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Comparative Distribution of Selected Essential Metals in Drinking Water by Atomic Absorption Spectrophotometric Method

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ABSTRACT

This study reports the concentration levels of selected essential metals; Ca, Mg, Na, K, Fe and Zn in the drinking water collected from different areas of Islamabad. The levels of these metals present in the drinking ground water were compared with standards reported worldwide. The analysis was carried out using atomic absorption spectrophotometry. The mean metal concentration for Na was far less than those reported worldwide, while the average concentrations of K and Zn were also less than those reported worldwide. The mean concentration of Fe was equal to those reported worldwide standards. Sodium showed maximum concentration while Fe was estimated to be the lowest among the selected metals.

Keywords: Essential Metals; Ground water; Atomic Absorption Spectrophotometry

1. INTRODUCTION

Environmental pollution especially in the metropolitan cities is generally expected to deteriorate the quality of drinking water. One of the important parameters of the quality of water is represented by the concentration of major, minor and trace elements. In industrial areas, some of the metals may be expected to present at considerably elevated level as a result of excessive industrial effluents which might find their way to the underground drinking water reservoir[1]. Contrary to such theory, one may suggest that, the underground drinking water resources may still be out of reach to the surface pollutants. In any of such cases, regular monitoring of trace metals is always recommended especially in the drinking water[2].

In Pakistan, only limited population has access to the purified public water supply while the rest of population is dependent upon direct withdrawal of water from both surface and underground sources. Most of the quality problems in Pakistan are due to lack of waste disposal regulations non-availability of treatment facilities and due to lack of public awareness about water quality[3].

Atomic absorption spectrophotometry is most commonly used for the determination of metal levels in the groundwater and soil[4]. In addition, few other techniques, such as X-ray fluorescence, ICPMS, ICPES, flame photometry, emission spectrography and voltammetry have been used for metal analysis on limited scale. Atomic absorption method is preferably used because it is more sensitive, and reproducible, relatively free of interferences and convenient to use than most of the other methods of analysis. For the quantitative measurements of trace metal levels, calibration line method has been most widely applied. The most selective light sources in the form of hollow cathode lamps have been in use since a long in atomic absorption spectroscopy[5].

Drinking water used in Rawalpindi and Islamabad is contributed by two main sources. First is the surface water, mainly in the form of dams and the other is groundwater which is drained off after proper boring. Water supplied to twin cities of Rawalpindi and Islamabad is mostly a run-off collected from the watershed of Murree hills. The contamination is due to the anthropogenic emissions and geological structure of the area bearing unhealthy minerals affecting the taste and characteristics of water[6]. The pathogenic organism is also responsible for health hazard, apart from the inorganic chemical[7]. The present study was carried out to estimate the concentration of selected essential metals Ca, Mg, Na, K, Fe and Zn in the drinking water and then to compare these metal levels with the international standards in order to evaluate their health effects.

2. EXPERIMENTAL

Water samples were collected from the residential areas of Islamabad. These samples were collected in plastic bottles and stored in proper place before analysis. Before filling, the sample bottles were first rinsed with the sample water and were then filled to overflow so that no air bubble was left trapped in the sample. The samples were collected during day time, mostly on a shiny day. Care was taken to collect the representative samples.

For calibration line, working standards of the metals were prepared. The stock solutions of 100 ppm of all these metals were prepared from pure metal salts, or metal salt having fixed H_2O molecules. The working standards were prepared by appropriately diluting 100 ppm stock solutions of these metals. All equipments used, were properly calibrated prior to experimental measurement.

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Atomic absorption spectrophotometer (Hitachi, 170-10, Japan) equipped with laminar flow burner. Air-acetylene flame was used for the determination of these metals under optimum analytical conditions shown in Table-1. Each metal was analyzed at its optimum wavelength under stipulated flow rate of oxidant and fuel, as recommended by the manufacturer of the instrument. Every care was taken to reduce the contamination during the analysis.

3. RESULTS AND DISCUSSION

The analysis of selected essential metals was performed under the optimum analytical conditions as shown in Table-1. The absorption wavelength used for Ca was 422.7 nm, for Mg 285.2 nm, for Na 589.0 nm, for K 766.5 nm, for Fe 248.3 nm,Zn 213.8 nm. The lamp currents were properly adjusted as recommended by the manufacturer and oxidant and fuel flow rates were also controlled for maximum absorption signal (Table-1).

The distributed parameters for the selected essential metals in the drinking water are shown in Table-2. Minimum levels for Ca, Mg, Na, K, Fe, and Zn were 1.15, 9.00, 11.21, 0.70, 0.20 and 0.23 ppm, while their maximum values were 32.43, 25.64, 25.95, 4.43, 0.63 and 0.56 ppm respectively. Ca, Mg and Na were present at dominant levels while K, Fe, and Zn showed relatively low concentrations. Mean and median values were found to be comparable in each case. Overall, the metal levels were quite divergent as manifested by relative high standard deviation values as well as appreciably large coefficient of variance.

In water, trace amounts of metals are common, and normally, these are not harmful to health. Infact, some metals are essential for the sustainability of life. Ca, Mg, K and Na must be present at relatively higher levels for normal body functions. Co, Cu, Fe,Mn, Mo, Se and Zn are needed as catalysts for enzyme activities at low levels. Drinking water containing high levels of these extremely important metals or poisonous metals such as Al, As, Ba, Cd, Cr, Pb, Hg. Se and Ag may be dangerous to health[8].

The presence of metals in water supply may be natural or may be the result of contamination. Natural presence of these metals is the result of dissolution of metals due to the connection of water with soil or rocks[9].Corroded material i.e corrosion of pipes and waste disposal leakage are the major sources of contamination of water. Metals present at high enough level than threshold limit value should be removed to be out of risk factor.

Comparison of present metal levels with the international standards is shown in Table-3. Ca is important in controlling nerve impulse conduction and muscle contraction in living organisms. It has very important role in blood clotting. It converts fibrinogen to fibrin during blood clotting[10].Ca is very important for good health. Most of the required portion of Ca for human body is provided by the drinking water containing Ca. This particular amount of Ca prevents ailments as hypertension, osteoporosis and cardiovascular disorders. The calcium level was found in the range of 1.15 to 32.43ppm. The WS-1, WS-2, WS-3 has approximately equal amount of Ca while the WS-6 has a maximum amount of Ca. The median of all these samples were 18.64 ppm. The WS-5 was found to have the minimum amount of Ca. All the observation shows that Ca has the low amount than the WHO standards. The standard deviation is 8.02 and the co–efficient of variance is 40.8 which is maximum than all the other elements.

Magnesium is driven out from the bodies of healthy persons. People may suffer from increase in blood pressure, muscle weakness and even coma if they have kidney disease. Mg is for signaling the nervous system and it also participates in osmotic and electrolyte balance. It is essentially required in photosynthesis. In human, it can cause genetic disorder[11]. In the present work the Mg mean value was found 18.04 ppm. The concentration of Mg ranges from 9.00–25.64 ppm. The lowest value was found in WS-6D and the highest was found in WS-2C. The median was found 16.36 ppm .All the values were found to be below the international standards of WHO. The maximum difference was found in WS-1 samples which is 15.93–25.23. The median was lower than the mean which shows asymmetry in its distribution. The standard deviation is 4.59ppm and co-efficient of variance is 23.21 which is lower than all other elements.

Sodium is beneficial to healthy adults at normal intake levels. But people having hypertension or heart problem should reduce Na intake to lower the danger of heart diseases and blood pressure. Na has serious effects on both human life and crop yield. Water high in Na is considered soft and generable for irrigation[12]. In present study, the result showed the mean value of Na was 19.80 ppm which was higher than Ca and Mg but this level was not the toxic level, so it has no bad effects. Na levels range from 11.21to 35ppm. The least Na levels were found in WS-6D and the highest was found in WS-4E. The median was higher than the mean value which showed the negative asymmetry in the data. The spread of the data is found in form standards deviation and was 6.02ppm and the co-efficient of variance was 33.39%. In comparison with the international standards, the Na levels found in the samples were low than WHO, EU, UK and Japan, but are just equivalent to USEPA standards.

In natural water, K is found in far smallest concentration than other metals. It acts in water as Na does, although it occurs in small concentration but plays an important role in metabolism of the fresh water environment and is regarded to be the vital macro-nutrients. It has an important role in maintenance of osmotic and electrolytic balance. It is important in proper rhythm of heart beat. It is important for creation of nerve impulse and its transmission[13]. In our analysis the K ranges from 0.70 to 4.43ppm and mean value was 3.06 ppm. The lowest level was found in WS-6A and the highest in WS-3A. The median is 3.53 ppm which showed the negative asymmetry and standard deviation is 1.19 and co-efficient of variance is 39%. K values in present study were much lower than EU and UK standards.

Iron in water has not hazardous for health by itself but it may be responsible for increasing the hazard of pathogenic organisms, because many of these organisms need Fe to grow. Iron is one of the most abundant metals in the earth crust and is essential for plants, animals and human being. The permissible limit placed on this metal has no health significance[14]. In our study the mean value found for the Fe was 0.39 ppm. The minimum value was found at 0.2ppm in the WS-4B, and the maximum was 0.63ppm in WS-1A. The median found for Fe was 0.40 which is greater than the mean and show asymmetry in the data. The standard deviation was 0.13 which showed small spread of the data. The co-efficient of variance value was 33.79%, in comparison with the international standards of WHO, EU, USEPA, UK, Russia and Japan present levels were almost same.The iron present in the sample seems to be ferrous iron since no discoloration of water was observed when collected.

Table-1: Optimum analytical conditions on FAAS for selected essential metals

Metals	Absorption Wavelength (nm)	Lamp Current (mA)	Fuel flow rate (kg/cm^2)	Oxidant flow rate(kg/cm^2)
Ca	422.7	7.5	0.20	> 1.0
Mg	285.2	10.0	0.20	> 1.0
Na	589.0	10.0	0.20	> 1.0
K	766.5	10.0	0.20	> 1.0
Fe	248.3	10.0	0.30	> 1.0
Zn	213.8	10.0	0.30	> 1.0

Table-2: Distribution of selected essential metal levels (ppm) in the drinking water
BDL = Below Detection Limits

Sample Code	Ca	Mg	Na	K	Fe	Zn
WS-1 A	15.62	25.23	17.94	3.73	0.63	0.50
WS-1 B	18.28	20.42	18.93	3.52	0.40	0.56
WS-1 C	12.83	23.65	21.57	3.27	0.41	0.52
WS-1 D	19.00	15.93	19.89	3.8	BDL	0.48
WS-2 A	15.64	23.70	13.73	4.15	0.6	0.52
WS-2 B	18.28	21.09	13.64	3.63	0.41	0.52
WS-2 C	14.83	25.64	18.41	3.2	0.34	0.48
WS-2 D	19.52	16.95	13.85	4.15	BDL	0.47
WS-3 A	16.45	23.70	14.73	4.43	0.62	0.50
WS-3 B	17.90	20.53	13.82	3.87	0.36	0.50
WS-3 C	15.13	23.64	20.00	3.52	0.44	BDL
WS-3 D	21.00	15.93	12.95	4.21	BDL	0.32
WS-4 A	29.00	25.43	24.43	4.15	0.40	BDL
WS-4 B	28.25	20.00	30.52	4.00	0.20	BDL
WS-4 C	25.64	21.93	35.00	3.53	0.43	0.31
WS-4 D	26.87	19.94	25.95	3.92	0.21	0.30
WS-5 A	2.00	25.43	15.83	2.41	0.30	BDL
WS-5 B	BDL	18.30	15.72	1.90	BDL	BDL
WS-5 C	1.15	24.07	20.00	1.83	BDL	0.24
WS-5 D	BDL	18.95	13.84	2.15	0.52	BDL
WS-6 A	28.90	11.95	11.65	0.70	0.24	BDL
WS-6 B	32.43	10.50	12.64	0.91	BDL	BDL
WS-6 C	29.64	11.00	16.91	1.58	0.25	0.36
WS-6 D	24.15	9.00	11.21	0.80	BDL	0.23
Mean	19.65	18.4	19.80	3.60	0.39	0.42
Median	18.64	16.37	20.48	3.53	0.40	0.48
SD	8.02	4.59	6.02	1.19	0.13	0.12
CV	40.81	23.21	33.39	39.00	33.79	27.49
Min.	1.15	9.00	11.21	0.70	0.20	0.23
Max.	32.43	25.64	30.52	4.43	0.63	0.56
N	22.00	24.00	24.00	24.00	17.00	16.00

Zinc is very important constituent in our diet. Zn has hazardous effects if we increase its amount 10-15 times higher than the amount required for good health. Large doses of Zn taken orally even for a short period of time can cause nausea, stomach cramps and vomiting. Its intake for longer time results in anemia and in decreasing the levels of good cholesterol. Metal fume fever, a short term disease, may be the result of inhaling Zn as dust or fumes of zinc. Breathing high levels of Zn for long time, no doubt, has long-term effects but these are still unknown. Zinc is essential element for plants and exists in water and soil as an organic complexes and inorganic salts. Zinc is required for

growth, sexual development, wound healing infection, sense of taste and night vision in human[15-17]. The mean value found in water samples was 0.42 ppm which ranged from 0.23 to 0.56 ppm. The median of the data reading was 0.48 which showed negative asymmetry in the data. The standard deviation shown was 0.12 ppm and co-efficient of variance was 27.49 %. When these values are compared with international standards the Zn level was found lower than WHO, US EPA, Russia, but was higher than EU.

Table-3: Comparison of selected essential metal levels (ppm) with the international standards reported world-wide[18]

	Ca	Mg	Na	K	Fe	Zn
WHO	100	30-50	200	12	0.3	3.0
EU	-	-	150	12	0.2	0.1
USEPA	-	-	20	-	0.3	5
UK	-	-	150	10.	0.2	-
Russia	-	-	-	-	0.3	1.0
Japan	-	-	200	-	0.3	-
Present level	19.65	18.40	19.8	3.06	0.39	0.42

4. CONCLUSION

It was observed during the present study that mean concentrations of Ca, Mg, Na, K, Fe, and Zn in the drinking water of Islamabad were found to be 19.65, 18.04, 19.80, 3.06, 0.39, and 0.42 ppm respectively. For Na, K, Ca, Mg and Zn, these values are far less in comparison to the concentrations reported worldwide, whereas for Fe present value is nearly equal to the reported values. Ca, Mg and Na were in high concentrations as they are macronutrients while K, Fe and Zn being the micronutrients were present in low concentrations. Over all, the selected metals revealed asymmetric distribution in their concentration duly reported by standard deviation and co-efficient of variation.

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