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Assessing the Hidden Public Health Risks of Heavy Metal Exposure through Facial Cosmetics (Foundation and Face Powder) in Calabar, Nigeria

[1]Emuru, Edward O., [2]Odey, Michael O., *[3]Udiba, Udiba U., [3]John Ama, [4]Amah Joseph E., [5]Sam-Uket Nwuyi O., [6]Ekanem, Sarah N.

[1]Department of Medical Biochemistry, University of Cross River State, Nigeria
[2]Department of Biochemistry, University of Calabar, Calabar, Nigeria
*[3]Department of Zoology and Environmental Biology, University of Calabar, Nigeria
[4]Department of Geography and Environmental Science, University of Calabar, Nigeria
[5]Department of Animal and Environmental Biology, University of Cross River State, Nigeria
[6]Department of Biological Sciences, Akwa Ibom State Polytechnic, Ikot Usurua, Akwa Ibom, Nigeria
*udiba.udiba@unical.edu.ng; udiba.udiba@yahoo.com.

Abstract

The study examined the heavy metal concentrations in facial cosmetics (Foundation and Face Powder) sold in four major markets in Calabar, Nigeria and the potential health risk for users. A total of 288 samples of four commonly used brand of foundation and face powder were purchased and analyzed over a period of six month, using Atomic Absorption Spectrophotometer (AAS) after wet digestion. The contents of foundation and powder were of the ranges: 0.105-0.433mg/kg and 0.067-0.430mg/kg, 0.103-0.288mg/kg and 0.183-0.339mg/kg, 0.165-0.371mg/kg and 0.077-0.332mg/kg, 0.276-0.904mg/kg and 0.341-0.843mg/kg, 0.034-0.357mg/kg and 0.254-0.702mg/kg, 0.034-0.357mg/kg and 0.254-0.702mg/kg and 0.043-0.109mg/kg and 0.065-0.113mg/kg for lead, cadmium, chromium, cobalt, nickel and iron respectively. The concentrations of metals under study all within the statutory standards given by WHO. The margin of safety (MoS), hazard quotient (HQ) and hazard index (HI) values for all the heavy metals were within the acceptable limits. Lifetime cancer risk (LCR) value was higher than the permissible limit (10^{-4}) in all the facial cosmetic products. The study concluded that, the use of these facial cosmetic products exposes users to carcinogenic risk. Public health enlightenment is strongly recommended.

Introduction: Cosmetics such as face powder and foundation are an essential part of daily beauty regimens for many persons, serving not only aesthetic purposes but also foster self-expression and self-confidence. The use of various cosmetics for personal care dates back to the dawn of humanity. The demand for cosmetics has risen drastically over time, all around the world, because people are increasingly concerned about their physical appearance and seek to improve it (Ullah, Rehman, Waseem, Zubair, Adnan, & Ahmad, 2017). However, growing evidence has raised concerns about the safety of these products, particularly regarding the presence harmful substances. Cosmetic products are regulated for health and safety, because of the presence of harmful chemicals in them, such as heavy metals. Even at low exposure levels, heavy metals including lead, cadmium, mercury, arsenic, and chromium which are frequently present in face cosmetics, pose serious health hazards because of their toxic nature. Cosmetics are made up of a variety of organic and inorganic ingredients. Mineral pigments are extensively employed in the production of colour cosmetics, resulting in the contamination of cosmetics with heavy metals (HMs), such as Cu, Ni, Co, Pb, Cr, Cd, and other elements.The HMs are intentionally added to cosmetic ingredients like colours, preservatives, UV filters, antiperspirants, antifungal, and antibacterial agents (Burger, Landreau, Azoulay, Michel, & Fernandez, 2016). These are of industrial and dermatological values. Yet, have some adverse effects on the body (Locatelli, Furton, Tartaglia, Sperandio, Ulusoy, & Kabir, 2019; Burger *et al.*, 2016). Sometimes, metals in cosmetics are contaminants that gain entry during production, distribution and use. Because of their antibacterial and antifungal qualities, certain metals and parabens are used as preservatives in cosmetics. It has been found that metals and parabens are also endocrine disruptors, which can easily be absorbed into the skin (Tartaglia, Kabir, Ulusoy, Sperandio, Piccolantoni, Ulusoy, & Locatelli, 2019). It is not just about the absorption, the health effects these materials exert on the skin and other parts of the body. Metals in cosmetics do not only whiten the skin, but they also peel the skin (Burger *et al.,* 2016). The peeling depends on the skin type.

It is the sustained efforts to checkmate the extent to which metals and parabens are put in cosmetic products that every country has a cosmetics regulatory body. The rising scholarly interest in, and investigation into cosmetics, rose from the recent discovery that cosmetic ingredients have adverse effects on both internal and external body organs of the users. Sequel to that realization, different dermatological studies have been carried out. A few examples suffice here: Jan, Azam, Siddiqui, Ali, Choi, & Haq, (2015) carried out skin tests to determine the capacity of certain products to penetrate or absorb certain chemicals and their toxicity. Bocca, Pino, Alimonti, & Forte, (2014) demonstrate that although the stratum corneum, the skin's outermost protective layer, does not allow for deep penetration, traces of HMs found in cosmetics may reach the circulatory system. Some metals tend to collect in the stratum corneum and induce allergic reactions, while others are diffusible in sweat, tears, and sebum excretion and may pass through the skin appendages or trans-cellular and intra-cellular pathways to enter the human blood circulatory system. As a result, everyday use of numerous cosmetic items may increase HM exposure to the human body (Brzoska, Galażyn-Sidorczuk, & Borowska, 2018). Skin allergies, extreme redness, swelling and ulcers, cellular death, DNA damage, oxidative stress, neurotoxicity, cognitive loss, reproductive failure, and carcinogenic health impacts may all occur from increased heavy metal exposure (Bocca *et al.*, 2014). This study aims to evaluate the exposure to heavy metals through the use of facial cosmetics, specifically foundation and face powder, in Calabar, Nigeria. By assessing the levels of heavy metals in these products and estimating the potential health risks to consumers, this research will contribute to a better understanding of the public health implications and inform strategies to mitigate these risk.

Materials and Methods: Administration of questionnaire: Three hundred (300) questionnaire were administered to randomly selected female responded, 18 year and above, at the four major markets in Calabar (8 miles, Marrian, Watt, and Mbukpa market), the University of Calabar and The University of Cross River State following Iwegbue, Bassey, Obi, Tesi, & Martincigh, (2016). The questionnaires were structured to obtain information about the commonly used brands of foundation and power in Calabar. The questionnaire revealed that Classic, Zaron, Tara and Davis were commonly used foundation and powder in Calabar.

Sample collection: Sample collection protocol was adopted from Udeme, Udiba, Akpan, & Antai, 2020). Three pieces each of the four commonly used brands of foundation and powder were bought from each of the four market once in two months. It was ensured that all the samples for a given sampling day belong to the same batch of the product. Sampling was carried out three times over a period of six months. Ninety six (96) samples of foundation and powder were collected on each sampling day. A total of 288 samples were collected and used for the study. Collected samples were transported to Biochemistry laboratory, University of Calabar for preparation and analysis.

Preparation and analysis of samples: The three pieces of each product (Foundation and powder) from the same market were thoroughly mixed together to form a composite sample for the product. 20g of the composite sample was digested with concentrated nitric and hydrochloric acid mixture ratio 3:1 on a hot plate, filtered into 50ml volumetric flask using Wattman No. 1 filter paper and made up to the make with distilled water. The concentration of metals in the digest was determined using the Buck 211VGP atomic absorption spectrophotometer (AAS).

Health Risk Assessment: Potential health risk via the exposure to Pb, Cd, Cr, Co, Ni, and Fe in foundation and powder brands under investigation was assessed following US-EPA, (2011) model using systemic exposure dosage (SED), safety margin assessment, the hazardous quotient, hazard index, and lifetime cancer risk.

Margin of safety (MoS)

Margin of safety is an uncertainty factor defined by SCCS, (2012), as the ration of the lowest no observed adverse effect level (NOAEL) value of the metal under study to the systemic exposure dosage (SED), as shown in equation 1 below:

$$\text{MoS} = \frac{\text{NOAEL}}{\text{SED}} \ldots (1)$$

Systemic exposure dosage (SED): The SED predicts the amount of chemicals that enter into human body by various exposure means. It was calculated using equation 2 following SCCS, (2012) equation 2

$$\text{SED (mg/kg/d)} = \frac{\text{Cs} \times \text{AA} \times \text{SSA} \times \text{F} \times \text{RF} \times \text{BF} \times 10{-}3}{\text{BW}} \ldots (2)$$

Where:
(i) Cs indicates metal concentration in the sample (mg/kg);
(ii) SSA is the surface area of skin onto which the product is applied (cm2);
(iii) AA shows the quantity applied (g/cm^2);
(iv) RF is the retention factor; F indicates the application frequency of a product per day;
(v) BF is the bio-accessibility factor, 10^{-3} (mg/kg) is used as the unit conversion factor;
(vi) BW is the average body weight (70 kg).

The lowest no observed adverse effect level (NOAEL) value was calculated using equation 3

NOAEL = RfD × UF × MF... (3)
Where:
(i) UF is an uncertainty factor (reflects overall confidence in the various data sets).
(ii) MF is a modifying factor (based on the scientific judgment).
(iii)RfDs represent dermal reference doses ($mg\ kg^{-1}d^{-1}$) of different metals.

Thedefault values for MF and UF are 1 and 100 respectively. The dermal reference doses for Cd, Cr, Fe, Ni, and Pb are 0.005, 0.015,140, 5.4, and 0.42 mg/kg/d (US-EPA, 2011; Kadiri, Etonihu, Opaluwa, & Kigbu, 2020).

Hazardous Quotient (HQ) and Hazard Index (HI): The hazard quotient (HQ) is the ratio of systemic exposure dosage (SED) of a substance to the dermal reference dose (RfD) of each metal (USEPA, 2011; Liu, Hammond, & Rojas-Cheatham 2013). The HQ was calculated using equation 4.

$$\text{HQ} = \frac{SED}{RfD} \ldots (4)$$

The summation of hazard quotients for all the heavy metals is the hazard index (HI). It is computed to evaluate human health risk due to the exposure of all metallic impurities. The HI value was calculated following El-Aziz, Abbassy, & Hosny (2017) equation 5

$HI = \Sigma HQ = HQ_{Pb} + HQ_{Cd} + HQ_{Cr} + HQ_{Co} + HQ_{Ni} + HQ_{Pb}$...(5)

Lifetime Cancer Risk (LCR): The lifetime cancer risk is usually investigated for carcinogenic metals. In this study, LCR was determined following El-Aziz *et al*., (2017), equation 6

$LCR = SED \times SF$ ... (6).

Where SF represents the carcinogenicity slope factor $(mg/kg/d)^{-1}$. The reported slope factor for Pb, Cr, Ni, and Cd are 0.0085, 0.5, 0.91, and 6.7 $(mg/kg/d)^{-1}$ respectively (USEPA, 2011; WHO (2008).

Statistical Analysis: To evaluate any significant differences in metal concentration between the brand of each product (foundation and powder), the analysis of variance (ANOVA) test was employed. ANOVA was also used assess the difference in metals concentrations between the three batches of each product brand. Probabilities less than 0.05 ($p < 0.05$), was regarded as statistically significant. Depending on whether the homogeneity test resulted in a value more than or less than 0.05, the Duncan multiple test or Donnette T was utilized for multiple comparisons across sampling months.

Results: Quality assurance: Two hundred and fifty seven (257) correctly completed questionnaires were recovered out of the three hundred (300) that were administered in order to ascertain the commonly used brands of foundation and powder in Calabar. Analysis of data obtained from the 257 questionnaires revealed that 66.6 % of respondents settled for four brands of the products (Zaron, Tara, Classic, and Davis). The four brands of foundations and powder were mostly selected by respondents between 18 and 45 age bracket.

Heavy metals concentrations in foundation: Results obtained from the determination of heavy metal concentrations in the foundation are presented in Table 1.Table 1 indicates that the mean concentrations of lead in the different brands of the foundation were: 0.354±0.001, 0.172±0.002, 0.106±0.002, and 0.430±0.003 mg/kg for Classic, Zaron, Tara, and Davis respectively. The variation in lead concentration between the different products was significant (ANOVA, $p \leq 0.05$).Lead concentration followed the trend: Davis > Classic >Zaron> Tara. The mean concentrations of cadmium were: 0.286±0.002, 0.285±0.003, 0.222±0.002, and 0.106±0.003 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The difference in cadmium concentration between the products was significant (ANOVA, $p \leq 0.05$). The cadmium concentration in foundation followed the sequence: Classic = Zaron> Tara > Davis.The mean concentrations of chromium were: 0.168±0.003, 0.256±0.004, 0.318±0.001, and 0.368±0.003 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The variation in chromium concentration between the different products was significant (ANOVA, $p \leq 0.05$). Chromium concentration followed the trend: Davis> Tara>Zaron> Classic.The mean concentrations of cobalt were: 0.894±0.009, 0.622±0.009, 0.282±0.007 and 0.381±0.007 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The difference in cobalt concentration between the products was significant (ANOVA, $p \leq 0.05$). Cobalt concentration followed the sequence: Classic>Zaron> Davis> Tara.The mean concentrations of nickel were: 0.040±0.007, 0.349±0.007, 0.323±0.009 and 0.085±0.007 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The variation in nickel concentration between the different products was significant (ANOVA, $p \leq 0.05$). Nickel concentration followed the trend: Zaron> Tara> Davis> Classic.The mean concentrations of iron were: 0.081±0.019, 0.088±0.019, 0.098±0.019, and 0.065±0.019 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The difference in iron concentration between the different products was not significant. The difference in metal concentrations between the different batches of the brands of foundation under study was not significant (ANOVA, $p > 0.05$).

Heavy metals concentrations in face powder: Results obtained from the determination of heavy metal concentrations in face powder are presented in Table 2. Table 2 indicates that the mean concentrations of lead in the different brands of face powder were: 0.428±0.002, 0.276±0.001, 0.067±0.001, and 0.230±0.002 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The variation in lead concentration between the different products was significant ($p \leq 0.05$). Lead concentration followed the trend: Classic >Zaron> Davis > Tara. The mean concentrations of cadmium were: 0.209±0.001, 0.184±0.001, 0.338±0.002, and 0.261±0.003 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The difference in cadmium concentration between the products was significant (ANOVA, $p \leq 0.05$). Cadmium concentration in powder followed the sequence: Tara> Davis> Classic>Zaron. The mean concentrations of chromium were: 0.101±0.002, 0.330±0.002, 0.079±0.002, and 0.256±0.002 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The variation in chromium concentration between the different products was significant (ANOVA, $p \leq 0.05$). Chromium concentration followed the trend: Zaron> Davis> Classic> Tara. The mean concentrations of cobalt were: 0.417±0.007, 0.825±0.006, 0.353±0.017, and 0.834±0.008 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The difference in cobalt concentration between the products was significant (ANOVA, $p \leq 0.05$). Cobalt concentration followed the sequence: Davis= Zaron> Classic> Tara. The mean concentrations of nickel were:0.284±0.007, 0.260±0.007, 0.695±0.007, and 0.652±0.014 mg/kg for Classic, Zaron, Tara, and Davis, respectively. The variation in nickel concentration between the different products was significant (ANOVA, $p \leq 0.05$). Nickel concentration followed the trend: Tara> Davis> Classic>Zaron. The mean concentrations of iron were: 0.092±0.019, 0.102±0.019, 0.092±0.019, and 0.087±0.019 mg/kg for Classic, Zaron, Tara and Davis, respectively. The difference in iron concentration between the different products was not significant (ANOVA, $p \leq 0.05$). The difference in metal concentrations between the different batches of the brands of foundation under study was not significant (ANOVA, $p > 0.05$).

TABLE 1: Heavy metals concentrations in foundation (mg/kg)

	Pb	**Cd**	**Cr**	**Co**	**Ni**	**Fe**
CLASSIC	0.354±0.001[a]	0.286±0.002[a]	0.168±0.003[a]	0.894±0.009[a]	0.040±0.007[a]	0.081±0.019[a]
Range	0.353-0.355	0.283-0.287	0.165-0.170	0.887-0.904	0.034-0.048	0.059-0.092
ZARON	0.172±0.002[b]	0.285±0.003[a]	0.257±0.004[b]	0.622±0.009[b]	0.349±0.007[b]	0.088±0.019[a]
Range	0.171-0.174	0.283-0.288	0.254-0.261	0.614-0.631	0.344-0.358	0.066-0.099
TARA	0.106±0.002[c]	0.222±0.002[b]	0.318±0.001[c]	0.282±0.007[c]	0.323±0.009[c]	0.098±0.019[a]
Range	0.105-0.108	0.220-0.224	0.318±0.319	0.276-0.290	0.316-0.334	0.076-0.109
DAVIS	0.430±0.003[d]	0.106±0.003[c]	0.368±0.003[d]	0.381±0.007[d]	0.085±0.007[d]	0.065±0.019[a]
Range	0.428-0.433	0.103-0.109	0.366-0.371	0.375-0.389	0.079-0.093	0.043-0.076
*WHO**(mg/kg)**	10.00	3.00	0.50	4.00	0.20	30.00
NAFDAC/HEALTH CANADA(mg/kg)**	10.00	3.00	1.50	25.00	0.40	40.00
***US FDA**(mg/kg)**	10.00-20	3.00	50.00	20.00	200.00	20.00

Means with different superscript within a column,indicates significant difference in metal concentration, (ANOVA, $p \leq 0.05$)

WH**O, (2011), * NAFDAC, (201**9b)**;** Health Canada, (2011), *******USFDA,(2015).

Health risk assessment: Systemic exposure dosage (SED): The Average systemic exposure dosage (SED) values for foundation and powder were: 0.109 and 0.103 for lead, 0.093 and0.103 for cadmium, 0.114 and 0.079 for chromium, 0.224 and 0.225 for cobalt, 0.082 and 0.195 for nickel and 0.034 and 0.038 for iron.

Margin of safety (MoS): The average margin of safety (MoS) values for foundation and powder were: **0.00052** and **0.00064** for lead, **5.14×10^{-6}** and **5.5×10^{-6}** for cadmium, **1.48×10^{-5}** and **2.68×10^{-5}** for chromium, **1.05×10^{-5}** and **9.25×10^{-6}** for cobalt, **0.014** and **0.004** for nickel, and **0.419** and **0.366** for iron.

Hazardous Quotient (HQ) and Hazard Index (HI) for foundation and powder: The hazard quotient (HQ) values for foundation and powder were: 0.260 and 0.248 for lead, 18.509 and20.418 for cadmium, 7.619 and 5.253 for chromium, 11.212 and 12.500 for cobalt, 0.015 and 0.0360 for nickel and 0.00025 and 0.000273 for iron. The hazard index for the different brands of foundation were: 0.000273, 43.534, 32.929, and 27.094 for Classic, Zaron, Tara, and Davis, respectively. The hazard index for the different brands of powder were: 29.051, 41.470, 37.382, and 45.897 for Classic, Zaron, Tara, and Davis, respectively.

Lifetime Cancer Risk (LCR): The Lifetime Cancer Risk (LCR) values for foundation and powder were: 0.00093 and 0.00088 for lead, 0.620 and0.684 for cadmium, 0.057 and 0.040 for chromium, 0.075 and 0.177 for nickel, respectively.

Discussion: Heavy metals concentrations in foundation: The mean concentrations of lead, cadmium, chromium, cobalt, nickel, and iron in the tested foundation brands (Classic, Zaron, Tara, and Davis) were found to be below the maximum allowable limits set by the World Health Organization (WHO), National Agency for Food & Drug Administration and Control (NAFDAC), Health Canada, and the United States Food and Drug Administration (US-FDA) for facial cosmetics (Table 1). This indicates that these products can be considered safe for human use regarding the heavy metals analyzed. However, lead and cadmium, being purely toxic elements with no known physiological benefits, pose potential long-term health risks. Lead is a possible human carcinogen and neurotoxin with no safe exposure threshold (Udiba, Ogabiela, Hammuel, Magomya, Yebpella, & Ade-Ajayi, 2012). Its presence in cosmetics raises concerns due to its neurotoxic, nephrotoxic, and hepatotoxic effects, as well as its potential impact on the reproductive system (Odey, Udiba, Adindu, Enyievi, Edu, Eteng, Uboh, & Emuru, (2022). Julius, Doe, & Smith, (2020) reported that regular users of facial cosmetics have thrice the blood lead levels compared to non-users. Cadmium, used in cosmetics for its vibrant salts, is a known human carcinogen capable of causing dermatitis, tissue accumulation, and systemic toxicities following topical application (Massadeh, El-Khateeb, & Ibrahim, (2017); Alam, Akhter, Mazumder, Ferdous, Hossain, Dafader, Ahmed, Kundu, Taheri, & Ullah, 2019). Chromium and cobalt, while present in trace amounts essential for normal physiological functions, can be toxic at elevated levels. Chromium (III) is poorly absorbed and relatively less toxic, whereas Chromium (VI) compounds are highly toxic (Udeme et al., 2020). Cobalt, primarily found as Co^{2+}, may cause sensitization and irritation upon prolonged exposure (Lim, Ho, & Hamsan, (2017). Nickel, another trace element, is an allergen that can cause skin sensitization, dermatitis, and respiratory toxicity, including nasal and lung cancers (Halicz et al., 2015; Yonma, Akporhonor, Agbaire, & Kpomah, 2023).

Comparison with other studies shows consistency and variations in metal concentrations. Hamna, Moniba, Munir, Magomya, & Arshad, (2020) reported significantly higher lead levels (1.94–3.95 mg/kg) in foundations sold in Pakistan, while Alaa, Mariam, Ali, Bayan, Afrah, Shafuq, Ghaidaa, Omniyah, & Azizah, (2023) reported much lower levels (0.02–0.05 mg/kg) in Saudi Arabia, aligning with the findings of this study. Similarly, cadmium concentrations in this study align with those reported by Yonma et al. (2023) in Delta State, Nigeria, and Alaa et al. (2023) in Saudi Arabia, but are lower than levels reported by Nasirudeen and Amaechi (2015) in Kaduna, Nigeria. Chromium levels in this study are far lower than the high concentrations (9.86–71.6 mg/kg) reported by Bayero, Kiyawa, & Firdausi, (2019) in Kano but are consistent with lower concentrations found in Pakistan and Delta State (Hamna et al., 2020; Yonma et al., 2023). Cobalt concentrations are comparable to those reported by Ullah et al. (2017) in Pakistan but significantly lower than those reported by Amel, Ageela, & Hamza, (2021) in Saudi Arabia. Nickel concentrations align with the findings of Yebpella, Magomya, Lawal, Gauje & Oko, (2014) in Wukari, Nigeria.

Heavy metal concentrations in face powder: Lead, cadmium, chromium, cobalt, and iron concentrations in the analyzed face powder brands (Classic, Zaron, Tara, and Davis) were found to be within acceptable limits set by the WHO, NAFDAC, Health Canada, and US-FDA standards, suggesting their safety for human use. However, nickel concentrations exceeded WHO, NAFDAC, and Health Canada limits (0.20 mg/kg) but remained below the US-FDA standard (200 mg/kg), implicating nickel in potential health risks. Nickel is a known allergen linked to contact dermatitis and chronic inflammation (Thyssen & Menne, 2010; Ricciardi & Milani, 2008). Chronic exposure to nickel, a Group 1 carcinogen (IARC, 2012), may pose long-term cancer risks. Previous studies revealed regional variations in heavy metal concentrations in face powders. Iwegbue et al. (2016) reported higher lead (5.9–3400 mg/kg) and cadmium (2.10–5.0 mg/kg) levels in Delta, Nigeria, compared to lower levels recorded in Enugu and Kaduna States (Ekere et al., 2014; Sani, Gaya, & Abubakar, (2016).. Chromium levels in this study were comparable to Sani et al. (2016) (0–0.012 mg/kg) but lower than Iwegbue, Bassey, Obi, Tesi, & Martincigh, (2016) (4.60–233 mg/kg). Iron and cobalt levels reported by Iwegbue et al. (2016) (157–47100 mg/kg and 5.2–15.2 mg/kg, respectively) were significantly higher than values observed by Ekere, Ihedioha, Oparanozie, Ogbuefi-Chima, & Ayogu, (2014) (0.085–0.121 mg/kg for cobalt). Nickel concentrations in Abraka, Delta State (5.30–27.7 mg/kg) also exceeded levels found in this study (Iwegbue et al., 2016).

TABLE 2: Heavy metal concentration in face powder (mg/kg)

	Pb	Cd	Cr	Co	Ni	Fe
CLASSIC	0.428±0.002[a]	0.209±0.001[a]	0.101±0.002[a]	0.417±0.007[a]	0.284±0.007[a]	0.092±0.019[a]
Range	0.427-0.430	0.209-0.211	0.100-0.103	0.409-0.423	0.279-0.292	0.070-0.103
ZARON	0.277±0.001[b]	0.184±0.001[b]	0.330±0.002[b]	0.825±0.006[b]	0.260±0.007[b]	0.102±0.019[a]
Range	0.276-0.278	0.183-0.184	0.328-0.332	0.822-0832	0.254-0.268	0.079-0.113
TARA	0.067±0.001[c]	0.338±0.002[c]	0.079±0.002[c]	0.353±0.017[c]	0.695±0.007[c]	0.092±0.019[a]
Range	0.067-0.068	0.335-0.339	0.077-0.081	0.341-0.372	0.688-0.702	0.070-0.103
DAVIS	0.230±0.002[d]	0.261±0.003[d]	0.256±0.002[d]	0.834±0.008[b]	0.652±0.014[d]	0.087±0.019[a]
Range	0.229-0.233	0.258-0.263	0.254-0.257	0.829-0.843	0.636-0.660	0.065-0.098
***WHO (mg/kg)**	10.00	3.00	0.50	4.00	0.20 mg/kg	30.00 mg/kg
****NAFDAC/HEALTH CANADA (mg/kg)**	10.00	3.00	1.50	25.00	0.40 mg/kg	40.00 mg/kg
*****US FDA (mg/kg)**	10.00-20	3.00	50.00	20.00	200.00 mg/kg	20.00 mg/kg

Means with different superscript within a column, indicates significant difference in metal concentration, (ANOVA, $p \leq 0.05$)

*** WH**O, (2011), **** NAFDAC, (201**9b)**;** Health Canada, (2011), ******* US FDA, (2015).

TABLE 3

Systemic exposure dosage (SED) for the different brands of foundation and face powder (mg/kg except otherwise stated)

SAMPLE		Pb	Cd	Cr	Co	Ni	Fe
FOUNDATION	CLASSIC	0.14582	0.11768	0.06926	0.36796	0.01651	0.03338
	ZARON	0.07066	0.11750	0.10554	0.25607	0.14391	0.03624
	TARA	0.04369	0.09135	0.13089	0.11609	0.13306	0.04031
	DAVIS	0.17728	0.04364	0.15144	0.15682	0.03491	0.02673
	Mean	**0.109**	**0.093**	**0.114**	**0.224**	**0.082**	**0.034**
POWDER	CLASSIC	0.17636	0.08623	0.04159	0.17181	0.11701	0.03787
	ZARON	0.11411	0.07563	0.13587	0.33987	0.10710	0.04194
	TARA	0.02777	0.13924	0.03247	0.14512	0.28594	0.03787
	DAVIS	0.09486	0.10725	0.10522	0.34315	0.26848	0.03599
	Mean	**0.103**	**0.102**	**0.079**	**0.250**	**0.195**	**0.038**
	PTDI (mg/kg^{-1}bw day^{-1})	0.025	0.056	0.23	0.12	0.84	**>45**

TABLE 4: Margin of safety (MoS) for the different brands of foundation and face powder (mg/kg)

SAMPLE		Pb	Cd	Cr	Co	Ni	Fe
FOUNDATION	CLASSIC	0.00029	4×10^{-8}	0.000025	0.000005	0.03271	0.41941
	ZARON	0.00059	0.000004	0.000014	0.000008	0.00375	0.38631
	TARA	0.00096	0.000005	0.000011	0.000017	0.00406	0.34731
	DAVIS	0.00024	1.15×10^{-5}	0.000009	0.000012	0.01547	0.52376
	Mean	**0.00052**	**5.14×10^{-6}**	**1.48×10^{-5}**	**1.05×10^{-5}**	**0.01399**	**0.41919**
POWDER	CLASSIC	0.00024	0.000006	0.000036	0.000011	0.00461	0.36969
	ZARON	0.00037	0.000007	0.000011	0.000006	0.00504	0.33381
	TARA	0.00151	0.000004	0.000046	0.000014	0.00189	0.36969
	DAVIS	0.00044	0.000005	0.000014	0.000006	0.00201	0.38899
	Mean	**0.00064**	**5.5×10^{-6}**	**2.68×10^{-5}**	**9.25×10^{-6}**	**0.00339**	**0.36555**

TABLE 5: Hazard quotient (HQ) and hazard index (HI) for the different brands of foundation and face powder (mg/kg)

SAMPLE		HQ_{Pb}	HQ_{Cd}	HQ_{Cr}	HQ_{Co}	HQ_{Ni}	HQ_{Fe}	HI
FOUNDATION	CLASSIC	0.34719	23.536	4.61733	18.398	0.00306	0.00024	28.52528
	ZARON	0.16824	23.5	7.036	12.8035	0.02665	0.00026	43.53434
	TARA	0.10402	18.27	8.726	5.8045	0.02464	0.00029	32.929
	DAVIS	0.42209	8.728	10.096	7.841	0.00646	0.00019	27.0935
	Mean	**0.26039**	**18.5085**	**7.61883**	**11.21175**	**0.01520**	**0.00025**	**33.02053**
POWDER	CLASSIC	0.41990	17.246	2.77267	8.5905	0.02167	0.00027	29.05101
	ZARON	0.27969	15.126	9.058	16.9935	0.01983	0.00029	41.46972
	TARA	0.06612	27.848	2.16467	7.256	0.05295	0.00027	37.3817
	DAVIS	0.22586	21.45	7.01467	17.1575	0.04972	0.00026	45.8972
	Mean	**0.24789**	**20.4175**	**5.25250**	**12.49938**	**0.03604**	**0.000273**	**38.44991**

TABLE 6: Lifetime cancer risk (LCR) and Cumulative cancer risk (CCR) from the different brands of foundation and face powder (mg/kg)

*Lifetime Cancer Risk (LCR) values between 10-4 (0.0001) to 10-6 (0.000001) are considered safe (IRIS, 2007; WHO, 2008; USEPA, 2010).

SAMPLE		Pb	Cd	Cr	Ni	CCR
FOUNDATION	CLASSIC	0.00124	0.78846	0.03463	0.01502	0.83935
	ZARON	0.0006	0.78725	0.05277	0.13096	0.97158
	TARA	0.00037	0.61205	0.06545	0.12108	0.79895
	DAVIS	0.00151	0.29239	0.07572	0.03177	0.40139
	Mean	**0.00093**	**0.62004**	**0.05714**	**0.07471**	**0.75282**
POWDER	CLASSIC	0.00149	0.57774	0.02079	0.10648	0.70651
	ZARON	0.00097	0.50672	0.06794	0.09746	0.67309
	TARA	0.00024	0.93291	0.01624	0.26021	1.20959
	DAVIS	0.00081	0.71858	0.05261	0.24432	1.01632
	Mean	**0.00088**	**0.68399**	**0.03939**	**0.17712**	**0.90138**

Comparison of Metal Levels between Different Brand of Foundation and Face Power (Classic, Zaron, Tara, and Davis): The significant difference observed in lead, cadmium, chromium, cobalt, and nickel concentration between the different brands of foundation and face powder could be attributed factors which may include:

Differences in Raw Materials: Different cosmetic companies obtain their raw materials from different sources, some of which may naturally contain higher concentrations of specific heavy metals.

Manufacturing Processes: The methods and standards used during manufacturing can influence the final metal concentrations. Brands with stricter quality control measures may have lower levels of heavy metals due to better purification processes.

Use of Contaminated Additives or Colorants: Some brands may include pigments, dyes, or other additives that contain heavy metals. These ingredients are often critical for achieving certain colors or textures in foundations but can vary greatly in their metal content.

Formulation Differences: Each brand may use a unique combination of ingredients, which can affect the metal concentrations. Some ingredients inherently contain or attract more metals, depending on their chemical properties.

Packaging Materials: Heavy metals could also leach into products from the packaging materials, especially if the packaging is not well-regulated or tested for such contamination.

Brand Reputation and Price Point: High-end brands might invest more in ingredient sourcing, testing, and quality assurance, leading to lower levels of contaminants, whereas cheaper products may compromise on such controls.

Comparison of Metal Levels between Different Batches of Foundation and Face Powder Brands (Classic, Zaron, Tara, and Davis)

The absence of significant differences in metal concentrations between different batches of a given brand of foundation implies consistency in the manufacturing process. It suggests that the brand maintains similar levels of metal content across different batches, indicating standardized production practices. This consistency could reflect quality control measures that ensure the product's formulation remains stable over time. This uniformity could also imply that the potential health risks related to metal exposure from a given brand of foundation would be similar regardless of the batch. However, consistent exposure across batches could pose a steady risk to consumersif harmful levels of metals are present.

Health risk assessment: The systemic exposure dosage (SED) values for heavy metals in foundation and face powders analyzed in this study exceeded the Provisional Tolerable Daily Intakes (PTDI) for cadmium, chromium (III), cobalt, and nickel, highlighting toxicological risks associated with their use. Although the PTDI for lead is no longer used due to its neurotoxic effects and the lack of a safe exposure level (WHO, 2003), its historical threshold of 0.0036 mg/kg body weight per day (0.025 mg/day for a 70 kg adult) serves as a benchmark for comparison. Other PTDI values for cadmium, chromium (III), cobalt, and nickel correspond to 0.056 mg/day, 0.23 mg/day, 0.12 mg/day, and 0.84 mg/day for an average adult weighing 70 kg (WHO, 2004; WHO, 2008; WHO, 2010). Chromium (VI), a known carcinogen, does not have a tolerable daily intake, with risk assessments focusing on minimizing exposure entirely. Excessive iron intake, though essential for physiological processes, can be toxic above 45 mg/day (WHO, 2004).

The calculated Margin of Safety (MoS) values for heavy metals in the products were below 100, indicating that these cosmetics are not safe for regular use. Furthermore, Hazard Quotient (HQ) and Hazard Index (HI) values for cadmium, chromium, and cobalt were greater than unity (>1), underscoring their potential threat to human health. Lead, cadmium, chromium, and nickel are classified as carcinogenic heavy metals by the International Agency for Research on Cancer (IARC, 2012). The Lifetime Cancer Risk (LCR) and Cumulative Cancer Risk (CCR) values for cadmium, chromium, and nickel exceeded the acceptable range for carcinogens (1×10^{-6} to 1×10^{-4}) as defined by the U.S. Environmental Protection Agency (USEPA, 2006; Loh et al., 2007), further emphasizing the long-term cancer risk from these metals.

Conclusion: Based on the findings made, the study concluded that facial cosmetics sold in Calabar major markets had low concentrations of the heavy metals studied. The metallic content of the examined facial cosmetics were below the permissible level stipulated by the regulatory agencies. Continuous use and frequent, though unintended, ingestion of these products, either through the mouth or the eyes as the case may be, exposed users to low concentrations of toxic heavy metals, which could constitute potential health risk to users. They are known to accumulate in biological systems over time thereby resulting to high risks of skin cancer and irritation, and acute respiratory, liver and kidney malfunctions, dysfunctions and diseases. Consequently, the investigated facial cosmetics had potential health implications for the users. Carcinogenic and non-carcinogenic health risks arise from the usage of the facial cosmetics, using lifetime and cumulative cancer risks, systemic exposure dosage, margin of safety, hazard quotient and hazard index.

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