Distribution of trace metals in water samples: A case study from Taiz city-Yemen

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Abstract

The levels of nine trace metals (Fe, Cu, Mn, Zn, Ni, Co, Pb, Cd and Cr) are determined in ground water, collection water tank and spring sources in Taiz city. The results show that among different water samples the average content of Fe, Cu, Mn, Zn, Ni, Co, Pb, Cr and Cd are in the range of 0.001 to 0.182, 0 to 0.088, 0.01 to 0.295, 0 to 0.2, 0 to 0.17, 0 to 0.438, 0 to 0.37, 0 to 0.086 and 0 mg/L respectively. Fe in water samples was slight higher than the permissible limit of 0.1 mg/L according to WHO. Cu in all samples did not exceed the permissible limit of 1 mg/L prescribed by the YSMO and WHO guidelines. From 4 samples are having Mn more than the permissible limit of 0.2 mg/L according to YSMO standard. Zn concentration is less than the permissible limit according to WHO and YSMO standards. Co is not detectable in three samples, there is no guideline for the maximum allowable level of cobalt in drinking water at this time. The concentration of Ni in twelve samples was higher than the permissible limit of 0.02 prescribed by WHO and YSMO standards. 11 samples show concentration of pb more than the permissible limit of 0.05 mg/L prescribed by WHO and YSMO guidelines. Cr element is not detectable in 3 samples and 4 samples have concentration of Cr more than the permissible limit of 0.05 mg/L prescribed by WHO and YSMO standards. Cd is not detectable in all the study samples. The statistical analysis indicated that Fe showed high significant positive correlation with Mn and Cu. Cu showed high significant positive Zn and significant negative correlation with Ni.

Abstract

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Key words: Trace elements, ground water, water tank, spring water, Taiz city, Yemen.

Introduction

Human health can be affected by the quality of the food and drink we take. Water intended for human consumption must be free from organisms and from concentrations of chemical substances that may be hazardous to health. Trace elements constitute a natural component of the earth crust. They are not biodegradable, hence persist in the environment. Trace elements may come from natural sources, leached from rocks and soils according to their geochemical mobility or come from anthropogenic sources, as the result of human land occupation and industrial pollution. Although trace metals at low concentrations are essential to life, at high concentrations, may become hazardous. Many trace metals are regarded as serious pollutants of aquatic ecosystems because of their environmental persistence, toxicity and ability to be incorporated into food chains. The chemical behavior of these elements in water (i.e. speciation) and accompanying transformations in sediments e.g. through methylations, Mercury (Hg) and Tin (Sn) result in even more toxic forms. Sediments and water provide pathways for trace metals. Metals may become bio-available to aquatic organisms, after deposition and translocation from various diffuse and point sources apart from geological sources (Mwanburi and Oloo, 1996/97). Heavy metal contamination of environment is a worldwide phenomenon that has attracted a great deal of attention (Wong *et al.* 2002). Recent studies show that the levels of trace elements present in drinking water could seriously affect human health (Alam and Sadiq, 1989). World Health Organization (WHO) great emphasis on the quality of drinking water and has recommended upper limits for a number of trace elements for drinking water (WHO, 1977 and 1980). The main natural sources of metals in water are chemical weathering of minerals and soil leaching. The anthropogenic sources are associated mainly with industrial and domestic effluents, urban storm, water runoff, landfill, mining of coal and ore, atmospheric sources and inputs rural areas (Kabata–Pendias and Pendias 1992, Biney *et al.* 1994, Zarazua *et al.* 2006). Water pollution by trace metals is an important factor in both geochemical cycling of metals and environmental health (Kabata–Pendias and Pendias 1992). Therefore this study will reveal the concentration levels of trace metals that are likely to be present in the water samples. It will help in determining the potability of drinking water. The data obtained can be a base for further studies.

Material and method

Study area

Taiz is one of the largest cities in Yemen located in the Southwest of Yemen (located at 13°35′ N and 44°01′E). Its average height from sea level is 1311 m on highlands at an altitude of 1500 meters above sea level. It lies very close to the famous foothill of Saber Mountain, which lies 3015 meters above the sea level. The weather in Taiz is fair and beautiful most of the time.

Sampling

Twenty samples were randomly collected from ground water (17 samples), water tank (2 samples) and water spring (one sample) from different areas within Taiz city. Each sample was collected in 1 L glass bottle, clean and rings well with deionized water, then the samples were preserved by the addition of concentrated nitric acid (HNO_3) to adjust the pH of the samples to below 2 to retard adsorption. The samples were kept in ice packs and transported to the laboratory where they were further preserved in a refrigerator before analysis (USEPA, 2007 and Christian, 1986).

Analysis of trace elements in water samples:

Nine trace elements Fe, Cu, Mn, Zn, Ni, Co, Pb, Cd and Cr of were analysed in water samples at the laboratory using Atomic Absorption Spectrophotometer (AAS). The procedures employed are as indicated in the AAS manufacturer's manual and referred to the standard methods for the examination of water and wastewater by American Public Health Association (APHA, 1992) .

Statistical analysis: The data were statistically analyzed using Statistical Package for Social Sciences (SPSS) version 16 getting the mean of the concentrations of metals and Standard Deviation (SD) and Coefficient of Variation (CV) of the all samples.

Results and discussion

Iron

Iron is an essential element in human body (Moore, 1973) and is found in groundwater all over the world. Higher concentrations of iron cause bad taste, discoloration, staining, turbidity, esthetic and operational problem in water supply systems (Dart, 1974, Vigneshwaran and Vishwanathan, 1995).

The iron concentration in water samples ranged from 0.001 in GW (6, 8, 9, 10, 11, 12, and 13) to 0.182 mg / L in GW 5 (Table 1) with the mean value of 0.051 mg / L (Table 3). The concentration of iron in most water samples was within the permissible limit of 1 mg / L according to YSMO guideline and the concentration of 4 samples was slight higher than the permissible limit of 0.1mg / L prescribed by WHO like GW1, GW4, GW5 and GW16.

Copper

Copper is an essential element, concentrated in several enzymes; its presence in trace concentrations is essential for the formation of hemoglobin. An over dose of copper lead to neurological complication, hypertension, liver and kidney dysfunctions (Krishna and Govil, 2004; Khan *et al*. 2010). Ingestion of copper causes infant death, short living, vomiting, diarrhea etc. (Barzilay, 1999).

The copper was not detectable in 5 water samples GW (7, 8, 9, 10 and 15). The highest concentration is 0.088 mg / L in GW1 (Table 1) with the mean value of 0.0219 mg / L (Table 3). From the results the concentration of Cu in all samples does not exceed the permissible limit of 1 mg/L prescribed by the YSMO and WHO guidelines.

Manganese

Mn element naturally occurring and commonly found in drinking water supplies and is essential for human health at low concentrations (Keen and Zidenberg-Cherr, 1994).

The manganese concentration in water samples ranged from 0.01 mg/L at GW 13 to 0.295 mg/L in GW5 (Table 1) and the mean value of Mn is 0.1124 mg/L (Table 3). Some samples were have concentration of manganese more than the permissible limit of 0.2

mg/L prescribed by YSMO standard like GW (1, 5, and 16) of ground water and WT1 collection water tank.

Zinc

Zinc is part of nature and exists naturally in air, water and soil. Most rocks and many minerals contain zinc in varying amounts. The average natural level of zinc in the earth's crust is 70 mg/kg (dry weight), ranging between 10 and 300 mg/kg (Malle, 1992).

The zinc element was not detectable in two samples GW 3 and 7, but other samples shows concentration between 0.007 mg/L in GW13 to 0.732 mg/L in GW1 (Table 1) with the mean value of 0.0743 mg / L (Table 3).

The results of the analysis of water samples in the studied areas are less than the permissible limit of 5 mg / L according to WHO and (5-15) mg / L prescribed by YSMO standards.

Cobalt

Cobalt is beneficial for humans because it is a part of vitamin B12, which is essential for human health. Cobalt is used to treat anaemia with pregnant women, because it stimulates the production of red blood cells. However, too high concentrations of cobalt may damage human health (Shahida *et al*. 2009)

Cobalt was not detectable in three samples of GW (9, 15 and 17). The concentration in other samples ranged from 0.034 mg/L in the sample taken from GW10 to 0.17 mg/L form sample taken from WT1 (Table 1) with the mean value of 0.09155 mg / L (Table 3). The increases of the cobalt concentration in water samples may due to the composition of the rocks with the studied areas.

There is no guideline for the maximum permissible level of cobalt in drinking water at this time (CCREM, 1995).

Nickel

Nickel is present in a number of enzymes in plants and microorganism. In the human body, nickel influences iron adsorption, metabolism and an essential component of the haemopoiitic process. Acute exposure of nickel in the human body is associated with a variety of chemical symptoms and signs such as nausea, vomiting, headache, giddiness etc. (Barzilay, 1999).

From the results the nickel is not detectable in seven samples while the concentration of nickel in the other samples was ranged from 0.02 mg/L in GW5 to 0.438 mg/L as highest concentration in GW15 (Table 1) with the mean value of 0.119 mg/L (Table 3).

The concentration of nickel in twelve GW samples 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16 and WT (1 and 2) collection water tanks was higher than the permissible limits of 0.02 mg/L prescribed by WHO and YSMO standards (Table 2).

Lead

Lead occurs geologically in association with sulphide minerals and present in elevated concentration in areas with ores and coal (Reimanne and Decarital, 1998).

The lead was not detectable in some samples like GW (1, 3, 5, 10 and 12) of ground water and WP water spring, the highest concentration was recorded in GW4 sample (Table 1). 11 samples out of 20 show concentration more than the permissible limit of 0.05 mg/L prescribed by WHO and YSMO guidelines with the mean value of 0.097 mg/L (Table 3). The reason for the increase the concentration of pb in some samples are the geological structure of the rocks in these areas, and beside to that, the decomposition of old batteries which have been draft into the area by runoff water particularly in GW4.

Chromium

Chromium is like metal ions that persist in the environment as either Cr (III) or Cr (VI). Cr (VI) is toxic to both plant and animals, being a strong oxidizing agent, corrosive and a potential carcinogen (National Research Council, 1974).

The chromium element is not detectable in three GW samples 5, 8 and 12 but other samples show concentration of chromium between 0.002 mg/L in GW6 to 0.086 mg/L in GW16 (Table 1) with the mean value of 0.032 mg / L (Table 3). Four samples have concentration of chromium more than the permissible limit of 0.05 mg/L prescribed by WHO and YSMO standards as 0.068 mg/L, 0.07 mg/L, 0.078 mg/L and 0.086 mg/L from WP, WT2, GW1 and GW16 samples, respectively.

Cadmium

Cadmium is a cumulative environmental pollutant and its exposure to the body results damage of the kidney, and causes renal dysfunction, arteriosclerosis, cancer etc. (Goel, 1997; Robards and Worsfold, 1991).

The Cadmium was not detectable in all the samples studied (Table 1).

Statistical analysis indicated that Fe showed high significant positive correlation with Mn, and Cu. Cu showed high significant positive Zn and significant negative correlation with Ni (Table 4).

Table 1: Show the concentration of trace elements (mg / l) in water samples in the study area

Sl. No.	Samples type	Fe	Cu	Mn	Zn	Co	Ni	Pb	Cr	Cd
1	GW1	0.177	0.088	0.249	0.732	0.164	ND	ND	0.078	ND
2	GW2	0.045	0.027	0.046	0.2	0.083	ND	0.23	0.034	ND
3	GW3	0.037	0.063	0.03	ND	0.091	ND	ND	0.038	ND
4	GW 4	0.15	0.04	0.043	0.057	0.103	ND	0.37	0.02	ND
5	GW 5	0.182	0.07	0.295	0.035	0.1	0.02	ND	ND	ND
6	GW 6	0.001	0.004	0.031	0.11	0.123	ND	0.18	0.002	ND
7	GW 7	0.079	ND	0.017	ND	0.052	0.387	0.13	0.009	ND
8	GW 8	0.001	ND	0.088	0.064	0.16	0.24	0.1	ND	ND
9	GW 9	0.001	ND	0.141	0.065	ND	0.064	0.24	0.034	ND
10	GW 10	0.001	ND	0.136	0.01	0.034	0.326	ND	0.027	ND
11	GW 11	0.001	0.008	0.112	0.02	0.055	0.081	0.21	0.034	ND
12	GW 12	0.001	0.012	0.086	0.015	0.153	0.158	ND	ND	ND
13	GW 13	0.001	0.012	0.01	0.007	0.077	0.189	0.2	0.003	ND
14	GW 14	0.10	0.03	0.165	0.012	0.144	0.138	0.06	0.049	ND
15	GW 15	0.013	ND	0.131	0.055	ND	0.438	0.02	0.022	ND
16	GW 16	0.146	0.015	0.237	0.016	0.141	0.092	0.07	0.086	ND
17	GW 17	0.058	0.031	0.041	0.027	ND	ND	0.02	0.049	ND
18	WT 1	0.001	0.018	0.216	0.021	0.17	0.052	0.03	0.016	ND
19	WT 2	0.01	0.011	0.113	0.028	0.113	0.199	0.08	0.07	ND
20	WP	0.015	0.009	0.061	0.013	0.068	ND	ND	0.068	ND

GW= ground water, WT= water collection tank, WP= water spring
Fe= Iron, Cu= Copper, Mn= Manganese, Zn= Zinc, Co= Cobalt, Ni= Nickel, pb= Lead, Cr = Chromium, Cd= Cadmium
ND = not detectable

Table 2: Permissible limits of trace elements by WHO and YSMO standards

Sl. No.	Elements	WHO Permissible limit (mg/L)	YSMO Permissible limit (mg/L)
1	Fe	0.1	1
2	Cu	1	1
3	Mn	0. 2	0.2
4	Zn	5	5-15
5	Co	---	---
6	Ni		0.02
7	Pb	0.05	0.05
8	Cr	0.05	0.05
9	Cd	0.005	0.005

Fe= Iron, Cu= Copper, Mn= Manganese, Zn= Zinc, Co= Cobalt, Ni= Nickel, pb= Lead, Cr = Chromium, Cd= Cadmium

nd= not detectable

Table 3: Trace elements (in mg/l) statistics of water in Taiz city

Sl. No.	Trace element	Mean(Min – Max)	SD	CV%
1	Fe	0.0500 (0.001-0.182)	٠.٠٦٤٨	١.٢٧٠٣٣٥٣٠٨٤٣٩٤٦٣٥
2	Cu	0.0219 (0.00-0.088)	٠.٠٢٥٥	١.١٦٣٢٠٧٢٥٠٨٤٢٠٦٢٨
3	Mn	0.1124 (0.01- 0.295)	0.0839	٠.٧٤٧١٧٧٠٩٠٦٢٢٦٨٣٢٩
4	Zn	0.0743 (0.00 – 0.732)	0.1616	٢.١٧٥٦٣٦٨٢٩٧٢٦٦٣٠٤
5	Co	0.0916 (0.00 – 0.17)	٠.٠٥٥٧	٠.٦٠٨٥٤٥٣٢٥٤١٦٣٩٨٩
6	Ni	0.1192 (0.00- 0.438)	0.1382	١.١٥٩٣٧٣٠٣٣٢٩٠٢٢٩٧
7	Pb	0.0970(0.00- 0.37)	٠.١٠٧٤	١.١٠٧٣٦٦٩٣٥٦٢٤٢٩٦٦
8	Cr	0.0320 (0.00 – 0.086)	٠.٠٢٧٤	٠.٨٥٦٢٢٦٦٨٠٧٣٦٤٨١٧
9	Cd	ND	ND	ND

Fe= Iron, Cu= Copper, Mn= Manganese, Zn= Zinc, Co= Cobalt, Ni= Nickel, pb= Lead, Cr = Chromium, Cd= Cadmium
Min= Minimum, Max= Maximum, ND= not detectable
SD= Standard deviation, CV= Coefficient of Variation

Table 4: Interrelationship between trace elements in the water of Taiz city.

Elements	Cd	Cr	Pb	Ni	Co	Zn	Mn	Cu	Fe
Fe	NS	NS	NS	NS	NS	NS	.504*	.727**	
Cu	NS	NS	NS	- .555*	NS	.671**	NS		
Mn	NS	NS	NS	NS	NS	NS			
Zn	NS	NS	NS	NS	NS				
Co	NS	NS	NS	NS					
Ni	NS	NS	NS						
Pb	NS	NS							
Cr	NS								
Cd									

Values are Pearson's correlation coefficient, a 2- tailed test was applied and calculated after log_{10} transformation of all parameters after scaling so that all values were > 1, n= 9, * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level and NS= Non-Significant.

Conclusion

This paper presents the trace element concentrations in groundwater, collection water tanks and spring samples in Taiz. The results from the analyzed samples were used to evaluate the impacts of trace metals on the quality of water samples. Fe concentration in 20% of the samples was slightly higher than the permissible limit prescribed by WHO. Cu and Zn concentration did not exceed the permissible limit prescribed by the YSMO and WHO guidelines. Mn concentration in 20% of the studied samples was more than the permissible limit according to YSMO standard, Co was detectable in 17 samples only and there is no guideline for the maximum permissible level of cobalt in drinking water (CCREM, 1995). Ni concentration in 60 % of the studied samples was higher than the permissible limits prescribed by WHO and YSMO standards. 55% of samples show concentration of pb more than the permissible limit prescribed by WHO and YSMO guidelines, 20% of the studied samples have concentration of Cr more than the permissible limit according to WHO and YSMO standards. Cd was not detectable in all samples studied.

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