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Assessment of metals in cosmetics commonly used in Saudi Arabia

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Abstract Cosmetics are one of the most important sources of releasing heavy metals. Different varieties of chemicals are used in cosmetic products as ingredients and some are used as preservatives. There are concerns regarding the presence of harmful chemicals in these products. Among the harmful chemicals, cosmetic products contain heavy metals. The present study was conducted to determine the content of certain heavy metals in the products made in different countries and marketed in Saudi Arabia. Thirty-one products of different brands or misbrands of commonly used cosmetic products (hair cream, beauty cream, skin cream, hair food formula, hair gel, whitening daily scrub, shampoo, shower gel, body care, body lotion, hand wash, daily fairness, shaving cream, toothpaste, germ and beauty soap, and cream soap) were purchased from local markets of Saudi Arabia. Samples were analyzed to determine the concentrations of ten metals (lead, aluminum, cadmium, cobalt, chromium, copper, manganese, nickel, mercury, and arsenic) using inductively coupled plasma mass spectrometer (ICP-MS). Based on the maximum concentrations, the heavy metal contents were arranged in the following decreasing order: Al > Cu > Mn > Pb > Cr > Ni > Hg > Co > As > Cd in cream products, Al > Pb > Cu > Cr > Mn > Ni > Hg > As > Co > Cd in shampoo products, Al > Cu > Pb > Cr > Mn > Ni > As > Co > Hg > Cd in soap products, and Al > Cu > Mn > Pb > Cr > Co > Ni > Cd > As > Hg in toothpaste products. Since the metal concentrations may relate to specific brands, product type, color, or cost, industrialist would have to check the raw materials before they are gathered into the final products to track the source of these contaminants.

Keywords Heavy metals · Cosmetics · Trace analysis · Inductively coupled plasma mass spectrometer

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Introduction

Cosmetic products are considered a part of routine body care. There are concerns regarding the presence of harmful chemicals in these products. Among the hazardous substances contained in cosmetic products, heavy metals such as lead, aluminum, cadmium, cobalt, chromium, copper, manganese, nickel, titanium, iron, zinc, mercury, and arsenic. Many investigators studied the heavy metals contents in cosmetic products of different countries (Chauhan et al., 2010; Omolaoye et al., 2010; Al-Dayel et al., 2011; Al-Saleh and Al-Enazi, 2011; Peregrino et al., 2011; Al-Saleh et al., 2009, Adepoju-Bello et al., 2012; Volpe et al., 2012; Al-Qutob et al., 2013; Brown, 2013; Faruruwa and Bartholomew, 2014; Borowska and Brzoska, 2015).

Heavy metals are widely diffused in pigmented make-up products (Sainio et al., 2000). Therefore, cosmetics are one of the most important sources of releasing heavy metals in the environment. Chauhan et al. (2010)

determined lead and cadmium in different cosmetics products collected from local market of India such as soap, face cream, shampoo, shaving cream, and talcum powder and they found that the lead was prominently detected in all of cosmetics products followed by cadmium. Among the different cosmetic products studied, the highest heavy metal contamination was found in bathing soap. Heavy metal assessment of some eye shadow products imported into Nigeria from China was carried out by Omolaoye et al. (2010). They showed that nickel, copper, zinc, cobalt, and manganese were detected in all the colors of eye shadow in varying concentrations. Chromium was also detected in all the colors except one (diamond pink). Amartey et al. (2011) indicated that Co, Cr, Cu, Fe, Mg, Mn, Ni, Zn, Cd, and Pb were found in hair pomade samples collected from female students at the University of Ghana campus. Volpe et al. (2012) determined the heavy metal contents in eye shadow cosmetics from China, Italy, and the USA, and they showed that the lead concentration was ranged from 0.25 to 81.50 μg/g, the cadmium concentration was ranged from 0.6 to 33.04 ng/g, the chromium concentration was ranged from 15.0 to 287.0 ng/g, the cobalt concentration was ranged from 0.15 to 303.7 ng/g, and the nickel concentration was ranged from 21.8 to 4148.0 ng/g. Al-Qutob et al. (2013) investigated the content of heavy metals in various types of cosmetics purchased from the Palestinian markets such as lipsticks, kohl (eyeliner), henna (hair dye or temporary tattoo), eye shadows, cream, freckles, moisturizing and foundation, and face powders. They found that the concentration levels of the heavy metals Ba, Pb, Bi, Al, Cr, Mn, Co, Ni, Cu, Zn, Mo, Ag, and Cd were 2.5–1895, 1.32–15.92, 0.37–698.1, 10.98–8530.25, 1.3–81.6, 0.70–48.89, 0.47–13.2, 2.89–214.54, 0.84–118.6, 1.68–284634, 0.23–2.18, 0.07–1.78, and 0.14–0.96 ppm, respectively. Comparative study of heavy metals content in cosmetic products of different countries marketed in Pakistan were carried out by Ullah et al. (2013), and they found that the overall mean concentrations of Pb, Cd, Cu, Co, Fe, Cr, Ni, Zn were 141.6, 0.238, 26.62, 0.527, 860.8, 0.074, 0.674, and 268.6 μg/g, respectively. Liu et al. (2013) found that lip products contained high concentrations of titanium, aluminum, manganese, lead. Study of heavy metals content in facial cosmetics obtained from open markets and superstores in Nigeria such as lipsticks, lip glosses, eyeliners, eye pencils, eye shadows, mascara, blushers, foundations, powders, and face cleansers was done by Faruruwa and Bartholomew (2014). Chromium, nickel, zinc, and iron were found in varying concentrations in all the samples; 85 % of the samples also contain Cd while 18 of the 40 samples have Pb. Metals concentrations of facial cosmetics obtained from open market were 0–31.7 ppm for Pb, 1.01–22.14 ppm for Cr, 0–3.6 ppm for Cd, 2.8–39.8 ppm for Ni, 3.7–487.9 ppm for Zn, and 72.9–261,275.6 ppm for Fe. However, the metal concentrations in those obtain from superstores were 0–14.0 ppm for Pb, 0.5–18.36 ppm for Cr, 0–9.5 ppm for Cd, 2.03–37.5 ppm for Ni, 3.6–425.0 ppm for Zn, and 74.9–217,691.2 ppm for Fe. Borowska and Brzoska (2015) reviewed metals in cosmetics and their implications for human health. They reported that cosmetic products in some cases are related to the occurrence of unfavorable effects resulting from intentional or the accidental presence of chemical substances, including toxic metals. They reviewed that lead, mercury, cadmium, arsenic, nickel, aluminum, copper, iron, chromium, and cobalt are detected in various types of cosmetics (color cosmetics, face and body care products, hair cosmetics, herbal cosmetics, etc.). These metals may undergo retention and act directly in the skin or be absorbed through the skin into the blood, accumulate in the body, and exert toxic effects on various organs.

The objectives of the current study are therefore to determine the concentrations of different heavy metals (lead, aluminum, cadmium, cobalt, chromium, copper, manganese, nickel, mercury, and arsenic) using ICP-MS in cosmetic products marketed in Saudi Arabia.

Materials and methods

Samples of commonly used personal care products were bought from local markets of Saudi Arabia. Thirty-one samples including hair cream, beauty cream, skin cream, hair food formula, hair gel, whitening daily scrub, shampoo, shower gel, body care, body lotion, hand wash, daily fairness, shaving cream, toothpaste, germ and beauty soap, and cream soap were selected. All samples were transported to the laboratory for the determination of heavy metal contents. Table 1 summarizes the test items, colors, and their origin market site used in the study.

Sample digestion

Sample preparation for heavy metal analysis was done by the dry-ashing method. The samples were first oven dried at 105 °C for 24 h. Three dried samples (5 g, each) with two replicates for each cosmetic item were accurately

Table 1 List of tested items, colors and their origin market site used in the study

No	Product name	Color	Origin/market site
1	Styling hair cream (Vatika)	Green whitish	Emirates (UAE)
2	Anti-dandruff hair cream (Himalaya)	White bluish	Emirates (UAE)
3	Beauty cream (Dove)	White	India
4	Skin cream (Kamill)	White	Germany
5	Skin cream (Nivea)	White	Germany
6	Skin cream (Himalaya)	White	Emirates (UAE)
7	Hair food formula (Palmer's)	Yellow	USA
8	Hair gel (Enliven)	Colorless	England
9	Hair style gel (Energy)	Slight blue	UK
10	Whitening daily scrub (Himalaya)	White	Emirates (UAE)
11	Shampoo co-creations (Sunsilk)	White	KSA
12	Shampoo with mandarin extract (PERT)	Green	KSA
13	Shampoo anti-dandruff (head & shoulders)	White	KSA
14	Smoothing OUD hydrates and smoothies (Jergens)	White	Emirates (UAE)
15	Shower gel (Nivea)	White	Germany
16	Body care (Johnson)	Slight rose	Italy
17	Body lotion (Nivea)	White	Thailand
18	Hand wash (Lux)	Violet	KSA
19	Hand wash (SUNOVA)	Sky blue	KSA
20	Daily fairness (Fair & Lovely)	Whitish rose	India
21	Shaving cream (Arko)	White	Turkey
22	Shaving cream (Nivea)	White	Germany
23	Toothpaste (Oral-b)	White	Germany
24	Toothpaste (Crest)	White and blue	Germany
25	Toothpaste (Colgate)	Bluish green	KSA
26	Toothpaste (DABUR HERBI)	Slight green	Emirates (UAE)
27	Beauty soap (FA)	Yellowish green	Emirates (UAE)
28	Beauty soap (DURU)	Sky blue	Egypt
29	Beauty soap (Camay)	Rose	Egypt
30	Germ shield soap (PEARS)	Blue	India
31	Cream soap (Nivea)	White	Germany

weighed and placed in crucibles and few drops of analytical grade nitric acid (65 %, Sigma Aldrich) were added to the solid as an ashing aid. Dry-ashing process was carried out in a muffle furnace by stepwise increase of the temperature up to 550 °C and then left to ash at this temperature for 4 h (Crosby, 1977). The ash was left to cool and then rinsed with 1 M nitric acid. The ash suspension was filtered into a 25-ml volumetric flask and the solution was completed to the mark with nitric acid (1 M). Samples such as cream and lotion were wet digested (Ullah et al., 2013), as we know that oily compounds are exothermic and burns with flame, with 5 ml mixture of nitric acid (65 %) and perchloric acid (70–72 %) on a hot plate for 2–3 h. In case black or brown color appeared then again add 3 ml of mixture of concentrated acids until white fumes and continuous heating near to dryness (Ayenimo et al., 2010). The solutions were allowed to cool and filtered into a calibrated flask (25 ml) and then diluted up to the mark.

Inductively coupled plasma mass spectrometry

The concentration levels of lead, aluminum, cadmium, cobalt, chromium, copper, manganese, nickel, mercury, and arsenic were determined in samples by means of a

NexION 300 D (Perkin-Elmer, USA) inductively coupled plasma mass spectrometer (ICP-MS). Table 2 highlights the operating conditions of the instrument used through the study.

Linearity of calibration curves and correlation coefficients

The ICP-MS calibration curve was carried out by external standards. The calibration curves of ten elements: lead, aluminum, cadmium, cobalt, chromium, copper, manganese, nickel, mercury, and arsenic were obtained by the instrument using the blank and three working standards 0, 50, 100, and 200 ppb for each element starting from 1000 mg/L single standard solutions for ICP-MS (Aristar grade, BDH laboratory supplies, England for the trace elements). Calibration curves showed an excellent linearity for all elements. Correlation coefficient values for all elements were within the range from 0.998 to 0.999. High purity water obtained from Millipore Milli-Q water purification system was used throughout the work.

Quality assurance

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. Samples were generally carefully handled to avoid contamination. Glassware was properly cleaned, and the reagents were of analytical grade. Reagents blank determinations were used to correct the instrument readings. For validation of the analytical procedure, a recovery study will be carried out by spiking and homogenizing several already analyzed samples with varied amounts of standard solutions of the heavy metals. The spiked samples were processed for the analysis by the same procedure and reanalyzed as described above.

Table 2 Operating conditions of inductively coupled plasma mass spectrometer (ICP-MS)

Parameter	Value
RF power	1600 W
Nebulizer gas flow	0.65 L/min
Lens voltage	9.55 V
Analog stage voltage	−1745 V
Pulse stage voltage	950 V
Number of replicates	3
Reading/replicates	20
Scan mode	Peak hopping
Dwell time	40 ms
Integration	1200 ms

Results and discussion

An analytical estimation test was performed for ten elements in the all samples and summarized in Tables 3, 4, 5, and 6. Metal concentrations varied substantially across the products.

The data presented in Table 3 showed the heavy metal concentrations in cream products. The heavy metal mean concentrations in cream products were found as the following: Pb was ranged from 2401.72 to 4379.24 ppb, Hg was ranged from 29.08 to 757.84 ppb, Cd was ranged from 15.48 to 28.48 ppb, As was ranged from 4.54 to 34.14 ppb, Cu was ranged from 4418.44 to 22,767.1 ppb, Ni was ranged from104.94 to 807.0 ppb, Co was ranged from 27.12 to 73.40 ppb, Mn was ranged from 350.34 to 4831.4 ppb, Cr was ranged from non-detectable amount to 1755.34 ppb, and Al was ranged from non-detectable amount to 512,607.9 ppb. Based on the maximum concentrations (Table 3), the heavy metal contents in cream products were arranged in the following decreasing order: Al > Cu > Mn > Pb > Cr > Ni > Hg > Co > As > Cd.

The data presented in Table 4 showed the heavy metal concentrations in shampoo products. The heavy metal mean concentrations were found as the following: Pb was ranged from 592.88 to 29,683.12 ppb, Hg was ranged from 12.68 to 53.70 ppb, Cd was ranged from non-detectable amount to 9.74 ppb, As was ranged from 1.54 to 23.08 ppb, Cu was ranged from 1365.8 to 8461.34 ppb, Ni was ranged from57.32 to 175.74 ppb, Co was ranged from 11.00 to 22.12 ppb, Mn was ranged from 259.12 to 1091.10 ppb, Cr was ranged from 457.3 to 1151.88 ppb, and Al was ranged from 65,104.4 to 339,869.0 ppb. Based on the maximum concentrations in shampoo products (Table 4), the heavy metal contents were arranged in the following decreasing order: Al > Pb > Cu > Cr > Mn > Ni > Hg > As > Co > Cd.

The data presented in Table 5 showed the heavy metal concentrations in soap products. The heavy metal mean concentrations were found as the following: Pb was ranged from 164.49 to 5812.78 ppb, Hg was ranged from non-detectable amount to 14.60 ppb, Cd was ranged from non-detectable amount to 8.74 ppb, As was ranged from non-

Table 3 Heavy metal concentration (mean ± SD) in tested cream products in ppb

	Styling hair cream (Vatika)	Anti-dandruff hair cream (Himalaya)	Beauty cream (Dove)	Skin cream (Kamill)	Skin cream (Nivea)	Skin cream (Himalaya)	Hair food formula (Palmer's)	Hair gel (Enliven)	Hair style gel (ENERGY)	Whitening daily scrub (Himalaya)
Pb	3997.04 ± 44.0	3042.74 ± 15.2	3063.98 ± 12.3	2925.64 ± 5.9	2550.58 ± 17.9	2401.72 ± 9.6	3035.78 ± 12.1	4379.24 ± 17.5	3304.64 ± 49.6	3315.6 ± 13.3
Hg	757.84 ± 9.1	210.82 ± 1.3	124.8 ± 2.0	76.28 ± 0.3	61.28 ± 1.1	47.17 ± 0.7	46.00 ± 0.5	40.54 ± 0.5	32.54 ± 0.4	29.08 ± 0.5
Cd	28.48 ± 0.1	19.74 ± 0.1	19.28 ± 0.1	22.20 ± 0.4	17.14 ± 0.1	15.48 ± 0.1	18.28 ± 0.2	20.74 ± 0.2	20.40 ± 0.2	18.08 ± 0.1
As	34.14 ± 0.6	8.80 ± 0.1	10.74 ± 0.2	8.00 ± 0.02	6.80 ± 0.01	5.08 ± 0.1	5.60 ± 0.1	5.34 ± 0.01	5.40 ± 0.03	4.54 ± 0.03
Cu	4962.3 ± 34.7	4418.44 ± 26.5	5089.28 ± 71.3	5986.14 ± 77.8	6463.2 ± 58.2	7568.46 ± 105.9	4686.92 ± 23.4	22,767.1 ± 227.7	7510.9 ± 22.5	7334.94 ± 73.3
Ni	118.86 ± 2.4	104.94 ± 4.0	190.74 ± 5.0	145.20 ± 3.3	129.06 ± 4.8	134.2 ± 6.4	171.2 ± 2.7	807.0 ± 30.7	245.02 ± 8.3	186.94 ± 1.7
Co	28.12 ± 0.3	53.80 ± 8.4	54.52 ± 1.0	73.40 ± 0.7	27.12 ± 0.2	35.00 ± 0.7	30.26 ± 0.6	56.20 ± 0.9	44.52 ± 0.9	30.26 ± 0.4
Mn	548.08 ± 14.3	350.34 ± 3.9	4831.4 ± 19.3	700.86 ± 4.2	707.92 ± 8.5	553.08 ± 1.7	677.86 ± 8.8	541.40 ± 8.1	871.14 ± 8.7	957.30 ± 3.8
Cr	225.08 ± 3.6	ND	821.38 ± 14.8	280.10 ± 2.5	891.32 ± 8.0	869.1 ± 12.2	1120.28 ± 14.6	1162.68 ± 5.8	1755.34 ± 8.8	1497.30 ± 13.5
Al	92,541.3 ± 647.8	25,582.8 ± 153.5	ND	158,348.7 ± 791.7	ND	69,109.2 ± 69.1	70,863.1 ± 212.6	91,751.2 ± 458.8	192,411.1 ± 1154.5	512,607.9 ± 512.6

ND not detectable

Table 4 Heavy metal concentration (mean ± SD) in tested shampoo products in ppb

	Shampoo co-creations (Sunsilk)	Shampoo with mandarin extract (PERT)	Shampoo anti-dandruff (head & shoulders)	Smoothing OUD hydrates and smoothies (Jergens)	Shower gel (Nivea)	Body care (Johnson)	Body lotion (Nivea)
Pb	29,683.12 ± 267.2	1526.20 ± 7.6	592.88 ± 7.7	1423.20 ± 11.4	1545.5 ± 15.5	682.98 ± 6.8	1595.42 ± 7.9
Hg	27.48 ± 0.3	19.60 ± 0.3	21.08 ± 0.3	16.68 ± 0.1	12.68 ± 0.08	53.70 ± 0.6	19.00 ± 0.2
Cd	8.00 ± 0.05	5.74 ± 0.01	9.74 ± 0.2	4.94 ± 0.02	3.48 ± 0.01	ND	0.28 ± 0.0002
As	5.54 ± 0.01	4.08 ± 0.01	23.08 ± 0.2	2.88 ± 0.02	5.74 ± 0.04	9.60 ± 0.05	1.54 ± 0.003
Cu	5061.2 ± 15.2	4023.5 ± 32.2	1365.8 ± 4.1	4962.1 ± 9.9	8461.34 ± 50.8	4675.36 ± 32.7	2991.84 ± 23.9
Ni	175.74 ± 6.9	68.4 ± 0.9	76.66 ± 0.9	103.86 ± 1.4	140.6 ± 1.7	57.32 ± 0.3	98.34 ± 2.9
Co	22.12 ± 0.2	12.00 ± 0.1	19.92 ± 0.3	12.92 ± 0.1	19.92 ± 0.1	11.00 ± 0.03	12.66 ± 0.1
Mn	495.92 ± 5.5	259.12 ± 2.3	1091.10 ± 20.7	403.82 ± 6.5	413.36 ± 3.3	352.08 ± 13.03	390.08 ± 6.6
Cr	1151.88 ± 17.3	487.46 ± 9.3	873.70 ± 13.1	807.98 ± 12.1	652.28 ± 11.7	457.30 ± 5.03	655.24 ± 14.4
Al	96,488.7 ± 578.9	106,978.4 ± 213.9	65,104.4 ± 455.7	126,538.6 ± 1265.4	284,644.3 ± 1423.2	339,869.0 ± 679.7	147,402.2 ± 589.6

ND not detectable

Table 5 Heavy metal concentration (mean ± SD) in tested soap products in ppb

	Hand wash (Lux)	Hand wash (SUNOVA)	Daily fairness (Fair & Lovely)	Shaving cream (Arco)	Shaving cream (Nivea)	Beauty soap (FA)	Beauty soap (DURU)	Beauty soap (Camay)	Germ shield soap (PEARS)	Cream soap (Nivea)
Pb	1631.62 ± 4.9	1135.22 ± 7.9	1414.24 ± 12.7	2568.68 ± 23.1	5527.3 ± 44.2	309.66 ± 3.7	432.46 ± 5.6	1153.32 ± 10.4	5812.78 ± 40.7	164.46 ± 2.1
Hg	7.60 ± 0.04	9.80 ± 0.05	7.40 ± 0.08	5.34 ± 0.08	14.60 ± 0.2	7.54 ± 0.1	14.40 ± 0.04	3.48 ± 0.006	3.08 ± 0.03	ND
Cd	3.94 ± 0.004	1.34 ± 0.004	3.40 ± 0.03	8.74 ± 0.2	8.00 ± 0.09	ND	ND	ND	ND	ND
As	1.68 ± 0.003	11.74 ± 0.005	2.94 ± 0.01	ND	3.34 ± 0.03	7.88 ± 0.1	8.94 ± 0.1	37.94 ± 0.6	35.94 ± 0.3	9.08 ± 0.07
Cu	6801.04 ± 47.6	2996.5 ± 26.9	3763.16 ± 33.9	2968.26 ± 14.8	3677.44 ± 33.1	15,475.6 ± 572.6	18,768.66 ± 112.6	22,218.36 ± 66.7	8811.6 ± 44.1	5902.74 ± 88.5
Ni	70.12 ± 3.0	41.66 ± 2.1	85.94 ± 1.9	54.72 ± 1.6	221.68 ± 6.7	99.80 ± 2.6	ND	17.12 ± 0.2	173.4 ± 2.08	25.52 ± 0.7
Co	13.80 ± 0.2	9.12 ± 0.09	13.46 ± 0.05	21.20 ± 0.1	35.86 ± 0.3	8.80 ± 0.07	6.92 ± 0.08	14.32 ± 0.4	18.12 ± 1.6	5.66 ± 0.02
Mn	548.62 ± 12.6	436.70 ± 2.6	476.32 ± 1.9	2335.70 ± 49.1	2543.38 ± 38.2	245.66 ± 2.2	157.24 ± 3.1	255.18 ± 7.4	557.68 ± 5.0	147.76 ± 3.3
Cr	575.18 ± 13.8	436.88 ± 2.6	662.66 ± 9.9	1256.46 ± 11.3	4364.34 ± 30.6	ND	ND	ND	1113.52 ± 11.1	ND
Al	86,136.8 ± 775.2	216,941.6 ± 1084.7	1,217,327.9 ± 7303.9	ND	686,946.3 ± 1373.8	635,000.2 ± 8255.0	673,385.2 ± 2693.5	1,017,960.3 ± 6107.8	1,224,314.1 ± 1224.3	790,050 ± 3950.3

ND not detectable

detectable amount to 37.94 ppb, Cu was ranged from 2996.5 to 22,218.36 ppb, Ni was ranged from non-detectable amount to 221.68 ppb, Co was ranged from 5.66 to 35.86 ppb, Mn was ranged from 147.76 to 2543.38 ppb, Cr was ranged from non-detectable amount to 4364.34 ppb, and Al was ranged from non-detectable amount to 1,224,314.1 ppb. Based on the maximum concentrations in soap products (Table 5), the heavy metal contents were arranged in the following decreasing order: Al > Cu > Pb > Cr > Mn > Ni > As > Co > Hg > Cd.

The data presented in Table 6 showed the heavy metal concentrations in toothpaste products. The heavy metal mean concentrations were found as the following: Pb was ranged from 1856.34 to 6313.00 ppb, Hg was ranged from non-detectable amount to 13.14 ppb, Cd was ranged from 2.08 to 55.28 ppb, As was ranged from 0.60 to 26.94 ppb, Cu was ranged from 5590.92 to 22,988.52 ppb, Ni was ranged from 73.60 to 1557.24 ppb, Co was ranged from 17.66 to 2608.88 ppb, Mn was ranged from 957.38 to 22,566.22 ppb, Cr was ranged from 838.80 to 4762.8 ppb, and Al was ranged from 224,049.2 to 1,435,929.5 ppb. Based on the maximum concentrations in toothpaste (Table 6), the heavy metal contents were arranged in the following decreasing order: Al > Cu > Mn > Pb > Cr > Co > Ni > Cd > As > Hg.

Heavy metals may undergo retention and act directly in the skin or be absorbed through the skin into the blood, accumulate in the body, and exert toxic effects on various organs. Adal and Tarabar (2013) indicated that exposure to metals may occur through the diet, from medications, from the environment, and the use of cosmetics. Dermal exposure is expected to be the most significant route because most of the cosmetics products are directly applied to the skin and then get absorbed and form complexes with carboxylic acid, amine, and thiol group of proteins leading to a variety of diseases. Metal intoxication may be treated using a chelating agent (Pachauri and Flora, 2010).

Health Canada (2011) reported that the acceptable limits for heavy metals vary according to the subpopulation of interest (for example, children are more susceptible to heavy metal toxicity than adults and have greater exposure potential due to hand-to-mouth activity), the amount of product used, and the site of application (for example arms versus lips). In this respect, heavy metal impurity concentrations in cosmetic products are seen to be technically avoidable when they exceed the following limits: 10 ppm for Pb, 3 ppm for As and Cd, 1 ppm for Hg, and 5 ppm for Sb.

Table 6 Heavy metal concentration (mean ± SD) in tested toothpaste products in ppb

	Toothpaste (Oral-b)	Toothpaste (Crest)	Toothpaste (DABUR HERBI)	Toothpaste (Colgate)
Pb	5069.22 ± 25.8	4037.4 ± 80.7	6313.0 ± 63.1	1856.34 ± 14.9
Hg	9.28 ± 0.09	13.14 ± 0.1	ND	3.34 ± 0.02
Cd	10.34 ± 0.2	18.28 ± 0.3	55.28 ± 0.6	2.08 ± 0.008
As	0.60 ± 0.0006	12.74 ± 0.2	26.94 ± 0.5	2.40 ± 0.005
Cu	12,745.92 ± 280.4	22,988.52 ± 459.8	5590.92 ± 72.7	6473.02 ± 58.3
Ni	212.22 ± 1.3	222.02 ± 4.7	1557.24 ± 12.5	73.60 ± 1.3
Co	47.52 ± 3.3	57.80 ± 3.8	2608.88 ± 26.1	17.66 ± 0.3
Mn	1268.94 ± 11.4	2364.74 ± 30.7	22,566.22 ± 157.9	957.38 ± 10.5
Cr	1434.7 ± 17.2	4762.8 ± 23.8	1041.98 ± 9.4	838.80 ± 1.7
Al	1,435,929.5 ± 5743.7	1,110,390.6 ± 5551.9	1,237,539.9 ± 13,612.9	224,049.2 ± 896.2

ND not detectable

Unfortunately, there are no current international standards for heavy metals such as aluminum and copper in cosmetics. Our results showed that aluminum was the highest heavy metal in all samples except in beauty cream (Dove), skin cream (Nivea), and shaving cream (Arco), and it was none detectable, followed by copper except in all selected shampoo products. However, cadmium was the lowest heavy metal except in toothpaste products which showed that mercury was the lowest heavy metal. Among the seven types of selected shampoo products, only one (shampoo co-creations, Sunsilk) showed exceeding the limit of the lead level (29.68 ppm) according to the Health Canada report.

Although some metals such as cobalt, chromium, copper, manganese, and nickel are essential trace minerals with various functions in the human body, others such as lead, mercury, arsenic, and cadmium are toxic to human beings. The FDA has determined that aluminum used as food additives and medicinal such as antacids are generally safe. Cobalt is necessary for normal functioning and maintenance of cells (Life Enthusiast Co-op International Inc., 2010). Chromium needed to facilitate the entry of glucose into the cell (Tamari, 1987). Copper is one of the most important blood antioxidants and prevents rancidity of polyunsaturated fatty acids (Life Enthusiast Co-op International Inc., 2010). Manganese is part of various enzymes in synthesis of erythrocytes and plays a role in nervous function. Nickel may play role in the activity of certain enzymes, metabolism of glucose, and hormonal functions. On the other hand, some studies report that any amount of cadmium is forbidden in all types of cosmetics because significant dermal exposure can cause irritant dermatitis (Ayenimo et al., 2010; Health Canada, 2009). Cadmium exposure above permissible limits has been reported to cause kidney damage and metabolic anomalies caused by enzyme inhibitions (CAOBISCO, 1996). Mercury compounds may cause allergic reactions, skin irritation, or adverse effects on the nervous system (Health Canada, 2012): lead toxicity, including anemia, colic, neuropathy, nephropathy, sterility, and coma. Exposure to low levels of lead has also been associated with behavioral abnormalities, learning impairment, decreased hearing, and impaired cognitive functions in humans, and in experimental animals (Saxena et al., 2006). Arsenic exerts adverse effects due to a pronounced affinity for skin and keratinizing structures including the hair and nails. Therefore, symptoms of acute overexposure include a variety of skin eruptions, alopecia, and characteristic striation of the nails. Carcinogenicity has been observed only in its inorganic form (Health Canada, 2012). Brain and bone disease caused by high levels of aluminum in the body have been seen in children with kidney disease. Bone disease has also been seen in children taking some medicines containing aluminum. In these children, the bone damage is caused by aluminum in the stomach preventing the absorption of phosphate, a chemical compound required for healthy bones. Some studies show that people exposed to high levels of aluminum may develop Alzheimer's disease, but other studies have not found this to be true (ATSDR, 2008).

Heavy metal concentrations in cosmetic products have been reported by many investigators in different countries (Table 7). In comparison with the previous studies, the highest concentration of aluminum found in cream products (158.4 ppm) was found to be higher than those

Table 7 Levels of heavy metals (ppm) in some cosmetic products in different countries

Cosmetics	Origin/market site	Al	Cr	Mn	Co	Ni	Cu	As	Cd	Hg	Pb	References
Cream	India, UAE, Germany	ND-158.4	0.28–0.89	0.55–4.83	0.03–0.07	0.13–0.19	5.09–7.57	0.005–0.011	0.016–0.022	0.05–0.13	2.40–3.06	This study
		–	–	–	–	–	–	–	–	3.37–57,000	–	Sin and Tsang, 2003 McKelvey et al., 2011
	UAE, India, Pakistan	–	ND	–	0.22–0.23	0.26–0.31	2.06–65.34	–	0.04–0.06	–	1.74–3.71	Ullah et al., 2013
	Marked at Bulgaria	–	–	–	ND-1.00	1.82–8.43	2.27–17.85	–	ND-1.33	–	ND	Theresa et al., 2011
	Marked at India	–	–	–	–	–	–	–	0.02–0.03	–	0.03–0.07	Chauhan et al., 2010
	–	–	0.19–0.47	–	–	–	0.57–0.93	–	0.06–0.36	–	–	Ayenimo et al., 2010
	Palestine	15.31–62.17	–	–	–	–	–	–	–	–	—	Al-Qutob et al., 2013
	Africa	ND-0.86	–	–	–	–	–	–	–	–	–	Oyedeji et al., 2011
	Europe	ND-0.96	–	–	–	–	–	–	–	–	–	Oyedeji et al., 2011
	USA	ND-1.00	–	–	–	–	–	–	–	–	–	Oyedeji et al., 2011
Hair cream	UAE	25.58–92.54	ND-0.23	0.35–0.55	0.03–0.05	0.10–0.12	0.05–4.42	0.01–0.03	0.02–0.03	0.21–0.76	3.04–4.00	This study
	–	–	0.01–0.49	–	–	0.01–2.03	0.52–0.81	–	0.28–6.95	–	ND-0.49	Ayenimo et al., 2010; Umar and Caleb, 2013
Hair gel	USA, UK	70.86–192.41	1.76–1.16	0.54–0.87	0.03–0.06	0.17–0.81	4.69–22.77	0.005–0.006	0.018–0.021	0.03–0.05	3.04–4.38	This study
	Marked at Ghana	–	ND	–	10.66–25.35	1.30–72.00	0.70–12.80	–	4.20–6.80	–	1.30–17.70	Amartey et al., 2011
Shampoo	KSA, UAE	65.10–126.54	0.49–1.15	0.26–1.09	0.01–0.02	0.07–0.18	1.37–5.06	0.003–0.023	0.005–0.010	0.02–0.03	0.59–29.68	This study
	Marked at India	–	–	–	–	–	–	–	0.03–0.04	–	0.98–1.59	Chauhan et al., 2010
		6.00	0.34–1.50		0.18–0.37	0.06–3.11	0.07–2.39		0.03–4.17		0.96–3.32	Abdel-Fattah and Pingitore, 2009; Chauhan et al., 2010; Umar and Caleb, 2013
	KSA, UAE, Pakistan	–	ND	–	0.18–0.37	0.10–0.39	0.07–2.39	–	0.06–0.20	–	1.78–3.32	Ullah et al., 2013

Table 7 (continued)

Cosmetics	Origin/market site	Al	Cr	Mn	Co	Ni	Cu	As	Cd	Hg	Pb	References
Body lotion	Germany, Italy, Thailand	147.40–339.87	0.46–0.66	0.35–0.41	0.01–0.02	0.06–0.14	2.99–8.46	0.002–0.010	ND-0.004	0.01–0.05	0.68–1.60	This study
		ND-6000										Abdel-Fattah and Pingitore, 2009
Hand wash	KSA	86.14–216.94	0.44–0.58	0.44–0.55	0.009–0.014	0.04–0.07	3.00–6.80	0.002–0.012	0.001–0.004	0.008–0.010	1.14–1.63	This study
Shaving cream	Turkey, Germany	ND-686.95	1.26–4.36	2.34–2.54	0.02–0.04	0.055–0.222	2.97–3.68	ND-0.003	0.008–0.009	0.005–0.015	2.57–5.53	This study
	Marked at India	–	–	–	–	–	–	–	0.01–0.02	–	0.66–0.69	Chauhan et al., 2010
		98,000										Abdel-Fattah and Pingitore, 2009
Toothpaste	Germany, KSA, UAE	224.05–1435.93	0.838–4.76	0.96–22.57	0.018–2.61	0.074–1.56	5.59–22.99	0.001–0.027	0.002–0.055	ND-0.013	1.86–6.31	This study
		–	0.01–6.29	–	–	0.01–29.39	0.10–0.31	–	ND-28.73	0.01–1.10	ND-8.89	Umar and Caleb, 2013; Odukudu et al., 2014
Soap	UAE, Egypt, India, Germany	635.00–1224.31	ND-1.11	0.15–0.56	0.006–0.018	ND-0.17	5.90–22.22	0.008–0.038	ND	ND-0.01	0.16–5.81	This study
	Marked at India	–	–	–	–	–	–	–	0.03–0.04	–	3.82–4.63	Chauhan et al., 2010
	–	170,000–650,000										Abdel-Fattah and Pingitore, 2009
	–	–	10–295	–	–	–	103–516	–	ND-50	–	–	Ayenimo et al., 2010
	Marked at Ghana	–	20–392	–	–	–	185–871	–	90–440	–	–	Ayenimo et al., 2010
			10–720		100–870	ND-5760			ND-12,850	ND-7400	ND-5800	Harada et al., 2001; Cristuado et al., 2013; Orisakwe and Otaraku,2013; Umar and Caleb, 2013

ND not detectable

obtained by Al-Qutob et al. (2013) and Oyedeji et al. (2011). The highest concentration of aluminum (126.54 ppm) found in shampoo was higher than that found by Abdel-Fattah and Pingitore (2009), in body lotion (339.87 ppm), in shaving cream (686.95 ppm), and in soap (1224.31 ppm) which were lower than that found by Abdel-Fattah and Pingitore (2009). The study also indicated that the highest concentration of lead found in cream (3.06 ppm) was close to that obtained by Ullah et al. (2013) but higher than that obtained by Chauhan et al. (2010). The highest concentration of lead found in shampoo (29.68 ppm) was higher than that obtained by Chauhan et al. (2010) or Abdel-Fattah and Pingitore (2009) or Ullah et al. (2013). The highest concentration found in hair cream (4.00 ppm), hair gel (4.38 ppm), shaving cream (5.53 ppm) was higher than that obtained by Ayenimo et al. (2010), Umar and Caleb (2013) in hair cream or Amartey et al. (2011) in hair gel or Chauhan et al. (2010) in shaving cream. However, the highest concentration of lead found in toothpaste (6.31 ppm) was lower than that obtained by Umar and Caleb (2013) and Odukudu et al. (2014). In soap, the highest concentration found of lead (5.81 ppm) was higher than that obtained by Chauhan et al. (2010) but lower than that obtained by Harada et al. (2001), Cristuado et al. (2013), Orisakwe and Otaraku (2013), and Umar and Caleb (2013). Mercury level that found in cream (0.13 ppm), in toothpaste (0.013 ppm), in soap (0.01 ppm) was lower than that found by Sin and Tsang (2003) and McKelvey et al. (2011) in cream, Umar and Caleb (2013) and Odukudu et al. (2014) in toothpaste, Harada et al. (2001), Cristuado et al. (2013), Orisakwe and Otaraku (2013) and Umar and Caleb (2013) in soap. Cadmium level that found in cream (0.022 ppm), in hair cream (0.03 ppm), in hair gel (0.021 ppm), in shampoo (0.010 ppm), in shaving cream (0.009 ppm), in toothpaste (0.055 ppm) was lower than that obtained by Ullah et al. (2013), Chauhan et al. (2010), Theresa et al. (2011), Ayenimo et al. (2010) in cream, Umar and Caleb (2013) and Ayenimo et al. (2010) in hair cream, Amartey et al. (2011) in hair gel, Chauhan et al. (2010), Abdel-Fattah and Pingitore (2009), Chauhan et al. (2010), Umar and Caleb (2013) in shampoo, Chauhan et al. (2010) in shaving cream, Umar and Caleb (2013), Odukudu et al. (2014) in toothpaste.

Since the metal concentrations may relate to specific brands, product type, color, or cost, industrialist would have to check the raw materials before they are gathered into the final products to track the source of these contaminants.

Conclusions

In the present study, lead, aluminum, cadmium, cobalt, chromium, copper, manganese, nickel, mercury, and arsenic were determined in various cosmetics of different brands using inductively coupled plasma mass spectrometer (ICP-MS). Based upon the results, we concluded that the continuous use of these cosmetics could result in an increase in the heavy metals level in human body beyond acceptable limits. Since the removal of metals from cosmetic products is not possible, the careful selection of the raw material that used in manufacturing could improve their quality and the extensive uses of such products should be avoided.

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