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Assessment of Concentration of Heavy Metals in Drinking Water in Assela Town, Oromia Region, Ethiopia

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Abstract

*This research was initiated to determine the level of heavy metals in drinking water of Assela town, Ethiopia. Analysis on 5 drinking water samples collected from three River water, and two tap waters was carried out. All the samples were analyzed for seven heavy metals (Pb, Cd, Cr, Fe, Co, Zn, and Ni) using FAAS. The samples were found to contain the following mean concentrations (mg/L) of the heavy metals: Pb (0.001-0.087), Cd (0.0020-0.0067), Cr (*0.014-0.101), *Fe (0.13-0.55), Co (0.011- 0.073), Zn (0.002-0.34) and Ni (0.006-0.84. Comparison of the results with accepted international standard was carried out. It has been revealed that the concentrations of (Pb, Cr, Cd, Fe, Co and Ni) in River water, (Pb, Cr, Cd, Co and Ni) in tap water were above the maximum limits recommended by WHO. Whereas Zn in river water and (Fe and Zn) in tap water were below the limits recommended by WHO. The concentrations (Pb, Cd, Fe and Ni) in river water and Pb in tap water were above the maximum limits recommended by USEPA. But the concentrations of (Cr, Co and Zn) in river water and (Cr, Cd, Fe, Co, Zn and Ni) in tap water were not above the maximum limits recommended by USEPA. The concentration levels of (Pb, Cr, Fe and Ni) in river water and (Pb, Cr, Fe and Ni) in tap water were above value recommended by EU. The results of the study clearly presented that there is a threat of pollution hazards in the study area with important human health implications.*

Keywords: Heavy metals, Drinking water, Contaminants, Toxic elements.

Introduction

Sustainable development, health and wellbeing of human life are dependent on availability of safe drinking water[1]. Nowadays water pollution is becoming one of the most critical environmental problems. Less attention has been given to chemical contaminants of drinking water as compared to microbial contaminants, as adverse health impacts from chemical contaminants are generally associated with long-term exposures, whereas the effects from microbial contaminants are usually immediate. However, chemicals in water supplies can cause very serious problems[2].

The presence of toxic chemicals in drinking water may risk human health among which cancer and chronic illness are worth mentioning[3]. Epidemiological studies have demonstrated a strong relationship between the prevalence of several diseases in humans, particularly cardiovascular diseases, kidney-related disorders, and various forms of cancer and the presence of many metals such as cadmium, mercury and lead[4].

Heavy metals by definition are metallic elements which have a high atomic weight and have much high density at least 5 times that of water. They are stable elements i.e. they cannot be metabolized by the body and bio-accumulative i.e. passed up the food chain to humans. Even at very low concentrations, they are highly toxic and can cause damaging effects. About only 17, out of a total of 50 heavy metal elements, are taken to be both very toxic and relatively accessible. Among these, Mercury, lead, arsenic, cadmium, selenium, copper, zinc, nickel, and chromium weighs the balance in terms of water pollution[5].

The heavy metals such as lead, iron, cadmium, copper, zinc, and chromium if found in drinking water beyond certain limit are often associated with human poisoning. Though these elements are required by the body in small amounts, but can also be toxic in large doses[6]. Trace elements are also essential for optimal growth, development and reproduction like zinc which is in small enough quantities to be considered. Trace metals serve mostly as catalysts for enzymatic activity in human bodies; however, their accumulation in the human body causes harmful effects[7]. Besides these elements, several metal ions such as sodium, calcium and magnesium are essential for proper functioning of biological life.

The earth's crust is one of the major sources of heavy metals. Weathering of rocks and leaching of soils, aerosol particles from the atmosphere and anthropogenic activities could be among the several ways through which heavy metals enter into the aquatic system[8]. Dramatically rising urbanization and industrialization have intensified the levels of heavy metals in drinking water supplies. The level of trace elements in water varies due to physiological, environmental and other factors[9].

The hexavalent Chromium when found in water supplies is generally highly toxic and carcinogenic in higher concentrations[10,11]. It has been confirmed that high level of nickel as both soluble and sparingly soluble compounds may be responsible for harm in vital organs of human body such as brain and kidney along with causing cancer[12].

An excess amount of Copper in drinking water is also a cause for its toxicity. It is this toxic effect of Copper on biota that made the recent increased attention given to the study of Copper aqueous systems[13].

Cadmium is extremely toxic even in low concentrations and has a potential of bio-accumulation in organisms and ecosystems. Renal damage, hypertension, arteriosclerosis, and cancer could be induced by long term exposures to Cadmium[14]. Many countries and international organizations monitor the level of cadmium in drinking water as it is one of the primary pollutants[15]. Lead is one of the most common heavy metal in drinking water. Beyond the 10 μg/L limit recommended by WHO, Pb may cause metabolic poisoning and inhibition of enzymes. Lead exhibits the potential to permanently substitute calcium in bone to form sites for long term replacements[15, 16].

A large number of literature reports exist regarding the concentration of heavy metals in drinking waters in different water sample like river, tap water, bottled water, wells water, and spring water[2,7,17-19]. This indicates that the assessing the level of heavy metals in drinking water to understand the level of quality of water is of paramount significance.

In Ethiopia, wells and springs are the major source of drinking water for increasing urban and rural population. Even though there are no systematic and wide-ranging water quality assessment and monitoring programs in the country, there are increasing signs of drinking water pollution problems in some parts of the country. The most important causes of this pollution could be soil erosion, domestic and dramatically increasing industrial effluents and wastes. Therefore, the analysis of the concentration of heavy metals and mitigation of their impact on human health and environment should be given due emphasis.

The level of heavy metals in drinking water in Assela town has not been studied as far as the knowledge of the researcher is concerned. This study is, thus, aimed at the determination of the level of heavy metals in river water and tap water samples in Assela town of South East Oromia, Ethiopia.

Materials and Methods

Description of the study area: The study area was Assela town which is found in Arsi zone, Oromia Regional State, Ethiopia. It is situated some 175 km from the capital Addis Ababa. Assela is situated at $6^0$59' to $8^0$49' N latitude and $38^0$41' to $40^0$44' E longitude in central Ethiopia. The town has total population[20] of 67, 269.

Collection of samples: Three river and two tap water samples were collected from Assela town in the radius of 5 km from the center of the town by using 2 L capacity plastic bottles. River water samples were randomly collected from three different areas in Assela town from Anku to the East of Assela town, Walkessa to the North of Assela town and Dosha to the South of Assela town. Each water sample collected from river water was during bright (shine) day. The two samples of the tap water were collected from Ardu to the South of Assela town and Silingo to the North of Assela town. Each water sample was collected from tap water used for drinking in the area that was left running for more than 5 minute before collecting the sample. The collected river water and tap water samples were kept in the sealed flasks and refrigerated with that of bottled waters at the same temperature (4^oC) until the time of analysis.

Instrumentation and Apparatus: Flame Atomic Absorption Spectrometer apparatus (FAAS): For the analysis of metals (Pb, Cr, Cd, Fe, Co, Zn and Ni), FAAS (Buck Scientific Model 210VGP AAS, East Norwalk, USA) was used. The Atomic Absorption Spectroscopy was equipped with deuterium ark background corrector hollow cathode lamps for each respective heavy metal and air acetylene flame was used.

Reagents and chemicals: All the chemicals used were of analytical reagent grade. HNO_3 (69-72%) was used for acidifying the sample solutions during the analysis of heavy metal elements (Pb, Cr, Cd, Fe, Co, Zn, and Ni). Calibration standards were prepared using spectroscopic Stock FAAS standard solutions containing 100 mg/L, in 2% HNO_3, of the metals, Cr, Cd, Fe, Co, Zn and Ni (BDH Chemicals Ltd Spectrosol, Poole England). The working standard solutions were obtained by suitable dilution from stock solution. Sample preparation and rinsing of apparatus prior to analysis were carried out using deionized water.

Analytical Procedures: Sample preparation: For this study, five water samples (three from river and two from tap water) were selected. All the samples were analyzed for heavy metals (Pb, Cr, Cd, Fe, Co, Zn, and Ni) by FAAS within 12 days from the time of sample collection. All samples were filtered using Whatman# 41/42 filter paper and the filtrate was acidified with concentrated nitric acid (69-72% HNO_3) by adding 1 mL of the acid into 50 mL of the sample solution. The acidified samples were preserved in refrigerator for analysis.

Analytical Procedures for Heavy metal Analysis: The concentrations of the heavy metals (Pb, As, Cr, Cd, Fe, Co, Zn, and Ni) in river water and tap water samples were quantitatively determined using FAAS. Calibration of the instrument was carried out with range of standard solution. After calibration, the samples were aspirated into the FAAS instrument according to standard method[21]. Three replicate measurements were carried out on each sample. The same analytical procedures were used for the determination of the heavy metals in all the blank samples.

Determination of the Heavy metal Concentrations in Water samples by FAAS: The concentration of Pb, Cr, Cd, Fe, Co, Zn and Ni were determined by FAAS using an air/acetylene flame. The analysis of the heavy metals involved further dilution of the acidified samples. Dilution was required to achieve concentration of the metals within the linear range of the calibration curve. All the analyses were carried out using FAAS at the specific wavelength of each heavy metal. Absorption mode of the instrument was used for the determination of the heavy metals. The real concentrations of metals in all water samples for these diluted heavy metals were calculated by multiplying the recorded results by the dilution factors.

Statistical Analysis: Analysis of data was carried out using SPSS software version 20.0. The mean concentrations of the heavy metals in the drinking water samples present in Assela town were compared by the use of one way ANOVA. The raw data was feed to the software and the mean value of the concentration of heavy metals was compared between each water samples. The significance value was compared with (P= 0.05) then, the conclusion about statistically significant difference or not was made according to the statistic rule. When the value (which is usually calculated p-value in drinking water) was less than (p=0.05) indicated that there was significant difference between the mean of samples analyzed. But in cases where the p-value was greater than or equal calculated (p=0.05), there was no significant difference between the means of heavy metals in all samples of drinking water.

Results and Discussion

The Concentration of Heavy Metals in Drinking Water Samples: The concentrations of the heavy metals analyzed vary widely in the drinking water samples. The concentrations of the heavy metals in river water, and tap water samples were summarized in the Tables-1 and 2.

Table-1
Mean Concentrations (mg/L) of Heavy Metals in River Water Samples

Water samples	Mean concentration of heavy metals (mg/L)						
	Pb	**Cr**	**Cd**	**Fe**	**Co**	**Zn**	**Ni**
Anku	0.087± 0.02	0.098 ±0.013	0.012 ±0.003	0.55±0.03	0.073±0.01	0.32±0.06	0.244±0.03
% RSD	8.5%	5%	9%	2.1%	7.8%	7.9%	5.5%
Dosha	0.013± 0.005	0.075 ±0.17	0.002±0.0004	0.16 ±0.04	0.023±0.05	0.22±0.03	0.006±0.001
% RSD	11.3%	9%	9.2%	9%	9%	6%	9.8%
Walkessa	0.072 ±0.01	0.101 ±0.03	0.012±0.0005	0.45±0.01	0.022±0.01	0.34±0.03	0.84±0.08
% RSD	6%	9.9%	2%	1.1%	2.3%	7.6%	3.6%
Total Mean±SD	0.05 ± 0.01	0.09±0.07	0.009±0.01	0.39±0.03	0.09±0.02	0.1±0.04	0.36±0.04

Table-2
Mean Concentrations (mg/L) of Heavy Metals in Tap Water Samples

Water samples	Mean concentration of heavy metals (mg/L)						
	Pb	**Cr**	**Cd**	**Fe**	**Co**	**Zn**	**Ni**
Ardu	0.047 ±0.01	0.098 ±0.007	0.0046±0.0007	0.31±0.03	0.039±0.008	0.063±0.01	0.0373±0.01
% RSD	5%	2.7%	7%	4.1%	8%	8%	9.8%
Silingo	0.035 ±0.01	0.095 ±0.005	0.0055 ±0.0006	0.25±0.07	0.011±0.001	0.073±0.01	0.037±0.01
% RSD	11%	2.1%	5%	9.9%	4%	7.6%	9.7%
Total Mean± SD	0.04±0.01	0.097±0.006	0.005±0.001	0.28±0.05	0.03±0.005	0.07±0.01	0.0371±0.01

In the current study, the concentrations of Pb in drinking water were in the range of 0.001-0.087 mg/L. The mean level of Pb obtained from River water (0.05mg/L) and tap water (0.04mg/L) were above the maximum permissible level stated by WHO, USEPA and EU.

The result of the present study showed that the concentration of Cr in drinking water ranges from 0.014-0.101 mg/L. The mean concentration of Cr obtained from River water (0.09 mg/L) and tap water (0.097 mg/L) were above the maximum permissible level stated by WHO and EU. However, the results from all sample of drinking water were below the maximum permissible level given by USEPA

The Cd concentration found in analyzed lies in the range of 0.0020-0.0067 mg/L. Cd mean concentration obtained from River water (0.009 mg/L) was above the maximum permissible level stated by WHO and EU. The mean concentration of Cd from tap water (0.005 mg/L) was at the maximum permissible level stated by USEPA and EU. However, the concentrations from all drinking water samples were above the permissible level set by WHO (Table-2).

In the areas studied the concentration of Fe in drinking water ranges from 0.13-0.55mg/L. The mean concentration of Fe obtained from River water sample (0.39 mg/L) was above the maximum permissible level stated by USEPA and EU whereas the mean concentration of Fe from tap water (0.28 mg/L) was found to be below the maximum permissible level stated by WHO and USEPA. But level Fe from river and tap water were above the maximum permissible level given by EU and from bottled water was at permissible level (Table-2).

The result of the study revealed that the concentration of Co found in analyzed samples ranged from 0.011- 0.073mg/L. The mean concentration of Co in river water (0.09 mg/L) and tap water (0.03mg/L) were all below the maximum permissible level stated USEPA and also Co concentration in tap water (0.03mg/L) was below the maximum permissible level stated by WHO. But the mean concentration of Co in River water (0.009mg/L) was above the maximum permissible level stated by WHO (Table-2).

In the study areas, the concentrations of Zn in drinking water were in the range 0.002-0.34mg/L. The mean concentration of Zn obtained from all samples areas were below the maximum permissible level stated by WHO and USEPA.

The level of Ni in drinking water samples ranged from 0.006-0.84mg/L. The mean concentration of Ni available in river water (0.36 mg/L) was above the maximum permissible level stated by WHO, USEPA and EU and also the mean concentration of Ni from tap water (0.037mg/L) was above the maximum permissible level indicated by WHO & EU. But the value was below the maximum permissible level stated by USEPA (Table-2).

Analysis of Variation of Drinking Water Samples Currently Analyzed: To know whether the composition of the samples of drinking water were significantly different or not it is important to use the application of analysis of variance (ANOVA). ANOVA is an extremely powerfully statistical technique which can be used to estimate the different causes of variation[22].

In this study, ANOVA was carried out for analysis of significant difference between mean of the concentrations for River water samples from Anku, Walkessa and Dosha whereas tap water samples from Ardu and silingo. Accordingly, the significant difference between the means of the concentrations was determined based on calculated p-value.

In the comparison of the composition of river water samples, there were significant differences observed between the means of the determination for all the analytes except Cr concentration in Anku, Walkessa and Dosha river water. In the case tap water samples, there were significant differences observed between the means of the determination for all the analytes except Cr, Zn and Ni concentration in Ardu and silingo tap water (Table-3)

Table-3
Analysis of Variation in Composition of Water Samples Currently Analyzed

Heavy metals	Comparison					
	River Water (P-critical=5.143)			Tap water (P-critical=7.709)		
	DF	F-value	P-value	DF	F-value	P-value
Pb	8	33.31	0.0006	5	20.08	0.01
Cr	8	0.4	0.69	5	2.45	0.19
Cd	8	227.12	$2.0x10^{-6}$	5	15.5	0.017
Fe	8	1009.5	$2.6x10^{-8}$	5	14.5	0.019
Co	8	203.9	$3.0x10^{-6}$	5	234.04	0.0001
Zn	8	33.31	0.0006	5	5.51	0.079
Ni	8	1503.9	$7.9x10^{-9}$	5	0.13	0.914

Comparisons of the Concentration of Heavy Metals between Drinking Water Samples: In this study, the total mean concentration of Fe was the highest and Cd was found to be the least. Generally, the overall mean concentration of heavy metals in River water in decreasing order of Fe (0.39±0.03) > Ni (0.36±0.04 mg/L) > Zn (0.1±0.04 mg/L) > Co(0.09±0.01 mg/L) > Cr (0.09±0.07 mg/L) > Pb (0.05±0.01 mg/L) > Cd (0.009±0.001mg/L), where as the concentrations of the heavy metals in tap water in decreasing order was as follows; Fe (0.28±0.0.05) > Cr (0.07±0.006 mg/L) > Pb (0.04±0.01 mg/L) > Ni (0.0371±0.01 mg/L) > Co (0.03±0.005 mg/L) > Zn (0.07±0.01 mg/L) > Cd (0.005±0.001mg/L).

The Comparisons between the Mean Concentrations of Heavy Metals in drinking water samples with international standards: The standard mean concentrations of heavy metals are given by WHO, USEPA, EU and present study are given in the Table-4.

The concentrations of (Pb, Cr, Cd, Fe, Co and Ni) in River water, (Pb, Cr, Cd, Co and Ni) in tap water were above the maximum desirable limits recommended by WHO. Whereas Zn river water and (Fe and Zn) in tap water were not above the maximum desirable limits recommended by WHO. The concentrations (Pb, Cd, Fe and Ni) in river water and Pb in tap water were above the maximum desirable limits recommended by USEPA. But the concentrations of (Cr, Co and Zn) river water and (Cr, Cd, Fe, Co, Zn and Ni) in tap water were not above the maximum desirable limits recommended by USEPA. The concentrations of (Pb, Cr, Fe and Ni) in river water and (Pb, Cr, Fe and Ni) in tap water were above the maximum desirable limits recommended by EU. But the concentration of Cd in tap water was not above the maximum admissible and desirable limits recommended by EU. The concentration of Co and Zn were not recommended by EU. So drinking water which was above the maximum permissive level may have causes some effects on human beings and other animals.

Comparison of the concentration of the heavy metals in drinking water in the study area with other countries: The comparison of heavy metals in the study area and literature reports on drinking water from different countries is tabulated Table-5. The concentration of heavy metals was compared with countries like Malaysia, Iran, Australia, India and New Zealand.

The concentration of Pb in river water (0.05 mg/L) and tap water (0.04 mg/L) in current study area were almost comparable to that of Malaysia and Iran (0.05) but below the concentration of Pb in India (0.1 mg/L) and New Zealand (0.1 mg/L). Whereas level of Pb in the current study area samples were greater than the value recorded in Australia (0.01 mg/L (Table-5).

The level of Cr in river water (0.09 mg/L) and tap water (0.097 mg/L) in the study area were above the concentrations of Malaysia, Iran, Australia, India and New Zealand which was 0.05 mg/L. The concentration Cd in river water (0.009 mg/L) and tap water (0.005 mg/L) were above the concentration of Malaysia (0.003 mg/L) and Australia (0.002 mg/L). While the level of Cd in river water, tap water and Bottled water in the current study were below the concentration of Iran (0.01 mg/L), New Zealand (0.04 mg/L) and India (0.01mg /L).

The level of Fe in river water (0.39 mg/L), tap water (0.28m g/L) were above the level of concentration of New Zealand (0.2 mg/L) and below in Iran (1 mg/L). While the concentration Fe in tap water was below the concentration of India (0.3 mg/L) and Australia (0.3 mg/L) and in river water above the level of India (0.3 mg/L) and Australia (0.3 mg/L).

Table-4
The mean concentrations of heavy metals given by WHO[21], USEPA[18], EU[23] and Present study

Heavy metals	WHO's Permissible Limits (mg /L)	U.S.EPA's Permissible Limits (mg /L)	EU standards (mg/L)	Assela, Ethiopia (Current study) (mg/L)	
				River water	Tap water
Lead (Pb)	0.01	0.015	0.01	0.05	0.04
Chromium (Cr)	0.05	0.1	0.05	0.09	0.097
Cadmium (Cd)	0.003	0.005	0.005	0.009	0.005
Iron (Fe)	0.3	0.3	0.2	0.39	0.28
Cobalt (Co)	0.05	0.1	NM	0.09	0.03
Zinc (Zn)	3	5	NM	0.1	0.07
Nickel (Ni)	0.02	0.1	0.02	0.36	0.037

NM= Not Mentioned.

Table-5
Permissible Limits for heavy metals of drinking water in some countries with the current study

Heavy Metals	Standard of drinking water in some countries and in current study (mg/L)						
	Malaysia ESDMHM[24]	**Iran** Sanayi et al.[25]	**Australia** ANZECC and ARMCANZ[26]	**India** BIS[27]	**New Zealand** NMH[28]	**Assela, Ethiopia**	
						River water	**Tap water**
Pb	0.05	0.05	0.01	0.1	0.1	0.05	0.04
Cr	0.05	0.05	0.05	0.05	0.05	0.09	0.097
Cd	0.003	0.01	0.002	0.01	0.04	0.009	0.005
Fe	NM	1	0.3	0.3	0.2	0.39	0.28
Co	NM	NM	NM	NM	1	0.09	0.03
Zn	3	NM	3	5	1.5	0.1	0.07
Ni	NM	NM	0.02	0.02	0.08	0.36	0.037

NM=Not Mentioned

The concentration of Co in river water (0.09 mg/L), and tap water (0.03 mg/L) were below the concentration of New Zealand (1 mg/L).

The level of Zn in river water(0.1 mg/L) and tap water (0.07 mg/L) in current study were below the concentrations of Malaysia (3 mg/L), Australia (3 mg/L), India (5mg/L) and New Zealand (1.5 mg/L).

The concentration Ni in river water (0.36 mg/L) in current study area was above the concentration of Australia (0.02 mg/L), Iran (0.02 mg/L) and New Zealand (0.08 mg/L). Whereas the tap water (0.037 mg/L) were below the New Zealand.

Conclusion

The current study was conducted to assess the status of drinking water quality in Assela areas of Oromia region, Ethiopia, with special emphasis on trace heavy metals. A total of 5 drinking water samples were collected from three River water and two tap waters. All the samples were analyzed for seven heavy metals (Pb, Cd, Cr, Fe, Co, Zn, and Ni) using FAAS instrument.

The following mean concentrations (mg/L) of the metals in water samples analyzed were found; Pb (0.001-0.087), Cd (0.0020-0.0067), Cr (0.014-0.101), Fe (0.13-0.55), Co (0.011-0.073), Zn (0.002-0.34) and Ni (0.006-0.84.

In general the results of the present study showed that some of analyzed heavy metals have shown values higher than the recommended maximum admissible limits by international standard (WHO, USEPA and EU). The results of the study clearly presented that there is a threat of pollution hazards in the study area with important human health implications.

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