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Trace metal levels in drinking water of Dhaka city

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Abstract

The levels of Pb, Cd, Cr, Cu, Co, Mn, Ni, Fe, Zn, As were determined in drinking water supplies (public taps, domestic taps and treated water from public water sources) in some places of Dhaka. Water samples have been collected from 13 different places and were analysed using flame and hydride-generation atomic absorption spectrometry method. The mean levels (μg/l) of all the elements were <5 for Pb, <1 for Cd, <5 for Cr, 2-35 for Cu, 5-10.98 for Co, 2-87.92 for Mn, <8 for Ni, 3-143 for Fe, <3.0 for Zn, 2-4 ppb for As. A comparison of the elemental concentrations with WHO guidelines showed that the levels of all the elements were below the allowable concentrations.

Keywords : Trace elements, AAS, drinking water, WHO regulations, Dhaka

1. Introduction

Safe and good quality drinking water is the basis for good human health. Water provides some elements, but when polluted it may become the source of undesirable substances dangerous to human health and cause disease such as, various cancers, adverse reproductive Outcomes, cardiovascular disease and neurological disease [1-4]. Therefore the heavy metal concentration in drinking water should be kept in the low ppb range.

Surface and groundwater sources are known to contain various trace elements, some of which have been widely implicated in human health and diseases. Elements such as Co, Cr, Fe, Mn, Ni, and Zn are essential for growth, As may have possible beneficial uses, while Cd, Hg and Pb appear to have no apparent metabolic function and so are termed non-essential elements [6]. Even though some trace elements are essential to man, at elevated levels essential as well as non-essential elements can cause morphological abnormalities, reduced growth, increased mortality and mutagenic effects in humans [7].

The important part played by water as a factor in the bodily intake of biologically active trace elements has been recognized for sometime now. Lead in drinking water seems to be more biologically available than lead in food [8]. This observation prompted the World Health Organization (WHO) to recommend general guidelines for trace elements in drinking water [9].These guidelines are usually perceived as upper limits for different components in connection with human health aspects.

The demand for potable water is rising rapidly in most communities in Dhaka. Dhaka, the capital of Bangladesh became the nerve centre for the entire country. All activities related to economy, culture, politics, administration, education, health and society as a whole are centred around Dhaka. Population of the city has grown more than 12 million. One of the main challenges for DHAKA WASA is to provide adequate and safe water for domestic, industrial and other uses. The present production from Deep Tube Wells and surface water treatment plants is around 1670 million litre per day. Of the total supply 82% is from groundwater. [5]

An estimation of the concentrations of trace elements in different water supplies in Dhaka is extremely important for proper assessment of the hazards associated with their intake. In this study we have carried out a multi-elemental analysis of drinking waters from domestic taps and public taps all over Dhaka cities.

The main aim of the present study is to check if the trace element levels comply with international standards for drinking water and also an effort by this group to determine baseline levels of trace elements in supplied drinking waters in the environment of Dhaka.

2. Materials and Methods

Sample collection:

Drinking water samples were collected from public and domestic taps over 13 different places in Dhaka city. The taps were allowed to run for at least 15 minutes before samples were taken. The samples were collected in 1 litre polyethylene bottles. The bottles were cleaned using a modified procedure (D) of Laxen and Harrison [10]: the bottles were first soaked in 20% HNO_3 for 24 hour then in deionised water for a few minutes, and finally rinsed three times with double distilled deionized water.

Analytical methodology:

Immediately after collection, the samples were acidified with 4 ml of supra-pure HNO_3 (pH <2.0) and stored at room temperature for about 16 hours. The samples were filtered through Whatman No. 41 filter papers and preconcentration method was followed for trace elements except arsenic. Trace metals were analyzed using Perkin Elmer 3110 model Flame Atomic Absorption Spectrometer and Varian Atomic Absorption Spectrometer (Model SpectrAA 240).

Pre-concentration method:

250 ml of the sample was taken in a 250 ml beaker and 2 ml of HNO_3 was added. The beaker is then covered with watch

glass and is kept on a hot plate to evaporate the sample near to dryness [11,12]. The sample was then removed from the hot plate and allowed to cool at room temperature. The sample was transferred to a 25 ml volumetric flask and leveled up to the mark with deionized water. The sample was filtered with Whatman No. 41 if necessary. Finally the samples were analysed with AAS for the trace metals of Pb, Cd, Cr, Cu, Co, Mn, Ni, Fe and Zn.

Sample preparation for As:

Reagents

All chemicals used were of analytical-reagent grade. Arsenic standard solutions were prepared immediately before use by appropriate dilution of the 1000 ppm stock solution from Spectra pure, USA. Extra pure grade 0.6 % Sodium borohydride ($NaBH_4$) was used to prepare a stabilized solution in 0.5 % (w/v) sodium hydroxide.

Sample preparation

The samples and standards were prepared by using 1% KI and 3M HCl and kept for 2 hrs to complete the reduction.

Sample Analysis

Analyses were performed by Varian Atomic Absorption Spectrometer (Model SpectrAA 240). The instrument is equipped with a Hydride generation system (Model VGA-77) and controlled with software Version 5.01. Samples were analyzed with HG-AAS using three-point calibration. In the analysis time, acid container contains 5M HCl and Reductant container contain 0.6 % Sodium borohydride ($NaBH_4$) in 0.5 % (w/v) sodium hydroxide.

Optimized conditions for hydride generation

Sample solution acidity: 3.0 M HCl; Sample solution flow rate: 7 ml/min; $NaBH_4$ concentration: 0.6 % (w/v) in 0.5 % (w/v) NaOH; $NaBH_4$ solution flow rate: 1 ml/min; HCl flow rate: 1 ml/min.

Quality assurance

Quality assurance measures included the calculation of method detection limit, inclusion of recovery and analysis of standard reference materials. Procedural blanks were used throughout sample preparation and analysis to evaluate contamination from reagent, container etc. Procedures for sample preparation and analysis were validated by carrying out analysis in triplicate of water samples, reference material, blank and spike samples.

Method accuracy was assessed by analysis of a certified Standard Reference Material (NIST 1640). This Standard Reference Material (SRM) is intended primarily for use in evaluating methods used in the determination of trace elements in fresh water. SRM 1640 is composed of natural fresh water collected from Clear Creek, CO, which has been filtered and stabilized with nitric acid at a concentration of 0.5 mol/L.

The average percentage recoveries for the spiked samples were also satisfactory with the falling between 87-102 % (Table 1). Method detection limits (DL) were calculated from the standard deviation of twenty replicates of a low level standard multiplied by 2.539 (In the present case, t test value is 2.539 for degree of freedom 19 at 99% confidence level), and these are also listed in **Table 1**.

Table 1: Analysis results of Standard Reference Material NIST 1640, % recovery of spikes of the samples with metals, method detection limits

Metal	Reference Water results		Spike Recovery (%)	DL((μg/l)
	Analysed (μg/l)	Certified (μg/l)		
Pb	26.69	27.89±0.14	102	5
Cd	21.9	22.79±0.96	90	1
Cr	37.98	38.6±1.6	99	5
Cu	85.1	85.2±1.2	89	2
Co	19.21	20.28±0.31	87	5
Mn	121.01	121.5±1.1	93	2
Ni	25.98	27.4±0.8	94	8
Fe	33.89	34.3±1.6	88	3.0
Zn	52.99	53.2±1.1	87	3.0
As	26.2	26.67±0.41	95	1.0

Results and Discussion

The concentrations of trace metals in drinking water samples are presented in **Table 2**. In the source waters, trace metals levels were low with the majority of samples being below detection limits. Where the metal concentrations were above detection limits they still fell below WHO guidelines [25] for safe drinking water (Table 2).

The main physical properties of the drinking water samples such as pH and electrical conductivity were in the range of 6.90 - 8.13 and 100 to 600 μs/cm, respectively.

The drinking water samples were collected from the thirteen water taps in Dhaka were analysed by atomic absorption spectrometry in triplicate to determine Pb, Cd, Cr, Cu, Co, Mn, Ni, Fe, Zn using the precontration and separate

procedure was taken for As given in the experimental section. The conentrations, which are given in **Table 2**, have been calculated on the assumption of 100% recovery of the metal ions.

Table 2: The concentrations of trace metals ions in drinking water samples supplies in Dhaka city together with WHO limits (WHO 1996)

Location Name	*Concentration, µg/l*									
	Pb	Cd	Cr	Cu	Co	Mn	Ni	Fe	Zn	As
Green road	<5	<1.0	4.38±0.63	35.3±3.7	<5.0	5.36±0.55	<8.0	18.5±1.3	<3.0	2.2±0.03
Baily road	<5	<1.0	<5	28.93±1.0	<5.0	<2.0	<8.0	11.2±0.66	<3.0	2.3±0.1
Section 14, Mirpur	<5	<1.0	<5	<2	5.88±1.2	43.5±0.56	<8.0	50.8±3.3	<3.0	3.0±0.1
Agargaw	<5	<1.0	<5	<2	5.49±0.78	73.8±4.89	<8.0	132±5.3	<3.0	3.32±0.02
Azimpur	<5	<1.0	<5	2.74±0.01	6.27±0.5	64.21±2.07	<8.0	47.5±1.3	<3.0	2.99±0.1
Ahamodbag	<5	<1.0	<5	5.62±0.01	<5.0	14.12±0.19	<8.0	26.4±1.3	<3.0	2.1±0.1
Iskaton garden	<5	<1.0	7.5±0.01	5.06±0.01	<5.0	45±3.0	<8.0	143±16	<3.0	2.3±0.1
AERE,SAVAR	<5	<1.0	<5	3.43±0.01	<5.0	<2.0	<8.0	3.6±0.99	<3.0	2.9±0.03
Mohakhali	<5	<1.0	<5	2.74±0.01	<5.0	43.3±1.29	<8.0	48.8±5.3	<3.0	4.0±0.2
Lalbag	<5	<1.0	<5	8.99±0.01	10.98±0.78	10.3±2.5	<8.0	33.7±0.66	<3.0	2.5±0.1
Pollobi	<5	<1.0	<5	6.74±0.01	5.49±0.5	26.74±0.01	<8.0	105±1.32	<3.0	2.4±0.04
Tongi	<5	<1.0	<5	<2	6.27±0.78	10.36±0.56	<8.0	128±7.3	<3.0	2.3±0.1
Golapbag	<5	<1.0	<5	3.93±0.56	5.49±0.01	87.92±2.0	<8.0	136±3.9	<3.0	4.2±0.1
WHO limits	10	3	50	2000	-	100	50	300	3000	10

Trace metal concentrations in the drinking water samples were generally influenced by types of pipes and plumbing, storage tanks used and also the form of water treatment carried out at the water works. This treatment usually involves the addition of $Al_2(SO_4)_3$ as a chemical coagulant to the waters, particularly those source from surface waters [13].

Significant concentration difference was observed for Cu. Elevated concentrations of Cu and Zn in tap water are usually due to corrosion of pipes and plumbing. In this study copper concentration in the drinking water samples were in the range of 2.74-35.3 µg/l [figure 2]. The lowest values were found in Azimpur and Mohakhali station, highest values in Green road station but in Section-14; Mirpur, Agargaw, Tongi station Cu was considerably low and below the detection limit <2.0 µg/l, permitted by WHO [25] in drinking water. Zn for all stations were below the detection limit (BDL is <3.0 for Zn). Consequently, no contamination due to copper and zinc exists in the drinking water samples from Dhaka.

Significant difference in Fe concentration between the locations was shown. As shown in figure 3 the highest iron level was found Iskaton Garden station as 143±16 µg/l and the lowest in AERE, Savar station as 3.6±0.99 µg/l. None of the drinking water samples analyzed for iron exceeded the limit permitted by WHO [14], which agrees with results obtained by other authors in other countries [13,15,16].

The action level for Pb recommended by the Environmental Protection Agency (EPA) is 15 µg/l. The levels of lead in all stations were below the detection limit and the detection limit is below this level. A major source of environmental lead, particularly in urban areas, is due to the combustion of leaded petrol. Lead is discharged by vehicles into air, and then adsorbed from the air by environmental samples such as soil and plants [13 & 17]. Pb then enters the waterways from soil, thus affecting the levels of lead in natural water. The primary adverse health from exposure to lead is permanent neurological impairment (particularly in children). Other adverse health effects associated with lead include sterility in males and nephrotoxicity.

Variation in Mn concentration at different location at Dhaka city was shown in figure 4. As seen in this figure, the highest manganese level was found in Golapbag station as 87.92±2.0 µg/l and the lowest in Green road station as 5.36±0.55 µg/l. However the concentrations for Baily road and AERE, Savar station were below the detection limit (BDL is <2 µg/l).

Cadmium levels were very low, below the detection limit (Table 2) in the present study with all samples. Cadmium concentrations in unpolluted natural waters are usually minimal and the levels found in the present study suggest

that no corrosion of cadmium containing pipe fittings was occurring. Elevated cadmium levels in water have also been associated with runoff from agricultural land where fertilizers are used [25] but the water catchment areas in the present study did not have a significant proportion of these types of land uses.

Ni for all stations were found to be the below detection limit (BDL is <8 μg/l for Ni).

The concentration of chromium was only detected in Iskaton Garden station as 7.5±0.01μg/l. Besides this, all stations had concentration less than 5 μg/l.

The highest cobalt level was found in Lalbag station as 10.98±0.78 μg/l and the lowest in Agargaw and Pollobi stations as 5.49±0.01 μg/l as seen in figure 5. However the concentrations for other stations were below the detection limit (BDL is <5 μg/l).

Millions of people worldwide are exposed to naturally occurring As contaminated ground water, which they use their only source of drinking water [18]. The highest arsenic level was found in Golapbag station as 4.2±0.1 μg/l and the lowest in Ahamodbag station as 2.1±0.1 μg/l. However the concentrations for other stations were in the range of 2.2-4.0 μg/l as seen in figure 6. As arsenic is known to be highly detrimental to human beings and animals, various regulatory agencies have revised the maximum contaminant level of arsenic in drinking water from 50 to 10 μg/l [19 & 20].

A comparison between the trace element levels in the drinking water samples with those of other countries were shown in **Table 3**. It can be seen that significant differences were observed for Cu, Mn and Fe in Dhaka, Bangladesh and also the concentration levels of Mn and Fe are higher compared to other countries. The concentration of Zn was higher in Southern Nigeria and Pb, Cu were higher in Britain.

Table 3: Comparison between trace element levels (μg/l) in drinking water supplies in Dhaka, Bangladesh with other countries.

Element (μg/l)	Dhaka, Bangladesh[a]	USA[b]	Norway[c]	Britain[d]	Southern Nigeria[e]
Pb	<5	3.7	<35	0.3-76.7	1.36
Cd	<1		<2.5	0.07-0.68	0.46
Cr	<5.0-7.5			0.40-1.58	1.41
Cu	<2.0-35.3	8.3		1.1-47.2	6.13
Co	<5-10.98				
Mn	<2-87.92	5	23	0.3-4.6	3.1
Ni	<8.0	<2.7	<15		1.99
Fe	3.6-143				
Zn	<3.0		50.9	8.2-40.9	87.3
As	2.1-4.2				2.69

a. Concentration range of trace elements in Dhaka water samples

b. Median values for finished drinking water from 100 largest cities in USA [21]

c. Mean values for drinking water in Norway [22].

d. Concentration range of trace elements in British water samples [23]

e. Trace element levels (μg/l) in drinking water supplies in Southern Nigeria [24]

5. Conclusion

This study has shown that the trace element quality of waters in Dhaka is generally good, the elements satisfying the WHO regulations for drinking waters and no risk to human health was detected. It should provide a good for setting standards for water quality in the country. It should be recommended that study of metals in drinking water in Dhaka should be repeated at least every 1 year to monitor if any changes in contamination levels are occurring. Further research on other cities for drinking water trace metal content is also required, as levels may vary considerably due to different soil types, water chemistry(e.g.; pH, hardness), and industrial activities.

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