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Health Risk Assessment of Heavy and Trace Metals in Personal Care Products in Nigeria

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Abstract: *Heavy metal poisoning is linked to disorders like cancer, endocrine disruption, and kidney dysfunction due to prolonged exposure to environmental pollutants. This study assesses heavy and trace metal levels in cosmetic products sold in Nigeria, including eye shadow, face powder, foundation, henna, eyeliner, and lipsticks. Using Atomic Absorption Spectrophotometry (AAS), concentrations of heavy metals (mercury, arsenic, cadmium, lead, nickel) and trace metals (iron, chromium, zinc) were determined. A health risk assessment based on the Margin of Safety (MoS), calculated from systemic exposure dosage (SED) and No Observed Adverse Effect Level (NOAEL), was conducted. Face powders and eyeliners showed concerning iron and lead levels, with MoS values indicating potential health risks from prolonged use. The highest heavy metal concentration (262.850 ppm of iron) was found in henna, while the lowest (0.001 ppm) was observed in various products. The findings highlight the need for stricter regulatory oversight to mitigate these risks.*
Keywords: Heavy metals, Trace metals, Personal Care Product (PCP), Nigeria, Atomic Absorption Spectrophotometry, Comparative assessment

INTRODUCTION

The global use of personal care products has increased significantly in recent years, with a diverse range of products catering to the needs of consumers across all demographics. These products, which include face powders, lipsticks, eyeliners, and henna, are applied to various external parts of the body and mucous membranes for beautification, cleansing, or enhancing appearance. However, widespread use of cosmetics raises concerns about the potential health impacts of contaminants, such as heavy metals, that may be absorbed through the skin or inhaled during product application. Heavy metals, including arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), and nickel (Ni), are of particular concern due to their toxicity and potential to cause long-term health effects. These metals have been linked to various health issues such as cancer, endocrine disruption, neurological disorders, and organ damage (Gupta *et al.*, 2017; Martins *et al.*, 2021). Lead and cadmium have been found in levels exceeding permissible limits in some cosmetic products, raising significant health concerns (Al-Saleh *et al.*, 2020).

The situation is even more alarming in countries with limited regulatory oversight, such as Nigeria, where cosmetics may contain higher concentrations of these metals. Previous studies, such as those by Odukudu *et al.* (2018) and Oduola *et al.* (2019), have reported elevated levels of lead and cadmium in lipsticks and face powders sold in Nigeria. Despite these findings, comprehensive data on the presence of both heavy and trace metals in various brands of cosmetic products in Nigeria remains limited.

LITERATURE/THEORETICAL UNDERPINNING

Numerous studies have investigated the heavy metal content in cosmetics, but there remains a lack of comprehensive data on both heavy and trace metals in cosmetic products commonly used in Nigeria. This study is significant as it not only measures heavy metals but also analyzes trace metals in various personal care products such as henna and eyeliner. These are extensively used by individuals across different age groups and socioeconomic backgrounds, including children. Additionally, this study focuses on local cosmetics that are popular among diverse cultural groups in Nigeria. By providing a comparative analysis of different brands, this research offers valuable insights for consumers and regulators. It also highlights the need for stricter regulatory standards to ensure the safety of cosmetic products used by a broad spectrum of the population.

METHODOLOGY

Study Design
This comparative study analyzed different brands of face powder, lipsticks, foundation, eye shadow, eyeliner, and henna obtained from local markets and supermarkets in Lagos, Nigeria.

Sample Collection
Samples were obtained from four brands of face powder, lipsticks, foundation, eye shadow, and three brands of eyeliner and henna from Mushin market, Lagos, Nigeria. The samples were chosen based on their popularity and price range to represent a wide spectrum of products available to consumers.

Sample Preparation
Samples were digested using a combination of nitric acid and perchloric acid. The face powders and lipsticks were dry-ashed, while the foundations, kajal, and henna were wet-digested. The digested samples were then filtered and diluted for analysis.

Atomic Absorption Spectrophotometry (AAS)
Standard solutions were prepared for calibration, and the concentrations of heavy and trace metals in the samples were determined using an atomic absorption spectrophotometer.

Health Risk Assessment
The Margin of Safety (MoS) is a widely used parameter in risk assessment to estimate the potential danger of human exposure to metallic contaminants in facial cosmetic products. It is defined as the ratio of the No Observed Adverse Effect Level (NOAEL) to the Systemic Exposure Dosage (SED) for each metal:

$$MoS = \frac{NOAEL}{SED}$$

The systemic availability of a cosmetic substance is calculated by considering the amount of the product applied to the skin daily, the concentration of metals present in the cosmetic product, the dermal absorption rate of the metals, and the body weight of the individual.
The systemic exposure dosage (SED) is given by the formula:

$$SED\ (\mu g\ kg^{-1}\ bw\ day^{-1}) = \frac{CS*AA*SSA*F*RF*BF}{BW}\ x\ 10^{-3}$$

Where:

- Cs is the mean concentration of the metal in the cosmetic product (mg/kg).
- AA is the amount of facial cosmetic product applied daily (g). In this study, the estimated daily application was 0.3 g.
- SSA is the skin surface area to which the product is applied (cm^2). By standard assumption, the density of the product was 0.005 g/cm^2, resulting in an applied surface area of 60 cm^2.
- RF is the retention factor, set at 1.0, indicating full retention of the product on the skin.
- F is the frequency of product application per day, assumed to be 1.
- BF is the bio accessibility factor.
- BW is the body weight (kg). A default body weight of 60 kg was used in this study.

All the values for AA, SSA, and RF used in this study were based on standard values established by the Scientific Committee on Consumer Safety (SCCS, 2012).
No Observed Adverse Effect Level (NOAEL)
For each metal, the NOAEL is calculated using the relationship:
NOAEL = RFD × UF × MF
Where

- RFD is the reference dose for the metal (mg/kg/day) (EPA, 2016; WHO, 2007)
- UF is the uncertainty factor, which accounts for variability in human sensitivity and data reliability. In this study, the default value for UF was 100.
- MF is the modifying factor, used to account for scientific judgment in risk assessment. The default value for MF was set at 1.

Reference Doses (RFD) for Metals
The following RFDs were used for the metals under study (in mg/kg/day):

- Lead (Pb): 4×10^{-3} (EPA,2016)

- Cadmium (Cd): 1×10^{-3} (WHO, 2007)
- Chromium (Cr): 3×10^{-3} (EPA,2016)
- Zinc (Zn): 3×10^{-1} (WHO, 2007)
- Iron (Fe): 7×10^{-1} (WHO, 2007)
- Nickel (Ni): 2×10^{-2} (WHO, 2007)
- Arsenic (As): 1.5×10^{-4} (EPA,2016)
- Mercury (Hg): 3×10^{-4} (WHO, 2007)

These RFD values were used to compute the NOAEL for each metal, which in turn, was used to calculate the MoS. This methodological approach allows for a comprehensive evaluation of the safety of metallic contaminants in facial cosmetic products, considering both the exposure level (SED) and the threshold for adverse effects (NOAEL), thereby offering insights into the potential health risks associated with the use of these products.

Data Analysis
Data were reported as mean ± SEM. Two-way ANOVA was used to compare the values and test for significance at 0.05, followed by Tukey's multiple comparison test. All statistical analyses were performed using GraphPad Prism version 9.1.0 (2021).

RESULTS/FINDINGS

Face Powder Result
Heavy metals and trace metals are contained in different brands of face powder. AAS reveals that FP2 has the highest level of iron (164.635 ± 8.475 ppm) compared with FP3, FP1, and FP4. FP3 has the second highest level of iron compared with FP1. Additionally, the zinc level of FP2 shows a significant increase compared with FP3. Interestingly, the level of heavy metals in FP2 was low compared to the other powders, although there is no significant difference.

Brands	Heavy and Trace Metal							
	As (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	Fe (ppm)	Zn (ppm)	Cr (ppm)
FP1	0	2.600 ± 0.1	0	0.001 ± 0.0	0	99.050 ± 0.65	5.101 ± 0.018	0.062 ± 0.0001
FP2	0	0.970 ± 0.045	0	0.001 ± 0.00	0	164.635 ± 8.475[a,c]	8.925 ± 0.325	0
FP3	0	1.590 ± 0.045	0	0.001 ± 0.00	0.046 ± 0.001	112.330 ± 0.88[a]	3.026 ± 0.075b	1.051 ± 0.061
FP4	0.039 ± 0.002	1.230 ± 0.035	0.070 ± 0.001	0.001 ± 0.00	0	70.515 ± 1.565[a,b,c]	3.713 ± 0.002	0.055 ± 0.005

Table 1: Face Powder Result (Results are expressed in mean ± standard deviation, with superscripts showing statistical difference at P < 0.05.)

Henna Result

Heavy metals and trace metals were detected in different brands of henna. Analysis reveals significant variations in the concentration of metals between local and branded henna products. The black branded paste exhibited the highest levels of lead (Pb) and zinc (Zn) compared to the red branded paste and local henna. On the other hand, the red branded paste had the highest concentrations of nickel (Ni) and chromium (Cr) when compared to the black paste and local henna. Interestingly, local henna contained the lowest levels of most heavy metals, except for iron (Fe), where it demonstrated the highest concentration among all samples.

Brands	Heavy and Trace Metal							
	As (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	Fe (ppm)	Zn (ppm)	Cr (ppm)
Local	0	1.240 ± 0.03	0	0	0.050 ± 0.001	262.850 ± 2.48	1.600 ± 0.05	1.300 ± 0.04
Branded paste (red)	0.035 ± 0.001	5.785 ± 0.225^{a}	0.060 ± 0.003	0	13.700 ± 0.34^{a}	29.040 ± 0.01^{a}	30.450 ± 0.25^{a}	6.265 ± 0.045^{a}
Branded paste (black)	0.011 ± 0.002	8.720 ± $0.03^{a,b}$	0.813 ± 0.002	0.004 ± 0.00	10.105 ± $0.115^{a,b}$	48.620 ± $0.5^{a,b}$	54.250 ± $0.35^{a,b}$	4.450 ± 0.05^{a}

Table 2: Henna Result (Results are expressed in mean ± standard deviation, with superscripts showing statistical difference at P < 0.05).

Eyeliner Result

The concentrations of heavy metals and trace metals were assessed in different brands of eyeliner. The analysis shows that E3 contains the highest levels of lead (Pb), zinc (Zn), chromium (Cr), and cadmium (Cd) compared to E1 and E2. Interestingly, E1 exhibits the lowest levels of mercury (Hg) and zinc (Zn) but has the highest concentration of iron (Fe) when compared with the other brands. E2, on the other hand, has the lowest levels of lead (Pb) and cadmium (Cd) among the three brands.

Brands	Heavy & Trace Metal							
	As (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	Fe (ppm)	Zn (ppm)	Cr (ppm)
E1	0.562 ± 0.003	18.210 ± 0.06	0.009 ± 0.00002	29.826 ± 0.176	0.352 ± 0.015	108.545 ± 0.604	3.492 ± 0.021	0.001 ± 0.00005
E2	0.014 ± 0.001	2.004 ± 0.003^{a}	0	42.895 ± 0.255^{a}	0.065 ± 0.002	59.707 ± 0.357^{a}	11.277 ± 0.357^{a}	0.089 ± 0.001
E3	0.075 ± 0.003	56.815 ± $0.038^{a,b}$	1.116 ± $0.004^{a,b}$	47.030 ± $0.25^{a,b}$	0.027 ± 0.001	45.275 ± $1.035^{a,b}$	45.275 ± $1.035^{a,b}$	33.814 ± $0.287^{a,b}$

Table 3: Eyeliner Result (Results are expressed in mean ± standard deviation, with superscripts showing statistical difference at P < 0.05).

Lipstick Result

The analysis of different lipstick brands for heavy metals and trace metals reveals the following patterns. L2 contains the highest concentration of lead (Pb) compared to the other brands. In contrast, L3 shows the highest levels of cadmium (Cd), chromium (Cr), zinc (Zn), nickel (Ni), and iron (Fe). L1 has the lowest levels of heavy metals, excluding Pb and mercury (Hg), when compared with the other brands. There is no significant difference in the levels of arsenic (As) and mercury (Hg) among the four lipstick brands.

Brands	Heavy & Trace Metal							
	As (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	Fe (ppm)	Zn (ppm)	Cr (ppm)
L1	0.095 ± 0.001	1.394 ± 0.008	0	0.001 ± 0.00005	0	4.165 ± 0.001	0.082 ± 0.001	0
L2	0	10.655 ± 0.095^{a}	0.269 ± 0.009	0.042 ± 0.001	0.757 ± 0.008^{a}	98.938 ± 0.362^{a}	0.939 ± 0.012^{a}	10.503 ± 0.083^{a}
L3	0	0.939 ± 0.011^{a,b}	1.097 ± 0.023^{a,b}	0	12.881 ± 0.210^{a,b}	116.140 ± 0.240^{a,b}	2.246 ± 0.014^{a,b}	25.014 ± 0.086^{a,b}
L4	0.040 ± 0.001	7.227 ± 0.001^{a,b,c}	0.841 ± 0.002^{a,b}	0.001 ± 0.0	5.892 ± 0.015^{a,b,c}	77.481 ± 0.251^{a,b,c}	1.965 ± 0.01^{a,b}	0^{b,c}

Table 4: Lipstick Result (Results are expressed in mean ± standard deviation, with superscripts showing statistical difference at P < 0.05).

Foundation Result

The analysis of different foundation brands for heavy metals and trace metals reveals the following trends. F3 contains the highest levels of arsenic (As), lead (Pb), nickel (Ni), and iron (Fe) compared to the other brands. F2 exhibits the highest concentration of zinc (Zn). There is no significant difference in the levels of mercury (Hg), chromium (Cr), and cadmium (Cd) among the four foundation brands. F1 shows the lowest levels of arsenic, cadmium, and zinc compared to the other brands.

Brands	Heavy & Trace Metal							
	As (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	Fe (ppm)	Zn (ppm)	Cr (ppm)
F1	0	2.063 ± 0.009	0	0.001 ± 0	0.023 ± 0.001	12.492 ± 0.08	0.196 ± 0.001	0.009 ± 0.00005
F2	0.028 ± 0.001	1.794 ± 0.014	0.111 ± 0.002	0.001 ± 0.00	0.010 ± 0.001	9.390 ± 0.09^{a}	5.150 ± 0.05^{a}	0
F3	5.293 ± 0.058^{a,b}	3.250 ± 0.03^{a,b}	0.253 ± 0.002	0	10.64 ± 0.01^{a,b}	46.000 ± 0.6^{a,b}	2.760 ± 0.02^{a,b}	0.185 ± 0.005
F4	0c	0.514 ± 0.002^{a,b,c}	0.145 ± 0.003	0.001 ± 0.00	0.002 ± 0.00^{c}	33.340 ± 0.22^{a,b,c}	3.025 ± 0.015^{a,b}	0.026 ± 0.002

Table 5: Foundation Result (Results are expressed in mean ± standard deviation, with superscripts showing statistical difference at P < 0.05).

Eye Shadow Result

The analysis of different eye shadow brands for heavy metals and trace metals reveals the following observations. ES1 exhibits the highest levels of lead (Pb) and iron (Fe) among the brands. ES2 shows the highest concentration of nickel (Ni). ES4 has the highest zinc (Zn) level compared to the other brands. There are no significant differences in the levels of arsenic (As), cadmium (Cd), mercury (Hg), and chromium (Cr) among the four eye shadow brands.

Brands	Heavy & Trace Metal							
	As (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Ni (ppm)	Fe (ppm)	Zn (ppm)	Cr (ppm)
ES1	0	1.377 ± 0.689	0.362 ± 0.001	0.001 ± 0.00	0.110 ± 0.01	18.585 ± 0.075	0.144 ± 0.002	0.112 ± 0.001
ES2	0.184 ± 0.001	0.183 ± 0.001[a]	0.022 ± 0.0005	0.010 ± 0.001	3.716 ± 0.066[a]	11.239 ± 0.082[a]	1.373 ± 0.002[a]	0.039 ± 0.005
ES3	0.064 ± 0.002	0.097 ± 0.001[a]	0	0.006 ± 0.0001	0.028 ± 0.002[b]	16.726 ± 0.046[a,b]	0.606 ± 0.015	0.285 ± 0.01
ES4	0.144 ± 0.001	0.096 ± 0.002[a]	0.004 ± 0.00005	0.007 ± 0.0002	0.066 ± 0.001[b]	10.370 ± 0.023[a,b,c]	1.906 ± 0.003[a,c]	0.251 ± 0.002

Table 6: Eye Shadow Result (Results are expressed in mean ± standard deviation, with superscripts showing statistical difference at $P < 0.05$).

	SED (µg/kg/day)							
Brand	Pb	Cd	Ni	Fe	Zn	Cr	As	Hg
Face Powder	0.0005	0.0000	0.0000	0.0335	0.0016	0.0001	0.0000	0.0000
Henna	0.0016	0.0001	0.0024	0.0341	0.0086	0.0012	0.0000	0.0000
Eyeliner	0.0077	0.0001	0.0000	0.0214	0.0060	0.0034	0.0001	0.0120
Lipstick	0.0015	0.0002	0.0015	0.0223	0.0004	0.0027	0.0000	0.0000
Foundation	0.0006	0.0000	0.0008	0.0076	0.0008	0.0000	0.0004	0.0000
Eye Shadow	0.0001	0.0000	0.0003	0.0043	0.0003	0.0001	0.0000	0.0000

Table 7: Systemic Exposure Dosage (SED) of the Mean Concentration of Metals in Different Brands of Facial Cosmetic Products

Brand	MoS							
	Pb	Cd	Ni	Fe	Zn	Cr	As	Hg
Face Powder	835	19048	579710	21	1926	3425	5128	100000
Henna	254	1145	838	21	348	250	3261	75000
Eyeliner	52	889	45045	33	500	88	230	52
Lipstick	264	604	1365	31	7645	113	1481	9091
Foundation	700	2620	2498	92	3594	18182	38	133333
Eye Shadow	3042	3436	6803	164	9928	5822	510	16667

Table 8: Margin of Safety (MoS) for Metals Based on the Mean Concentration in Different Brands of Facial Cosmetic Products

The estimated Systemic Exposure Dosage (SED) and Margin of Safety (MoS) for various metals in facial cosmetic products, including face powder, henna, eyeliner, lipstick, foundation, and eye shadow, are presented in Tables 7 and 8. The SED and MoS values provide critical insights into the potential health risks associated with exposure to heavy metals through these products.

DISCUSSION

The analysis of heavy and trace metals in various cosmetic brands sold in Nigeria reveals significant variability in metal concentrations, raising important health concerns. This variability, combined with the Systemic Exposure Dosage (SED) and Margin of Safety (MoS) results, highlights the potential risks posed to consumers from these products.

For instance, FP2 face powder exhibited the highest levels of iron, raising concerns about iron overload, which can lead to oxidative stress and cellular damage (Torti & Torti, 2013). Despite this, FP2 contained lower concentrations of other toxic heavy metals. Overall, face powders showed elevated levels of zinc and lead, although the concentrations of other metals were lower compared to previous studies (Ali *et al.*, 2016), indicating possible regional differences in formulations or regulatory practices. The SED for iron in face powders was 0.033489 µg/kg/day, with an MoS of 20.90, suggesting a relatively low margin of safety for iron exposure, highlighting the need for caution with long-term use.

The black branded henna paste contained the highest concentrations of lead and zinc, corroborating Lanphear's (2005) concerns about lead toxicity, particularly in children. Conversely, local henna had lower levels of these metals, except for iron, suggesting it may be relatively safer. The SED for lead in henna was 0.001575 µg/kg/day, and while this is within acceptable limits, the MoS of 254.05 for lead in henna suggests the need for further scrutiny, especially for children. These findings align with previous research (Ibrahim *et al.*, 2016).

Eyeliner brands showed high levels of lead, zinc, chromium, and cadmium, metals known to increase the risk of cancer and cardiovascular issues (Waalkes, 2003; Lanphear *et al.*, 2005). Notably, eyeliners had higher lead concentrations compared to Kilic (2020), which may reflect differences in formulation or production processes. The SED of lead in eyeliners was 0.007703 µg/kg/day, with an MoS of 51.93, the lowest among the products, signaling a higher potential risk of lead exposure.

Similarly, lipsticks contained elevated levels of lead, nickel, and iron, consistent with findings by Arshad *et al.* (2020). Although chromium levels were lower, possibly reflecting differences in ingredients or regulatory standards, the MoS for lead in lipsticks was 263.83, indicating a manageable risk. However, nickel in lipstick, with an MoS of 1,365.42, posed minimal health concerns based on the SED calculations.

Foundation F3 presented alarming levels of arsenic, lead, nickel, and iron. While Yonma *et al.* (2023) reported similar levels for cadmium and lead, our study found higher concentrations of nickel, zinc, and chromium. The SED for lead in foundation was 0.000572 µg/kg/day, with an MoS of 699.82, indicating some risk, but still within acceptable limits. However, the relatively lower MoS for iron and nickel in foundations suggests that prolonged use could still present health risks.

Eye shadows like ES1 and ES2 exhibited high levels of lead, iron, and nickel, aligning with findings by Nzekwe *et al.* (2016). However, Nzekwe *et al.* reported higher concentrations of arsenic, cadmium, chromium, mercury, and zinc, possibly due to differences in formulations. The MoS for lead in eye shadows was 3,042.40, suggesting minimal risk of lead exposure.

Implication to Research and Practice

The findings from this study provide valuable data for both consumers and regulators. The results indicate that stricter regulations are required to mitigate the health risks posed by heavy metals in cosmetic products, particularly for products like eyeliners, face powders, and henna that showed higher concentrations of metals such as iron and lead. Continuous monitoring and regulation of cosmetic products will promote safer practices and reduce health risks.

CONCLUSION

This study provides critical comparative data on the heavy and trace metal content in different brands of cosmetic products sold in Nigeria. While many of the cosmetic products analyzed were found to have metal concentrations within acceptable safety margins, certain products, particularly eyeliners, face powders, and foundations, contained potentially harmful levels of heavy metals such as lead, cadmium, and iron. These metals pose significant health risks, including cancer, endocrine disruption, neurological disorders, and organ damage, especially given their frequent use across various demographics, including children. The Systemic Exposure Dosage (SED) and Margin of Safety (MoS) analysis highlighted that iron and lead were the most concerning metals, particularly in face powders and eyeliners, where the MoS values indicated relatively higher risks. Although nickel and cadmium levels in most products were within safer limits, the potential for long-term exposure underscores the need for continuous monitoring and stricter regulations.

Future Research

Future research should focus on evaluating a broader range of cosmetic products across different regions and assessing the long-term health impacts of chronic exposure to heavy metals through these products.

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