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LEVELS OF HEAVY METALS IN DRINKING WATER, COSMETICS AND FRUIT JUICES FROM SELECTED AREAS IN DAR ES SALAAM, TANZANIA

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ABSTRACT

Heavy metals were determined in samples of drinking water, cosmetics (nail polish, lip glosses and hair dye) and fresh fruit juices in Dar es Salaam. The samples were analyzed using Atomic Absorption Spectrometry (AAS) after digestion with concentrated acids, filtration and dilution. Lead, zinc and iron were detected in the water samples and the concentration ranges were below detection limit (BDL) to 0.114, 0.01 to 1.47 and 0.027 to 0.39 mg/L, respectively, whereas cadmium was not detected. The concentrations of lead in 70.83% of the samples exceeded the WHO permissible limit, implying that the water in most of the areas was not suitable for human consumption. Lead, zinc, and cadmium were detected in all the cosmetics at concentrations ranging from 6.6 to 37400, 21.5 to 2600, and up to 0.25 mg/kg, respectively. Most of the concentrations of lead in cosmetics exceeded the EU/US permissible limits. The continued use of products containing such heavy metals may increase the body intake of the metals and cause harmful effects. Only copper was detected in the fruit juices and the water used for their preparations at concentrations ranging from 0.008 ± 0.003 to 0.215 ± 0.014 mg/L, which were below the WHO permissible limit.

Keywords: Heavy metals, drinking water, tap water, cosmetics, fruit juice, Tanzania

INTRODUCTION

One of the most important environmental issues in the world is water contamination (Vodela *et al*. 1997) and among the wide diversity of the contaminants affecting water resources, heavy metals receive particular concern considering their high toxicity even at low concentrations (Marcovecchio *et al*. 2007). Dar es Salaam being the most populated region in Tanzania, various anthropogenic activities including industrial processes, agricultural activities, and construction activities are carried out. Such activities generate large amounts of wastes and the disposal facilities are very limited. As a result, the discharges and some of the wastes which may contain potential hazardous heavy metals get their ways into the water supply systems thereby reducing the quality of the water and creating risks due to pollution in the environment.

On the other hand, due to the important uses of cosmetics for enhancing the appearance or odour of the human body, the supply and uses of cosmetics in Tanzania have increased rapidly in recent years. Most of the cosmetics are imported and few are manufactured by the domestic factories. The cosmetics include skin-care creams, lotions, face powders, perfumes, lipsticks, fingernail and toe nail polishes, eye and facial make-ups, permanent waves, coloured contact lens, hair colours, hair sprays and gels, hand sanitizers, bath oils, mouthwashes and many other types of products (Chauhan *et al*. 2010). The cosmetics may contain hazardous heavy metals such as arsenic, mercury, lead, cadmium, zinc and chromium. Some of the heavy metals are of particular importance hence are introduced as ingredients in the cosmetics. The main ingredients in mineral make-ups are usually coverage pigments, such as zinc oxide and titanium dioxide, both of which are also physical sunscreens. Other main ingredients include mica and pigmenting minerals, such as iron oxide and tin oxide. Other heavy metals are introduced as impurities; they can be from the raw materials used and or they can be introduced illegally (Sahu *et al*. 2014).

Fruit juices are some of the most widespread beverages in the habitual diet, and they are becoming an essential part of the modern diets in many communities. In many countries, the hot climate means that the intake of fluids such as fruit juices should be high to compensate for the expected losses from perspiration and respiration (Al-Jedah and Robinson 2002*).* Fruit juices may be contaminated by heavy metals and this can be due to contamination of the fruit crops in the areas where they are grown and through the use of contaminated water for the preparations. Many people consume raw fruit juices at high rates, thus, great attention on the levels of contaminants such as heavy metals is very important as these may have adverse effects even at very low concentrations.

The exposure to heavy metals such as cadmium, lead, mercury and arsenic can cause adverse health effects in human beings and other organisms (Smith and Flegal 1995, Dwivedi 1996, Cekic 1998, Koller *et al*. 2004, Borowska and Brzóska 2015). Chronic exposure to these metals can have serious health consequences such as renal diseases, kidney damage, central and peripheral nervous system toxicity, depressed biosynthesis of protein, metabolic interference, cancer, irritability, mental retardation in children, severe depression of sperm count, exhibit weakness, general disability, nervous disorders and eventually death. Generally, accumulation of heavy metals in the bodies of organisms disturbs their body functions (Chan 1998, Borowska and Brzóska 2015). Some studies have been conducted to assess the levels of heavy metals in soil, sediments, vegetables, sea water and wastewater in Tanzania. However, to the best of our knowledge, there is no study that has been conducted recently to assess the levels of heavy metals in drinking water in key areas in Dar es Salaam and in the cosmetics that were available in cosmetics shops as well as in fruit juices in Tanzania. Therefore, this study was carried out to investigate the levels of selected heavy metals in drinking (tap) water, some cosmetics and fruit juices.

MATERIALS AND METHODS

Sampling

Water samples were collected during the morning from tap water supplies in residential and commercial areas (water supplied from the Dar es Salaam Water and Sewerage Corporation (DAWASCO) stations). Drinking water samples (500 mL each) were collected from twelve (12) sampling stations located in Kimara, Masaki and Mbagala in Ubungo, Kinondoni and Temeke districts, respectively, in Dar es Salaam region, Tanzania. The sampling points were randomly selected at each site. The samples were kept in sealed plastic bottles, transported to the laboratory on the same day in an ice container and were processed within two days. Cosmetics samples, which included hair dye (named 'vaida slip'), lip glosses (brands A and B) and nail polishes (brands A and B), were purchased randomly from retail outlets in Dar es Salaam. Cosmetics samples were collected in January 2013 while the water samples were collected in April 2014. Fresh fruit juice samples (mango and pineapple juices) and the water that was used to make those juices were collected from small restaurants of food vendors in Gongolamboto, Kimara, Mabibo market, Mbagala and Tegeta areas in Dar es Salaam region in February 2017. The samples (*ca*. 300 mL each) were collected in plastic bottles. Three samples of each type were collected at each site.

Chemicals and reagents

The chemicals used included nitric acid AR (69-71%, HOPKIN & Williams Ltd, England), perchloric acid AR (60%, Blulux Laboratories Pvt. Ltd) and hydrochloric acid AR (35-38%, LOBA CHEMIE Pvt, Mumbai, India). The standards for the metals were of ≥ 99% purity (obtained from BDH Chemicals Ltd, Poole, England).

Sample preparation and processing

Concentrated nitric acid (5 mL) was added to each water sample (50 mL) into a beaker and then covered with a watch glass. The sample was heated gently and evaporated on a hot plate to about 10 mL. The heating process continued with the addition of concentrated nitric acid until digestion was complete (generally indicated when the solution became light in colour and its appearance remained unchanged with continued heating). The sample was filtered using Whatman No. 4 filter paper to remove insoluble materials that could clog the atomizer. The filtrate was then transferred to a 50-mL volumetric flask and diluted to the mark with distilled water for AAS analysis (EPA 1989). Sample preparation for the heavy metal analysis in cosmetics involved digestion with concentrated acids according to the procedures described by Sahu *et al*. (2014). Briefly, each sample (about 1 g) was digested with a mixture of concentrated HNO_3 and $HClO_4$ in a 3:1 ratio (25 mL) for 1-2 hours on a hot plate. The digestion process continued till no evolution of white fumes was observed. Each digested sample was dissolved in distilled water (10 mL) and filtered through a Whatman No. 4 filter paper into a 100-mL volumetric flask and made up to the mark with distilled water ready for the metal analysis in AAS. The fruit juices and the associated water samples were extracted by digestion with aqua regia (a mixture of concentrated hydrochloric acid and concentrated nitric acid in the ratio of 3:1) (Khan *et al*. 2016). A subsample (10.0 mL) was taken into a conical flask then aqua regia (1.0 mL) was added to the sample in the conical flask. The mixture was shaken and then placed on a hot plate. When the solution started boiling, concentrated nitric acid (1.0 mL) was added and continued boiling until a clear solution was obtained. The sample was removed from the hot plate and allowed to cool. The solution was then filtered using a Whatman No. 4 filter paper and the filtrate obtained was diluted with distilled water up to 10 mL ready for analysis by AAS.

Sample analysis

Analyses were carried out using atomic absorption spectrometry (AAS) applying EPA method 1620 (EPA 1989). Standard solutions (1000 ppm) were used for preparing intermediate standard solutions (0.5 ppm to 10 ppm) and working standards using deionized water. Whereas intermediate standards of the metal solutions were prepared in 100-mL volumetric flasks, working standards were prepared in 50-mL volumetric flasks by diluting the standards with deionized water. The points for the calibration curves were established by running the prepared working standard solutions in a flame atomic absorption spectrometer to get the linear correlation coefficient (r^2) greater than 0.999 for all the analytes. After calibration, the sample solutions were aspirated into the AAS. The solutions were analyzed for the heavy metals at the Chemistry Department, University of Dar es Salaam using an air-acetylene flame AAS (Thermo Scientific Model iCE 3000) by the standard calibration technique. The same analytical procedures were employed for the determination of the metals in blank and recovery samples. The absorbance for each analyte in the sample solution was obtained by subtracting the blank reading.

Analytical quality assurance

The tools and glassware were washed thoroughly with detergent, rinsed with distilled water and concentrated nitric acid to remove contaminants and interferences. Distilled water was used for the determination of the blanks. The results obtained for the blank tests were generally below the detection limits and hence showed no significant change to the concentrations of the heavy metals in the samples. Recovery tests were performed using standard solutions and the recoveries were acceptable (ranged from 92% to 104%). The detection limits were 0.0001 ppm, 0.0008 ppm, 0.0002 ppm, 0.0005 ppm and 0.0008 ppm for lead, zinc, iron, cadmium and copper, respectively.

Data analysis

Data analysis was performed mainly by analysis of variance (One way ANOVA) and comparison of means by *t*-test using the GraphPad InStat software.

RESULTS AND DISCUSSION

Concentrations of heavy metals in drinking (tap) water samples

The concentrations of the heavy metals (zinc, iron, lead and cadmium) detected in the tap water samples are presented in Table 1 and the mean concentrations are summarized in Table 2. The concentrations of the metals ranged from below detection limit (BDL) to 0.114 mg/L for lead, 0.01 to 1.47 mg/L for zinc and from 0.027 to 0.39 mg/L for iron. Cadmium was not detected in all the samples. The mean concentrations of the heavy metals detected in the samples from all the sampling points were in the order zinc > iron > lead. The mean concentrations ± standard deviation (SD) of lead ranged from 0.012 ± 0.018 mg/L to 0.08 ± 0.03 mg/L. The mean concentrations ± SD of zinc ranged from 0.019 ± 0.005 mg/L to 0.811 ± 0.108 mg/L, while the mean concentrations ± SD of iron ranged from 0.057 ± 0.032 mg/L to 0.237 ± 0.095 mg/L. The World Health Organization (WHO) and Tanzania Bureau of Standards (TBS) permissible limits for the heavy metals in drinking water are also included in Table 1.

Concentrations of lead

The highest concentrations of lead were found in the samples from Mbagala and the lowest were in the samples from Masaki. There were significant differences in the concentrations of lead among the tap water samples from Mbagala, Kimara and Masaki ($F(2, 23) = 24.458$, $p < 0.0001$), but no significant difference was found between the mean concentrations of lead in samples from Kimara and Masaki ($t = 0.8654$, 14 degrees of freedom, $p = 0.4014$). The results may be attributed to corrosion of lead based plumbing materials (pipes and fittings) where lead has been used, as well as contamination due to perforation or leakage of pipes. Perforated and leaking pipes were more commonly found in Mbagala and Kimara than Masaki. The low levels of lead observed in Masaki samples may be attributed to the natural sources and some contamination from the sources, pipes and tanks. The concentrations of lead in most of the samples (17 out of 24 or 70.83%) were greater than the WHO permissible limit of 0.01 mg/L (WHO 2011). The maximum concentration of lead was about 11 times greater than the WHO permissible limit. This implies that the water from most of the sites was not suitable for human consumption. Lead is linked with health effects such as cancer, brain damage, renal, endocrine and reproductive disorders (Vella *et al*. 2010). A similar study conducted in Peshawar city in Pakistan by IIyas and Sarwar (2003) indicated that the concentrations of lead in drinking water from shallow and deep wells exceeded the WHO permissible limit of 0.01 mg/L. The concentrations of lead found in the present study were greater than the levels found by Saria *et al*. (2011) in tap water in outskirts of Dar es Salaam city (mean < 0.01 mg/L), Raj *et al*. (2013) in tap water in Delhi, India (mean = 0.002 mg/L), and Bugeja and Shoemake (2015) in tap water in Maltese Islands (mean < 0.004 mg/L, maximum = 0.012 mg/L), but were lower than the levels of lead found by Cobbina *et al*. (2015) in drinking water from boreholes and hand dug wells in small-scale mining communities in Ghana where the mean levels ranged from 0.031 to 0.250 mg/L.

Table 1: Levels of heavy metals in drinking water samples (mg/L)

Study area/site	Sampling point	Lead	Zinc	Iron	Cadmium
Mbagala	Karibu Textile Mill 1	0.090	0.302	0.160	BDL
	Karibu Textile Mill 2	0.036	0.301	0.141	BDL
	Stand 1	0.1022	0.161	0.0731	BDL
	Stand 2	0.114	0.160	0.078	BDL
	Mission 1	0.051	0.160	0.1032	BDL
	Mission 2	0.0522	0.086	0.10	BDL
	Gengeni 1	0.080	1.300	0.183	BDL
	Gengeni 2	0.110	1.470	0.157	BDL
Kimara	Mwisho-1	0.030	0.862	0.236	BDL
	Mwisho-2	0.018	0.610	0.227	BDL
	Korogwe-1	0.028	0.940	0.226	BDL
	Korogwe-2	0.034	0.840	0.241	BDL
	Baruti-1	0.018	0.785	0.340	BDL
	Baruti-2	0.019	0.720	0.390	BDL
	Resort-1	BDL	0.924	0.130	BDL
	Resort-2	BDL	0.810	0.105	BDL
Masaki	Oysterbay-1	0.055	0.0191	0.110	BDL
	Oysterbay-2	0.0102	0.022	0.100	BDL
	Oysterbay-3	0.0114	0.015	0.042	BDL
	Oysterbay-4	0.0051	0.0202	0.027	BDL
	Sudan-1	0.0035	0.018	0.030	BDL
	Sudan-2	0.003	0.010	0.064	BDL
	Hamza Aziz street-1	0.002	0.0262	0.039	BDL
	Hamza Aziz street-2	0.003	0.0231	0.0423	BDL
WHO/TBS permissible limits		0.01	3.0/5.0	0.3	0.003

BDL= Below detection limit

Table 2: The mean levels of heavy metals (± SD) in drinking water samples (mg/L)

Location	Lead	Zinc	Iron	Cadmium
Mbagala	0.08 ± 0.03	0.493 ± 0.558	0.124 ± 0.041	BDL
Kimara	0.02 ± 0.013	0.811 ± 0.108	0.237 ± 0.095	BDL
Masaki	0.012 ± 0.018	0.019 ± 0.005	0.057 ± 0.032	BDL

BDL= Below detection limit; SD = Standard deviation

Concentrations of zinc

The highest concentrations of zinc were observed in drinking water samples from Kimara which may reflect contamination due to perforation of pipes. Leaching of zinc from pipes and fittings also influence the distribution of zinc as explained by Elinder (1986). Masaki had the lowest concentrations of zinc as for lead. One way ANOVA showed significant differences in the concentrations of zinc in drinking water samples among the sampling locations ($F(2, 23) = 11.814$, $p = 0.0004$). The concentrations of zinc in the samples from all the sites were below the Tanzania Bureau of Standards (TBS) permissible limit of 5.0 mg/L (TBS 2003) and WHO permissible limit of 3.0 mg/L (WHO 2011), suggesting that no serious health hazards are expected. The results obtained for the concentrations of zinc in tap water were comparable to the levels reported by IIyas and Sarwar (2003) in Peshawar Pakistan in water from wells. The concentrations of zinc were higher than the concentrations of zinc found in tap water by Raj *et al*. (2013) in Delhi, India (mean = 0.174 mg/L) and Bugeja and Shoemake (2015) in Maltese Islands (mean = 0.115 mg/L, maximum = 0.504 mg/L) and in drinking water from the wells in small-scale mining areas in Ghana where the mean levels ranged from 0.002 to 0.034 mg/L (Cobbina *et al*. 2015). The study by Saria *et al*. (2011) did not analyze zinc.

Concentrations of iron

The highest concentrations of iron were observed in samples from Kimara, followed by Mbagala and Masaki. In Kimara and Mbagala, there are many garages and other activities that certainly release considerable amounts of iron in the environment which eventually find their ways into the water systems through perforated pipes. Dissolution of iron from pipes and storage tanks and construction activities are the major processes and sources that possibly cause the presence of high levels of iron in the drinking water of Kimara and Mbagala. Perforation and leakage of pipes were not common in Masaki areas. Most of the concentrations of iron in the samples from all the sites were generally low. There is no WHO permissible guideline for iron in drinking water because it is not of health concern at concentrations normally observed in drinking water, but may affect the acceptability of water at concentration above 0.3 mg/L (WHO 2011) and 25% of the samples from Kimara had concentrations above this limit. One way ANOVA showed significant differences in the concentrations of iron among the sampling stations in the order Kimara > Mbagala > Masaki ($F(2, 23) = 16.934$, $p < 0.0001$). In the study on drinking water of Peshawar, the levels of iron were up to 0.30 mg/L (IIyas and Sarwar 2003) and were comparable to the levels found in the present study. The levels of iron found in the present study were lower than the levels found in tap water in samples collected from the outskirts of Dar es Salaam (mean 2.3 mg/L) (Saria *et al*. 2011). Bugeja and Shoemake (2015) found higher levels of iron (mean = 0.132 mg/L, maximum = 1.225 mg/L) in tap water samples in Maltese Islands than the concentrations found in the present study.

Concentrations of cadmium

Cadmium concentrations were below the detection limit in all the drinking water samples. This implied that there were no significant sources that could contribute to the emission of cadmium into the environments of the study areas. The study by Saria *et al*. (2011) reported cadmium levels of < 0.01 mg/L in tap water. Raj *et al*. (2013) detected cadmium in tap water in Delhi, India at concentration of 0.001 mg/L. Similarly, Bugeja and Shoemake (2015) found cadmium in tap water at maximum level of 0.002 mg/L. High levels of cadmium, with mean values ranging from 0.023 to 0.534 mg/L, were found in drinking water from dug wells in small-scale mining areas in Ghana (Cobbina *et al*. 2015).

Concentrations of heavy metals in cosmetics

The concentrations of the heavy metals detected in the cosmetics studied are shown in Table 3. All the samples were found to contain lead with mean concentrations ranging from 6.6 to 37400 mg/kg. The highest concentrations of lead were found in hair dye and this may be due to the use of lead compounds such as lead acetate in hair dye as ingredients. Comparable concentrations of lead were found in the lip glosses (brands A and B) and nail polishes (brands A and B). The concentrations of zinc, on the other hand, were much higher than the corresponding concentrations of lead and cadmium in each cosmetic sample, except for hair dye where the concentrations of lead were higher than of zinc and cadmium. The highest concentrations of zinc (mean = 2600 mg/kg) were found in lip gloss. The high concentrations of zinc in lip gloss may be due to its application as skin protector (sunscreen) because it is widely used in cosmetics as zinc-oxide and zinc-stearate (Jones and Selinger 2017). Generally low concentrations of cadmium of up to 0.25 ± 0.03 mg/kg were found in hair dye, while in other cosmetics cadmium was not detected. The presence of cadmium in low levels suggested that it mainly occurred in cosmetics as an impurity or contaminant in the ingredients used during manufacturing.

The concentrations of lead and zinc in cosmetics were generally greater than those found in cosmetics by Ullah *et al*. (2013) in Pakhtunkhwa, Pakistan, where the values ranged from 1.74 to 1071 mg/kg for lead and from 0.637 to 1500 mg/kg for zinc. The levels of cadmium were lower than those found in the study done in Pakistan (ranged from 0.41 to 0.942 mg/kg).

Table 3: Concentrations of lead, zinc and cadmium in cosmetics (mg/kg)

Sample	Lead	Zinc	Cadmium
Hair dye	37400 ± 411	88.8 ± 0.44	0.25 ± 0.03
Nail polish (brand A)	6.60 ± 0.18	92.0 ± 0.50	BDL
Nail polish (brand B)	39.5 ± 0.30	46.2 ± 0.28	BDL
Lip gloss (brand A)	19.8 ± 0.20	21.5 ± 0.10	BDL
Lip gloss (brand B)	16.8 ± 0.13	2600 ± 46.5	BDL
EU permissible limit	10.0	NCI	3.0
US permissible limit	20.0	NCI	NCI

NCI = No Clear Information; concentration = mean ± standard deviation

All the lead concentrations in all the cosmetics samples except nail polish brand A exceeded the permissible limit for EU (10 mg/kg) (EU 2009). The concentrations of lead in hair dye and nail polish brand B exceeded the permissible limit for Germany and US (20 mg/kg) (Bundesgesundheitsblatt 1985, US FDA 2014). The concentrations of lead in hair dye exceeded all the permissible limits indicated. Cadmium concentrations were below the EU permissible limit, whilst there was no clear information for the permissible limits for zinc. The use of these cosmetics may enhance the absorption of the heavy metals during eating for lip glosses and during sweating for the other cosmetics, which may lead to accumulation in bodies. Exposure to lead can contribute to significant toxicity. Significantly high levels of lead and cadmium have been observed in human lenses of people suffering from cataract. The use of eye cosmetics may be a major source of these metals in human lenses (Cekic 1998). Extensive data are available on lead intoxication on the central nervous system (Dwivedi 1996). The heavy metals occurring in cosmetics are associated with many health effects (Smith and Flegal 1995, Borowska and Brzóska 2015).

Concentrations of heavy metals in fruit juices and water

Copper was detected in all the fruit juices and water samples. Lead and cadmium were not detected in all the samples. The concentrations of copper ranged from 0.008 ± 0.003 mg/L to 0.215 ± 0.014 mg/L (Table 4). The concentrations of copper in the fruit juices were greater than the concentrations in the water samples, indicating that the fruit juices had other sources of contamination. Between the two types of fruit juice samples, the trend of the concentrations of copper showed that the concentrations in the pineapple juices were greater than those of mango juices from all the study areas. This might be due to the fact that there are differences on how the fruits are located on the plants relative to the soil in which they are grown and which could be one of the possible sources of contamination. The mango tree is taller than the pineapple plant, thus, the location of the pineapple fruit from the soil is shorter compared to that of the mango fruit in the mango tree which is far above from the soil. Therefore, the uptake of nutrients and other materials like heavy metals from the soil is greater and faster in pineapple as it is near the soil than it is in the mango.

Table 4: Concentrations of heavy metals in fruit juices and water samples (mg/L)

Sampling site	Sample type	Lead	Cadmium	Copper
Gongolamboto	Mango juice	BDL	BDL	0.095 ± 0.017
	Pineapple juice	BDL	BDL	0.122 ± 0.015
	Water	BDL	BDL	0.039 ± 0.038
Kimara	Mango juice	BDL	BDL	0.073 ± 0.030
	Pineapple juice	BDL	BDL	0.113 ± 0.011
	Water	BDL	BDL	0.008 ± 0.003
Mabibo market	Mango juice	BDL	BDL	0.065 ± 0.033
	Pineapple juice	BDL	BDL	0.085 ± 0.019
	Water	BDL	BDL	0.038 ± 0.037
Mbagala	Mango juice	BDL	BDL	0.135 ± 0.015
	Pineapple juice	BDL	BDL	0.122 ± 0.002
	Water	BDL	BDL	0.039 ± 0.045
Tegeta	Mango juice	BDL	BDL	0.215 ± 0.014
	Pineapple juice	BDL	BDL	0.110 ± 0.007
	Water	BDL	BDL	0.030 ± 0.010
WHO permissible limit		0.01	0.003	2.00

BDL = Below detection limit; Concentration = mean ± standard deviation (n = 3)

According to the World Health Organization, the permissible limits for copper, lead and cadmium in fruit juice and water are 2.0 mg/L, 0.01 mg/L and 0.003 mg/L, respectively (WHO 2011). Therefore, the concentrations of all the heavy metals (lead, cadmium and copper) in all the mango juices, pineapple juices and the water samples from the study areas were below the WHO permissible limits. The findings on copper and cadmium are comparable to the findings of the study in Pakistan by Khan *et al*. (2016) where copper was detected at concentrations of up to 0.3515 mg/L while cadmium was not detected in any sample. The levels of the heavy metals found in the present study are generally lower than the levels found in some commercial juices in other countries. For example, the study by Iwegbue *et al*. (2008) in Nigeria found that the concentrations of copper, lead and cadmium in canned pineapple drinks ranged from 2.65 to 2.72, 0.50 to 0.66 and BDL to 0.002 mg/L, respectively, and in canned mango drinks they ranged from 2.56 to 3.45, 0.002 to 0.006 and 0.38 to 0.60 mg/L, respectively. Hassan *et al*. (2014) reported concentrations of copper ranging from 5.2 to 13.64 mg/kg in commercial mango juice in Egypt. Ajai *et al*. (2014) found copper at concentrations of up to 0.40 mg/L in canned pineapple and mango juices in Minna, Nigeria, but lead and cadmium were not detected. Lead and cadmium were detected in packaged fruit juices in the study by Mohammadi and Ziarati (2015). The concentrations of lead ranged from 0.0452 ± 0.002 to 1.9621 ± 0.0013 mg/L in mango juice and from 0.0427 ± 0.0003 to 0.345 ± 0.0003 mg/L in pineapple juice. The concentrations of cadmium ranged from BDL to 0.157 ± 0.0024 mg/L and BDL to 0.064 mg/L in mango juice and pineapple juice samples, respectively. The findings of lower concentrations of heavy metals in fresh fruit juices than those found in commercial (canned) fruit juices can partly be explained by the fact that the fresh fruit juices are normally diluted with a lot of water while the commercial fruit juices are normally concentrated.

CONCLUSIONS

Most of the drinking water samples (70.83%) had lead concentrations higher than the WHO drinking water permissible limit, while the levels of zinc, iron and cadmium in all the locations were below the permissible limits. The levels of the heavy metals in the water samples from some of the areas can be considered as a serious matter of concern for consumption as they signify the degradation of the quality of the drinking water. It is recommended that drinking water should be regularly monitored for the heavy metals and the drinking water should be properly treated before consumption. Heavy metals were detected in all the cosmetics samples and based on the results, it is concluded that cosmetics products contain appreciable levels of heavy metals such as lead and zinc. The continued uses of products contaminated with such heavy metals could be significant sources of human exposure and may be linked with harmful effects. So, the extensive uses of such products should be avoided and regular monitoring of the quality of cosmetics is required. The levels of lead, cadmium and copper in all the mango juices, pineapple juices and water samples did not exceed the permissible limits; therefore, the fruit juices were safe for human consumption.

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