Journal of Consumer Protection and Food Safety
https://doi.org/10.1007/s00003-018-1180-y

Journal of Consumer Protection and Food Safety
Journal für Verbraucherschutz und Lebensmittelsicherheit

RESEARCH ARTICLE

Determination of lead and cadmium contents in lipstick and their potential health risks to consumers

Marian Asantewah Nkansah[1] · Emmanuel Owusu-Afriyie[1] · Francis Opoku[1]

Received: 27 February 2018 / Accepted: 19 July 2018

Abstract
In Ghana, a complete profile of heavy metals in lipstick products is lacking. Therefore, this study aimed to assess the level of some toxic metals in lipstick sold at different markets and shopping malls in Kumasi Metropolis. Twenty lipstick brands were analysed. The lipstick was chemically digested and then analysed for lead (Pb) and cadmium (Cd) using atomic absorption spectroscopy (model 210 VGP). The concentrations of Pb and Cd in lipsticks ranged from 0.20 ± 0.00 to 36.70 ± 0.26, and 1.83 ± 0.06 to 412.23 ± 0.40 mg kg^{-1}, respectively. The actual Pb concentration measured in 18 lipstick samples was far below the recommended limits of the United State Food and Drug Administration (20 mg kg^{-1}), Ghana Standards Authority (1 mg kg^{-1}) and Health Canada (10 mg kg^{-1}). The Cd concentration in 19 lipsticks was above the Health Canada threshold for impurities, indicating a potential toxicological effect for lipstick users. The hazard quotient for Cd in almost all the lipstick samples, except sample C12 were above 1, indicating adverse non-carcinogenic health risk exposure to Cd via the lipsticks ingestion. Thus, the continuous usage of these brands of lipsticks can pose a high risk of Cd on human health. Therefore, quality control is recommended to check lipstick products imported into the country. Similarly, regular monitoring of other heavy metal containing components and chemicals used in the manufacture of cosmetics products, which may cause health risks to consumers should be ensured.

Keywords Lipstick · Cosmetics · Heavy metals · Health risks

1 Introduction

Millions of people are continuously using personal facial cosmetics and care products across the globe. The application of these products can expose the human skin to certain ingredients (Loretz et al. 2008; Nohynek et al. 2010). Natural and synthetic substances in cosmetic products can cause sensitisation, irritation, photoreactions and allergy to the skin (Davies and Johnston 2011; Nohynek et al. 2010; Tomankova et al. 2011). Cosmetic products form a major component of modern lifestyle for cleansing and beautifying. There is a great demand for cosmetic products, such as body lotion, hair dyes, makeup etc. (Ackah 2015). The high demand can be attributed to the beauty consciousness of many people of all forms of socio-economic standings (Chauhan et al. 2010). Some of the heavy metals in cosmetic products are water-soluble, and therefore can be absorbed through the skin (Lilley et al. 1988; Sainio et al. 2000).

Lipsticks consist of oils, emollients, antioxidant materials, silica, titanium dioxide, mica and colourants that give different properties, appearance and colours to the final product (Batista et al. 2016). Lipsticks have been used during the ancient times and the Filipino women were the pioneers. In the year 1921, Lipstick was common in the United Kingdom, but before then it was already a common cosmetic product in France (Schaffer 2007). Lipsticks have been grouped into sheer and satin, moisturising, matte, frosted and pearl, cream, long and glossy wearing lipsticks (Schaffer 2007). A characteristic feature of lipsticks is the wide diversity of colours, which are obtained from added pigments, such as organic or mineral, may contain heavy metals e.g. Cd, Cr, Cu, Co, Pb and Ni (Resano and García-Ruiz 2011; Valet et al. 2007; Volpe et al. 2012).

✉ Marian Asantewah Nkansah
maan4gr@yahoo.co.uk

1 Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Published online: 26 July 2018

Metallic-based colours containing Pb are usually used as dyes in lipstick (Al-Saleh et al. 2009; USFDA 2013). The concentrations of heavy metals in beauty products has become an international health interest due to its daily usage as face makeup, eye shadows, foundations and blush (Piccinini et al. 2013). Lipsticks have been found to contain heavy metals, such as Cr, Cd, Pb, Al, As, Sb and Ni (Al-Saleh and Al-Enazi 2011). The presence of heavy metals in lipstick products can also be attributed to the metallic devices used during the manufacturing process (Volpe et al. 2012).

The safety of cosmetic, personal care products, as well as their exposure to heavy metals has received considerable attention in recent times (Atz and Pozebon 2009; Gardner et al. 2013; Liu et al. 2013; Loretz et al. 2005; Piccinini et al. 2013), and parameters such as content, sources, mobilisation potential, and toxic effects of several contaminants in cosmetic products have also been investigated (Becker et al. 2013; Fiume et al. 2013; Johnson et al. 2013; Lu et al. 2011). To analyse the potential hazard associated with heavy metals in lipstick products, it is necessary to know the concentrations and types of ingredients contained in the products (Bocca et al. 2014). Human exposure to inorganic and organic contaminants in lipstick products via dermal and ingestion absorption may significantly contribute to non-carcinogenic and carcinogenic risks (Liu et al. 2013). For example, chronic exposure to Pb may cause blood systemic, teratogenic and neurological effects (Zakaria and Ho 2015). Long-term exposure to Cd can cause cardiovascular diseases, such as hypertension and atherosclerosis (Angeli et al. 2013).

Recently, there have been published reports on heavy metal concentrations in cosmetic products, such as body creams, kohl, lipsticks, rouge, eye pencils, eye shadow and others (Ackah 2015; Agorku et al. 2016; Amartey et al. 2011; Amponsah et al. 2014; Voegborlo et al. 2008). However, there is limited data on heavy metal concentrations in lipsticks in the Ghanaian market. Additionally, due to the vast pursuit of beauty there is a higher popularity of lipstick, regardless of e.g. the literacy or age of people. Therefore, there is a need to investigate the content of heavy metals of lipstick, which are available in the Kumasi Metropolis. The aim of this study was to evaluate the concentrations and human health risks associated with Cd and Pb in lipstick products sold on the Kumasi market. These heavy metals are among the most toxic heavy metals encountered in cosmetics preparation.

2 Materials and methods

2.1 Sampling area

The sampling locations were carefully chosen in order to acquire values that represent background levels. This was done by choosing areas that have a high percentage of usage. The sampling was done in two different locations, namely the Kwame Nkrumah University of Science and Technology (KNUST) and the Kumasi Central market. KNUST was established in the year 1952 with an area of about 7 sq mi and 13 km east of Kumasi. The student populations are about 21,285 undergraduates and 2306 postgraduates. The sampling at KNUST was done based on the type and colours of lipsticks that were not available at the Kumasi Central market. About 90% of women population in Ghana use lipstick (Amartey et al. 2011). Most of the lipsticks available on KNUST are more expensive compared to the Kumasi Central Market. The Kumasi Central Market is an open-air market, located in south central of the Ashanti region. Most traders within the region buy their wares from here and later convey to other market centres within the region. There is the availability of different types of lipsticks in the market where people buy them based on the packaging, price and the brand.

2.2 Sample collection

A total of 20 different lipsticks sold in the KNUST and Kumasi Central market were purchased from the cosmetic shops. Based on the coded names selected lipsticks were imported from 11 different countries [India, United States of America (USA), China, South Korea, United Kingdom (UK), Malaysia, South Africa, France, Kenya, Hong Kong, and Uganda]. The lipstick brands were chosen based on their popularity and availability during the period of study. Table 1 lists the studied lipstick based on the country of origin and brand names.

2.3 Sample preparation and analysis

The sample preparation was carried out using the method described by Okamoto et al. (1971). About 1 g of each lipstick sample was measured into a beaker. The samples were digested by adding 20 mL of hydrogen peroxide (H_2O_2) and nitric acid (HNO_3) in a ratio of 1:3. The solution was then filtered using Whatman No. 1 and the residual material after digestion was further diluted with deionised water to a final volume of 50 mL. The digestion was done at a temperature of 225 °C for 2 h each in a fume chamber.

Table 1 Different brands of lipstick, origin and colour

Sample number	Country of origin	Colour
C1	India	Black
C2	USA	Wine dregs
C3	China	Purple
C4	South Korea	Pink
C5	UK	Pink
C6	USA	Brown
C7	Malaysia	Red
C8	China	Orange
C9	China	Red orange
C10	South Africa	Orange
C11	UK	Red
C12	France	Orange
C13	USA	Red
C14	Kenya	Pink
C15	Malaysia	Red
C16	Hong Kong	Red–orange
C17	USA	Brown
C18	USA	Red
C19	China	Orange
C20	Uganda	Pink

The heavy metal levels were determined using Atomic Absorption Spectrophotometer (model 210 VGP). The instrument was calibrated with each element at a ten-point calibration curve. The linearity of the calibration curve for each element was evaluated by the coefficient determination (R^2). Each sample was analysed in triplicates in order to establish the accuracy of the method used.

2.4 Quality control

Initially, the glassware used was soaked in 10% (v/v) HNO_3 solution for 24 h and then rinsed with deionised water. The reagents and procedural blank analyses were carried out using the analytical steps contained in the experimental procedure. Three blanks were analysed in each analysis. The calibration of the instrument was done after 10 runs. The accuracy and precision of the analytical procedure employed were validated using the spike recovery approach. Here, with 3 concentration levels, a known standard of the test element was introduced into fresh portions of the analysed samples. The limit of detection (LOD) and limit of quantification (LOQ) were calculated with 3 and 10 times of standard deviation of the prepared blank solution (Khan et al. 2013). Linear range, linearity, recovery, LOQ, and LOD of Pb and Cd are presented in Table 2.

The mean and relative standard deviations (RSDs) of the spike recoveries for the triplicate analyses were 92 ± 8% for Cd and 85 ± 5% for Pb. The LOD was 0.19 and 0.02 mg kg^{-1} for Pb and Cd, respectively, while the LOQ was 1.87 and 0.17 for Pb and Cd, respectively. The calibration curve exhibited a good linearity in the concentrations range of 4×10^{-4} and 4 mg L^{-1}.

2.5 Health risk assessment

Heavy metals in lipstick may enter the human body through ingestion. The dose received through ingestion was evaluated according to Eq. (1) (USEPA IRIS 2011):

$$ADD_{ing} = \frac{C \times IR \times EF \times ED}{BW \times AT} \times CF \quad (1)$$

where C, ADD_{ing}, IR, EF, BW, CF and AT are the heavy metals concentrations (mg kg^{-1}), the average daily dose of ingestion (mg kg^{-1} day^{-1}), the intake rate of the lipstick (40 mg day^{-1}), the exposure frequency (260 days $year^{-1}$), the body weight of the exposed population (57.9 kg), exposure duration (35 years), the conversion factor (10^3), and the averaging time (365 days $year^{-1}$), respectively (SCCP 2006).

Based on the ADD_{ing} results, the hazard quotient (HQ) for the non-carcinogenic risk was calculated using Eq. (2).

$$HQ = ADD_{ing}/RfD \quad (2)$$

where RfD represents the reference oral dose. $RfDs$ for Cd and Pb were 0.001 and 0.0004 mg kg^{-1} day^{-1}, respectively (USEPA IRIS 2011). By definition, ADD_{ing} value higher than the RfD value indicated adverse effects on human health and HQ > 1 signifies adverse health effects. To evaluate the health risk of heavy metals contamination, the hazard index (HI) was calculated following Eq. (3):

$$HI = \sum HQ. \quad (3)$$

3 Results and discussion

3.1 Lead concentration in lipstick

The concentrations of Pb in the lipstick samples ranged from 0.20 ± 0.00 to 36.70 ± 0.26 mg kg^{-1} (Table 3) with 2 brands above the 20 and 10 mg kg^{-1} set by the United States Food and Drug Administration (USFDA) (USFDA 2013) and Canadian Health (Health Canada 2012), respectively. The variation of Pb concentrations might be due to the higher amount of dyes and pigments in lipstick compared to lip gloss (Al-Saleh et al. 2009). The concentrations of Pb in two brands of lipstick were above the Ghana Standard Authority guideline of 1 mg kg^{-1} for Pb

Table 2 Linear range, linearity, recovery, LOD and LOQ for the target heavy metals

Element	Linear range	R^2	Recovery ± RSD (%)	LOD (mg kg^{-1})	LOQ (mg kg^{-1})
Pb	0.0004–4	0.9993	85 ± 5	0.19	0.27
Cd	0.0004–4	0.9997	92 ± 8	0.02	0.17

Table 3 Concentrations of lead (Pb), and cadmium (Cd) in the lipstick samples (n = 3)

Code	Origin	Colour	Cd		Pd	
			Mean ± SD	Range	Mean ± SD	Range
C1	India	Black	16.83 ± 0.29	16.50–17.00	0.53 ± 0.06	0.50–0.60
C2	USA	Wine dregs	13.33 ± 0.29	13.00–13.50	0.82 ± 0.03	0.80–0.85
C3	China	Purple	46.67 ± 0.58	46.00–47.00	36.70 ± 0.26	36.40–36.90
C4	South Korea	Pink	5.83 ± 0.58	5.50–6.50	0.38 ± 0.08	0.30–0.45
C5	UK	Pink	4.43 ± 0.06	4.40–4.50	0.57 ± 0.06	0.50–0.60
C6	USA	Brown	364.67 ± 1.53	363.00–366.00	0.77 ± 0.06	0.70–0.80
C7	Malaysia	Red	10.83 ± 0.06	10.80–10.90	0.20 ± 0.00	0.20–0.20
C8	China	Orange	7.67 ± 0.12	7.60–7.80	0.82 ± 0.03	0.80–0.85
C9	China	Red orange	18.13 ± 0.06	18.10–18.20	0.38 ± 0.08	0.25–0.70
C10	South Africa	Orange	10.29 ± 0.01	10.28–10.30	0.28 ± 0.03	0.25–0.35
C11	UK	Red	14.58 ± 0.01	14.57–14.58	0.53 ± 0.06	0.50–0.60
C12	France	Orange	1.83 ± 0.06	1.80–1.90	0.53 ± 0.06	0.50–0.60
C13	USA	Red	8.21 ± 0.01	8.20–8.22	0.53 ± 0.06	0.50–0.60
C14	Kenya	Pink	12.81 ± 0.01	12.80–12.81	0.68 ± 0.03	0.65–0.70
C15	Malaysia	Red	11.48 ± 0.08	11.40–11.55	0.55 ± 0.04	0.50–0.60
C16	Hong Kong	Red–orange	35.33 ± 0.12	35.20–35.40	22.40 ± 0.10	22.30–22.50
C17	USA	Brown	412.23 ± 0.40	411.80–412.60	0.53 ± 0.06	0.50–0.60
C18	USA	Red	153.60 ± 1.44	153.40–155.30	0.52 ± 0.03	0.50–0.60
C19	China	Orange	56.70 ± 0.10	56.60–56.80	0.50 ± 0.03	0.80–0.85
C20	Uganda	Pink	98.40 ± 0.26	98.20–98.70	0.82 ± 0.21	1.50–1.90

All units are in mg kg^{-1}

in cosmetic products (Ghana Standards Board 2012). In the present study, the level of Pb was higher than values found in lipsticks by Zakaria and Ho (2015) and Ackah (2015), which were 0.77–15.44 and 10.9–15.25 mg kg^{-1}, respectively. In addition, the Pb concentrations were also higher than those reported by Piccinini et al. (2013), Gunduz and Akman (2013) and Soares and Nascentes (2013). Furthermore, higher levels of Pb have also been reported in other cosmetic products compared to the present study (Al-Saleh et al. 2009; Gunduz and Akman 2013; Nnorom et al. 2005; Volpe et al. 2012). Higher concentrations of Pb were found in lipstick samples imported from South Africa, while those imported from the United Kingdom had the lowest concentrations. The difference in Pb concentrations might be due to the added pigment components during the production process (Material safety data sheet 2012). A potential Pb source for contamination in lipstick can also be the added auxiliary components. Also, the presence of Pb in the analysed lipstick samples might be due to Pb contaminated dust and water used during the manufacturing of the lipstick products.

3.2 Cadmium concentration in lipstick

The Cd concentrations in the studied lipstick samples varied from 1.83 ± 0.06 to 412.23 ± 0.40 mg kg^{-1}. The highest Cd content was found in lipsticks imported from China, and the lowest was found in lipsticks imported from Kenya (Table 3). The Canadian Health established a guideline of 3.0 mg kg^{-1} for Cd in cosmetic products (Health Canada 2012). The concentrations of Cd in 19 lipstick brands were above the Canadian guideline value. Zakaria and Ho (2015) reported Cd concentrations of 0.06–0.33 mg kg^{-1}, in lipstick, which was lower than those we found in this study. In addition, the Cd content in the present study was higher than that reported by Gondal et al. (2010), Oluremi and Oluyemi (2014), and Ullah et al. (2017) in other cosmetic products.

Table 4 Human health risk assessments of Pb and Cd in the analysed lipstick samples

Cd			Pb		
Lipstick Code	ADD (10^{-3})	HQ	ADD (10^{-3})	HQ	HI
C1	8.30	8.30	0.26	1.01	9.30
C2	6.57	6.57	0.40	45.23	51.80
C3	23.00	23.00	18.09	0.47	23.48
C4	2.88	2.88	0.19	0.70	3.57
C5	2.19	2.19	0.28	0.94	3.13
C6	179.77	179.77	0.38	0.25	180.01
C7	5.34	5.34	0.10	1.01	6.35
C8	3.78	3.78	0.40	0.47	4.25
C9	8.94	8.94	0.19	0.35	9.29
C10	5.07	5.07	0.14	0.66	5.73
C11	7.19	7.19	0.26	0.66	7.84
C12	0.90	0.90	0.26	0.66	1.56
C13	4.05	4.05	0.26	0.84	4.89
C14	6.31	6.31	0.34	0.67	6.99
C15	5.66	5.66	0.27	27.61	33.27
C16	17.42	17.42	11.04	0.66	18.08
C17	203.21	203.21	0.26	0.64	203.86
C18	75.72	75.72	0.26	1.01	76.73
C19	27.95	27.95	0.40	2.14	30.09
C20	48.51	48.51	0.85	0.00	48.51

3.3 Health risk assessment

In comparison to food, air or water, a number of heavy metals in cosmetic products may seem like a small fraction that can affect human health. However, their adverse effects on human health should not be overlooked, since they have been continuously applied to sensitive areas of the skin, such as eye contours and the lips. Pb and Cd have been regarded as possibly carcinogenic to humans. To appraise the human health risk related to heavy metals contamination in lipstick, the daily intake of metals and risk index were calculated. The ADD_{ing}, HQ, and HI for all the analysed lipstick samples are presented in Table 4.

With a daily usage of lipstick, the ADI value for Pb in all lipstick samples was 0.10×10^{-3}–18.09×10^{-3} mg day^{-1} (Table 4) and above the recommended reference dose 1×10^{-4} mg day^{-1}, while the ADI of Cd in 19 lipstick samples exceeded the acceptable reference dose of 1×10^{-3} mg day^{-1} (2.19×10^{-3}–203.21×10^{-3} mg day^{-1}). The HQ of Cd and Pb ranged from 0.90 to 203.21 and 0.00 to 45.23. The HQ of Cd were all above 1 except sample C12, indicating a high non-carcinogenic adverse risk to consumers. In addition, the HQ values for Pb in C2, C15 and C19 samples were above 1. The potential hazard indices (HI) was evaluated based on the summation of the HQ results. The HI for all lipsticks was above 1, therefore, there was a non-carcinogenic health risk from the ingestion of Cd and Pb through the lipstick. Chronic human exposure to Cd results in hepatic dysfunction, renal dysfunction, anaemia, and cancer in multiple organs, like kidney (Mandel et al. 1995; Waalkes et al. 1996).

4 Conclusion

This study determined the levels of cadmium and lead in lipstick products sold on the Kumasi market in Ghana. The results reveal that the concentrations of Pb and Cd in lipsticks ranged from 0.20 ± 0.00 to 36.70 ± 0.26 mg kg^{-1}, and 1.83 ± 0.06 to 412.23 ± 0.40 mg kg^{-1}, respectively. The concentrations of Pb in C3 and C16 were higher than the USFDA (20 mg kg^{-1}), Health Canada (10 mg kg^{-1}) and the Ghana Standard Authority (1 mg kg^{-1}) permissible limit. The overall results indicate that Cd concentrations in 19 lipsticks was above the Health Canada limit (3 mg kg^{-1}) as impurities and might have significant toxicological effects on consumers. The HQ for Cd in almost all the lipstick samples, except sample C12 were above 1, indicating adverse non-carcinogenic health risk exposure to Cd via the lipsticks ingestion. This study gives intrinsic and useful data for future toxicology study on the ingestion of poisonous substances in lip cosmetic products. The findings of this study calls for an immediate mandatory regular testing program for cosmetic imports to Ghana in order to curtail their access and safeguard consumer health. In addition, a regular monitoring of other heavy metals and chemicals used for the manufacturing of cosmetics that may cause health risks to consumers should be accentuated.

Acknowledgements The Researchers are grateful to the Department of Chemistry of the Kwame Nkrumah University of Science and Technology for the use of its facilities for this study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Ackah M (2015) Status of some metals contained in imported nail polish and lipsticks on the Ghanaian market. Proc Int Acad Ecol Environ Sci 5:142–147

Agorku ES, Kwaansa-Ansah EE, Voegborlo RB, Amegbletor P, Opoku F (2016) Mercury and hydroquinone content of skin toning creams and cosmetic soaps, and the potential risks to the health of Ghanaian women. SpringerPlus 5:1–5

Al-Saleh I, Al-Enazi S (2011) Trace metals in lipsticks. Toxicol Environ Chem 93:1149–1165

Al-Saleh I, Al-Enazi S, Shinwari N (2009) Assessment of lead in cosmetic products. Regul Toxicol Pharmacol 54:105–113

Amartey E, Asumadu-Sakyi A, Adjei C, Quashie F, Duodu G, Bentil N (2011) Determination of heavy metals concentration in hair Pomades on the Ghanaian market using atomic absorption spectrometry technique. Br J Pharmacol Toxicol 2:192–198

Amponsah D, Sebiawu GE, Voegborlo R (2014) Determination of amount of mercury in some selected skin-lightening creams sold in the Ghanaian market. Int J Eng 3:344–350

Angeli JK, Pereira CAC, de Oliveira Faria T, Stefanon I, Padilha AS, Vassallo DV (2013) Cadmium exposure induces vascular injury due to endothelial oxidative stress: the role of local angiotensin II and COX-2. Free Radic Biol Med 65:838–848

Atz VL, Pozebon D (2009) Graphite furnace atomic absorption spectrometry (GFAAS) methodology for trace element determination in eye shadow and lipstick. At Spectrosc 30:82–91

Batista ÉF, Augusto AdS, Pereira-Filho ER (2016) Chemometric evaluation of Cd Co, Cr, Cu, Ni (inductively coupled plasma optical emission spectrometry) and Pb (graphite furnace atomic absorption spectrometry) concentrations in lipstick samples intended to be used by adults and children. Talanta 150:206–212

Becker LC et al (2013) Safety assessment of borosilicate glasses as used in cosmetics. Int J Toxicol 32:65S–72S

Bocca B, Pino A, Alimonti A, Forte G (2014) Toxic metals contained in cosmetics: a status report. Regul Toxicol Pharmacol 68:447–467

Chauhan AS, Bhadauria R, Singh AK, Lodhi SS, Chaturvedi DK, Tomar VS (2010) Determination of lead and cadmium in cosmetic products. J Chem Pharm Res 2:92–97

Davies RF, Johnston GA (2011) New and emerging cosmetic allergens. Clin Dermatol 29:311–315

Fiume MM et al (2013) Safety assessment of decyl glucoside and other alkyl glucosides as used in cosmetics. Int J Toxicol 32:22S–48S

Gardner P, Bertino M, Weimer R, Hazelrigg E (2013) Analysis of lipsticks using Raman spectroscopy. Forensic Sci Int 232:67–72

Ghana Standards Board (2012) Food, chemistry and material standards, 3rd edn. Ghana Standards Board, Accra

Gondal MA, Seddigi ZS, Nasr MM, Gondal B (2010) Spectroscopic detection of health hazardous contaminants in lipstick using Laser Induced Breakdown Spectroscopy. J Hazard Mater 175:726–732

Gunduz S, Akman S (2013) Investigation of lead contents in lipsticks by solid sampling high resolution continuum source electrothermal atomic absorption spectrometry. Regul Toxicol Pharmacol 65:34–37

Health Canada (2012) Guidance on heavy metal impurities in cosmetics. Health Canada, Ottawa

Johnson W et al (2013) Safety assessment of alkyl glyceryl ethers as used in cosmetics. Int J Toxicol 32:5S–21S

Khan N et al (2013) Method validation for simultaneous determination of chromium, molybdenum and selenium in infant formulas by ICP-OES and ICP-MS. Food Chem 141:3566–3570

Lilley S, Florence T, Stauber J (1988) The use of sweat to monitor lead absorption through the skin. Sci Total Environ 76:267–278

Liu S, Hammond SK, Rojas-Cheatham A (2013) Concentrations and potential health risks of metals in lip products. Environ Health Perspect 121:705–710

Loretz L et al (2005) Exposure data for cosmetic products: lipstick, body lotion, and face cream. Food Chem Toxicol 43:279–291

Loretz L et al (2008) Exposure data for cosmetic products: facial cleanser, hair conditioner, and eye shadow. Food Chem Toxicol 46:1516–1524

Lu Y, Yuan T, Wang W, Kannan K (2011) Concentrations and assessment of exposure to siloxanes and synthetic musks in personal care products from China. Environ Pollut 159:3522–3528

Mandel JS et al (1995) International renal-cell cancer study. IV. Occupation. Int J Cancer 61:601–605

Material safety data sheet (2012) Kings Mountain Mica. http://www.dar–technic.com/doc/MicaMSDS.pdf. Accessed 10 Oct 2017

Nnorom I, Igwe J, Oji-Nnorom C (2005) Trace metal contents of facial (make-up) cosmetics commonly used in Nigeria. Afr J Biotechnol 4:1133–1138

Nohynek GJ, Antignac E, Re T, Toutain H (2010) Safety assessment of personal care products/cosmetics and their ingredients. Toxicol Appl Pharmacol 243:239–259

Okamoto M, Kanda M, Matsumoto I, Miya Y (1971) Fast analysis of trace amounts of lead in cosmetics by atomic absorption spectrophotometry. J Soc Cosmet Chem 22:589–598

Oluremi O, Oluyemi E (2014) Lipsticks and nail polishes: potential sources of heavy metal in human body. Int J Pharm Res Allied Sci 3:45–51

Piccinini P, Piecha M, Torrent SF (2013) European survey on the content of lead in lip products. J Pharm Biomed Anal 76:225–233

Resano M, García-Ruiz E (2011) High-resolution continuum source graphite furnace atomic absorption spectrometry: is it as good as it sounds? A critical review. Anal Bioanal Chem 399:323–330

Sainio EL, Jolanki R, Hakala E, Kanerva L (2000) Metals and arsenic in eye shadows. Contact Dermat 42:5–10

Schaffer SE (2007) Reading our lips: the history of lipstick regulation in Western seats of power. Food Drug Cosmet Law J 62:165–225

Soares AR, Nascentes CC (2013) Development of a simple method for the determination of lead in lipstick using alkaline solubilization and graphite furnace atomic absorption spectrometry. Talanta 105:272–277

The SCCP's notes of guidance for the testing of cosmetic ingredients and their safety evaluation (2006). http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_s_004.pdf. Accessed 9 Oct 2017

Tomankova K et al (2011) In vitro cytotoxicity and phototoxicity study of cosmetics colorants. Toxicol In Vitro 25:1242–1250

Ullah H et al (2017) Comparative study of heavy metals content in cosmetic products of different countries marketed in Khyber Pakhtunkhwa, Pakistan. Arab J Chem 10:10–18

Usepa IRIS (2011) Integrated risk information system. Environmental protection agency region I. United State Environmental Protection Agency, Washington, DC

USFDA (2013) Addressing lead at superfund sites. Information for risk assessors. USEPA, Washington, DC

Valet B, Mayor M, Fitoussi F, Capellier R, Dormoy M, Ginestar J (2007) Colouring agents in cosmetic products (excluding hair dyes): types of decorative cosmetic products. In: Salvador A, Chisvert A (eds) Analysis of cosmetic products, vol 1. Elsevier BV, Cambridge

Voegborlo R, Voegborlo S, Buabeng-Acheampong B, Zogli E (2008) Total mercury content of skin toning creams and the potential risk to the health of women in Ghana. J Sci Technol 28:88–96

Volpe M, Nazzaro M, Coppola R, Rapuano F, Aquino R (2012) Determination and assessments of selected heavy metals in eye shadow cosmetics from China, Italy, and USA. Microchem J 101:65–69

Waalkes M, Misra R, Chang L (1996) Cadmium carcinogenicity and genotoxicity, in toxicology of metals. CRC Press, Taylor & Francis Group, Boca Raton

Zakaria A, Ho YB (2015) Heavy metals contamination in lipsticks and their associated health risks to lipstick consumers. Regul Toxicol Pharmacol 73:191–195