

## Biomonitoring of Heavy Metal Concentration of Selected Personal Care Products (PCPs) Used by Students of Clifford University, Owerinta (Ihie Campus), Abia State, Nigeria

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### Abstract:

**Background:** This study assessed the heavy metal content of selected personal care products (PCPs) used by students of Clifford University, Owerinta (Ihie Campus), Abia State, Nigeria. The presence of contaminants, particularly heavy metals, in cosmetics is a major concern due to potential health risks.

**Methods:** A total of 24 cosmetic samples, including foundations, face powders, lip glosses, and body creams, were collected from six female hostel rooms. Samples were analyzed for lead (Pb), chromium (Cr), cadmium (Cd), arsenic (As), and mercury (Hg) using atomic absorption spectrophotometry (AAS).

**Results:** Lead concentrations in face powders and lip glosses frequently exceeded Maximum Permissible Limits (MPLs) of 10.00 mg/kg, reaching as high as 20.00 ± 1.01 mg/kg. Mercury in foundations reached 5.73 ± 0.16 mg/kg, far exceeding the 1.00 mg/kg MPL. Cadmium was also above limits in foundation samples. Arsenic and chromium levels generally remained within safe limits.

**Conclusion:** Findings indicate potential health risks due to high levels of toxic metals, particularly lead and mercury. The results highlight a need for stricter regulatory controls and continuous monitoring to safeguard consumer health.

**Keywords:** *Biomonitoring; Heavy Metals; Personal Care Products; Cosmetics; Clifford University; Public Health.*

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## Introduction

The global demand for personal care and cosmetic products has grown rapidly, yet the presence of heavy metal contaminants remains a major health concern. Chronic exposure through dermal absorption or inadvertent ingestion can lead to localized reactions like contact dermatitis or systemic toxicity affecting internal organs (Silva *et al.*, 2025). The various categories of cosmetics include, but are not limited to, lipsticks and lip glosses (for enhancing lip colour), facial powders and rouges (for toning the face and creating a youthful look), mascaras (for defining eyelashes), eyeliners and eyeshadows (for eye definition), and nail polishes (for beautifying nails) (Reed, 2007). Products like lipsticks and facial creams can expose users to hazardous substances through dermal absorption or inadvertent ingestion (Tunde *et al.*, 2024).

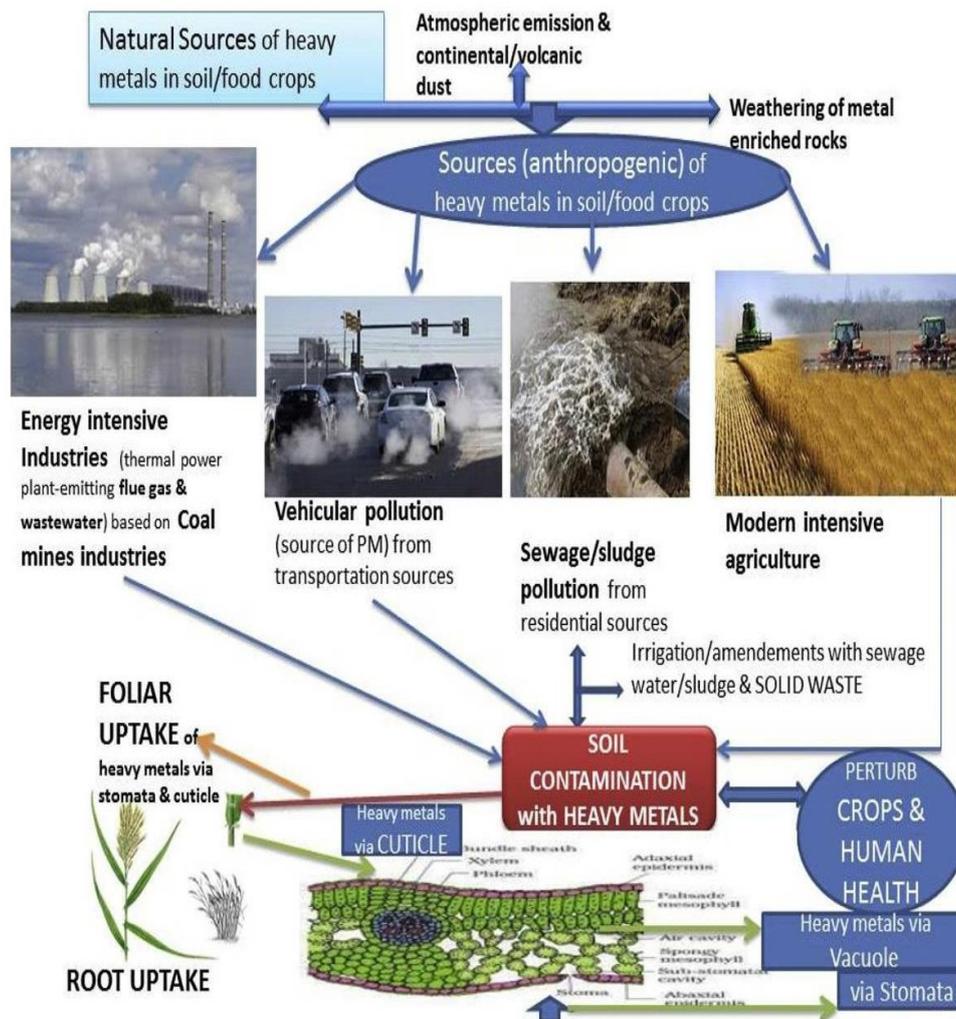
In Nigeria, many cosmetic products reach the market without mandatory clinical testing or regulatory evaluation due to loopholes in the legal framework of agencies like the National Agency for Food and Drug Administration and Control (NAFDAC). Cosmetic products are complex formulations intended for cleansing, beautifying, or modifying appearance. Human exposure typically occurs through contaminated food, water, and

air, with bioaccumulation occurring over extended periods (Onakpa *et al.*, 2018). These metals enter the environment through both natural and anthropogenic pathways. Heavy metals such as lead, cadmium, and chromium are of public health concern due to their toxicological effects on human organ systems, including the nervous, reproductive, and respiratory systems (Balali-Mood *et al.*, 2021).

These metals enter the human body via dermal absorption or ingestion, where they may bind to proteins and DNA, potentially leading to mutations or carcinogenesis. Repeated use of cosmetics containing heavy metals can lead to their accumulation in specific skin regions, which may then act as reservoirs, prolonging exposure even after product discontinuation (Franken *et al.*, 2015). In certain cases, topical inflammation can extend beyond the skin, resulting in systemic toxicity, and can penetrate deeper skin layers and reach internal organs through the bloodstream (Tamara and Everaldo, 2022). Entry pathways may include sweat glands and hair follicles. Metals binding to DNA or RNA can also lead to mutations or defective gene expression, potentially culminating in carcinogenesis (Ullah *et al.*, 2017; Tamara and Everaldo, 2022). The identification and tracking of heavy metal sources remain

critical to assessing environmental and human health risks and

ensuring sustainable soil and crop management (Rai *et al.*, 2019).



**Figure 1:** Pathways and Effects of Heavy Metal Contamination in Food Systems and Living Organisms (Source adapted from Rai *et al.*, 2019).

Previous studies have shown wide variations in metal concentrations in cosmetic brands, often influenced by differences in raw material sourcing and regulatory enforcement, and proposed a potential link between the use of underarm cosmetic products and increased incidence of breast cancer, due to the absorption and bioaccumulation of carcinogenic heavy metals in breast tissues (Arshad *et al.*, 2020; Jităreanu *et al.*, 2025). These findings underscore the toxic potential of heavy metals not only at the superficial level but also within deep-seated cellular and molecular systems. This study aims to evaluate the concentration of heavy metals (Pb, Cr, Cd, As, and Hg) in selected PCPs commonly used by students at Clifford University to raise awareness about possible health risks.

**Methods**

**Sample Collection**

Four commonly used personal care products—foundation, lip gloss, face powder, and body cream—were selected for this study. These samples were obtained from six (6) different rooms within the female hostels of Clifford University, Owerri (Ihie Campus), Abia State, Nigeria. The sampling locations were designated as L1, L2, L3, L4, L5, and L6. At each location,

samples were collected in triplicate using clean polythene bags, properly labeled to reflect their source and product type. All collected samples were immediately transported to the laboratory for further processing and analysis.

**Sample Preparation and Digestion**

The sample preparation for heavy metal analysis was conducted using an acid digestion method adapted from Sahu *et al.* (2014). Approximately 1.0 g of each cosmetic product was accurately weighed and transferred into a digestion flask. A 25 mL acid mixture containing concentrated nitric acid (HNO<sub>3</sub>) and perchloric acid (HClO<sub>4</sub>) in a 3:1 ratio was added to the flask. The digestion was carried out on a hot plate for 1 to 2 hours, continuing until the evolution of white fumes ceased, indicating complete digestion.

The resulting digests were cooled and diluted with 10 mL of distilled water, then filtered using Whatman No. 4 filter paper into 100 mL volumetric flasks. The solutions were then made up to the 100 mL mark with additional distilled water. The prepared samples were stored and subsequently analyzed for heavy metal.

**Heavy Metal Analysis**

The concentrations of lead (Pb), chromium (Cr), cadmium (Cd), arsenic (As), and mercury (Hg) were determined using an atomic absorption spectrophotometer (AAS).

**Statistical Analysis**

Data obtained from the heavy metal analysis were subjected to descriptive statistical analysis, including the computation of means and standard errors (SE) for each metal concentration across the various products and locations. All statistical analyses were performed using GraphPad Prism version 6 software to facilitate data visualization and interpretation.

**Results**

**Profile of Selected Personal Care Products (PCPs)**

The evaluation of personal care products (PCPs) collected from six distinct locations within female hostels at Clifford University, Owerri (Ihie Campus), Abia State, Nigeria, revealed

notable discrepancies in product labeling and adherence to regulatory standards. Several of the examined products lacked the mandatory NAFDAC registration numbers, with the compact powders from Locations 1 and 2, as well as the foundation from Location 5, identified as unregistered. Additionally, critical labeling details such as net weight, manufacturing date, and expiration date were absent on numerous products. For instance, the luxury radiance foundation obtained from Location 1 and the lip gloss sampled from Location 2 did not indicate either the manufacturing or expiry dates, potentially posing risks related to product efficacy and safety due to uncertain shelf life. Conversely, some products, including the body cream from Location 4 and the powder from Location 5, displayed complete and compliant labeling information, reflecting the presence of both regulated and non-compliant products among the student population.

*Table 1: List of Selected Personal Care Products (PCPs) Used by students of Clifford University, Owerri (Ihie Campus), Abia State, Nigeria*

S/N	PCP	Location	Product name	NAFDAC No	Net Weight	Manufacturing Date	Expiry Date
1	Powder	L1	Compact powder	-	06202/20g	11/2023	11/2026
2	Foundation	L1	Luxury radiance	-	45g	-	-
3	Lip gloss	L1	Asolute	-	-	2022	2025
4	Body cream	L1	Clear Therapy	0723	250ml/18.456	11/2023	11/2025
5	Powder	L2	Green tea	-	-	11/2020	11/2025
6	Foundation	L2	Normal bliss	Ny10118	-	-	-
7	Lip gloss	L2	-	-	-	-	-
8	Body cream	L2	Skin pride	0013	380ml	04/2023	04/2026
9	Powder	L3	Fair makeup	-	21.68g	2023/09	2027/09
10	Foundation	L3	Adventure	-	30ml/101/fl0z	-	-
11	Lip gloss	L3	Shine Luobalabra	CBB158	-	-	-
12	Body cream	L3	African queen	A2-5639	275ml	07/2023	07/2026
13	Powder	L4	Melilai compact	-	1bo1040313	-	-
14	Foundation	L4	HD foundation	30ml	-	-	-
15	Lip gloss	L4	Beauty model	CBB158	-	-	-
16	Body cream	L4	Body treat	02-4793	-	05/2023	05/2025
17	Powder	L5	Sacha macre	-	-	09/2023	09/2027
18	Foundation	L5	Mary kay	-	1f/02/29ml	-	-
19	Lip gloss	L5	Aloe lipgloss	-	-	-	-
20	Body cream	L5	Dove fair body smooth	LG2214	15g10.53f10.	12/12/2023	12/12/2026
21	Powder	L6	Msyaho	-	21.6g	2023/09	2023/09
22	Foundation	L6	Zaron	F002	-	09/2023	09/2026
23	Lip gloss	L6	Absolute	-	-	19/02/2024	13/08/2028
24	Body cream	L6	Skin docker	-	-	-	-

*L1 = Location 1 (Room 106), L2 = Location 2 (Room 113), L3 = Location 3 (Room 125), L4 = Location 4 (Room 200), L5 = Location 5 (Room 218), L6 = Location 6 (Room 222).*

**Heavy Metal Concentrations in Foundation Samples from Different Locations**

Analysis of foundation samples collected from various locations revealed that lead was undetectable in all samples except for the one from Location 1, which contained lead at a concentration of 0.43 mg/kg. Chromium concentrations ranged between 0.23 and 0.45 mg/kg, while cadmium levels varied from

0.37 to 0.58 mg/kg. Arsenic and mercury concentrations were recorded within ranges of 1.25 to 2.28 mg/kg and 0.21 to 5.23 mg/kg, respectively. Notably, cadmium concentrations in samples from Locations 1, 2, and 3 exceeded the World Health Organization's maximum permissible limits (MPLs). Similarly, mercury levels in samples from Locations 2, 3, 4, 5, and 6 surpassed the WHO MPLs. On a positive note, all samples

exhibited lead and chromium concentrations below the WHO-established permissible limits, suggesting relatively safe levels for

these metals in the foundation products analyzed.

**Table 2:** Heavy Metal Concentrations in Foundation Samples from Different Locations.

Heavy metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Lead, Pb	10.00	0.43 ± 0.01	ND	ND	ND	ND	ND
Chromium, Cr	1.00	BDL	0.45 ± 0.02	BDL	0.23 ± 0.01	BDL	BDL
Cadmium, Cd	0.30	0.44 ± 0.00*	0.58 ± 0.01*	0.37 ± 0.01*	BDL	BDL	BDL
Arsenic, As	3.00	1.45 ± 0.23	2.22 ± 0.45	1.85 ± 0.05	1.25 ± 0.85	1.58 ± 0.47	2.28 ± 0.10
Mercury, Hg	1.00	0.81 ± 0.01	2.3 ± 0.06*	1.83 ± 0.09*	5.23 ± 0.11*	3.42 ± 0.12*	5.73 ± 0.16*

Values represent the mean concentrations of heavy metals determined in triplicate. Sampling locations are designated as L1 (Room 106), L2 (Room 113), L3 (Room 125), L4 (Room 200), L5 (Room 218), and L6 (Room 222). Abbreviations used include BDL (Below Detection Limit), ND (Not Detected), MPLs (Maximum Permissible Limits), and \* indicating values that exceeded the MPL.

**Heavy Metal Concentrations in Face Powder Samples from Different Locations**

The concentrations of heavy metals in face powder samples collected from six different locations within the female hostels of Clifford University are summarized in Table 3. Lead levels ranged from 0.46 to 20.60 mg/kg across all samples. Chromium concentrations varied between 0.44 and 0.68 mg/kg, while cadmium was not detected in any of the samples analyzed. Arsenic and mercury concentrations ranged from 1.78 to 2.11 mg/kg and

2.45 to 3.01 mg/kg, respectively. Except for cadmium in samples from locations 1 and 4 and mercury in samples from locations 1 and 2, all measured heavy metal concentrations were within the World Health Organization’s (WHO) maximum permissible limits. These findings indicate that, although most heavy metal levels in the face powders are within safe limits, certain samples exhibited elevated cadmium and mercury levels, which may pose potential health risks to users.

**Table 3:** Heavy Metal Concentrations in ‘Face Powder’ Samples from Different Locations

Heavy metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Lead, Pb	10.00	20.00 ± 1.01*	5.21 ± 0.46	4.96 ± 0.75	18.24 ± 1.55*	3.05 ± 0.96	6.11 ± 0.71
Chromium, Cr	1.00	0.68 ± 0.01	0.44 ± 0.01	ND	0.56 ± 0.02	ND	ND
Cadmium, Cd	0.30	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic, As	3.00	ND	ND	ND	ND	2.11 ± 0.01	1.78 ± 0.09
Mercury, Hg	1.00	2.45 ± 0.01*	3.01 ± 0.05*	BDL	BDL	BDL	BDL

Values represent the mean of triplicate determinations. Sampling locations are designated as L1 = Location 1 (Room 106), L2 = Location 2 (Room 113), L3 = Location 3 (Room 125), L4 = Location 4 (Room 200), L5 = Location 5 (Room 218), and L6 = Location 6 (Room 222). Abbreviations used include BDL (Below Detection Limit), ND (Not Detected), MPLs (Maximum Permissible Limits), and \* indicating values that exceeded the MPL.

**Heavy Metal Concentrations in ‘Lip Gloss’ Samples from Different Locations**

Table 4 presents the concentrations of heavy metals in lip gloss samples collected from various locations within the female hostel rooms at Clifford University. Lead concentrations ranged between 3.22 and 15.23 mg/kg. Chromium and cadmium were not detected in any of the lip gloss samples across all six locations. Arsenic and mercury levels varied from 1.14 to 1.78 mg/kg and

0.28 to 0.32 mg/kg, respectively. All measured heavy metal concentrations fell below the World Health Organization’s (WHO) maximum permissible limits, with the exception of lead concentrations in samples from locations 1 and 4, which exceeded the recommended limits.

**Table 4:** Heavy Metal Concentrations in ‘Lip Gloss’ Samples from Different Locations.

Heavy metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Lead, Pb	10.00	10.67 ± 1.34*	15.23 ± 1.26*	7.55 ± 0.98	12.49 ± 1.26*	3.22 ± 0.85	6.11 ± 0.92
Chromium, Cr	1.00	ND	ND	ND	ND	ND	ND
Cadmium, Cd	0.30	ND	ND	ND	ND	ND	ND
Arsenic, As	3.00	1.45 ± 0.57	1.26 ± 0.15	1.14 ± 0.94	1.78 ± 0.46	1.21 ± 0.20	1.32 ± 0.74
Mercury, Hg	1.00	0.32 ± 0.01	0.28 ± 0.00	BDL	BDL	BDL	BDL

Values represent the mean of triplicate determinations; L1 = Location 1 (Room 106), L2 = Location 2 (Room 113), L3 = Location 3 (Room 125), L4 = Location 4 (Room 200), L5 = Location 5 (Room 218), L6 = Location 6 (Room 222). Abbreviations: BDL = Below Detection Limit, ND = Not Detected, MPLs = Maximum Permissible Limit, and \* indicates values that exceeded the MPL.

**Heavy Metal Concentrations in ‘Body Cream’ Samples from Different Locations**

The concentrations of heavy metals in body cream samples collected from various locations within Clifford University female hostel rooms are summarized in Table 5. Lead was not detected in any of the samples from the six locations. Chromium concentrations ranged from 0.25 to 0.51 mg/kg, cadmium ranged from 0.11 to 0.41 mg/kg, arsenic ranged from 1.03 to 2.50 mg/kg,

and mercury ranged from 1.89 to 2.78 mg/kg. Notably, all measured heavy metals were below the World Health Organization's maximum permissible limits (MPLs), except for cadmium in the sample from location 6 and mercury in samples from locations 1, 2, 3, and 4, which exceeded the WHO MPLs.

**Table 5:** Heavy Metal Concentrations in 'Body Cream' Samples from Different Locations.

Heavy metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Lead, Pb	10.00	BDL	BDL	BDL	BDL	BDL	BDL
Chromium, Cr	1.00	ND	0.25 ± 0.01	0.44 ± 0.06	ND	ND	0.51 ± 0.01
Cadmium, Cd	0.30	ND	0.20 ± 0.01	0.11 ± 0.00	ND	ND	0.41 ± 0.04*
Arsenic, As	3.00	1.37 ± 0.21	1.83 ± 0.21	2.05 ± 0.26	1.23 ± 0.11	2.50 ± 0.26	1.03 ± 0.01
Mercury, Hg	1.00	1.89 ± 0.01*	2.44 ± 0.20*	2.78 ± 0.52*	1.99 ± 0.22*	ND	ND

Values for heavy metal concentrations are expressed as the mean of triplicate determinations; L1 = Location 1 (Room 106), L2 = Location 2 (Room 113), L3 = Location 3 (Room 125), L4 = Location 4 (Room 200), L5 = Location 5 (Room 218), L6 = Location 6 (Room 222). Abbreviations: BDL = Below Detection Limit, ND = Not Detected, MPLs = Maximum Permissible Limit, and \* denotes concentrations exceeding the MPL.

## Discussion

The presence of unregulated chemical constituents in skin-lightening and cosmetic products is a significant concern, particularly in developing countries where regulatory enforcement may be weak. The European Union Cosmetics Directive explicitly prohibits lead and its compounds in cosmetic formulations due to their toxicity (Tamara and Everaldo, 2022). This study focused on commonly used cosmetic products, such as whitening creams and lipsticks, among students at Clifford University. The detection of heavy metals in several samples underscores the urgent need to understand permissible limits, considering that different age groups—especially children—are more vulnerable to heavy metal toxicity depending on usage patterns and application sites (Ababneh and Al-Momani, 2018).

Table 1 identifies 24 personal care products (PCPs) used by students across six locations, with many lacking essential regulatory features such as NAFDAC registration numbers, net weights, and expiry dates. The absence of such information, as seen in products like the compact powder from Location 1 and luxury radiance foundation, poses potential health risks due to unverified product authenticity and uncertain shelf life (Tamara and Everaldo, 2022).

Regarding heavy metals, the World Health Organization (WHO) recommends a permissible limit of 10.00 mg/kg for lead (Pb) in cosmetics. Lead was detected only in the foundation from Location 1 at 0.43 mg/kg, well below the WHO limit (Table 2). However, face powder samples from Locations 1 and 4 recorded lead concentrations of 20.00 and 18.44 mg/kg, respectively, exceeding the permissible limit (Table 3). Similarly, lip gloss from Locations 1 and 4 exhibited elevated lead levels above the WHO standard (Table 4), while body creams showed no detectable lead (Table 5). These findings are consistent with previous reports by Orisakwe and Otaraku (2013) and Lim *et al.* (2018), indicating a potential public health risk from chronic lead exposure via cosmetic use. Lead accumulation in the body may lead to kidney damage, bone demineralization, and increased cancer risk, particularly through dermal absorption or inadvertent ingestion from lip products (Vafaei *et al.*, 2018).

Chromium (Cr), found naturally in the environment, exists in various forms with different toxicities. The WHO permissible limit for chromium in cosmetics is 1.0 mg/kg. In this study, chromium concentrations ranged from 0.23 to 0.58 mg/kg in foundation and face powder samples (Tables 2 and 3) and were undetected in lip gloss and body cream (Tables 4 and 5). All detected values were below WHO limits. Despite this, chromium, especially hexavalent chromium (Cr(VI)), poses significant health risks, including carcinogenicity and allergic contact dermatitis (Piccinini *et al.*, 2013). Reports from India and Europe show sporadic chromium levels exceeding limits, emphasizing the need for continued surveillance (Malvandi and Sancholi, 2018).

Cadmium (Cd), a highly toxic heavy metal with no biological function, was detected in foundation samples at concentrations between 0.37 and 0.58 mg/kg, with levels in Locations 1 to 3 exceeding the WHO limit of 0.30 mg/kg (Table 2). Cadmium was absent in lip gloss (Table 4) but present in body cream (0.11 to 0.41 mg/kg), exceeding limits in Location 6 (Table 5). Chronic cadmium exposure can cause kidney damage, bone demineralization, and increased cancer risk, with dermal absorption and ingestion as potential exposure routes (Alam *et al.*, 2019). Cadmium also disrupts zinc-dependent enzymatic functions, catalyzes free radical generation, and is linked to carcinogenicity primarily through inhalation occupational exposure, with emerging evidence for environmental and dermal exposure risks (Chavatte *et al.*, 2020; Alam *et al.*, 2019).

Arsenic (As) concentrations ranged from 1.25 to 2.28 mg/kg in foundation samples, 1.78 to 2.11 mg/kg in face powders, and 1.14 to 2.05 mg/kg in lip gloss and body creams (Tables 2–5). These levels were below the WHO permissible limit of 3.00 mg/kg, suggesting a lower immediate risk; however, chronic exposure may still pose health hazards (Demissie *et al.*, 2024). Arsenic is a known carcinogen associated with skin lesions, cardiovascular diseases, neurotoxicity, and cancers of the skin, bladder, and lung. Even low-level chronic exposure through cosmetics demands caution due to potential bioaccumulation (Alam *et al.*, 2019).

Mercury (Hg) concentrations in several samples exceeded WHO limits, raising significant public health concerns. Mercury is a potent neurotoxin affecting the central nervous system, kidneys, and cardiovascular system. Chronic dermal exposure can result in neurological disorders, kidney damage, hypertension, and developmental impairments in fetuses and infants (Saadatzadeh *et al.*, 2019; Lim *et al.*, 2018). Mercury's accumulation in hair, blood, and urine has been documented among cosmetic users, underscoring systemic exposure risks (Soo *et al.*, 2003). Clinical manifestations of mercury toxicity include tremors, cognitive decline, sensory impairments, and autoimmune nephritis (Agorku *et al.*, 2016). Given these grave effects, stringent quality control and regulatory oversight are critical to prevent mercury contamination in cosmetics and protect vulnerable populations, particularly pregnant women and children.

## Conclusion

The analysis of cosmetic products collected from various locations within Clifford University revealed notable contamination by heavy metals, with lead, mercury, and cadmium being the most prevalent. Mercury concentrations exceeded the Maximum Permissible Limits (MPLs) in several foundation and body cream samples, while lead levels in certain face powders and lip glosses were found to be significantly above the MPL.

The widespread presence of these toxic metals across multiple cosmetic product types is alarming, given their well-documented adverse health effects. Due to the frequent and direct application of these personal care products on the skin and mucous membranes, there is a heightened risk of chronic exposure, which may contribute to serious long-term health complications.

Overall, the findings underscore the critical necessity for enhanced regulatory oversight, rigorous quality assurance, and proactive safety measures within the cosmetics industry to protect consumers from harmful heavy metal exposure.

## Recommendations

In light of the study's findings, the following recommendations are proposed to mitigate heavy metal contamination in cosmetic products:

1. **Strengthening Regulatory Frameworks:** Regulatory authorities should implement and enforce stringent guidelines for the manufacture, importation, and sale of personal care products. This includes mandatory heavy metal testing of both raw materials and finished products before market approval.
2. **Enhancing Quality Control by Manufacturers:** Cosmetic manufacturers must adopt routine and comprehensive quality control protocols that encompass periodic analysis of heavy metals to ensure compliance with established safety standards.
3. **Consumer Awareness and Education:** Targeted educational campaigns should be developed to inform consumers—particularly students and young adults—about the potential health risks associated with cosmetics containing heavy metals. Empowering consumers with knowledge will enable safer product choices.
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4. **Promotion of Safer Alternatives:** Research and development efforts should prioritize the formulation of cosmetics utilizing safer, non-toxic ingredients. Emphasizing natural and organic components may substantially reduce exposure to hazardous metals.
5. **Policy Review and Updates:** Regulatory bodies should regularly review and revise permissible heavy metal limits in cosmetic products, incorporating the latest scientific evidence and technological advances to ensure ongoing consumer protection.

## Conflict of interest

There's no conflict of interest.

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