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Assessment of some heavy metals in selected cosmetics commonly used in Bangladesh and human health risk

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Abstract

In Bangladesh, use of beauty cream is very much popular and a common daily task for the people. The current study is focusing on the assessment of some toxic heavy metals such as lead, cadmium, chromium, and mercury contamination in some beauty creams commonly used by Bangladeshi people. The results indicate that the concentrations of lead, cadmium, and chromium exceed the maximum allowable concentrations, whereas mercury is found below the acceptable limit set by WHO/EU. However, according to Health Canada, the concentrations of cadmium and chromium for all the selected samples (except cadmium in sample coded A) was within the permissible limit. Health risks associated with these metal intakes via dermal exposure route are evaluated in terms of chronic daily intake (CDI) and hazard quotient (HQ). The carcinogenic risk (CR) estimated for chromium indicates that it is within the acceptable range. The cancer and non-cancer risk results indicate that although the chances of cancer risk and non-cancer risk resulting from the use of these cosmetic products were unlikely, buildup of these toxic heavy metals overtime on continuous usage could be detrimental for Bangladeshi people.

Keywords: Beauty cream, Heavy metals, Chronic daily intake, Hazard quotient, Health risk

Introduction

Cosmetics have been used as a part of routine body care by all classes of people throughout the world. They are classified as any item intended to be rubbed, poured, sprinkled or sprayed on, or introduced into or otherwise applied to the human body or any part of the body for cleansing, beautifying, promoting attractiveness, or altering the appearance, and include any item intended for use as a component of cosmetics (Drug and Cosmetic Act 1940). Cosmetics are mixtures of some surfactants, oils, and other ingredients and are required to be effective, long-lasting, stable, and safe to human use.

With many new products released into the market every season, it is hard to keep track of the safety of every product and some products may carry carcinogenic contaminants (Peter and Viraraghavan 2005). There are concerns regarding the presence of harmful chemicals, including heavy metals, in these products. Many cosmetic products contain heavy metals such as lead, cadmium, chromium, arsenic, mercury, cobalt, and nickel as ingredients or impurities. Recent research has reported that these metals can easily cause many types of skin problems (Nesterenko and Jones 1997; Sainio et al. 2000). The use of some heavy metals in cosmetic has been controversial due to the biological accumulation of those metals and their toxicity in human body. In most countries, it is legally prohibited to use lead, arsenic, and mercury in skin cosmetic products (Hostynek 2000). It is also reported that these metals can cause allergic contact dermatitis or other skin problems (Maibach and Menne 1989; Kerosuo et al. 1996). Since the issue of heavy metals as deliberate cosmetic ingredients has been addressed, attention is turned to the presence of these substances as impurities. The metals of primary toxicological concern in cosmetics are lead, cadmium, arsenic, chromium, mercury, and antimony (Sainio et al. 2000). Dermal exposure is expected to be the most significant route for cosmetic products since the majority of

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cosmetics are applied to the skin. Oral exposure can occur for cosmetics used in and around the mouth as well as from hand to mouth contact after exposure to cosmetics containing heavy metal impurities. However, inhalation exposure is typically considered to be negligible (Saleh et al. 2009).

At higher concentrations, heavy metals have been shown to have negative effects. Lead, which may be an impurity, is a proven neurotoxin linked to learning, language, and behavioral problems (Ayenimo et al. 2010). It has also been linked to miscarriage, reduced fertility in men and women, hormonal changes, menstrual irregularities, and delays in puberty onset in girls. Pregnant women and young children are also vulnerable because lead crosses the placenta and may enter the fetal brain (Horowitz et al. 2002). Cadmium found in body and hair creams are absorbed into the body through dermal contact (Ayenimo et al. 2010) and stored in the kidney and the liver, although it can be found in almost all adult tissues. It is considered to be “carcinogenic to humans” by the IARC (ATSDR 2012) and its compounds, categorized as known human carcinogens by the United States Department of Health and Human Services. Ingestion of high levels of cadmium can lead to severe stomach irritation, vomiting, and diarrhea, while exposure to lower level for a long time can lead to kidney damage, bone deformity, and the ability of bones to break easily (Campaign for Safe Cosmetics 2007). Chromium is also corrosive and causes allergy to the skin. Adverse effects of the chromium on the skin may include ulcerations, dermatitis, and allergic skin reactions. Mercury is linked to nervous system toxicity, as well as reproductive, immune, and respiratory toxicity. It is also found in thiomersal, which is a mercury-based preservative and used as direct ingredients or impurities. But the high toxicity of this metal means that the presence of mercury in any cosmetic is a concern. Other heavy metals show a similar tendency to be toxic (UNEP 2008). A recent assessment by WHO reported that mercury in skin lightening creams and soaps that are commonly used in Asian and Central African nations is potentially dangerous as they have serious side effects and can be fatal (WHO 2011).

The use of cosmetics by Bangladeshi women is an ancient tradition. They believe that cosmetics help them to improve their features and cover the blemishes of the skin. A survey, conducted by Environment and Social Development Organization (ESDO) Bangladesh, reported that there are so many toxic chemicals present in both imported and exported beauty products of Bangladesh which is so alarming for human health and environment. However, there are very few reports published about the heavy metal concentration in Bangladeshi cosmetics. To the best of the authors’ knowledge, this is the first study in Bangladesh regarding the study of heavy metal contents in the beauty cream samples and also calculated the possible health risk assessment. As the use of cosmetic products is increasing rapidly in Bangladesh and various chemicals including the heavy metals are used in the cosmetics which pose health risk to consumers, the aim of the present study is to assess toxic metals like lead, cadmium, chromium, and mercury in some fairness creams highly used by the Bangladeshi people and their effect on human health.

Materials and methods

Sample collection

In June 2017, six different brands of beauty cream samples were purchased from the local market of Dhaka City Bangladesh. Global positioning system (GPS) was used to locate the sampling positions (Fig. 1). To keep the brand names anonymous, the samples were coded from A to F. The details of the samples are presented in Table 1.

Reagents and chemicals

All the reagents and chemicals used in the study were of analytical grade. HNO_3 (69%, BDH), HCl (36%, Sigma-Aldrich), H_2SO_4 (98%, Sigma-Aldrich), $HClO_4$ (70%, Sigma-Aldrich), H_2O_2 (30%, Sigma-Aldrich), $KMnO_4$ (Merck), hydroxylamine (BDH), and deionized water (Resistivity > 18 MΩ/cm) were used for digestion and dilution of samples and preparation of intermediate metal standard solutions prior to analysis. Standard solutions for calibration of lead, cadmium, chromium, and mercury were prepared from 1000 mg/L standard stock solution of Wako Chemicals (Japan) AAS Reference Standard.

Sample preparation and analysis

Sample preparation for the determination of lead, cadmium, and chromium has been carried out according to the method adopted by Chauhan et al. (Chauhan et al. 2010). Briefly, about 1.0 g of sample was digested in 5.0 mL mixture of concentrated HNO_3:$HClO_4$ (3:1) for 2–3 h on a hot plate at 90 °C. The mixture was heated about to dryness. Then, 3.0 mL of acid mixture was again added and heated for 2–3 h for complete digestion. The digested samples were cooled at room temperature, and about 5.0 mL deionized water was added, mixed well, and made a volume up to 25 mL in volumetric flask. The solution is then finally filtered through Whatman filter paper (number 41). The solution was used for metal quantification. For Hg estimation, the sample was prepared

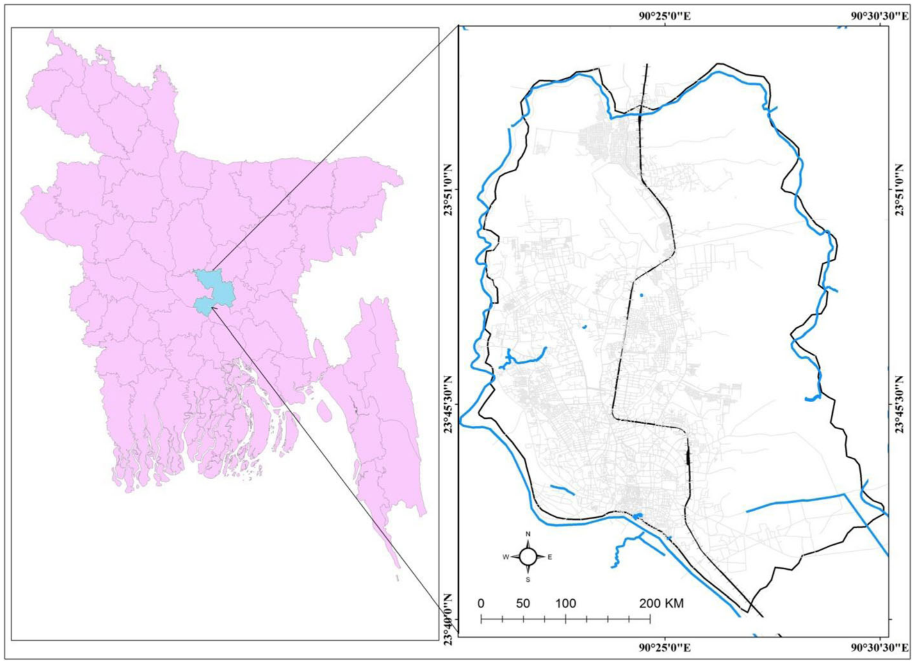

Fig. 1 Sampling location of Dhaka city, Bangladesh

according to Clarke et al. (Clarke et al. n.d.); briefly, about 0.5 g of samples was weighed into the beaker. Then, the samples were predigested with a mixture of 2 mL H_2SO_4 and 2 mL HNO_3 for 1.5 h at 80 °C. After cooling the sample solution at room temperature, 7.0 mL 5% $KMnO_4$ and 5 mL 3% HCl were added into the beaker and then heated at 95 °C for 2 h. After again cooling to room temperature, 6.0 mL 12% hydroxylamine solution was added to reduce the $KMnO_4$. The beakers were swirled to assure complete reaction with the excess $KMnO_4$ and then made a volume with 3% HCl and mixing thoroughly prior to AAS analysis.

Flame atomic absorption spectrophotometer (FAAS) (Shimadzu AA-6800, Japan) with air-acetylene flame was used to conduct the analysis of lead, cadmium, and chromium. However, mercury analysis was conducted by cold vapor-atomic absorption spectrophotometer (CV-AAS). The instrumental conditions during the analysis of heavy metals are listed in Table 2 giving details about parameters which are defined for respective metals.

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. Reagents blank determinations were used to correct the instrument readings. For validation of the analytical procedure, standard addition method which is considered as a validation method (Ullah et al. 2017a) was used. Hence, a recovery study was performed (Table 5) by spiking and homogenizing several 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 the analysis of sample.

Table 1 Details about collected beauty cream samples

S/N no.	Sample code	Manufacture date	Expiry date
1	A	June 2016	Nov, 2017
2	B	July 2016	July, 2018
3	C	January 2016	Jan, 2018
4	D	August 2016	July, 2018
5	E	January 2016	May, 2018
6	F	January 2016	June, 2018

Table 2 Operating parameters for FAAS which are used in analysis of metals

Element	Wavelength (nm)	HCL current (mA)	Acetylene flow rate (L/min)	Slit width (nm)	Minimum limit of detection (mg/kg)
Lead	283.3	8.0	1.8	1.0	0.05
Cadmium	228.8	10.0	1.6	1.0	0.1
Chromium	357.9	10.0	2.2	0.5	0.05
Mercury	253.7	10	2.0	0.5	0.02

Health risk assessment

In this study, human health risk models including carcinogenic and non-carcinogenic risks raised by United States Environmental Protection Agency (USEPA) were calculated. The threshold values proposed by USEPA were employed to assess the potential health risks on the consumers. Currently, there is no agreed limit for acceptable maximum carcinogenic and non-carcinogenic risk levels in Bangladesh.

Estimated chronic daily intake of heavy metals

Health risk assessment is examined via dermal contact with cosmetic particles. Three main pathways may occur when target analytes expose to human being are (a) direct ingestion, (b) inhalation through the mouth and nose, and (c) dermal absorption. For metals in cosmetics environment, only dermal absorption plays the most important role (Kim et al. 2004) for skin care cream. Considering this pathway, the expose dose, chronic daily intake (CDI) was calculated using the equation in Table 3 and the detailed explanation for all the parameters are listed in Table 4. The equation is adapted from the USEPA (USEPA 1989; Miguel et al. 2007).

Non-carcinogenic risk

The hazard quotient, HQ (non-carcinogenic risk), of the different metals in the cosmetic samples was calculated. HQ is the ratio of exposure to hazardous substances to the chronic reference dose (RfD) of the toxicant (mg/kg/day) and expressed as:

$$\text{Non-carcinogenic risk, HQ} = \text{CDI}_{\text{dermal}}/\text{RfD}_{\text{dermal}}.$$

The dermal reference doses are 0.04, 0.001, 0.000015, and 0.0013 mg/kg/day for lead, cadmium, chromium, and mercury respectively (USEPA 2015). In order to determine the appropriate RfD for HQ, it was assumed that all chromium ions in the cosmetics sample are trivalent (non-carcinogenic). If HQ < 1, the exposed population is unlikely to experience obvious adverse effects. If HQ > 1, there is a potential health risk (Ullah et al. 2017b), and related interventions and protective measurements are needed to be taken. To estimate the risk to human health through more than one heavy metal (HM), the hazard index (HI) has been developed (USEPA 1989). The hazard index is the sum of the hazard quotients for all HMs, which was calculated by the equation (Guerra et al. 2010):

$$\text{HI} = \Sigma\,\text{HQ} = \text{HQ}_{\text{Pb}} + \text{HQ}_{\text{Cd}} + \text{HQ}_{\text{Cr}} + \text{HQ}_{\text{Hg}}$$

Carcinogenic risk

Carcinogenic risk is defined as the incremental probability that an individual will develop cancer during one's lifetime due to chemical exposure under specific scenarios (Chen and Liao 2006; Obiri et al. 2006). It is necessary to calculate the carcinogenic risk value to estimate whether the consumers are likely to suffer from cancer, and this can be evaluated from equation:

$$\text{Carcinogenic risk} = \text{CDI} \times \text{SF}$$

where CDI is the chronic daily intake of carcinogens ($\text{mg kg}^{-1}\,\text{d}^{-1}$) and SF is the slope factor of hazardous substances ($\text{mg kg}^{-1}\,\text{d}^{-1}$) obtained from the integrated

Table 3 Formula for calculating dermal absorption

Exposure pathway	Calculation formula
Dermal contact	$\text{CDI}_{\text{dermal}} = \frac{\text{CS}\times\text{SA}\times\text{AF}\times\text{ABS}\times\text{EF}\times\text{ED}\times\text{CF}}{\text{BW}\times\text{AT}}$

Table 4 Parameters for exposure of metals in cosmetics samples used in the study

Exposure factor	Unit	Value
Exposure-point concentration (CS)	mg/kg	–
Exposure frequency (EF)	Days/year	350
Exposure duration (ED)	Year	30
Average time for non-carcinogens (AT)	Days	25,550
Body weight (BW)	kg	70
Exposed skin area (SA)	cm^2	5700
Adherence factor (AF)	mg cm^{-2}	0.07
Dermal absorption fraction (ABS)		0.001
Units conversion factor (CF)	kg mg^{-1}	10^{-6}

Table 5 Concentration (μg/g) of toxic metals in beauty cream samples

Sample code	Lead Conc. ± SD	Cadmium Conc. ± SD	Chromium Conc. ± SD	Mercury Conc. ± SD
A	50.39 ± 4.3	6.27 ± 0.91	BDL	0.168 ± 0.004
B	30.75 ± 3.3	2.77 ± 0.92	BDL	0.128 ± 0.007
C	14.38 ± 1.8	2.40 ± 0.23	BDL	0.481 ± 0.009
D	35.66 ± 3.6	2.60 ± 0.28	2.82 ± 0.03	0.174 ± 0.009
E	26.65 ± 2.5	2.48 ± 0.17	BDL	0.292 ± 0.005
F	15.25 ± 1.8	2.85 ± 0.22	BDL	0.245 ± 0.005
Mean	28.85	3.23	0.47	0.25
WHO	10	0.3	NA	1.0
EU	0.5	0.5	1.0	NA
CANADA	10	3.0	NA	3.0

BDL below detection limit, *NA* not available

risk information system (USEPA 2015) database, which was 2×10^1 (mg/kg/day) for chromium.

Results and discussion

Concentrations of toxic metals in cosmetics

Heavy metals have been implicated in cosmetics that are commonly used by women (Popoola et al. 2013; Ramakant et al. 2014). Heavy metals which can be absorbed in the body through dermal absorption for a long time may cause various health problems. The contents of trace elements in the fairness cream as means of triplicate determination are summarized in Table 5. From the results, it can be seen that the lead content was found to be in the range of 14.38 to 50.39 μg/g, whereas the lowest amount was found in C coded sample and the highest concentration was found in coded A sample. According to the WHO, the permissible limit for lead is 10 μg/g (Sukender et al. 2012), and it is observed that all the samples contain lead content above the permissible limit. The concentration of cadmium was found in all the samples and varied from 2.40 to 6.27 μg/g. Sample C contains the lowest cadmium concentration and sample A contains the highest. According to the WHO, the permissible limit for cadmium is 0.3 μg/g, and unfortunately, all the cosmetic products were found to contain cadmium concentration higher than the permissible limit (Sukender et al. 2012).

Table 6 Recovery studies for toxic elements in the present study

Element	Primary value (μg/g)	Added amount (μg/g)	Quantity found (μg/g)	Recovery (%)
Lead	35.66 ± 3.6	5.0	40.25	91.8
Cadmium	2.60 ± 0.28	1.0	3.52	92.0
Chromium	2.82 ± 0.03	1.0	3.71	89.0
Mercury	0.174 ± 0.009	0.2	0.354	90.0

Among the heavy metals, data presented in Table 5, it reveals that chromium was obtained as 2.82 μg/g in only one sample D and the other samples showed the content below the detection limit. According to the EU, the permissible limit for chromium is 1 μg/g (Umar and Caleb 2013). In that way, sample D exceeds the permissible limit. The mercury concentrations varied from 0.128 to 0.481 μg/g, whereas the highest concentration was found in sample C and the lowest concentration was observed in sample B. According to the WHO, the permissible limit for mercury is 1 μg/g (Sukender et al. 2012). So it can be said that all the samples contain mercury below the acceptable limit. It is also mentioned that according to Health Canada, it may be seen that the metal concentration of lead, cadmium, and chromium was within the permissible limit (Umar and Caleb 2013) (Table 5). Generally, the concentrations of the heavy metals in the cosmetics analyzed in this study are in the order of Pb> Cd > Cr > Hg with mean concentrations of 28.85 μg/g, 3.23 μg/g, 0.47 μg/g, and 0.25 μg/g respectively as shown in Table 5. The results of recovery study were within the acceptable range verifying the validity of the proposed method for analysis (Table 6) and reveal that any small change in the drug concentration in the solution could be accurately determined by the proposed method.

Implication of the calculated chronic daily intake

The degree of toxicity of heavy metal to humans depends on their daily intake (Ullah et al. 2018). The chronic daily intake (CDI) of four metals—lead, cadmium, chromium, and mercury—was calculated according to the mean concentration of each metal. The CDI and maximum tolerable daily intake (MTDI) of the studied metals are shown in Table 7. Total daily intake of lead, cadmium, chromium, and mercury was calculated as 4.05E−07, 4.54E−08, 6.61E−09, and 3.49E−09 mg/day respectively. Daily intakes of all the metals are less than the MTDI. In the cosmetics samples, mean values of CDI are decreased in the order: Pb> Cd >Cr > Hg.

Non-carcinogenic risk

The health risks from the use of contaminated cosmetics items by populations are assessed based on HQ, which is the ratio of determined dose of a pollutant to a reference dose level. If HQ > 1, the exposed population will likely to experience a detrimental effect (Ullah et al. 2017b). HQ of the four studied metals for each sample are listed in Table 8. It is

Table 7 Comparison of the chronic daily intake (CDI) of heavy metals (mg/day) from cosmetics samples with the corresponding maximum tolerable daily intake (MTDI) (Shaheen et al. 2016) in the Bangladeshi population

CDI of metals (mg/day)	Sample						Total intake	MTDI
	A	B	C	D	E	F		
Pb	1.18E−07	7.20E−08	3.37E−08	8.35E−08	6.24E−08	3.57E−08	4.05E−07	0.21
Cd	1.47E−08	6.49E−09	5.62E−09	6.09E−09	5.81E−09	6.68E−09	4.54E−08	0.021
Cr	ND	ND	ND	6.61E−09	ND	ND	6.61E−09	0.2
Hg	3.94E−10	2.99E−10	1.13E−09	4.0E−10	6.84E−10	5.74E−10	3.49E−09	NA

ND not detected, *NA* not available

Table 8 Non-carcinogenic risk (HQ_{dermal} and HI) of heavy metals in collected cosmetics sample

Sample	HQ_{Pb}	HQ_{Cd}	HQ_{Cr}	HQ_{Hg}	HI
A	2.95E−06	1.47E−05	–	3.03E−07	1.79E−05
B	1.80E−06	6.49E−06	–	2.31E−07	8.52E−06
C	8.42E−07	5.62E−06	–	8.67E−07	7.33E−06
D	2.09E−06	6.09E−06	4.40E−04	3.14E−07	4.49E−04
E	1.56E−06	5.81E−06	–	5.26E−07	7.90E−06
F	8.93E−07	6.68E−06	–	4.41E−07	8.01E−06

apparent from the table that HQ of all the metals are < 1 obtained for all the beauty cream samples, indicating residents in Bangladesh would not experience any significant health risk via dermal adsorption of the studied beauty creams. The HI value expresses the combined non-carcinogenic effects of multiple elements. For the utilization of selected cream, HI was < 1 (Table 8) indicating that consumers are found to be safer.

Carcinogenic risk

Due to unavailability of dermal slope factor (SF_{dermal}) for the element lead, cadmium, and mercury, carcinogenic risk (CR) was calculated only for using chromium metal and presented in Table 9. Carcinogenic risk between 10^{-6} and 10^{-4} is considered to be acceptable (Chen and Liao 2006). From the result, it is seen that the cancer risk of chromium was found to be 1.32E−07 in sample B, which is lower than the negligible range, indicating no CR from chromium consumption from dermal exposure of beauty cream for Bangladeshi inhabitants.

Conclusion

The investigated fairness creams were varied in their metal concentrations, and the estimated amounts of lead, cadmium, and chromium were found to be higher than the respective maximum allowable concentration (MAC), according to the WHO/EU standard. But according to Health Canada, the concentration of lead exceeded the permissible value, whereas cadmium and chromium concentrations were found below the permissible limit, except cadmium in B coded sample. This study recommends continuous monitoring of this field including other items of cosmetics and the agencies that control the safety of cosmetic products will have to work hard to ensure safety of the consumers of these products. However, no metals were found to be considered as potential health hazard for human.

Table 9 Carcinogenic risk of chromium for dermal exposure pathway for beauty cream samples

Sample	CDI_{dermal}	Slope factor	Cancer risk
D	1.1010E−07	2.00E+01	1.32E−07

Abbreviations

CDI: Chronic daily intake; CV-AAS: Cold vapor-atomic absorption spectrophotometer; FAAS: Flame atomic absorption spectrophotometer; HQ: Hazard quotient; MTDI: Maximum tolerable daily intake; USEPA: United States Environmental Protection Agency

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Availability of data and materials

Not applicable

Authors' contributions

MFA and NCD designed the experiment. MFA, MA, BM, AF, MDH, NCD, FTA, SKK, TT, and AKMAU collected the samples and carried out the sample preparation and analysis. MFA wrote the manuscript, and AKMAU revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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