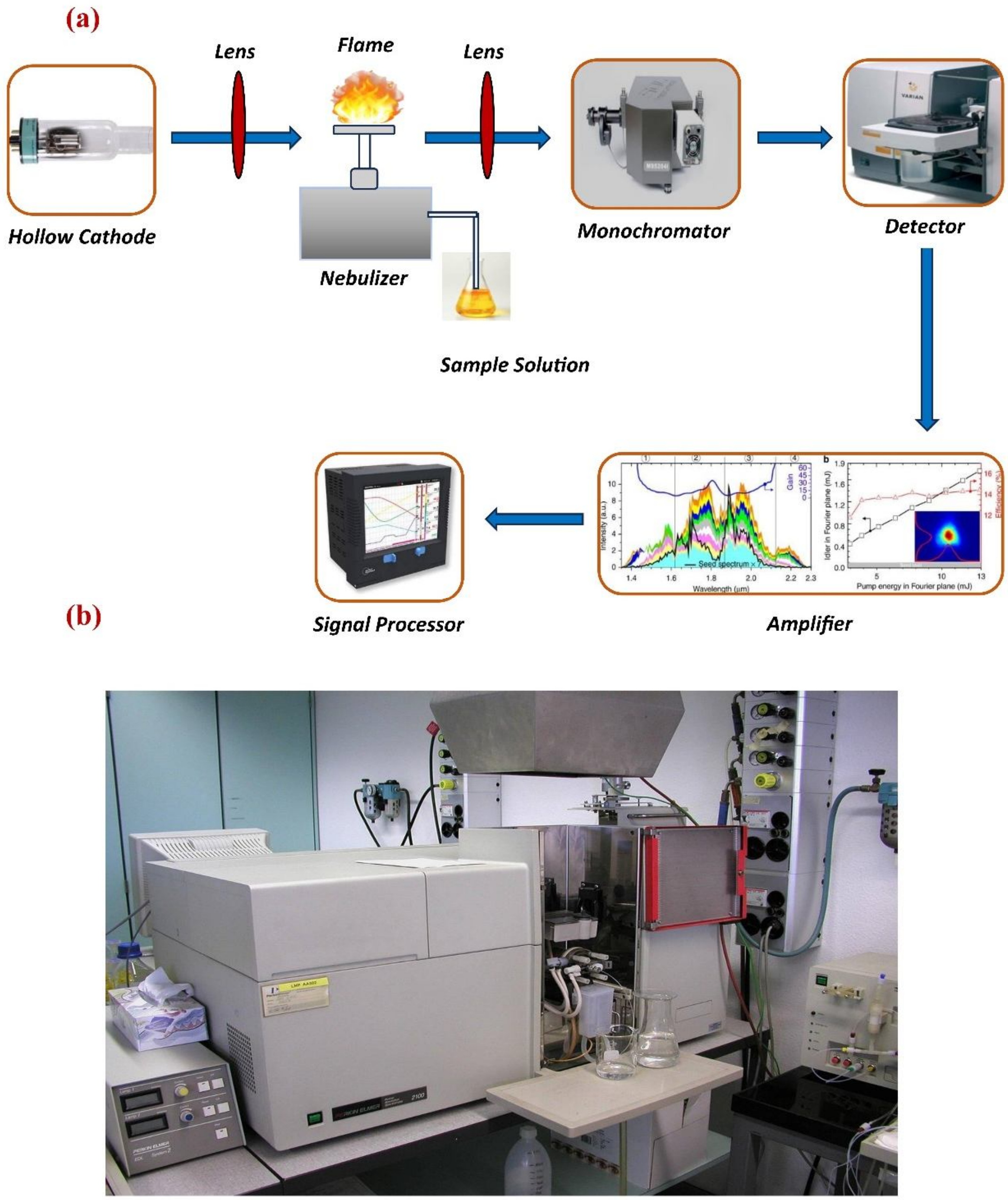

Fig. 1. (a) Block diagram of AAS and (b) instrumental skeleton of AAS.

Analytical conditions for measurement of the Iron (Fe) in aqueous solution using AAS have been reported. The values that were certified and those that were observed agreed well. Reference standard solutions with established concentrations of all measured elements were used as control samples to ensure measurement accuracy. To evaluate the measurement's repeatability, each sample was measured a minimum of twice. In cases where the measurement's relative standard deviation was higher than 10.0 % and double-distilled water was utilized throughout the inquiry, samples were reanalyzed.

4. Results and Discussion

The experimental results of Fe, Mn, Pb, Cd and Zn presented in various types of groundwater samples of Kushtia and Jhenaidah municipals area are given in Table 2, Fig. 2. and Fig. 3.

4.1 Iron (Fe) in Groundwater

Fe is not considered hazardous to health. Fe is essential for good health because it transports oxygen in our blood. Under Department of Nature Resources (DNR) rules, iron is considered a secondary or "aesthetic" contaminant. The present recommended limit for iron concentration in drinking water is 0.30 mg/L (ppm) prescribed by WHO [22, 25] and is based on taste and appearance rather than on any detrimental health effect. Bangladesh guideline is also selected 0.30 mg/L [24]. If the iron concentration in groundwater is found above this range, then this water may have adverse effects on health. The experimental result of the Iron concentration of groundwater in Kushtia and Jhenaidah is given in Table 2 and Fig. 2. Table 2 shows that the groundwater samples contain Iron concentrations of 0.74 mg/L in Kushtia and 0.49 mg/L in Jhenaidah.

Table 2. Trace elements concentration of groundwater samples in the municipals of Kushtia and Jhenaidah districts.

Trace elements concentration in Kushtia					
Sl.	**Water Quality Parameters**	**Analysis Method**	**Concentration Present**	**Bangladesh Standard (ECR'97)**	**Unit**

1.	Iron (Fe)	AAS-Direct Flame	0.740	0.30 - 1.0	mg/L (ppm)
2.	Lead (Pb)	AAS-Direct Flame	0.040	0.050	mg/L (ppm)
3.	Cadmium (Cd)	AAS-Direct Flame	0.004	0.005	mg/L (ppm)
4.	Manganese (Mn)	AAS-Direct Flame	0.370	0.100	mg/L (ppm)
5.	Zinc (Zn)	AAS-Direct Flame	0.057	5.00	mg/L (ppm)
Trace elements concentration in Jhenaidah					
6.	Iron (Fe)	AAS-Direct Flame	0.490	0.30 - 1.0	mg/L (ppm)
7.	Lead (Pb)	AAS-Direct Flame	0.030	0.05	mg/L (ppm)
8.	Cadmium (Cd)	AAS-Direct Flame	0.003	0.005	mg/L (ppm)
9.	Manganese (Mn)	AAS-Direct Flame	0.220	0.10	mg/L (ppm)
10.	Zinc (Zn)	AAS-Direct Flame	0.031	5.00	mg/L (ppm)

4.2 Manganese (Mn) in Groundwater

Mn is an essential element for many living organisms, including humans. Adverse health effects can be caused by inadequate intake or overexposure. Mn deficiency in humans appears to be rare because available manganese is present in many common foods. According to WHO guidelines, Mn concentration in drinking water is (0.10 - 0.50) mg/L [22, 25]. Bangladesh guideline is 0.10 mg/L [24]. The experimental result of the manganese concentration of groundwater in Kushtia and Jhenaidah is given in Table 2. and Fig. 2. From Table 2, it is observed that the amount of Mn concentration is 0.37 mg/L in Kushtia and 0.22 mg/L in Jhenaidah.

4.3 Lead (Pb) in Groundwater

JECFA established a provisional tolerable weekly intake (PTWI) of 25.0 µg of Pb per kilogram of body weight (equivalent to 3.5 µg/kg of body weight per day) for infants and children which took into account the fact that Pb is a cumulative poison so that any increase in the body burden of Pb should be avoided. In Bangladesh, the guideline for Pb concentration in water is 0.05 mg/L [24]. The experimental result of the Pb concentration of groundwater in Kushtia and Jhenaidah is given in Table 2 and Fig. 2. From Table 2, it is observed that the water samples contain Pb concentrations is 0.04 mg/L in Kushtia and 0.03 mg/L in Jhenaidah. So, there is no adverse effect of Pb.

4.4 Cadmium (Cd) in Groundwater

On the assumption of an absorption rate for dietary cadmium of 5.0 % and a daily excretion rate of 0.005 % of body burden, JECFA concluded that, if levels of Cd in the renal cortex are not to exceed 50.0 mg/kg, the total intake of Cd should not exceed 1.0 μg/kg of body weight per day. The guideline for Cd concentration in water in Bangladesh is 0.005 mg/L [24]. The experimental result of the Cd concentration of groundwater in Kushtia and Jhenaidah is given in Table 2 and Fig. 2. Table 2 shows that the water samples contain Cd concentrations of 0.004 mg/L in Kushtia and 0.003 mg/L in Jhenaidah. So, there is no adverse effect for Cd and these water sources are safe for drinking and other purposes.

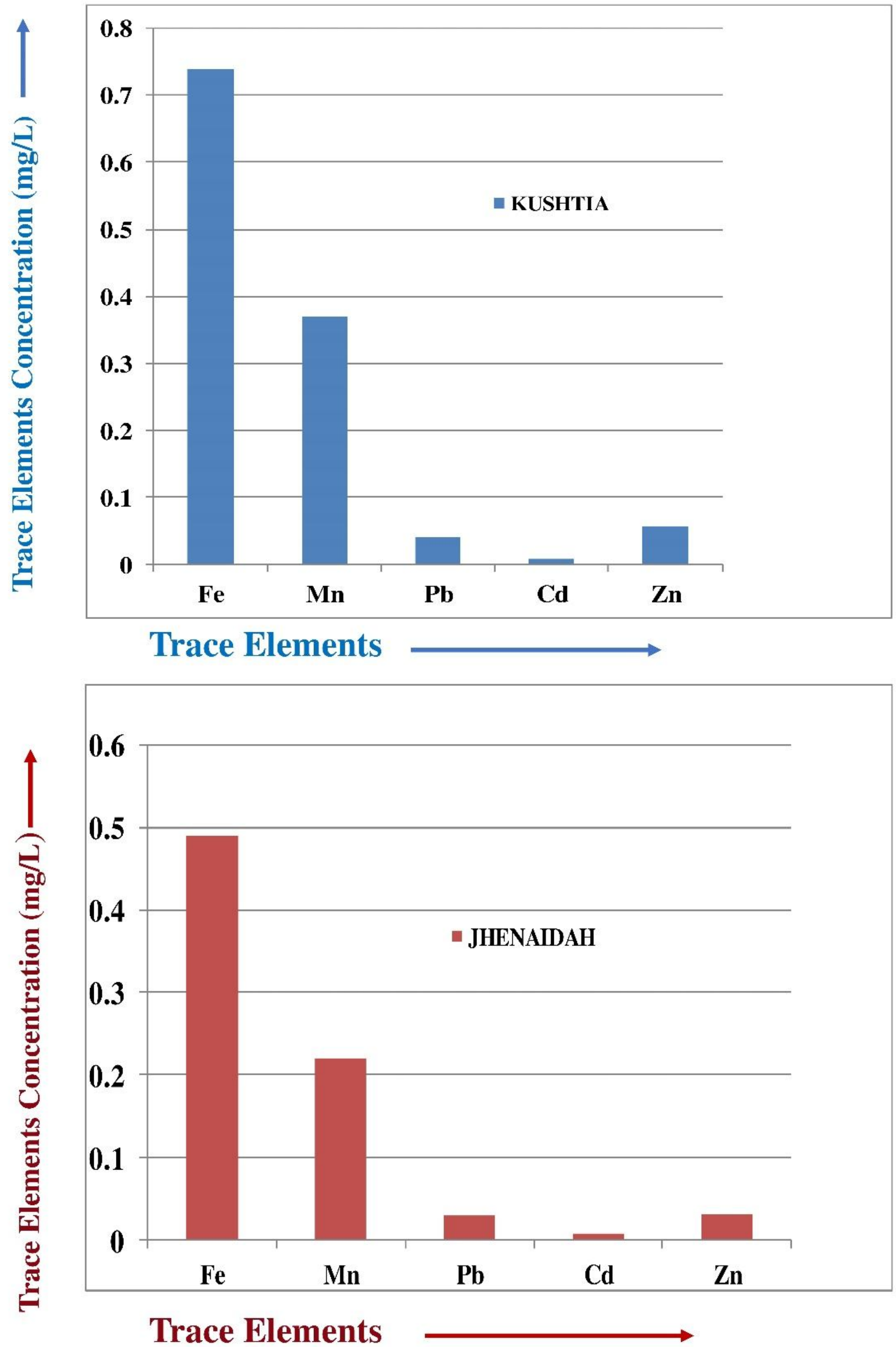

Fig. 2. Trace elements concentration present in groundwater samples of Kushtia and Jhenaidah.

4.5 Zinc (Zn) in Groundwater

Zn is an essential element for humans and most health issues are focused on a deficiency of Zn rather than an excess. Adverse effects of an excess of Zn are centred around gastrointestinal issues. An excess of Zn in water at concentrations greater than 3.0 mg/L can be detrimental to the appearance of the water with a greasy surface film developing and an unpleasant metallic taste. The USEPA sets a secondary maximum contaminant level (SMCL) for zinc of 5.0 mg/L. Bangladesh has set a 5.0 mg/L [24] standard for Zn. The experimental result of the Zn concentration of groundwater in Kushtia and Jhenaidah is given in Table 2 and Fig. 2. From Table 2, it is observed that the groundwater samples containing Zn concentrations are 0.057 mg/L in Kushtia and 0.031 mg/L in Jhenaidah which is below the Bangladesh guideline.

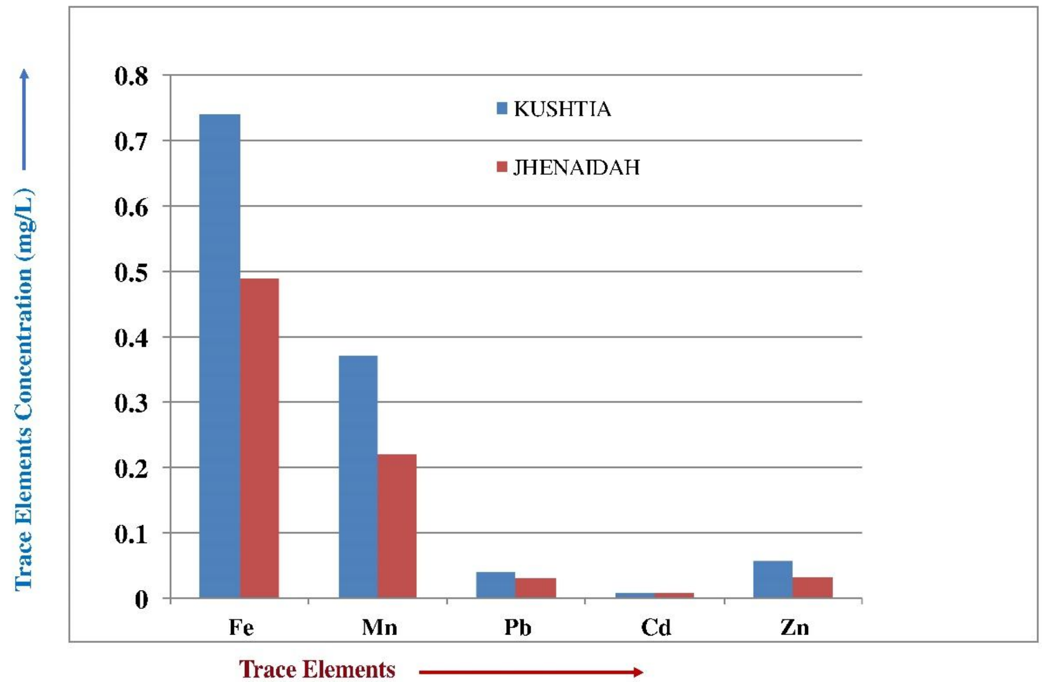

Fig. 3.Comparison between trace elements concentration present in groundwater samples of Kushtia and Jhenaidah.

Fig. 3. shows the relative amounts of trace element concentrations in the groundwater samples of the Kushtia and Jhenaidah municipal areas. the comparison shows that the concentration of trace elements in the Kushtia is higher than in the Jhenaidah. Fe is an important mineral in groundwater. Anaerobic ground waters may contain Fe at concentrations up to several milligrams per litre without discolouration or turbidity in the water when directly pumped from a

well. Taste is not usually noticeable at Fe concentrations below 0.30 mg/L, although turbidity and colour may develop in piped systems at levels above 0.05 - 0.10 mg/L. Fe is an essential element in human nutrition. Concentrations of 1.0 – 3.0 mg/L can be acceptable for people drinking anaerobic well water. The concentration of Fe is 0.74 mg/L in Kushtia and 0.49 mg/L in Jhenaidah. At very high concentrations, Fe can however be toxic with side effects such as rapid and shallow respiration, coma, convulsions, respiratory failure and cardiac arrest being reported. So, everybody should drink water to ensure iron concentration and must avoid water which contains iron overexposure, if it is drunk, then it may cause fatal disease. Mn is also a mineral element that remains in groundwater and it is an important element for all living organisms. But when this Mn concentration in drinking water is overexposed, then it may be harmful to us. So, we should be cognizant of Mn concentration in drinking water before drinking. The concentration of Mn is 0.37 mg/L in Kushtia and 0.22 mg/L in Jhenaidah.

Pb is also found in groundwater. It needs to be recognized that lead is exceptional, in that most Pb in drinking water arises from plumbing in buildings and the remedy consists principally of removing plumbing and fittings containing Pb which requires much time and money. It is therefore emphasized that all other practical measures to reduce total exposure to Pb, including corrosion control, should be implemented. The concentration of Pb is 0.04 mg/L in Kushtia and 0.03 mg/L in Jhenaidah. The regulations for Cd levels in groundwater are sufficient to maintain human intake at low levels. Cd can cause health effects to humans such as kidney, liver and lung damage. The highest Cd exposure to humans is known to come from Cd contaminated food, not drinking water. But care should be taken to the drinking water source. The concentration of Cd is 0.004 mg/L in Kushtia and 0.003 mg/L in Jhenaidah.Zn is another element which remains in the water. JECFA proposed a daily dietary requirement of Zn of 0.3 mg/kg of body weight and a provisional maximum tolerable daily intake (PMTDI) of 1.0 mg/kg of body weight. The daily requirement for adult humans is 15.0 to 22.0 mg/day. The concentration of Zn is 0.057 mg/L in Kushtia and 0.031 mg/L in Jhenaidah. It was concluded that in light of recent studies on humans, the derivation of a health-based guideline value is not required at this time. However, drinking water containing Zn at levels above 3.0 mg/L tends to be opalescent, develops a greasy film when boiled and has an undesirable astringent taste.

5.0 Heath Effect of the Trace Elements in Groundwater

Some special issues were concerned with the intake of the groundwater that was responsible for major risk factors included in Table 3 and Fig. 4. An excess of iron in the water can result in hemochromatosis, hyperglycemia, nausea and gastrointestinal issues [26, 31]. Mn concentration in older people's hair and the prevalence of neurological symptoms and skin rush of chronic Mn poisoning are correlated with increasing increases in Mn concentration in drinking water [27, 32].

Table 3. Responsible health effect of the trace elements of Fe, Mn, Pb, Cd and Zn.

Serial No.	Elements	Health Effects	References
1.	Iron (Fe)	High iron in water content leads to an overload which can cause diabetes, hemochromatosis, stomach problems and nausea.	[26, 31]
2.	Manganese (Mn)	Progressive increases in Mn concentration in drinking water are associated with progressively higher prevalences of neurological signs of chronic manganese poisoning (CMnP) and Mn concentration in the hair of older persons.	[27, 31]
3.	Lead (Pb)	Lead in drinking water has occurred as a result of	[28, 32]

		contamination from piping and distribution systems contamination has led to acute and chronic toxicity in humans and cirrhosis of the liver.	
4.	Cadmium (Cd)	Chronic exposure to Cd resulted in ‘itai–itai’ disease in humans. Some correlations were suggested between cadmium levels and the age-adjusted prostate or breast cancer rates distributed in the European countries under study.	[29, 32]
5.	Zinc (Zn)	Excessive levels of zinc are associated with human health effects such as arthralgia and osteomalacia. High levels of Zinc salts in water may cause eye irritation, pain and erythema.	[30, 32]

Humans have been exposed to acute and chronic poisoning as well as liver cirrhosis due to lead pollution in drinking water which resulted from piping and distribution systems [28]. Chronic exposure to Cd resulted in age-adjusted prostate or breast cancer for Cd toxicity [29]. High concentrations of Zn salts in water can irritate, hurt and cause erythema in the eyes and stomach cramps[30, 32].

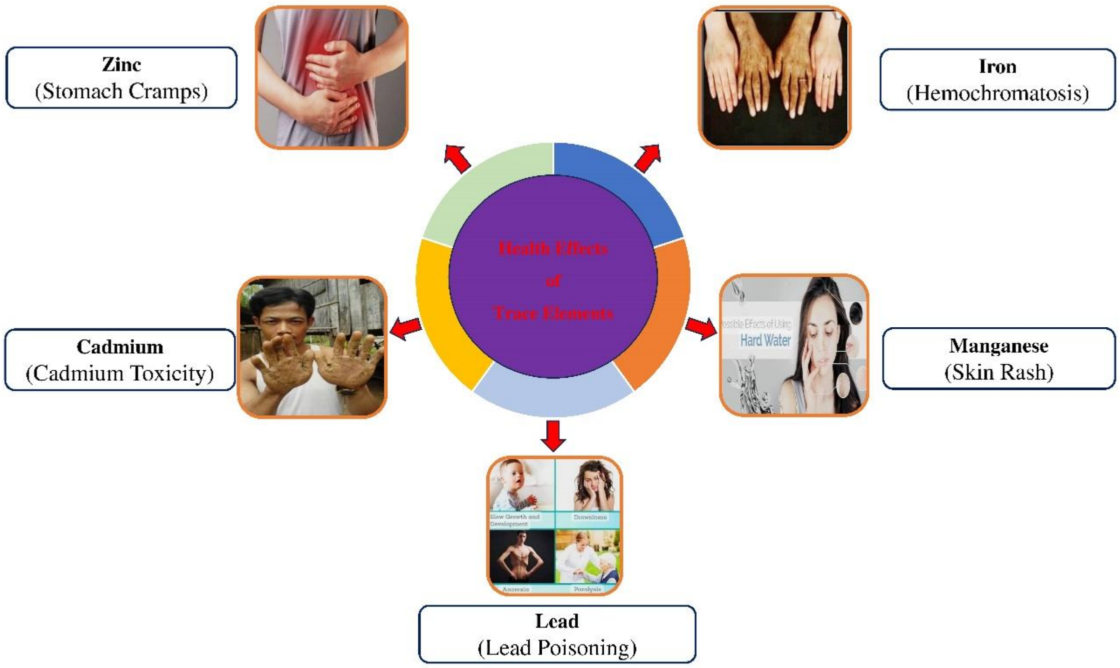

Fig. 4. Health effects of the trace elements (Fe, Mn, Pb, Cd and Zn) in groundwater.

Conclusion

Groundwater samples collected from the municipal areas of Pearatola, Kushtia and DPHE, Jhenaidah districts were analyzed for the determination of trace elements Fe, Mn, Pb, Cd and Zn investigated by AAS with direct flame methods. The evaluated concentrations of Fe, Mn, Pb, Cd and Zn were respectively 0.74 mg/L, 0.37 mg/L, 0.04 mg/L, 0.004 mg/L and 0.057 mg/L which were presented in the Kushtia. The absolute concentrations of Fe, Mn, Pb, Cd and Zn were respectively 0.49 mg/L, 0.22 mg/L, 0.03 mg/L, 0.003 mg/L and 0.031 mg/L which were presented in Jhenaidah. Fe contamination of examined areas samples in 0.740 ppm and 0.490 ppm of cases exceeded the WHO criteria and 0.30 ppm exceeded BD standards which is a very scary risk factor for human health. Drinking water is essential for any living being. Without water, we cannot go even a single day. Water contains various types of minerals that are indispensable for us. But sometimes these minerals were present at overexposure, then it became an adverse effect on our health. So, determination of mineral content of Fe, Mn, Pb, Cd and Zn present in drinking water is important. In this respect present work is a tremendous effort. However, the data obtained will be useful for public awareness.

Data availability

The data is available on request.

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