Modern Scientific Press
International Journal of Environment and Bioenergy
Journal homepage:www.ModernScientificPress.com/Journals/IJEE.aspx
ISSN: 2165-8951
Florida, USA

Article

Spectroscopic Determination of Heavy Metal Concentrations in Tap Water for Health Benefits

Birhan Belay[1] and Kusse Gudishe Goroya[2,*]

[1]*Dilla University, College of Natural and Computational Sciences, Department of Physics, Ethiopia*
[2]*Wolaita Sodo University, College of Natural and Computational Sciences, Department of Physics, Ethiopia*

* Author to whom correspondence should be addressed; E-Mail:anaxorma@gmail.com

Article history: Received 10 December 2018, Revised 6 January 2019, Accepted 13 March 2019, Published 25 March 2019.

Abstract: This study was aimed to measure concentration of six heavy metals: Cadmium(Cd), Chromium(Cr), Copper(Cu), Lead(Pb), Nickel(Ni), and Zinc(Zn) at sub-ppm levels in tap water using Inductively Coupled Plasma-Optical Emission Spectrometry. Results showed that only the heavy metals Cd and Zn present in studied samples reaching maximum average value of 0.0005±0.0002 ppm and 0.0050±0.0010 ppm, respectively. However, the maximum levels of the concentration of the both detected heavy metals did not reach the maximum limit allowed for human health. The rest of the heavy metals that underwent test in this research work were under the limit of detection method.

Keywords: Heavy metals, ICP-OES, water, concentration, limit of detection.

1. Introduction

Some heavy metals are taken as essential trace elements for human body because they take role in different reactions and are deeply involved in the metabolism of glucose and lipids. These metals are helpful at low and permissible amount when consumed. In contrast, they turn to higher toxicity and carcinogenicity when the concentration exceeds limit for human being for proper functions.

Heavy metal accumulation at higher levels can result to death. Heavy metal toxins contribute to a variety of adverse health effects (Romer *et al*., 2004). Accumulation of heavy metals within the body can lead to a decline in the mental, cognitive and physical health of individuals (Aziz *et al.*, 2005). Heavy metals may cause chronic poisoning with some considered to be a human carcinogen (Ferguson *et al.*, 2007).

Some transition metals at trace levels in our metabolism are important for good health. Heavy metals normally occurring in nature are not harmful to our environment, because they are only present in very small amounts. However, if the levels of these metals are higher than the levels of healthy life, the roles of these metals change to a negative dimension. The main sources of the heavy metal ions directly are food and water and, indirectly, industrial activities (Farid *et al.*, 2004). Heavy metal elements are well known for their unique bioaccumulation characteristic. Bioaccumulation characteristic is the main reason that causes toxicity in heavy metals in the long term period. Bioaccumulation occurs when an organism absorbs toxic substances at a greater rate. Thus, heavy metals cause severe health effect when their concentration accumulated exceeds permissible level. In addition, they are not degradable into other harmless product.

Heavy metal is a general collective term and applies to group of metals and metalloids with atomic density greater than 4 g/cm^3, or 5 times or more, greater than that of water. Heavy metals are also defined as those elements with a specific density at least five times the specific gravity of the water. Heavy metals include Cadmium (Cd), Copper (Cu), Lead (Pb), Zinc (Zn), Chromium (Cr), Mercury (Hg) and Arsenic (As) (WHO, 2004).

There are different factors contributing to higher concentration of heavy metals. Geochemical conditions lead to naturally occurring higher levels of heavy metals in ground water (Kim *et al.*, 2000). Because of the importance of the heavy metal ions in human metabolism, trace heavy metals analysis is an important part of public health studies (Gnaws *et al.*, 2004). Global environmental changes have dramatically increased the overall environmental 'load' of heavy metals (Lee *et al.*, 2002).

Zinc is an essential micronutrient for plants and animals, and its bio-availability is critically dependent on its chemical forms. Surface water and ground water rarely contain zinc at high concentrations, however, concentration levels of heavy metals in tap water can be much high as a result of dissolution of Zn from pipes (WHO, 2008). Copper (Cu) primarily presents in food and water in developed countries and in drinking water. It comes from household plumbing systems or from erosion of natural deposits. Corrosion is most often associated with acidic waters and waters with pH below 6.5. Copper has beneficial to the body in small amounts but long term exposure can cause liver and kidney damage (WHO, 2008). In natural waters, cadmium is found mainly in bottom sediments and suspended particles (WHO, 2004). Copper and Zinc are essential trace elements for living organisms at low concentration (<10mg/L). However, they become toxic at high concentration (>10mg/L) (WHO, 2008).

Lead is toxic towards the aquatic life, although its toxicity is less than that of copper. Lead produces structural alterations in chromosomes and bind strongly to mitochondria membrane. Toxicity to plants, microorganisms and aquatic organisms has been reported in the presence of lead (kuzovkina *et al.*, 2004; Boonyapookana *et al.*, 2005; Khan, 2011). Chromium (Cr) below toxic limit balances blood sugar levels, regulates hunger, reduces cravings, protects DNA and RNA, improves heart functions, helps control of fat and cholesterol levels in the blood (Krejpcio, 2001). Nickel is not required by our body and according to WHO, dietary intake of nickel should not exceed 2 mg/day.

Today researchers have turned their attention to studying heavy and trace elements. Instrumental sensitivity is not always sufficient for the determination of heavy metals in water because their concentrations are generally at sub-ppm and ppb levels. Therefore, it is necessary to combine a pre-concentration technique with an instrumental analysis method.Different researchers have used different spectroscopic techniques for determination of elemental analysis such as atomic absorption spectrometry (AAS), inductively coupled plasma atomic emission spectrometry (ICP-AES), and inductively coupled plasma mass spectrometry (ICP-MS), for the determination of heavy metals in water (Lee *et al.*, 2002). In this paper we report the concentration of some heavy metals in tap water that is used for drinking by the society using inductively coupled plasma optical emission spectrometry (ICP-OES) for the sake of health benefit of the society.

2. Materials and Methods

Tap water is randomly collected from three different locations (Abay Mado, Kebele 14, and Georgis) in Bahir Dar city, Ethiopia, with bottles. The bottles were rinsed with distilled water before use.In each place an amount of 500 ml of tap water was collected.

2.1. Reagents

Glassware used in this work was cleaned by concentration of nitric acid (HNO_3) in order to clear out any heavy metal on their surfaces. Apparatus were thoroughly washed with detergents and tap water and then rinse with deionized water before use.

2.2. Experimental Procedures

Stock solutions for each of the selected metals were prepared using corresponding standard solutions. Sample concentrations within the range established by the standard were measured for all the heavy metals under investigation in this research. Samples were shaken gently by using microwave oven. Exactly 12 ml of each tap water sample were taken to 50 ml volumetric beaker. Without any acid regents added, these samples were heated up to250 ^{0}C at a pressure of 1200 psi for 15 minutes. After digestion process, samples were cooled for 30 minutes in the microwave and then diluted into 50 ml Erlenmeyer flask. A 0.45 µm pore diameter membrane filter was used for filtering the samples to ensure solution is particulates free.

2.3. Instruments

Samples solutions were converted to aerosols via a nebulizer. The aerosols were transported to the inductively coupled plasma optical emission spectroscopy (Agilent 700 Series, USA) which is at high temperature zone (250^{0}C) and pressure of 1200 psi. Argon gas was used as plasma, nebulizer and optics interface purge with its purity 99.996% and metals were analyzed by using ESISO11885:2014 test method by using a microwave digestion Milestone Start D (Switzerland) (Figure 1) equipped at maximum temperature of 250 ^{0}C. The analytes were heated (exited) at different atomic or ionic states and produced characteristics optical emissions. These emissions are separated based on their respective wavelength and their intensities are measured from the PC interfaced with the spectrometry.

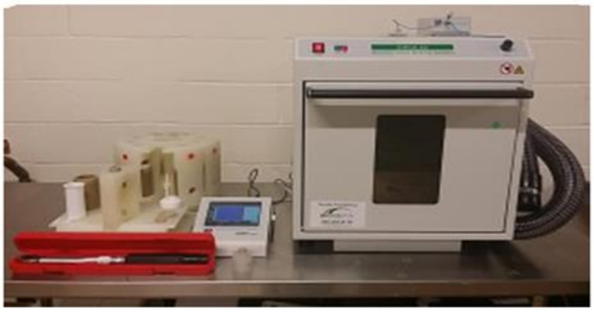

Figure 1: Microwave assisted milestone start D digester.

3. Results and Discussion

3.1. Results

Samples were analyzed using inductively coupled plasma-optical emission spectrometer for the determination of cadmium, chromium, copper, lead, nickel, and zinc at their corresponding wave length 214.439 nm, 205.560 nm, 324.754 nm, 220.353 nm, 231.604 nm, and 206.200 nm respectively. The concentrations of these metals in tap water samples were obtained by applying the liner calibration curve equation as shown in Figure 2 (only for Cd and Cr). Result obtained in this work is displayed in Table 1.

Table 1: Heavy metal concentrations in this work (Mean± SD) where n = 3.[a]

Heavy Metal	Concentration in this work (ppm)			Permissible concentration by WHO (WHO, 2004; WHO, 2008)
	Kebele 14	Georgis	AbayMado	
Cd	0.0005±0.0002	ND	0.0001±0.0006	0.005
Cr	ND	ND	ND	0.05
Cu	ND	ND	ND	1.00
Pb	ND	ND	ND	0.01
Ni	ND	ND	ND	0.50
Zn	ND	0.005±0.001	0.001±0.003	5.00

[a]ND means below detection limit

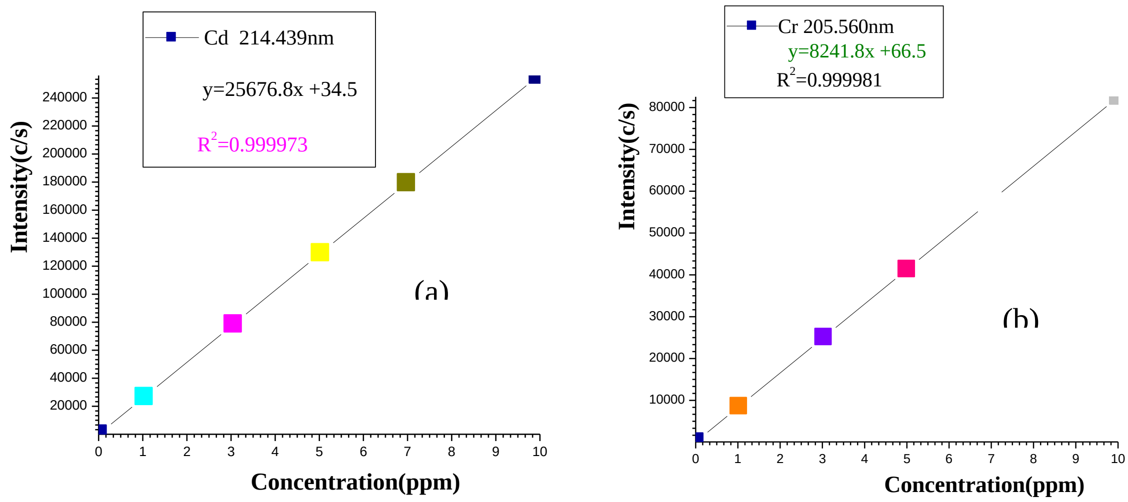

Figure 2: Calibration curves (a) Cadmium (b) Chromium.

As can be seen from Table 1, the mean concentrations of heavy metals in tap water is either very low as compare to the permissible limit by WHO or below limit of detection by the technique used in this experiment. The mean concentration of chromium, copper, lead and nickel levels in tap water samples are not sufficiently found to be detected in this experiment. The concentration of Cd was detected in two of the study areas: Kebele 14 and Abay Mado. Samples taken from Kebele 14 have relatively high concentration (0.0005±0.0002 ppm) as compared with the one found in Abay Mado (0.0001±0.0006 ppm). Zinc was found in Geogis and Abay Mado but not in Kebele 14. The higher one was observed in Geogis area of study, found to be 0.0050±0.0010 ppm.

3.2. Discussion

It can be observed from the results displayed in Table 1 that the highest mean concentration of cadmium is recorded to be 0.0005±0.0002 ppm and the lowest mean concentration is 0.0001±0.0006 ppm, although all are far below permissible range. A similar result of cadmium concentration in tap water below the permissible limit was reported by Afghani *et al.* (2006) and Krejpcio *et al.* (2001). However, higher level of cadmium above the permissible limit concentrations was reported in previous studies (Gnaws *et al.*, 2004; WHO, 2004). Results indicated that concentration of Zn in the present study is found to be in the range 0.001±0.003 ppm and 0.005±0.001 ppm. A similar result of zinc concentration in water below the permissible limit was reported by Lone *et al*. (2008). Except zinc and cadmium, most of the investigated metals are below the level of detection. The detected metals concentrations are very minimal as compared to the permissible levels and are safe for health conditions.

4. Conclusion

Concentrations of six heavy metals were determined by ICPOES with microwave digestion method in argon gas plasma. Results indicated that the maximum mean concentration is 0.005±0.001 ppm in zinc and 0.0005±0.0002 ppm for Cd. The values observed in this experiment are below the permissible levels. The presence of heavy metals at very low concentrations in the water samples indicates that water in the studied area is safe to consumers. However, continual assessment and enlightenment is highly essential as well as other heavy metals to be included in further studies.

References

Romero FM, Armenia MA, Carrillo-Chavez A. (2004). Arsenic sorption by carbonate- rich aquifer material, a control on arsenic mobility at Zimapan, Mexico. Arch. *Environ. Contam. Toxicol*., 47: 1-13.

Aziz HA, Aldan MN, Hui CS, Zahari MS, Hameed BH. (2005). Removal of Ni, Cd, Pb, Zn and color from aqueous solution using potential low cost absorbent. *Indian J. Eng. Mater. Sci*., 12: 248-258.

Ferguson MA, Fernandez DP, Hering JG. (2007).Lowering the Detection Limit for Lead:-Implications for a Future Practical Quantitation Limit. *J. Am. Water Works Assoc*., 99: 92-98.

Farid SM, Enani MA, Wajid SA. (2004). Determination of trace elements in cow milk in Saudi Aribia, *JKAU. Eng. Sci.,* 15: 131-140.

WHO. (2004).World Health Organization.

Gnaws E, Shi WW, Su QD. (2004). Determination of cadmium by ICPS using nebulous phase reaction vapor generation system. *Atom Spectrosc*., 25: 245.

Kim MJ, Niangua J, Hack S. (2000).Carbonate Ions and Arsenic Dissolution by Ground Water.*J. Environ. Sci. Technol.*, 34: 3094-3100.

Lee KH, Oshima M Motomizu S. (2002).Inductively Coupled Plasma Mass Spectrometric Determination of Heavy Metals in Sea-Water Samples after Pre-Treatment with a Chelating Resin Disk by an On-Line Flow Injection Method. *Analyst*, 127: 769-774.

WHO. (2008).World Health Organization.

Kuzovkina YA, Knee M, Quigley MF. (2004).Cadmium and copper uptake and translocation in five Willow (Salix L.) species. *Int. J. Phytoremediation*, 6: 269-287.

Boonyapookana B, Parkpian P, Techapinyawat S, DeLane RD, Jugsujinda A. (2005). Toxic/Hazardous Substances and Environmental Engineering. *J. Environ. Sci. Health A*, 40: 117-137.

Khan TA. (2011).Trace elements in the Drinking water and their possible health effects in Aligarh city. *Indian J. Water Resource Prot.*, 3: 522-530.

Krejpcio Z. (2001).Essentiality of Chromium for Human Nutrition and Health. *Pol. J. Environ. Stud*.,10: 399-404.

Afghani A, Madrakian T, Siampour H. (2006).Flame atomic absorption spectrometric determination of trace quantities of cadmium in drinking water samples after cloud point extraction in Triton X-114 without added chelating agents. *J. Hazard. Mater. B*, 138: 269-272.

Lone MI, He Z, Stoffella PJ, Yang X. (2008). Phytoremediation of heavy metals polluted soils and water: progress and perspectives. *J. Zhejiang Univ. Sci. B*, 9: 210-220.