Proceedings of Science and Mathematics
Faculty of Science,
Universiti Teknologi Malaysia
Volume 33, 2026, page 85-91

Determination of Selected Heavy Metal Concentrations in Unbranded Cosmetic Products using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)

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Abstract

The purpose of this study is to investigate the presence of selected heavy metals which are arsenic (As), cadmium (Cd), and lead (Pb) in unbranded cosmetic products which famously sold on popular platforms. Throughout the years, some findings have discovered that prolonged exposure to heavy metals can lead to several potential hazards which involve cancer, as well as sterility, and erroneous conduct. Therefore, there can be several sources of heavy metals, notably synthetic cosmetics, especially soaps and whitening creams which focused on in this research. Both whitening creams and soaps are deemed hazardous and would be sought out, particularly if their concentration levels are above the permissible limit set by the World Health Organization (WHO). However, it is important in this research to study the toxicity level of heavy metals in cosmetic products using spectroscopic instruments hence to do method validation based on their concentration detected. In addition, the unbranded cosmetic products were randomly chosen from major platforms which are TikTok and Shopee which show the highest sales among consumers in different countries. All the selected heavy metals were quantified using inductively coupled plasma-optical emission spectroscopy (ICP-OES). ICP-OES was chosen in this study because of the lowest limit of detection and simultaneously detection of heavy metals which are arsenic, cadmium and lead hence it can save time. Furthermore, the method validation was determined based on limit of detection, limit of quantification, linearity, and other parameters related to it. Some of the parameters were calculated using ANOVA in Microsoft Excel software. On the other hand, wet digestion method was used for sample preparation before analyzing the metals using ICP-OES. In this study, concentrated nitric acid (65%) was used for wet digestion method to break down the organic matter or matrices in the cosmetic samples. In addition, this method is applicable for this study because of the sample in form of semi solid and solid where it can be directly dissolved forming a solution. To sum up, the mean levels (ppm) of heavy metals were found to fall in the following ranges: In creams, As (-0.015 ± 0.00293 to -0.037 ± 0.00183), Cd (-0.0037 ± 6.67 x 10^{-5} to 0.0093 ± 0.0003) and Pb (-0.0023 ± 0.0018 to 0.4507 ± 0.0060) while in soaps, As (-0.031 ± 0.0031 to -0.02 ± 0.0032), Cd (-0.003 ± 0.0002 to -0.003 ± 0.0001) and Pb (0.0027 ± 0.0012 to 0.03533 ± 0.0013). Although the concentrations were listed below the WHO's maximum permissible limits, their presence in cosmetics can nevertheless be categorized as an impurity, an indication that these unbranded cosmetics products are potentially safe to use.

Keywords: heavy metals, arsenic, cadmium, lead, ICP-OES,

Introduction

Cosmetic products play a significant role in daily personal care routines and are widely used to enhance physical appearance, promote skin health, and improve self-confidence across diverse societies. In recent years, the demand for cosmetic products—particularly skin-whitening formulations—has increased rapidly, driven by aggressive marketing strategies and widespread availability through digital platforms such as TikTok, Shopee, and Instagram (M. Iman, 2022). Whitening creams and soaps are among the most frequently used cosmetic products, as they are perceived to reduce hyperpigmentation, lighten skin tone, and improve overall complexion by decreasing melanin production (Mylo, 2022). However, despite their popularity, growing concern has emerged regarding the safety and quality of these products, especially unbranded cosmetics that are sold at unusually low prices and often lack regulatory oversight.

One of the major safety concerns associated with cosmetic products is contamination by heavy metals, including arsenic (As), cadmium (Cd), and lead (Pb). These metals do not serve any beneficial biological function in the human body and are well documented for their toxic, carcinogenic, and bioaccumulative properties (Attard & Attard, 202; Raza-Naqvi et al., 2022). Heavy metals may be intentionally or unintentionally introduced into cosmetic formulations through contaminated raw materials, pigments, preservatives, or manufacturing processes (Dinake et al., 2023). Prolonged exposure to heavy metals, even at low concentrations, has been linked to severe health effects such as skin irritation, contact dermatitis, kidney and liver damage, neurological impairment, and increased cancer risk.

Lead is considered one of the most hazardous heavy metals commonly detected in cosmetic products. Chronic exposure to lead has been associated with neurotoxicity, hematological disorders, and impaired organ function, and studies have shown elevated blood lead levels among frequent users of certain cosmetic products (Mohiuddin, 2019;). Cadmium is another highly toxic metal, known for its carcinogenic nature and its ability to accumulate in the kidneys and bones, potentially leading to renal dysfunction and skeletal damage upon prolonged exposure (Alam et al., 2019; Lim et al., 2018). Arsenic, a metalloid with high systemic toxicity, has historically been used in cosmetic formulations and remains a contaminant of concern due to its strong association with skin disorders and malignancies (Anitha & Ray, 2018; Kerry, 2022). Recognizing these risks, international regulatory bodies such as the World Health Organization (WHO) and the Food and Drug Administration (FDA) have established maximum permissible limits for heavy metals in cosmetic products to protect consumer health.

Despite existing regulations, unbranded cosmetic products remain largely unregulated, particularly those marketed online, raising concerns about their chemical safety and long-term health implications. Several studies have reported detectable levels of heavy metals in cosmetic products that, although below regulatory limits, may still pose risks through cumulative exposure and combined product usage (Chauhan et al., 2010). Therefore, continuous monitoring and analytical assessment of heavy metal contamination in cosmetic products are essential to ensure consumer safety and regulatory compliance.

In this context, the present study aims to determine the presence and concentration of selected heavy metals which is arsenic, cadmium, and lead in unbranded whitening creams and soaps commonly sold on online platforms in Malaysia. Inductively coupled plasma–optical emission spectroscopy (ICP-OES) was employed due to its capability for simultaneous multi-element detection with high sensitivity and reliability. In addition to quantifying heavy metal concentrations, method validation parameters such as linearity, limit of detection, and precision were evaluated to ensure analytical accuracy. The findings of this study contribute valuable data on the chemical safety of unbranded cosmetic products and provide insight into potential long-term health risks associated with their continuous use.

Materials and methods

Chemicals and reagents

As, Cd, and Pb standard from Perkin Elmer, United States. Analytical grade of nitric acid from Merck, Germany and MilliQ from Millipore, USA.

Sample collection and preparation

Unbranded cosmetic products were selected to evaluate the presence of heavy metal contamination in widely used skin-whitening formulations. Two types of unbranded whitening creams (designated as WC1 and WC2) and two types of unbranded whitening soaps (designated as WS1 and WS2) were purchased in November 2023 from popular online platforms in Malaysia, namely TikTok Shop and Shopee. These platforms were selected due to their high consumer traffic and extensive sales of unregulated cosmetic products. For each product, three replicates were prepared to ensure analytical reliability. All cosmetic samples were already homogenized in their commercial form; therefore, no additional sample homogenization was required prior to analysis.

Working standard solutions were prepared by serial dilution of the stock solutions to generate calibration curves. For arsenic and cadmium, standard concentrations of 0, 0.05, 0.10, and 0.20 mg/L were prepared, while for lead, concentrations of 0, 0.10, 0.50, and 1.20 mg/L were used. These concentration ranges were selected to encompass the expected levels of heavy metals in cosmetic samples. Calibration curves were constructed by plotting emission intensity against analyte concentration, and acceptable linearity was confirmed by a correlation coefficient (R^2) greater than 0.995.

Sample Digestion Procedure

An open wet digestion method was employed to decompose the organic matrix of the cosmetic samples prior to instrumental analysis. Approximately 1.0 g of each whitening cream or soap sample was accurately weighed and transferred into a digestion vessel. Subsequently, 6 mL of concentrated nitric acid (65%) was added to each sample. The mixture was heated on a hot plate for 1 hour to ensure complete digestion of the organic components. After digestion, the samples were allowed to cool to room temperature and were then filtered using a Whatman No. 41 filter paper to remove any insoluble residues. The filtrates were quantitatively transferred into 25 mL volumetric flasks and diluted to volume with deionized water. The resulting solutions were used for heavy metal determination.

Instrumental Analysis Using ICP-OES

The concentrations of arsenic, cadmium, and lead in the digested samples were determined using inductively coupled plasma-optical emission spectroscopy (ICP-OES). This technique was selected due to its ability to simultaneously detect multiple elements with high sensitivity and low detection limits. The specific analytical wavelengths employed were 193.7 nm for arsenic, 217.0 nm for lead, and 228.8 nm for cadmium. Instrument calibration was performed prior to sample analysis using the prepared standard solutions, and quality control checks were conducted to ensure analytical accuracy.

Method validation

Method validation was carried out to assess the reliability and accuracy of the ICP-OES analytical procedure. Validation parameters included linearity, precision, accuracy, limit of detection (LOD), and limit of quantification (LOQ). Linearity was evaluated through calibration curves, with correlation coefficients exceeding 0.995 indicating excellent linear response. Precision was assessed by repeated analysis of samples and standards, while accuracy was evaluated by comparing measured concentrations against known values. The limits of detection and quantification were calculated based on standard deviation and calibration slope as shown in Equation 1 and Equation 2. Statistical analysis, including analysis of variance (ANOVA), was performed using Microsoft Excel to evaluate the reproducibility and significance of the results.

$$LOD = \frac{3.3 \times standard\ deviation}{slope\ of\ calibaration\ curve} \qquad \text{Equation 1}$$

$$LOD = \frac{3.3 \times standard\ deviation}{slope\ of\ calibaration\ curve} \qquad \text{Equation 2}$$

Data analysis

All measurements were conducted in replicate, and results were expressed as mean concentration values ± standard deviation (SD). Heavy metal concentrations were reported in parts per million (ppm). Samples with concentrations below the instrument's detection limit were recorded as below limit of detection (BLD). The measured concentrations were compared with the maximum permissible limits established by the World Health Organization (WHO) and the Food and Drug Administration (FDA) to evaluate potential safety concerns associated with the use of unbranded cosmetic products.

Results and discussion

Instrument calibration and linearity

The performance of the ICP-OES instrument was first evaluated through calibration using standard solutions of arsenic (As), cadmium (Cd), and lead (Pb). Calibration curves were constructed by plotting mean corrected emission intensity against analyte concentration, as shown in Figures 1. Excellent linearity was achieved for all three elements, with correlation coefficients (R^2) of 1.0000 for arsenic, 0.9999 for lead, and 1.0000 for cadmium (Table 1). These values exceed the minimum acceptable criterion of $R^2 > 0.995$, indicating strong linear relationships between concentration and signal response and confirming the suitability of the analytical method for quantitative determination of heavy metals in cosmetic matrices. The high degree of linearity further demonstrates the reliability and sensitivity of ICP-OES for multi-element analysis in complex cosmetic samples.

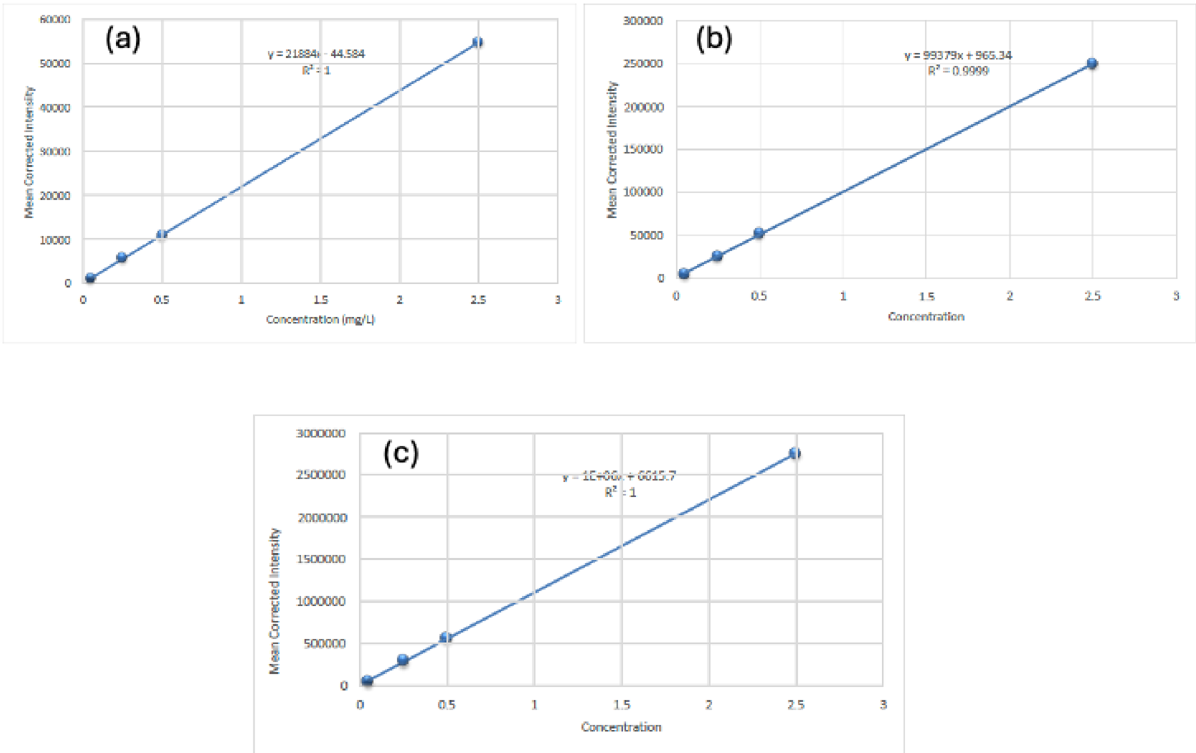

Figure 1 Calibration cure of (a) arsenic, (b) lead, nad (c) cadminum.

Table 1: Correlation coefficient and regression equation for each metal.

Instrument	Heavy metal	Correlation coefficient (R^2)	Regression equation
ICP-OES	As	1.0000	y = 21884x - 44.584
	Pb	0.9999	y = 99379x + 965.34
	Cd	1.0000	y = 1E+06x + 6615.7

Concentration of heavy metals in unbranded whitening creams

The mean concentration levels of As, Pb, and Cd in unbranded whitening creams (WC1 and WC2) are presented in Table 2. Arsenic was not detected in either cream sample, with concentrations reported below the limit of detection (BLD). The calculated negative values indicate instrumental noise or baseline fluctuation rather than actual presence of arsenic, suggesting that arsenic contamination in these products is negligible. These findings are consistent with previous reports indicating that arsenic levels in cosmetic products rarely exceed the WHO permissible limit of 3 ppm (Attard et al., 2016).

Lead was detected only in WC2, with a mean concentration of 0.45067 ± 0.00597 ppm, while WC1 showed lead concentrations below the detection limit. Although the detected lead level in WC2 is substantially lower than the maximum permissible limits established by WHO (10 ppm) and FDA (5 ppm), its presence remains a concern due to the cumulative and bioaccumulative nature of lead. Chronic exposure to low levels of lead has been associated with neurological disorders, hematological effects, and organ toxicity, particularly with prolonged cosmetic use (Mohiuddin, 2019).

Cadmium was similarly detected only in WC2 at a mean concentration of 0.00933 ± 0.00027 ppm, while WC1 exhibited cadmium levels below the detection limit. This concentration is significantly lower than the WHO permissible limit of 0.3 ppm, indicating minimal cadmium contamination. However, cadmium is a known carcinogen and nephrotoxic metal that accumulates in the kidneys and bones over time, and even trace amounts may pose health risks upon continuous exposure (Alam et al., 2019; Lim et al., 2018). The variation in metal concentrations between WC1 and WC2 may be attributed to differences in raw material sources, formulation processes, or manufacturing conditions.

Table 2: Mean concentration level of heavy metals in unbranded whitening cream.

Heavy metal	Mean concentration (ppm ± SD; n = 4)	
	WC1	**WC2**
As	BDL	BDL
Pb	BDL	0.45067±0.00597
Cd	BDL	0.00933±0.00027

Concentration of heavy metals unbranded whitening soaps

The mean concentration levels of heavy metals in unbranded whitening soaps (WS1 and WS2) are summarized in Table 3. Similar to the cream samples, arsenic and cadmium were not detected in either soap, with concentrations recorded below the limit of detection. This suggests that these metals are not significant contaminants in the soap formulations analyzed. Lead was detected in both soap samples, although at considerably lower concentrations than in whitening creams. WS1 exhibited a mean lead concentration of 0.03533 ± 0.00130 ppm, while WS2 contained 0.00267 ± 0.00117 ppm. These values are well below the regulatory limits set by WHO and FDA, indicating compliance with international safety standards. Nevertheless, the presence of lead in both soap samples highlights the potential for contamination during manufacturing or from environmental sources, such as contaminated raw materials or water used in production. Previous studies have reported similar findings, where soaps and cleansing products contained trace levels of heavy metals despite being within permissible limits.

Table 3: Mean concentration level of heavy metals in unbranded whitening soap.

Heavy metal	Mean concentration (ppm ± SD; n = 4)	
	WC1	**WC2**
As	BDL	BDL
Pb	0.03533±0.0013	0.00267±0.00117
Cd	BDL	BDL

Comparative analysis between whitening creams and soaps

A comparative analysis of heavy metal concentrations between unbranded whitening creams and soaps is presented in Table 4.4. Overall, whitening creams were found to contain higher concentrations of lead and cadmium compared to soaps, while arsenic remained below detection limits in all products. The highest concentrations of both lead and cadmium were observed in WC2, suggesting that cream-based formulations may have a greater tendency to retain heavy metal impurities due to their complex composition and prolonged skin contact. Soaps, on the other hand, contained lower levels of lead and no detectable cadmium, which may be attributed to differences in formulation, processing techniques, and usage patterns. Unlike creams, soaps are typically rinsed off shortly after application, potentially reducing the risk of dermal absorption. However, the repeated and long-term use of multiple cosmetic products may increase cumulative exposure to heavy metals, even when individual products comply with regulatory limits.

Health implication and regulatory considerations

Although all detected heavy metal concentrations in this study were below the maximum permissible limits set by WHO and FDA, the presence of lead and cadmium in unbranded cosmetic products raises concerns regarding long-term health risks. Heavy metals are non-biodegradable and can accumulate in the body over time, potentially leading to adverse health effects such as skin disorders, organ damage, and carcinogenic outcomes (Attard & Attard, 2022; Raza-Naqvi et al., 2022). The unregulated nature of unbranded cosmetic products, particularly those sold through online platforms, further exacerbates these concerns, as consumers may unknowingly expose themselves to multiple sources of heavy metal contamination. The findings of this study emphasize the importance of continuous monitoring and strict quality control of cosmetic products, especially those lacking regulatory approval. While compliance with permissible limits suggests short-term safety, long-term exposure and combined usage of multiple cosmetic products may still pose significant health risks.

Conclusion

The results obtained in this study show evidence of the presence of heavy metals in unbranded whitening products, creams, and soaps. The levels, however, were lower than those set by WHO and FDA. These results do not warrant safety though for use of these products since it is evidenced from literature that continuous use of cosmetics would be detrimental to health. Statistical analysis of experimental data showed evidence that the levels of selected heavy metals under study in the unbranded whitening products (creams and soaps) were significantly different at a 95% confidence level. This may raise alarm especially when users apply a combination of these cosmetics.

Acknowledgement

The authors declared no conflict interest and research funding.

References

Abd Wahil, M. S., Ishak, M. F. M., & Daud, F. (2020). Awareness of health effects from skin whitening product usage: a systematic review. *International Journal of Public Health and Clinical Sciences*, 6(6), 20-32.

Ahmed, A. Y., Asada, A., & Hamza, I. A. (2021). Cobalt and lead concentrations in cosmetic products sold at local markets in Saudi Arabia. *Toxicology Reports*, 8, 1693–1698.

Alam, M. F., Akhter, M. S., Mazumder, B., Ferdous, A., Hossain, M. D., Dafader, N. C., Ahmed, F., Kundu, S. K., Taheri, T., & Ullah, A. K. M. A. (2019). Assessment of some heavy metals in selected cosmetics commonly used in Bangladesh and human health risk. *Journal of Analytical Science and Technology*, 10(1), 1-8.

Anitha, J., & Ray, J. G. (2018). Toxic content of certain commercially available fairness creams in Indian market. *Cogent Medicine*, 5(1), 1433104.

Arshad, H. M., Mehmood, M. Z., Shah, M. H., & Abbasi, A. M. (2020). Evaluation of heavy metals in cosmetic products and their health risk assessment. Saudi Pharmaceutical Journal, 28(7), 779–790.

Attard, T., Attard, E., 2022. Heavy metals in cosmetics. Hosam M. Saleh, Amal I. Hassan (Eds.). Environmental Impact and Remediation of Heavy Metals, 1st ed. Intech Open, London, pp. 1–21. www.intechopen.com.

Bamidele, O. D., Kayode, B., Eniayewu, O., Adegbola, A. J., Olatoye, R. S., Njinga, N. S., Abdullahi, S. T., & Odunola-Bakare, M. T. (2021). Evaluation of hydroquinone, mercury and arsenic in skin-lightening cosmetics marketed in Nigeria. *Social Science Research Network*.

Chavatte, L., Juan, M., Mounicou, S., Noblesse, E., Pays, K., Nizard, C., & Bulteau, A. (2020). Elemental and molecular imaging of human full thickness skin after exposure to heavy metals. *Metallomics*, 12(10), 1555–1562.

Dinake, P., Motswetla, O., Kereeditse, T. T., & Kelebemang, R. (2023). Assessment of level of heavy metals in cosmetics. *Toxicology Research and Application*, 7, 239784732311566.

Jose, A., & Ray, J. G. (2018). Toxic content of certain commercially available fairness creams in Indian market. *Cogent Medicine*, 5(1), 1433104.

Kerry, G. (2022, July 29). Dangerous beauty: Hazardous chemicals and poisons in historic cosmetics. Science Museum Group Blog. https://www.sciencemuseumgroup.org.uk

Medsafe. (2021). Medsafe warning on mercury and lead in skin whitening products. Ministry of Health New Zealand. https://www.medsafe.govt.nz

Mohiuddin, A. K. (2019). Heavy metals in cosmetics: The notorious daredevils and burning health issues. *American Journal of Biomedical Science & Research*, 4(5), 332–337.

Posin, S. L. (2023, August 8). Mercury toxicity. In StatPearls. National Center for Biotechnology Information. https://www.ncbi.nlm.nih.gov/books/

Raza-Naqvi, S. A., Idrees, F., Sherazi, T. A., Anjum-Shahzad, S., Ul-Hassan, S., & Ashraf, N. (2022). Toxicology of heavy metals used in cosmetics. Journal of the Chilean Chemical Society, 67(3), 5615–5622.

Safavi, S., Najarian, R., Rasouli-Azad, M., Masoumzadeh, S., Ghaderi, A., & Eghtesadi, R. (2019). A narrative review of heavy metals in cosmetics; health risks. *International Journal of Pharmaceutical Research*, 11(4), 182-190.

Sani, A., Gaya, M. B., & Abubakar, F. A. (2016). Determination of some heavy metals in selected cosmetic products sold in kano metropolis, Nigeria. *Toxicology reports*, 3, 866-869.