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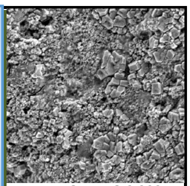

JEBAT VOL 7 NO 2 2024
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Comparative Study of Heavy Metals in Some Selected Local and Foreign Cosmetics Used in Gombe Metropolis

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ABSTRACT

Skin absorption continues to be a significant pathway for heavy metal toxicity in humans. This study investigated the concentrations of heavy metals (copper, iron, cadmium, arsenic, nickel, chromium, and lead) in locally produced and imported cosmetic products sold in Gombe Metropolis, Nigeria, using Atomic Absorption Spectrometry (AAS). Results indicated variable compliance with regulatory standards: certain metals exceeded permissible limits, while others remained within acceptable thresholds. For instance, Pb levels in Powder C1, Creams A1 and A2, Lotions B1 and B2, and Lipsticks D1 and D2 were below the 0.01 mg/kg limit. However, Arsenic (As) concentrations in Powders C1 and C2 (0.2964 mg/kg and 0.4725 mg/kg, respectively) surpassed the 0.05 mg/kg threshold. Similarly, Nickel (Ni) in these powders exceeded the 0.02 mg/kg limit, and Chromium (Cr) levels in Powder C2 (0.2981 mg/kg) and Cream A1 (0.1659 mg/kg) far exceeded the 0.05 mg/kg standard. Iron (Fe) remained within safe limits across all samples. Notably, locally manufactured cosmetics demonstrated greater adherence to permissible levels of heavy metals compared to imported products. Elevated concentrations of these metals in cosmetics pose health risks via dermal absorption or accidental ingestion, underscoring the need for stricter regulatory compliance by manufacturers to safeguard consumer health.

INTRODUCTION

Heavy metals are dense metallic elements known for their toxicity even at trace concentrations. Examples include mercury (Hg), lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), arsenic (As), zinc (Zn), and copper (Cu). As non-degradable components of the Earth's crust, these metals enter the human body through food, water, dermal contact, or inhalation [1]. While trace amounts of metals like Cu and Zn are vital for metabolic functions, elevated concentrations can induce toxicity [2]. Their environmental and health impacts stem from associations with chronic conditions such as cancer, neurological disorders, cardiovascular diseases, kidney dysfunction, respiratory ailments, and dermatological issues like contact dermatitis. Cosmetic use has been identified as a key route of human exposure to metals, contributing to sensitization and allergic reactions [3]. Cosmetics are chemically formulated products applied externally to alter appearance or odour [4–5]. Common forms include lipsticks, powders, mascaras, and nail polishes, which often contain stabilizers, oils, and surfactants [6, 4]. Rising global cosmetic consumption has heightened concerns about contaminants like Hg, Pb, Cd, and As in these products. Although heavy metals naturally occur in soil, water, and rocks, their presence in cosmetics, either through raw materials or manufacturing processes, poses risks of systemic toxicity through skin absorption or mucosal exposure. Contaminated products may trigger skin irritation, photoreactions, or sensitization. In Nigeria, public awareness of metal exposure via cosmetics remains low compared to risks from food, water, or soil [7].

Unregulated cosmetic use necessitates rigorous pre-market safety evaluations. Dermatologists caution that many cosmetics contain carcinogenic or teratogenic ingredients linked to reproductive harm and developmental defects [8]. Despite the skin's protective role, direct application of metal-laden cosmetics enables transdermal absorption, increasing risks of cancer, mutations, allergies, and respiratory issues [9–10]. Metals such

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as chromium hydroxide [$Cr(OH)_3$] and lead acetate [$Pb(C_2H_3O_2)_2$], used as colorants in lipsticks and eye shadows, exemplify intentional additives with potential adverse effects [11].

Lead (Pb) is a prevalent contaminant that can enter the body via food, water, or air. It can damage the liver, brain, and kidneys. Prolonged exposure to lead can result in hormonal imbalances, infertility, and developmental delays, leading to its classification as a human carcinogen [12–13]. Nickel (Ni) is a prevalent allergen responsible for contact dermatitis in approximately 8.6% of the global population. This figure increases to 17% for young women. Research involving animals has demonstrated that excessive exposure to nickel carbonyl [$Ni(CO)_4$] can adversely affect the liver, kidneys, and stomach [14]. Inhalation of nickel carbonyl [$Ni(CO)_4$] can induce headaches, cause illness, or potentially result in fatality. The USFDA monitors arsenic (As) in cosmetics due to its potential to induce skin lesions, cancer, and chronic toxicity.

Cadmium (Cd) is a pigment utilized in lipsticks and powders. It accumulates in the body and is associated with osteoporosis, glomerular dysfunction, and sensory loss [17–20]. Copper (Cu) is beneficial in minimal quantities; however, excessive intake can be detrimental. It frequently originates from contaminants in the raw materials utilized in cosmetic production. Mercury can substitute for copper in melanin synthesis; however, the use of copper peptides in minimal quantities is generally considered safe [21–22]. Iron (Fe) is beneficial for skin health and facilitates oxygen utilization in the body; however, excessive intake can be detrimental. It is frequently utilized to enhance the coloration of cosmetics [24–26].

Research has identified significant concentrations of iron (Fe), zinc (Zn), lead (Pb), and copper (Cu) in cosmetics. Lead and cadmium can accumulate in the body and result in complications, while nickel is a prevalent allergen [27–28]. In Gombe, Nigeria, the widespread use of cosmetics raises concerns about the potential for unregulated heavy metal content linked to raw materials or production practices [30–31]. This study assesses the safety of locally sold cosmetics against international standards to inform regulatory actions, promote safer manufacturing practices, and educate consumers about the risks of metal exposure. Findings aim to guide product selection, industry reform, and quality control efforts to protect public health [29–31].

MATERIALS AND METHODS

Study area and location

This study focuses on Gombe State, located in Nigeria's Northeastern geopolitical region, at coordinates 10.24640°N latitude and 11.16170°E longitude. The state spans approximately 20,265 km² and had an estimated population of 1.8 million according to the 2005 census. Its topography is characterized by rugged hills, undulating terrain, and mountainous landscapes in the Southeastern region, while gently sloping plains dominate the central, northern, northeastern, western, and north-western areas.

Sample collection

Eight (8) cosmetic samples, comprising both locally produced and imported products, were acquired from Gombe Main Market. These included two samples from each category: creams, lotions, lipsticks, and face powders. **Table 1** summarizes the specific brands and types of cosmetics analysed in this study.

Table 1. Overview of cosmetic samples (types and brands) evaluated in the research.

Sample code	Type	Brand name
Cream 1	Cream	Carotone
Cream 2	Cream	African queen
Lotion 1	Lotion	Paw-paw
Lotion 2	Lotion	Sateen
Lipstick 1	Lipstick	Beot beautys
Lipstick 2	Lipstick	Iman
Powder 1	Powder	Kiss beauty
Powder 2	Powder	Zainab powder

CODES 1: Represent foreign sample 2: Represent local sample

Sample preparation and digestion

All laboratory glassware was cleansed thoroughly with tap water, followed by immersion in a 5% nitric acid (HNO_3) solution for 24 hours. After acid treatment, the glass wares were rinsed repeatedly with deionized water to eliminate residual contaminants.

Sample Digestion

For digestion, 1 g of each cosmetic sample was weighed and transferred to a flask containing a 3:1 mixture of hydrochloric acid (HCl) and nitric acid (HNO_3). The mixture was heated until a pale yellow solution formed, indicating complete digestion. After cooling, 20 mL of deionized water was added, and the solution was filtered into a 100 mL volumetric flask. The volume was adjusted to the mark using additional deionized water.

Calibration Standards Preparation

Calibration standards for lead (Pb), chromium (Cr), cadmium (Cd), copper (Cu), iron (Fe), and nickel (Ni) were derived from a 1000 mg/L stock solution (GFS Fishers' AAS Reference Standard). Serial dilutions in distilled water yielded the following concentrations; Cadmium: 0, 0.5, 1.0, and 1.5 mg/L, Chromium: 0, 1, 2, and 3 mg/L, Lead: 0, 0.1, 0.3, and 0.5 mg/L, Iron: 0.5, 1.0, 1.5, and 2.0 mg/L, Nickel: 0, 0.2, 0.6, and 1.0 mg/L and Copper: 0, 1.5, 2.5, and 3.5 mg/L

Calibration Curve Development

Working standards were aspirated into an atomic absorption spectrophotometer (AAS), and absorbance readings were recorded. Calibration curves were generated by plotting absorbance against concentration for each metal.

Determination of Heavy Metals

Metal concentrations (Pb, As, Cd, Fe, Cr, Cu, and Zn) in digested samples were determined using a BUCK 205 Atomic Absorption Spectrophotometer (BUCK SCIENTIFIC, USA), with results displayed via an integrated LCD interface.

Data Analysis

A one-way analysis of variance (ANOVA) was used to determine whether there were significant differences in metal concentrations among the various categories of cosmetic products.

JEBAT, 2024, Vol 7, No 2, 42-48
https://doi.org/10.54987/jebat.v7i2.1036

When the ANOVA results indicated significance, Tukey's Honest Significant Difference (HSD) post-hoc test was applied to pinpoint specific group differences. In addition, the student's t-test was performed to compare mean metal concentrations between the two selected categories of cosmetics, considering $p < 0.05$ as statistically significant. All statistical analyses were carried out using SPSS (version XX) or R software to ensure accurate data interpretation.

RESULT AND DISCUSSION

This study examined eight (8) cosmetic samples, including four product categories (cream, lotion, face powder, and lipstick) of both local and international origin. The results, averaged across seven replicate measurements, revealed detectable concentrations of lead, copper, nickel, arsenic, cadmium, iron, and chromium in all product types analysed.

Table 2. Quantification of heavy metals in cosmetic samples.

Samples	Pb mg/kg	Cu mg/kg	Ni mg/kg	As mg/kg	Cd mg/kg	Fe mg/kg	Cr mg/kg
Cream A1	0.0000± 0.0000	0.2253± 0.0005e	0.0494±	0.0352±	B.D.L	0.0755±	0.1657± 0.0012d
			0.0001b	0.02c		0.0002e	
	0.0000±	0.0109± 0.0000a					
Cream A2	0.0000		0.0632±	0.0046± 0.0003a	0.0126± 0.0005c	0.0422±	0.0791± 0.002c
		0.1181	0.0000c			0.0001d	
	0.0000			0.0199	0.0063		
mean		0.0314±	0.0563			0.0589	0.1224
	0.000±	0.0001c		0.0103±	B.D.L		
Lotion B1	0.00000		0.1883±	0.001b		0.0259±	0.0127± 0.0000a
		0.0721± 0.0001d	0.0001d			0.0002b	
	0.0000±			0.0344±	B.D.L		
Lotion B2	0.0000	0.0518	0.0107±	0.002c		0.0107±	0.0395± 0.0001c
			0.0001a			0.0001b	
mean	0.000	0.0211± 0.0002b		0.0224	-		
			0.0995			0.0366	0.0261
Powder C1	0.0000±	0.0083± 0.0001a		0.1641±	0.0083± 0.0001a		
	0.0000	0.0147	0.2964±	0.001d		0.1536±	0.2556± 0.001d
			0.0003d		B.D.L	0.0000e	
Powder C2	0.0208±	0.0201± 0.0000b		0.1033±			
	0.0005b		0.4725±	0.0012d	0.0042	0.0766±	0.0259±0.0002e
mean	0.0104	0.0089± 0.0001a	0.0002e	0.1337		0.0001c	
			0.3845		B.D.L	0.1151	0.1408
Lipstick D1	0.0000±	0.0145		B.D.L			
	0.0000		0.0795±			0.0384±	0.2981± 0.0001b
			0.0001b		B.D.L	0.0001b	
Lipstick D2	0.0000±	0.05b		B.D.L			
	0.0000		0.0232±			0.0026±	0.0575±0.0005a
			0.0001a		-	0.0001a	
Mean	0.0000			-			
			0.0514			0.0205	0.1778
NAFDAC/WHO					0.003b		
permissible limit [20,	0.01a			0.05a			
38, 52-54]			0.02a			0.30f	0.02a

Values with different superscripts down the group are statistically different at $p<0.05$.
CODES: 1 represent foreign sample
2 represent local sample
B.D.L: Below detectable level

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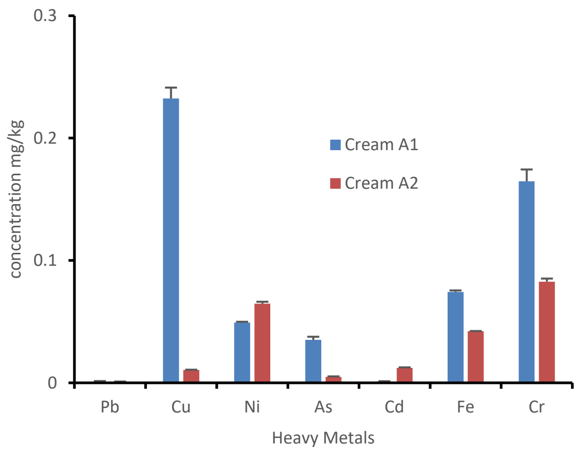

Fig. 1. Quantified heavy metal content in body cream samples.

Fig. 1 illustrates the metal concentrations in cream samples A1 and A2. Sample A1 exhibited the highest levels of copper (Cu: 0.2253 mg/kg) and chromium (Cr: 0.1657 mg/kg), while sample A2 showed elevated chromium (Cr: 0.0791 mg/kg) and nickel (Ni: 0.0632 mg/kg). These results align with Umar and Caleb [32], who reported higher Cu and Ni levels in imported creams compared to locally manufactured ones. Similarly, our findings corroborate those of Ramarant et al. [33], who detected Cr in 50% of the tested cosmetics, with concentrations ranging from 0.45 to 17.83 mg/kg. Lead (Pb) and cadmium (Cd) were either below detectable limits or present in negligible amounts across all cream samples (Fig. 1), consistent with the result of Ramankat et al. [33]. This suggests that both foreign and locally produced creams contain Pb and Cd at non-hazardous levels.

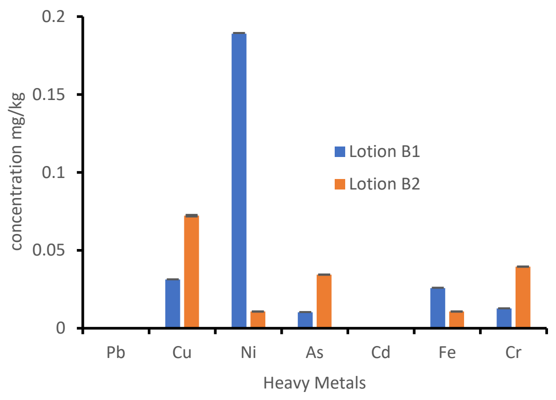

Fig. 2. Quantified heavy metal content in body lotion samples.

Evaluation of lotion samples revealed elevated nickel (Ni) levels in sample B1 (0.1883 mg/kg), while lead (Pb) and cadmium (Cd) remained undetectable across all analysed lotions at a 10% sample dilution (**Fig. 2**). These results align with Ramankat et al. [33], underscoring potential health risks, as prior research [34] associates excessive Ni exposure with hypersensitivity, skin irritation, and kidney damage. These factors may explain skin burns reported by some users. In contrast, lotion sample B2 displayed the highest copper (Cu) concentration (Fig. 2), which aligns with Umar and Caleb's findings [32], who identified elevated Cu levels in imported cosmetics.

This could originate from impurities in raw materials, leaching during manufacturing, or the deliberate inclusion of these substances in formulations. Notably, Pb and Cd levels in B2 were also below detection limits. Both imported and locally produced lotions exhibited elevated heavy metal content, with Ni and Cu being the most prevalent, highlighting the need for stricter quality control in cosmetic production.

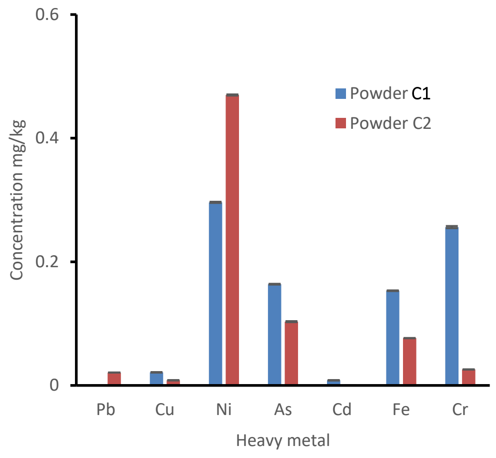

Fig. 3. Quantified heavy metal content in face powder samples.

Evaluation of powder samples revealed that both C1 and C2 exhibited the highest nickel (Ni) levels, followed by chromium (Cr), iron (Fe), and arsenic (As) in descending order, respectively (Fig. 3). These findings are consistent with those of Ayenimo et al. [35]. Lead (Pb) and cadmium (Cd) were either undetectable or present in trace amounts across all analysed powder samples at a 10% sample dilution. Notably, Ni and As concentrations in all samples surpassed permissible thresholds established by regulatory standards [27]. However, the Ni levels observed in this study were markedly lower than those documented by Onwardi et al. [36] and Chung [37].

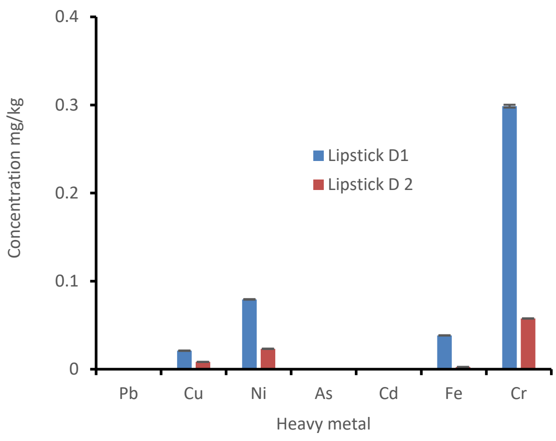

Fig. 4. Quantified heavy metal content in lipsticks samples.

Fig. 4 displays the metal concentrations in lipstick samples D1 and D2. Sample D1 showed the highest chromium (Cr: 0.2981 mg/kg), trailed closely by nickel (Ni), while sample D2 similarly exhibited elevated Cr (0.0575 mg/kg) followed by Ni (0.0232 mg/kg). These observations align with those of Umar and Caleb [32], who reported heavy metal levels in lipsticks in the order of Mn > Ni > Cu > Cd > Pb > Cr. Contrary to expectations, iron (Fe) concentrations in both local and imported lipsticks were notably lower than anticipated, diverging from Basketter et al. [25], who associated lipsticks with high Fe content due to its use as a colorant. Lead (Pb), arsenic (As), and cadmium (Cd) remained undetectable in all lipstick samples at a 10% sample dilution, consistent with Umar and Caleb's findings [32].

DISCUSSION

Lead is a harmful element that, when it interacts with vital organs, can cause damage to the liver, nerves, and kidneys [12]. Chronic exposure of lead is associated with hormonal disruptions, reproductive challenges (including miscarriages and reduced fertility), and delayed puberty in adolescent females, and its compounds are classified as suspected human carcinogens [13]. The use of traditional eye cosmetics, such as Surma, Kohl, and Alkol, has been documented to elevate blood lead levels in pediatric and female populations [38]. Biochemically, lead mimics calcium ions, disrupting bone mineralization and contributing to osteomalacia [39]. In this study, lead concentrations across eight cosmetic samples from Gombe Metropolis ranged from non-detectable to 0.0208 mg/kg (**Table 2**). Powder C2 showed the highest detectable lead level, while other products remained undetectable at a 10% sample dilution. The lead levels observed here were below those reported by Yoeza et al. [41] but higher than those found by Adepoju-Bello in lipsticks and creams [40]. This aligns with Ullah et al. [27], who documented similar lead ranges in analogous products.

Although detected concentrations were low, chronic use of such cosmetics risks progressive accumulation in tissues, potentially exacerbating organ toxicity. However, statistical analysis ($p > 0.05$) indicated no significant variations between sample categories. Cadmium (Cd) is a non-essential transition metal known for its toxicity, posing health risks to both humans and animals. Its presence can increase the excretion of low molecular weight proteins, such as β2-microglobulin and retinol-binding proteins, in urine, a condition termed proteinuria [39]. Chronic cadmium exposure may impair glomerular function [18], and its impact on bone tissue can contribute to osteoporosis [19], as well as tooth discoloration and loss of smell [20]. Dermal exposure to cadmium in cosmetics is one potential route that can lead to adverse effects, including cancer. In our study, cadmium levels in cosmetics from Gombe ranged between 0.00 and 0.0126 mg/kg (**Table 2**).

The highest cadmium concentration was found in cream A2 at 0.0126 mg/kg, followed by powder sample C1 at 0.0083 mg/kg (**Table 2**), while lipstick, lotion, cream A1, and powder C1 exhibited no detectable cadmium when 10% of the samples were examined. Although cream A2 had higher cadmium content than other samples, the overall means were not significantly different. In contrast, Yoeza et al. [41] reported cadmium levels as undetectable in products such as lipstick, eyeliner, and foundation. Their finding is notably lower than our results. These differences emphasize the importance of on-going monitoring to ensure consumer safety, and our findings align with those of Rajagopal et al. [42] and Aminat et al. [43].

Arsenic, a naturally occurring element found in the Earth's crust, is widely dispersed in air, water, and soil, and is particularly toxic in its inorganic form. Long-term exposure to inorganic arsenic can lead to chronic poisoning, with skin lesions and skin cancer being common manifestations. Arsenic is sometimes used in cosmetic pigments and is regulated by the US Food and Drug Administration (USFDA) [16]. Although earlier studies have identified arsenic in products such as eye shadows, lotions, and lipsticks, strict regulations, including a total ban, are enforced only by the European Union, as neither the US FDA nor the WHO has set definitive limits for arsenic in cosmetics [27]. Arsenic exposure interferes with DNA repair mechanisms, thereby raising the risk of cancer [44]. In Taiwan, sustained dermal exposure to inorganic arsenic has been connected to black foot disease, which severely damages blood vessels in the lower extremities [45].

Our analysis revealed that arsenic concentrations in cosmetics ranged from 0.00 mg/kg to 0.1641 mg/kg (Table 2), with powder samples (C1 and C2) exhibiting higher levels than other products, although the mean differences were not statistically significant. The descending order of arsenic concentration was: powder > cream > lotion > lipstick. These results are similar to those of Nancy et al. [46] but lower than the levels reported by Nasirudeen and Ameachi [47] and Adejupo-Bello [40]. Iron compounds are extensively used in plastics, textiles, and cosmetics due to their diverse colour range and the safety offered by various ferrous and ferric salts. Beyond its industrial applications, iron is an essential nutrient that plays a key role in oxygen metabolism and is crucial for maintaining healthy skin and its appendages. Although the benefit of iron in cosmetics for skin health remains unclear, the inherent permeability of human skin suggests that only minimal amounts of substances are absorbed topically [24].

The relatively high iron content in cosmetics is likely due to its common use as a colorant [25], yet even essential metals can be toxic in excessive amounts [26]. Ullah [27] noted that iron, along with zinc, lead, and copper, was present at higher levels than other metals in the products studied. Excessive iron absorption through the skin can damage cellular organelles such as mitochondria and microsomes [44]. Our results indicate that iron levels in cosmetics from Gombe ranged from 0.0107 mg/kg to 0.1536 mg/kg, with powder sample C1 exhibiting the highest concentration and the lotion samples showing the lowest (**Table 2**). This variability, possibly due to the brown colour of sample C1, did not yield statistically significant differences in mean values. The hierarchy of iron concentrations was: powder > cream > lipstick > lotion, which is consistent with the findings of Ekere et al. [48] and Elzbieta et al. [34], although differing from those reported by Arshad et al. [44].

Nickel is known to provoke allergic reactions upon skin contact. Animal studies suggest that high levels of nickel ingestion can harm the kidneys, stomach, and liver. Globally, nickel is a major cause of allergic contact dermatitis, affecting approximately 8.6% of the general population and about 17% of young females [14]. Increased exposure to nickel has also been associated with a heightened risk of cancers such as prostate, lung, laryngeal, and nasal cancers [49]. In our study, nickel concentrations varied from 0.0107 mg/kg to 0.4725 mg/kg (**Table 2**) and were comparatively higher than those of other metals analyzed. The ranking of nickel levels in cosmetic categories was as follows: powder > lotion > cream > lipstick. High nickel exposure is linked to hypersensitivity reactions, skin irritation, and kidney toxicity [34].

For example, a case involving a Belgian woman who used a nickel-containing eye pencil resulted in itching, dermatitis, redness, moderate scaling of the eyelids, and tissue infiltration [34]. These observations underscore the pressing need for stringent regulations to control nickel contamination in cosmetic products. Moreover, the nickel concentrations did not vary significantly among the different samples. Chromium (Cr) is a potent toxin known to induce carcinogenic changes in human cells, although its trivalent form (Cr^{3+}) is essential for normal metabolic function [42]. Excessive chromium exposure can cause skin ulcers and hypersensitivity reactions marked by redness and swelling, while prolonged exposure to hexavalent chromium (Cr^{4+}) in cosmetics can severely damage organs such as the liver, kidneys, circulatory system, and nervous system [50]. Chromium exposure has also been linked to nasal irritation, rhinitis, pulmonary congestion, and tympanic membrane perforation [27], as well as kidney disease, lung cancer, and skin allergies like dermatitis [42]. In our analysis of cosmetic products from Gombe, chromium levels ranged from 0.0127 mg/kg in lotions to 0.2981 mg/kg in lipsticks (**Table 2**), with no significant statistical differences among the samples.

The descending order of chromium concentration was: powder > lipstick > lotion > cream. These findings align with those of Nancy et al. [12], but are lower than the values reported by Usman et al. [10] and Yahya et al. [9] in various cosmetics. Copper is present in cosmetics either as an impurity from raw materials, due to leaching from manufacturing equipment, or through intentional addition. It plays a role as the active centre of tyrosine, which can be replaced by mercury, thereby inhibiting melanin production [21]. Although copper peptides are generally safe and widely used, heavy metals such as mercury, cadmium, lead, nickel, chromium, and copper are commonly found in cosmetic products [51]. Our study confirms that body creams tend to contain higher levels of copper. In the analysed samples from Gombe, copper concentrations ranged from 0.0083 mg/kg to 0.2253 mg/kg, with the lowest levels detected in lipsticks and powders, and the highest in creams (**Table 1**). The order of copper content was: lipstick = powder < lotion < cream, with no significant differences observed among the samples. These results are consistent with those reported by Yoeza et al. [41], although Nasirudeen and Amaechi [47] noted comparatively higher copper levels. In summary, most of the cosmetic products analyzed in this study contained heavy metals within the permissible limits, with notable exceptions being nickel and chromium.

CONCLUSION

This study evaluated the concentrations of heavy metals in selected cosmetic products used in Gombe Metropolis. The analysis demonstrated variable compliance with regulatory thresholds: certain metals remained within permissible limits, while others significantly exceeded established safety standards. For instance, lead (Pb) levels in Powder C1, Creams A1 and A2, Lotions B1 and B2, and Lipsticks D1 and D2 were below the 0.01 mg/kg limit. However, arsenic (As) concentrations in Powders C1 and C2 surpassed the 0.05 mg/kg threshold. Nickel (Ni) levels in these powders (0.2964 mg/kg and 0.4725 mg/kg, respectively) also far exceeded the 0.02 mg/kg limit. Chromium (Cr) levels in Powder C2 (0.2981 mg/kg) and Cream A1 (0.1659 mg/kg) were notably higher than the 0.05 mg/kg standard. Iron (Fe), however, remained within safe limits across all samples. The elevated concentrations of toxic metals like As, Ni, and Cr in cosmetics raise significant public health concerns, as chronic exposure through dermal absorption or ingestion can lead to acute or chronic health complications. Such metals, even in trace amounts, may accumulate in vital organs over time, overwhelming the body's detoxification mechanisms and causing systemic damage. Continuous use of products containing these metals, particularly those exceeding regulatory thresholds, heightens the risks of bioaccumulation, hypersensitivity, and organ dysfunction. To mitigate these risks, stricter enforcement of regulatory standards is imperative. Manufacturers must prioritize transparency by labelling metal content, enabling informed consumer choices. Regulatory agencies should mandate pre-market testing to verify compliance with safety limits. Further research is also critical to assess long-term effects of low-level metal exposure from cosmetics and refine safety guidelines.

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