

ULTRA-TRACE QUANTIFICATION OF LEAD, CADMIUM AND MERCURY IN COSMETICS AND ASSOCIATED HEALTH RISKS

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Abstract

Cosmetics are everyday personal care product which may be harmful if they contain toxic metals. This study was conducted to assess the lead, cadmium and mercury in ten commercially available cosmetics in local market of Jamshoro, Sindh by using the flame atomic absorption spectroscopy after the wet acid digestion. Lead was found in the range of 0.001 to 0.007 $\mu\text{g/g}$ and cadmium 0.001 to 0.006 $\mu\text{g/g}$. mercury was not detected in any of the analyzed samples. The presence of these metals at ultra trace metals raises the possibility of cumulative exposure especially from every item like skin creams and lipsticks, though none of the sample had violated the WHO and USP allowable limits. Given the potential risks, drug regulatory authorities must prioritize the regular monitoring of cosmetics and the enforcement of safety limits to prevent harm to public health.

INTRDOCUTION

Cosmetics are beautifying products which includes soaps, cream, lotion, lipsticks, eye shadows, nail polish and multiple hair formulations (Sharma et al., 2018). These are used by millions of peoples worldwide. The use of these products has increased substantially in developing countries like Pakistan with aim to make the skin brighter (Kamran, 2010; Khan et al., 2021). Because of its easy availability and directly applied on skin, this may pose serious health issue to the peoples, if they contain toxic heavy metals like lead, cadmium, mercury and arsenic (Lawal et al., 2021).

Inclusion of heavy metals in cosmetics may be possible by two ways; first as a active ingredient like lead acetate in hair dyes and mercury as skin lightening and second it may come from the

contaminated raw material (Disha et al.) Human skin act as protective layer, but at the same time it absorbs the chemicals if they apply directly on it (Semple, 2004). Lips and eyes are very sensitive parts of the skin where from maximum absorption usually occurs allowing the transdermal uptake (Prausnitz et al., 2012). Heavy metals in lipsticks are especially concerning due to the dual exposure pathways: absorption through the skin and accidental ingestion (da Costa¹ et al.)

Over use of contaminated cosmetics create a serious health issue, as they bioaccumulate even if present in lower quantities. Chronic exposure to lead may causes anemia, kidney damage and cognitive problem in children and can cross both the blood-brain and placental barriers, posing a serious risks to developing fetus (Singhal et al., 2022). Due to its toxicity FDA has set a

recommended maximum limit of 10 $\mu\text{g/g}$ for lead in cosmetics (Guidance, 2016). Cadmium classified as human carcinogen and linked to renal tubular dysfunction, cardiovascular diseases and hypertension (Rasin et al., 2025). Use of the cadmium in cosmetics is prohibited through the EU Regulation No. 1223/2009 (Rasin et al., 2025). Mercury is found in skin lightening creams which may cause neurotoxicity, tremors, memory loss and immune suppression (Abbas et al., 2020). World health organization recommends mercury in cosmetics should not exceed 1 $\mu\text{g/g}$ and its use is banned across many countries (Rai et al., 2015). In Pakistan, Drug Regulatory Authority of Pakistan (DRAP) is responsible for cosmetics oversight, but enforcement remains inconsistent and large-scale contamination studies are rare (Liaqat et al., 2025). Therefore, this study was

conducted to quantify Pb, Cd, and Hg concentrations in ten commercially available cosmetics from Jamshoro and to evaluate the associated health risks.

Material and methods

2.1 Study Area and sample collection

Ten samples covering lipsticks, soaps, creams, powder and lotions were collected from the local market Jamshoro. Collected samples include products manufactured by both local and international manufacturers. The identity of the manufacturers has been kept confidential due to market competition concerns. All samples were purchased in their original sealed packaging and assigned a numerical code (1–10) with the full brand-to-code distribution presented in Table 1.

Table 1: Brand Codes and Product Details of Cosmetic Samples

Code	Brand code	Manufacturer / Origin	Product Type
1	LP1	Local	Lipstick
2	LP2	Local	Lipstick
3	CR1	Local	Cream
4	LOT1	Local	Lotion
5	CR2	International	Cream
6	CR3	Local	Cream
7	LOT2	International	Lotion
8	POW	Local	Powder
9	S1	Local	Soap
10	S2	International	Soap

2.2 Reagents and Apparatus

Nitric acid and perchloric acid were purchased from the sigma Aldrich. Deionized water was used for all dilutions and standard preparation. Working standards for calibration were prepared from original stock solution of 1000 $\mu\text{g/g}$ for each metal. Lead and cadmium were quantified by flame atomic absorption spectroscopy, whereas mercury was analyzed by cold vapor atomic

absorption spectroscopy (CV-AAS) with hydride generation accessory

2.3 Sample Preparation and Acid Digestion

Samples were prepared for the analysis by following official wet acid digestion procedure adapted from AOAC Method 999.10 (Chemists, 2000). Briefly 1.0 of each sample was weighed and 10 ml of HNO_3 and 2 ml of HClO_4 in ratio 5:1 was added and allowed to stand for 30 minutes.

After thirty minutes the mixture was heated to 80 °C for 30 minutes and temperature was raised to 120 °C until brown NO₂ fumes ceased, indicating complete oxidation of organic matter (Bocca et al., 2014). After cooling, the solution was filtered through Whatman No. 42 filter paper and quantitatively transferred into a 10 mL volumetric flask and fill up to the mark.

Calibration curve was generated with correlation coefficient (R²) was obtained above 0.998 for all three metals. Instrumental detection limit (DL) was determined for lead (0.0005 µg/g), Cd (0.0003 µg/g) and mercury (0.001 µg/g). External standard addition was used to assess the recoveries and were found in the range of 93–98% with relative standard deviation was less than five percent for all metals. The instrumental parameters used for these metals are presented in table 2.

2.4 Instrument Calibration and Quality Control

Table 2. Instrumental parameters for determination of metals

Parameter	Pb	Hg*	Cd
Wavelength (nm)	217	253.7	228.8
Slit Width (nm)	1	0.5	0.5
Lamp Current (mA)	5	4	4
Flame Type	Air-C ₂ H ₂	Air-C ₂ H ₂ *	Air-C ₂ H ₂
Detection Limit (mg/L)	0.01	0.001	0.001
Replicates	3	3	3

* Determined by using cold vapor AAS (CV-AAS)

3. Results and discussion

Analysis of cosmetics showed that Lead was detected in trace amount in all ten samples, with concentrations ranging from 0.001 to 0.007 µg/g and cadmium 0.001 to 0.006 µg/g. Mercury was not detected in any of the sample analyzed. The results are shown in table 3. Lead detected in this study were well below the FDA's recommended maximum of 10 µg/g for cosmetics. The lowest

lead concentration was recorded in LP1 Lipstick 0.001, while the highest was found in CR3 cream POW powder 0.007 µg/g. Lipsticks raise concerns because of its risk of ingestion. different studies suggested women may consume up to 24 mg of lipstick daily. Even at the modest concentrations observed here, cumulative daily oral exposure could meaningfully contribute to overall lead body burden, especially among frequent users.

Table 3: Concentrations of Pb, Cd, Hg in different cosmetics products

Code	Brand Name	Pb (µg/g)	Cd (µg/g)	Hg (µg/g)	Product Type
1	LP1	0.001	0.006	BDL	Lipstick
2	LP2	0.003	0.004	BDL	Lipstick
3	CR1	0.005	0.005	BDL	Cream
4	LOT1	0.005	0.004	BDL	Lotion
5	CR2	0.006	0.001	BDL	Cream
6	CR3	0.007	0.005	BDL	Cream
7	LOT2	0.005	0.003	BDL	Lotion
8	POW	0.007	0.004	BDL	Powder
9	S1	0.004	0.003	BDL	Soap
10	S2	0.004	0.005	BDL	Soap
	Mean ± SD (all)	0.0047	0.0040	—	
	WHO/FDA Limit	10 (FDA)	0.006 (USP)	1 (WHO)	

BDL = Below Detection Limit

These results align with the findings of (Nnorom et al., 2005) and (Al-Saleh et al., 2009) who identified similar low levels of the lead contamination in cosmetics from Pakistan.

Cadmium was detected in the range of 0.001 $\mu\text{g/g}$ in CR2 Cream to 0.006 $\mu\text{g/g}$ in LP1 Lipstick. The all samples had cadmium well below than the permissible limits set by World Health Organization (WHO) for heavy metals in cosmetics (WHO, 2007). The presence cadmium in pigment rich products such as lipsticks and skin cream is consistent with its known use as a yellow-to-orange colorant in cosmetic manufacturing (Sainio et al., 2000). Even at sub- $\mu\text{g/g}$ concentrations, chronic dermal and oral exposure through daily cosmetic use may contribute to measurable cadmium body burden over time (Järup & Åkesson, 2009).

Absence of mercury in all samples is positive findings, however mercury has previously been identified at levels far exceeding WHO safety thresholds in skin-lightening products sold across South Asia and Africa (Al-Saleh et al., 2009; Kinabo, 2005). Their complete absence in the current samples may reflect the relative effectiveness of import regulations. It is important to acknowledge that this study did not include unbranded, counterfeit, or informally imported cosmetics products that are widely accessible in Pakistan's unofficial markets and may carry substantially greater mercury-related health risks (Organization, 2019).

Results of metals in this study are much lower as compared to reported in earlier Pakistani research and several international studies. Studies conducted in Pakistan has reported lead in the range of 0.012–0.089 $\mu\text{g/g}$ (Abrar et al., 2022; Ullah et al., 2017). Al-Saleh et al. (2009) detected lead up to 0.65 $\mu\text{g/g}$ in Saudi Arabian products. Even higher values up to 2.1 $\mu\text{g/g}$ were reported in Nigerian cosmetics (Ghaderpoori et al., 2020; Omolaoye et al., 2010; Safavi et al., 2019). While these comparisons suggest a favorable trend in formal-sector cosmetic safety in Sindh, the risks posed by unmonitored informal-market products

remain a pressing public health concern that warrants dedicated future investigation.

3.1 Health Risk Assessment

The metals found in this study were within permissible limits, however cumulative exposure from multiple cosmetic products remains a concern. Regular use of several products can lead to combined dermal and oral intake, making total exposure more relevant than single-product safety (Crosera et al., 2009; Ficheux et al., 2015). Lipsticks are particularly important due to ingestion during use; studies estimate daily intake of about 24 mg of lipstick, contributing to trace metal exposure (Loretz et al., 2005). Although cadmium levels observed are below tolerable intake limits set by the World Health Organization, additional exposure from diet and smoking common in South Asia may increase total body burden (Authority, 2012; Satarug et al., 2011). Given cadmium's long biological half-life, even low-level chronic exposure is significant (Organization, 2023). Therefore, cumulative risk assessment is essential for accurate evaluation of cosmetic safety.

Conclusion

This study was conducted to determine the lead, cadmium and mercury in commonly available cosmetic products in Jamshoro Pakistan. Results have showed that lead and cadmium were found in the range of 0.001 to 0.007 $\mu\text{g/g}$ and 0.001 to 0.006 $\mu\text{g/g}$ respectively. Mercury was absent in every sample. All recorded values fell within internationally recognized permissible limits set by the WHO and USP suggesting no immediate acute toxicity risk to consumers. Compared to earlier Pakistani and international literature, the concentrations recorded here reflect encouraging improvements in formal-sector cosmetic quality. However, the consistent trace-level presence of lead and cadmium across all products raises legitimate concerns about cumulative long-term exposure, particularly among frequent lipstick users and individuals with elevated dietary metal intake.

Conflict of interest

Author declares no conflict of interest

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