

Human health risk assessment of heavy metals in cosmetics in Nigeria

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Synopsis

Forty two different cosmetics were purchased from supermarkets and cosmetic shops within Onitsha Main Market and Eke-Awka markets in Anambra, Nigeria. Of the cosmetics, 16% were locally manufactured in Nigeria while 83.33% were imported into Nigeria. The cosmetics were ashed before digestion and filtration. The filtrates were assayed for lead, cadmium, manganese, nickel, chromium, mercury, and arsenic with atomic absorption spectrophotometry at 205 Å. The health risk assessment methods developed by the United States Environmental Protection Agency were employed to explore the potential human health risk of heavy metals in cosmetics. About 61.91% of the cosmetic samples contained lead with concentration in the range of 0.10–42.12 mg/kg. Cadmium levels of the cosmetics ranged from 0.01 to 1.32 mg/kg, manganese from 0.02 to 67.65 mg/kg, nickel from 0.05 to 17.34 mg/kg, chromium from 0.11 to 9.81 mg/kg, mercury from 0.003 to 0.07 mg/kg, and arsenic from 0.002 to 0.005 mg/kg. Although the target hazard quotients and the hazard indices suggest a measure of safety, cosmetics may add to the body burden of potential toxic metals after chronic exposure.

INTRODUCTION

Cosmetics have formed an integral part of human civilization as evidenced by its use even by primitive men to clean, beautify, and alter their appearance (1). Certain chemicals that are a part of cosmetic formulations have been found to be harmful, and the usage of cosmetics products containing such chemical portends danger for human health. Notable examples of such chemicals are heavy metals. Heavy metals such as lead, cadmium, manganese, nickel, chromium, mercury, and arsenic are found in a wide

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variety of cosmetic products (2–6). Reasons for their presence in cosmetic products include their existence as components of the major raw materials used in cosmetics products manufacture (5) and their deliberate inclusion as ingredients (4). Exposure to metals has been associated with health concerns including reproductive, immune, and nervous system toxicity (7).

Lead is a potential impurity in many color cosmetics (7) and may be absorbed into the body by ingestion, inhalation, and through the skin (8,9). Lead is a well-known and proven neurotoxin associated with learning, language, and behavioral problems (10). Cadmium, a deep yellow to orange pigment whose presence in cosmetic products is attributed to its color property (11), is highly toxic to humans and is listed by the United States Environmental Protection Agency (USEPA) as one of the priority pollutant metals (12). Trace amounts of manganese are essential for animals but in large quantities, the metal may be toxic. Chronic inhalation of metal dust or fumes can cause manganism, a nonfatal disease that affects the central nervous system. The symptoms are mental disorder and disturbance in speech (13). Nickel on contact with the skin can cause dermatitis and a type of chronic eczema known as “nickel itch” caused by hypersensitivity reactions (13). Chromium in its hexavalent form is corrosive to the skin, carcinogenic (14), and causes denaturation and precipitation of tissue proteins. Mercury can be absorbed through the skin and mucous membranes and its salts inhibit the formation of melanin (4). Arsenic is notoriously poisonous to multicellular life, and epidemiological evidence shows a dose-dependent connection between chronic arsenic exposure and various forms of cancer, in particular when other risk factors, such as cigarette smoking, are present. These effects have been demonstrated to persist below 50 ppb (15). Although many studies exist on the presence of these elements in cosmetic products, human health assessments are scarce. This study is a risk assessment of potential toxic metals in cosmetics commonly used in Nigeria.

EXPERIMENTAL

MATERIALS AND METHODS

In August 2013, using market basket protocol, 42 brands of cosmetic samples consisting of 16 facial cosmetics, 6 soaps, 1 shower gel, 12 emulsions, 2 underarm cosmetics, 3 nail cosmetics, and 2 perfumes were purchased from supermarkets and cosmetic shops in Onitsha and Awka in Anambra State, Nigeria, and used in the study. The samples were ashed and digested in Teflon labware that had been cleaned in a high-efficiency particulate air filtered (class 100), trace-metal-clean laboratory to minimize contamination. This protocol involved sequential cleaning of the labware in a series of baths in solutions (1 week each) and rinses (five per solution) in a three-step order, namely a detergent solution bath and deionized water rinses, then 6 N HCl (reagent grade) solution bath and ultrapure water rinses, and finally 7.5 N HNO₃ (trace metal grade) solution bath and ultrapure water rinses. The labware was then air-dried in a polypropylene laminar airflow-exhausting hood. A dry ashing method was used by adding 30 ml of each sample into a conical flask and heating on a hot plate at 200°C for 45 min and then in a furnace at 500°C until the volume was drastically reduced to near dryness. Digestion was performed by addition of 10 ml concentrated aqua regia (HCl:HNO₃, 3:1); this was then

heated to dryness. Then, 20 ml deionized water was added, stirred, and the mixture was filtered. The filtrate was made up in a standard volumetric flask and lead, cadmium, chromium, cobalt, and nickel concentrations were assayed with atomic absorption spectrophotometry at 205 Å. The limit of detection (LOD) for Cd, Cr, As, Hg, Mn, and Ni was 0.001 whereas the LOD of Pb was 0.01 ppm, with blank values reading as 0.00 ppm for all the metals in deionized water with electrical conductivity value of lower than 5 µS/cm. Samples were analyzed in triplicate.

The human health risk models including carcinogenic and noncarcinogenic ones raised by USEPA were adopted. These models and their threshold values were employed to assess the potential human health risks posed by heavy metal pollution for this study. Human beings could be exposed to heavy metal pollution from cosmetic products via dermal contact with cosmetic particles.

The daily dermal exposure to Pb, Cd, Cr, As, Hg, Mn, and Ni was calculated using the equation, according to EPA (16):

$$CDI_{\text{dermal}} = \frac{CS \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT}, \quad (1)$$

where CDI is chronic daily intake, CS is exposure point concentration: mg/kg (mg/l), EF is exposure frequency: 350 350 days a year, ED is exposure duration: 30a, AT is averaging time for noncarcinogens: 365 × EDd (Exposure Duration dermal), AT is averaging time for carcinogens: 365 × 70 d, BW is body weight : 70 kg, SA is exposed skin area: 5700 cm², AF is adherence factor: 0.07 mg/cm², ABS is dermal absorption fraction: 0.03 (As) and 0.001 (other metals), and CF is units conversion factor: 10⁻⁶ kg/mg.

The risk effect is made up of carcinogenic and noncarcinogenic risk assessments for all the metals through dermal exposure pathway. Cancer risk can be evaluated from the following formula:

$$\text{Cancer risk} = CDE \times SF, \quad (2)$$

where cancer risk represents the probability of an individual lifetime health risks from carcinogens; CDE is the chronic daily exposure of carcinogens (mg/kg/d); SF is the slope factor of hazardous substances (mg/kg/d), slope factor was calculated using the formula: slope factor = 1/6 (ED₁₀) (16). The total cancer risk due to cadmium, chromium, and arsenic were calculated.

The cumulative cancer risk can be calculated from:

$$\text{Total cancer risk due to heavy metal} = \sum_{k=1}^n CDE_k SF_k, \quad (3)$$

where CDE_k is the chronic daily intake (mg/kg/d) of substance k (i.e., in a given cosmetic), SF_k is the slope factor for substance k (kg/d/mg) (i.e., the sum of the calculated slope factor for the heavy metals detected in a given cosmetic), whereas total cancer risk is “exposure times toxicity” and hazard index (HI) is the “exposure divided by threshold value” where threshold value is the highest safe dose. The sum of all the individual ingredient values is then obtained. The acceptable or tolerable risk for regulatory purposes is within the range of 10⁻⁶–10⁻⁴.

The noncarcinogenic risk from individual heavy metal can be expressed as the hazard quotient (HQ):

$$HQ = CDE/RFD, \quad (4)$$

where the noncancer HQ is the ratio of exposure to hazardous substances and RFD is the chronic reference dose of the toxicant (mg/kg/d).

$$\text{Hazard index due to heavy metals} = \sum_{k=1}^n CDE_k/RFD_k, \quad (5)$$

where the HI is the sum of more than one HQ for multiple substances, CDE_k is the daily exposure of heavy metal (k), and RFD_k is the chronic reference dose for the heavy metal k. The acceptable value for the HI is <1 (17).

RESULTS

Table I shows the heavy metals in cosmetics manufactured in Nigeria. About 57.14% of the cosmetics, namely Royal Gold Cortex Remover[®] (Lagos, Nigeria), Classic White Whitening Cream[®] (Lagos, Nigeria), Royal Acrylic Nail Dissolver[®] (Lagos, Nigeria), and Ballin Glycerin Oil[®] contained no lead whereas 42.86% namely Beauty Fair Complexion Lotion[®], Beauty Fair Multi-Active Toning Cream[®] (Onitsha, Nigeria), and Tura Medicated Soap[®] (Lagos, Nigeria) contained 0.13 mg/l, 0.28 mg/l, and 1.32 mg/kg lead, respectively. Cadmium was not detected in 28.57% of the cosmetics namely Royal Gold Cortex Remover[®] and Ballin Glycerin Oil[®] (Onitsha, Nigeria) whereas 71.43% of the cosmetics contained cadmium. Manganese was detected in all the cosmetics with highest concentration (1.49 mg/kg) seen in Tura Medicated Soap[®]. Royal Gold Cortex Remover[®], Beauty Fair Multi-Active Toning Cream, Royal Acrylic Nail Dissolver[®], and Ballin Glycerin Oil[®] representing 57.14% had no nickel whereas 28.57% contained nickel. Chromium and mercury were not detected in any of the cosmetic samples manufactured in Nigeria. Royal Gold Cortex Remover[®] had an arsenic content of 0.002 mg/l.

The heavy metals in cosmetics manufactured outside Nigeria is shown in Table II. Lead was not detected in 31.43% of the cosmetics samples namely St. Ives Apricot Facial Scrub[®] (Hangzhou, China), Cucumber Extract Facial Cleanser[®], Chris Adams Active Woman Perfume[®], Fruity Lip Balm (Strawberry)[®] (Jackson, MS), Mary Kay Crème-to-Powder[®]

Table I
Heavy Metals in Cosmetic Manufactured in Nigeria

Cosmetic	Metal content (mg/kg)						
	Pb	Cd	Mn	Ni	Cr	Hg	As
Beauty Fair Complexion Lotion	0.13	0.06	0.90	0.13	ND	ND	ND
Royal Gold Cortex Remover	ND	ND	1.28	ND	ND	ND	0.002
Beauty Fair Multi-Active Toning Cream	0.28	0.03	0.76	ND	ND	ND	ND
Classic White Whitening Cream	ND	0.01	0.36	0.42	ND	ND	ND
Royal Acrylic Nail Remover	ND	0.04	0.50	ND	ND	ND	ND
Tura Medicated Soap	1.32	0.58	1.49	4.53	ND	ND	ND
Ballin Glycerin Oil	ND	ND	0.52	ND	ND	ND	ND

ND: Not detected.

Table II
Heavy Metals in Cosmetics Manufactured Outside Nigeria

Sample code	Metal content (mg/kg)						
	Pb	Cd	Mn	Ni	Cr	Hg	As
Fem Tight Antiseptic Vaginal Wash Soap	1.61	0.70	0.16	4.65	0.21	ND	ND
Face to Face Facial Mask	1.00	0.06	0.90	0.53	0.11	ND	ND
St. Ives Apricot Facial Scrub	ND	ND	0.85	0.13	ND	ND	ND
Palmer's Cocoa Butter Body Cream	0.22	0.02	0.86	0.12	ND	ND	ND
Cucumber Extract Facial toner	ND	0.09	0.50	0.06	ND	ND	ND
Fantasy Body Spray (Rapsberry)	0.48	0.04	0.80	ND	ND	ND	ND
Chris Adams Active Woman Perfume	ND	ND	0.71	0.05	ND	ND	ND
Veet Hair Removing Cream	1.95	0.30	3.27	1.88	ND	ND	ND
Sleek Concealer Powder	ND	ND	ND	ND	ND	ND	ND
Black Opal Crème Stick Foundation	11.50	1.32	67.75	17.34	9.81	ND	ND
Fruity Lip Balm (Strawberry)	ND	ND	ND	ND	ND	ND	ND
Baolishi Eyeliner	42.12	ND	17.58	1.93	ND	ND	ND
Mary Kay Crème-to-Powder	ND	ND	ND	ND	ND	ND	ND
Far Away Body Shimmering Powder	0.99	0.08	9.34	3.55	8.49	ND	ND
Island Beauty Lipstick	0.220	0.23	17.67	1.29	2.08	ND	ND
St. Ives Body Cream	0.66	0.16	1.10	0.44	ND	ND	0.002
Vovi Milk Complex Cream	ND	0.02	0.97	0.59	ND	ND	ND
Empire Fade Cream Lotion	0.11	0.03	0.75	0.13	ND	ND	ND
Fair and White Exfoliating Soap	2.07	0.72	1.42	4.96	ND	ND	ND
Clear Essence Maxi-tone	0.30	ND	0.95	0.48	ND	ND	ND
Ushas Eye Shadow	1.17	0.06	30.55	0.82	ND	ND	ND
Bouquet Roll-on Deodorant	ND	0.01	1.15	ND	ND	ND	ND
Sally Hansen Nail Color	0.78	0.03	0.02	0.49	ND	ND	ND
Jordana Loose Powder	0.12	ND	1.88	0.75	ND	ND	ND
Pop Facial Cream	ND	ND	ND	ND	ND	ND	ND
Jennifer Lopez Secret	1.03	0.38	1.66	1.23	ND	ND	ND
Eden Apricot Scrub Soap	2.41	0.64	1.68	4.40	0.31	ND	ND
Crusader Medicated Soap	0.71	0.74	1.32	5.44	ND	0.07	ND
Lentheric Anti-perspirant Roll-on	0.59	0.63	2.26	5.31	0.53	0.003	ND
Swiss Luxury Bath Shower Gel	0.16	0.26	1.01	2.37	ND	ND	ND
Dove Body Fairness Lotion	ND	ND	0.76	ND	ND	ND	ND
Mac Waterproof Mascara	ND	ND	ND	ND	ND	ND	ND
Dark and Lovely Compact Powder	1.28	0.19	37.79	1.78	ND	ND	ND
Bio Claire Body Lightening Lotion	0.10	0.01	0.86	ND	ND	ND	0.005
Absolute Juicy Lip Shimmer	ND	ND	0.41	ND	ND	ND	ND

ND: Not detected.

(New York, NY), Vovi Milk Complexion Cream[®] (New York, NY), Bouquet Roll-on Deodorant[®] (London, UK), Dove Body Fairness Lotion[®] (London, UK), Mac Waterproof Mascara[®] (London, UK), Sleek Concealer Powder[®] (Bangalore, India), and Absolute Juicy

Lip Shimmer[®] (Beijin, China) whereas 68.57% of the cosmetics contained various lead levels ranging from 0.1 to 42.12 mg/kg.

Cadmium was detected in 65.71% of the cosmetics and the concentrations ranged from 0.01 to 1.32 mg/kg but 34.29% (St. Ives apricot Facial Scrub[®], Chris Adams Active Woman Perfume[®], Sleek Concealer Powder[®], Fruity Lip Balm (Strawberry)[®], Baolishi Eyeliner[®], Mary Kay Crème-to-Powder[®], Clear Essence Maxi-tone[®], Jordana Loose Powder[®], Pop Facial Cream[®], Dove Body Fairness Lotion[®], Mac Waterproof Mascara[®], and Absolute Juicy Lip Shimmer[®]) contained no cadmium.

Manganese was not detected in 14.29% of the cosmetics (Sleek Concealer Powder[®], Fruity Lip Balm[®], Mary Kay Crème-to-Powder[®], Pop Facial Cream[®], and Mac Waterproof Mascara[®]) whereas 85.71% had manganese content in the range of 0.02–67.65 mg/kg. Nickel was not detected in 28.57% of the cosmetics viz Fantasy Body Spray[®], Sleek Concealer Powder[®], Fruity Lip Balm[®], Mary Kay Crème-to-Powder[®], Bouquet Roll-on Deodorant[®], Pop Facial Cream[®], Dove Body Fairness Lotion[®], and Mac Waterproof Mascara[®]. Chromium was not detected in 80% of the cosmetics, however 20% had chromium content of range 0.11–9.81 mg/kg. Only 5.71% of cosmetics manufactured outside Nigeria, namely Crusader Medicated Soap[®] and Lentheric Anti-perspirant Roll-on[®], had mercury content of 0.07 mg/kg and 0.003 mg/l, respectively, whereas 94.29% did not contain mercury. Arsenic was not detected in 94.29% of the cosmetics manufactured outside Nigeria and only 5.71% namely St. Ives Apricot Facial Scrub[®] and Bio Claire Body Lightening Lotion[®] have arsenic content of 0.002 and 0.005 mg/l, respectively.

The noncarcinogenic risks (HQ) of heavy metal contaminants in cosmetics manufactured in and outside Nigeria are shown in Tables III and IV, respectively. In Table III, the lead contained in Tura Medicated Soap[®] had the highest noncarcinogenic risk value (HQ = 2.06E-06) while arsenic in Royal Gold Cortex Remover[®] had the least noncarcinogenic risk value (HQ = 1.56E-08). Manganese contained in Ushas Eye Shadow[®] had the highest noncarcinogenic risk (HQ = 8.20E-06) among the heavy metals found in cosmetic products manufactured outside Nigeria (Table IV) while chromium detected in Fem Tight Antiseptic Vaginal Wash[®] recorded the least value (HQ = 3.28E-10).

Table III
Noncarcinogenic Risk [Hazard Quotient (HQ)] of Heavy Metal Contaminants in
Cosmetics Manufactured in Nigeria

Cosmetics	Heavy metal						
	Pb	Cd	Mn	Ni	Cr	Hg	As
Beauty Fair Complexion Lotion	2.03E-07	1.41E-07	2.46E-07	3.53E-08	ND	ND	ND
Royal Gold Cortex Remover	ND	ND	3.50E-07	ND	ND	ND	1.56E-08
Beauty Fair Multi-Active Toning Cream	4.37E-07	7.03E-08	2.08E-07	ND	ND	ND	ND
Classic White Whitening Cream	ND	2.34E-08	9.84E-08	1.14E-07	ND	ND	ND
Royal Acrylic Nail Remover	ND	9.37E-08	1.37E-07	ND	ND	ND	ND
Tura Medicated Soap	2.06E-06	1.36E-06	4.07E-07	1.24E-06	ND	ND	ND
Ballin Glycerin Oil	ND	ND	1.42E-07	ND	ND	ND	ND

ND: Not detected.

Table IV
Noncarcinogenic Risk [Hazard Quotient (HQ)] of Heavy Metal Contaminants in
Cosmetics Manufactured Outside Nigeria

Cosmetics	Heavy metal						
	Pb	Cd	Mn	Ni	Cr	Hg	As
Fem Tight Antiseptic Vaginal Wash Soap	2.05E-06	1.64E-06	4.37E-08	1.27E-06	3.28E-10	ND	ND
Face to Face Facial Mask	1.56E-06	1.41E-07	2.46E-07	1.45E-07	1.71E-10	ND	ND
St. Ives Apricot Facial Scrub	ND	ND	2.32E-07	3.55E-08	ND	ND	ND
Palmer's Cocoa Butter Body Cream	3.44E-07	4.69E-08	2.35E-07	3.28E-08	ND	ND	ND
Cucumber Extract Facial toner	ND	2.11E-07	1.37E-07	1.64E-08	ND	ND	ND
Fantasy Body Spray (Rapsberry)	7.50E-07	9.37E-08	2.19E-07	ND	ND	ND	ND
Chris Adams Active Woman Perfume	ND	ND	8.32E-08	5.86E-09	ND	ND	ND
Veet Hair Removing Cream	1.31E-06	7.03E-07	8.94E-07	5.14E-07	ND	ND	ND
Sleek concealer Powder	ND	ND	ND	ND	ND	ND	ND
Black Opal Crème Stick Foundation	1.83E-05	3.09E-06	1.85E-05	4.74E-06	3.58E-08	ND	ND
Fruity Lip Balm (Strawberry)	ND	ND	ND	ND	ND	ND	ND
Baolishi Eyeliner	6.58E-05	ND	4.81E-06	5.37E-07	ND	ND	ND
Mary Kay Crème-to-Powder	ND	ND	ND	ND	ND	ND	ND
Far Away Body Shimmering Powder	3.01E-06	1.87E-07	2.55E-06	9.70E-07	1.32E-08	ND	ND
Island Beauty Lipstick	3.44E-07	5.39E-06	4.84E-06	3.53E-07	3.25E-09	ND	ND
St. Ives Body Cream	1.03E-06	3.75E-07	3.01E-07	1.21E-07	ND	ND	4.68E-07
Vovi Milk Complex Cream	ND	4.69E-08	2.46E-07	1.61E-07	ND	ND	ND
Empire Fade Cream Lotion	1.72E-07	7.03E-08	2.05E-07	3.55E-08	ND	ND	ND
Fair and White Exfoliating Soap	3.24E-06	1.69E-06	3.88E-07	1.36E-06	ND	ND	ND
Clear Essence Maxi-tone	4.69E-07	ND	2.60E-07	1.32E-07	ND	ND	ND
Ushas Eye Shadow	1.83E-06	1.41E-07	8.20E-07	2.24E-07	ND	ND	ND
Bouquet Roll-on Deodorant	ND	2.34E-08	3.14E-07	ND	ND	ND	ND
Sally Hansen Nail Color	1.22E-06	7.03E-07	5.47E-09	1.34E-07	ND	ND	ND
Jordana Loose Powder	1.87E-07	ND	5.14E-07	2.05E-07	ND	ND	ND
Pop Facial Cream	ND	ND	ND	ND	ND	ND	ND
Jennifer Lopez Secret	1.61E-06	8.90E-07	4.54E-07	3.36E-07	ND	ND	ND
Eden Apricot Scrub Soap	3.76E-06	1.50E-06	4.59E-07	1.20E-06	1.13E-06	ND	ND
Crusader Medicated Soap	1.11E-06	1.73E-06	3.61E-07	1.49E-06	ND	1.28E-07	ND
Lentheric Anti-perspirant Roll-on	9.21E-07	1.48E-06	6.18E-07	1.45E-06	8.28E-10	5.47E-09	ND
Swiss Luxury Bath Shower Gel	2.50E07	6.09E-07	2.76E-07	6.78E-07	ND	ND	ND

Table IV
Continued

Cosmetics	Heavy metal						
	Pb	Cd	Mn	Ni	Cr	Hg	As
Dove Body Fairness Lotion	ND	ND	2.08E-07	ND	ND	ND	ND
Mac Waterproof Mascara	ND	ND	ND	ND	ND	ND	ND
Dark and Lovely Compact Powder	2.00E-06	4.45E-07	1.03E-05	4.87E-07	ND	ND	ND
Bio Claire Body Lightening Lotion	1.56E-07	2.34E-08	2.35E-07	ND	ND	ND	1.17E-06
Absolute Juicy Lip Shimmer	ND	1.12E-07	ND	ND	ND	ND	ND

ND: Not detected.

Table V shows the HI of heavy metal contaminants in cosmetics manufactured in Nigeria. Cadmium in Tura Medicated Soap[®] had the highest HI (7.55E-12) while arsenic in Royal Gold Cortex Remover[®] with a HI of 2.59E-14 was the least. Cadmium was detected as the only carcinogenic metal present in Classic White Whitening Cream[®], Beauty Fair Multi-Active Toning Cream[®], Royal Acrylic Nail Remover[®], Beauty Fair Complexion Lotion[®], and Tura Medicated Soap[®] with corresponding HIs of 1.30E-13, 3.90E-13, 5.21E-13, 7.81E-12, and 7.55E-12, respectively. Royal Gold Cortex Remover[®] contained arsenic with a cancer risk value of 2.59E-14.

The HI of heavy metal contaminants in cosmetics manufactured outside Nigeria is shown in Table VI. About 25.71% of the cosmetics manufactured outside Nigeria had no carcinogenic metal contents. Cadmium in Face to Face Facial Mask[®] and arsenic in St. Ives Body Cream[®] showed an HI of 7.81E-13 while cadmium in Baolishi Eyeliner[®] had the highest HI of 4.77E-09. The HI of chromium in Black Opal Crème Stick Foundation[®] was 1.27E-10 while Face to Face Facial Mask[®] had the least chromium HI of 1.42E-12. Seven cosmetic samples had both cadmium and chromium (carcinogenic metals) with Black Opal Crème Stick Foundation having the highest total HI of 2.89E-10 while Face to Face Facial Mask had the least total HI of 4.40E-12. Two cosmetic samples, namely St. Ives Body Cream[®] and Bio Claire Body Lightening Lotion[®], had cadmium and arsenic (carcinogenic metals) with both having a total HI of 4.17E-12.

Table V
Hazard Index (HI) of Heavy Metal Contaminants in Cosmetics Manufactured in Nigeria

Cosmetics	Heavy metal		
	Cd	Cr	As
Beauty Fair Complexion Lotion	7.81E-13	ND	ND
Royal Gold Cortex Remover	ND	ND	2.59E-14
Beauty Fair Multi-Active Toning Cream	3.90E-13	ND	ND
Classic White Whitening Cream	1.30E-13	ND	ND
Royal Acrylic Nail Remover	5.21E-13	ND	ND
Tura Medicated Soap	7.55E-12	ND	ND
Ballin Glycerin Oil	ND	ND	ND

ND: Not detected.

Table VI
Hazard Index (HI) of Heavy Metal Contaminants in Cosmetics Manufactured outside Nigeria

Cosmetics	Heavy metal		
	Cd	Cr	As
Fem Tight Antiseptic Vaginal Wash Soap	9.11E-12	2.73E-12	ND
Face to Face Facial Mask	7.81E-13	1.42E-12	ND
St. Ives Apricot Facial Scrub	ND	ND	
Palmer's Cocoa Butter Body Cream	2.60E-13	ND	ND
Cucumber Extract Facial toner	1.17E-12	ND	ND
Fantasy Body Spray (Rapsberry)	5.21E-13	ND	ND
Chris Adams Active Woman Perfume	ND	ND	ND
Veet Hair Removing Cream	3.90E-12	ND	ND
Sleek Concealer Powder	ND	ND	ND
Black Opal Crème Stick Foundation	1.72E-11	2.98E-10	ND
Fruity Lip Balm (Strawberry)	ND	ND	ND
Baolishi Eyeliner	4.77E-09	ND	ND
Mary Kay Crème-to-Powder	ND	ND	ND
Far Away Body Shimmering Powder	1.04E-12	2.75E-10	ND
Island Beauty Lipstick	2.99E-12	6.32E-11	ND
St. Ives Body Cream	2.08E-12	ND	7.81E-13
Vovi Milk Complex Cream	2.60E-13	ND	ND
Empire Fade Cream Lotion	3.90E-13	ND	ND
Fair and White Exfoliating Soap	9.37E-12	ND	ND
Clear Essence Maxi-tone	ND	ND	ND
Ushas Eye Shadow	7.81E-12	ND	ND
Bouquet Roll-on Deodorant	1.30E-13	ND	ND
Sally Hansen Nail Color	3.90E-13	ND	ND
Jordana Loose Powder	ND	ND	ND
Pop Facial Cream	ND	ND	ND
Jennifer Lopez Secret	4.95E-11	ND	ND
Eden Apricot Scrub Soap	8.33E-11	4.04E-12	ND
Crusader Medicated Soap	ND	ND	ND
Lentheric Anti-perspirant Roll-on	8.20E-12	4.04E-11	ND
Swiss Luxury Bath Shower Gel	3.38E-12	ND	ND
Dove Body Fairness Lotion	ND	ND	ND
Mac Waterproof Mascara	ND	ND	ND
Dark and Lovely Compact Powder	2.47E-12	ND	ND
Bio Claire Body Lightening Lotion	1.30E-13	ND	1.95E-12
Absolute Juicy Lip Shimmer	ND	ND	ND

ND: Not detected by method employed.
Sample code from Table III.

The total noncancer risk (chronic HI) and total cancer risk of cosmetics manufactured in Nigeria is shown in Table VII. Tura Medicated Soap[®] has the highest HI value (9.32E-07) and Classic White Whitening Cream[®] as having the least HI value

Table VII
Total Noncancer Risk [Chronic Hazard Index (HI)] and Total Cancer Risk of
Cosmetics Manufactured in Nigeria

Cosmetics	HI due to heavy metals	Total cancer risk due to heavy metals
	$\sum_{k=1}^n \text{CDE}_k / \text{RFD}_k$	$\sum_{k=1}^n \text{CDE}_k \text{SF}_k$
Beauty Fair Complexion Lotion	1.03E-07	7.81E-13
Royal Gold Cortex Remover	3.04 E-07	2.59E-14
Beauty Fair Multi-Active Toning Cream	2.35 E-07	3.90E-13
Classic White Whitening Cream	1.05 E-07	1.30E-13
Royal Acrylic Nail Remover	1.35 E-07	5.21E-13
Tura Medicated Soap	9.32 E-07	7.55E-12
Ballin Glycerin Oil	1.42 E-07	ND

ND: Not detected.

(1.05E-07). Table VIII shows the total noncancer risk (HI due to heavy metals) and total cancer risk of cosmetics manufactured outside Nigeria. Ushas Eye Shadow[®] had the highest HI value (3.93E-06) while Face to Face Facial Mask[®] recorded the least HI value (8.86E-09).

DISCUSSION

Hitherto, there seem to be no international standards for impurities including heavy metals in cosmetics. Notwithstanding, limits and guidelines have been established by governmental agencies in advanced countries around the world. Many heavy metals are banned as intentional ingredients albeit not as product impurities since their presence as such is considered unavoidable.

Beauty Fair Complexion Lotion[®], Beauty Fair Multi-Active Toning Cream[®], and Tura Medicated Soap[®] had lead in concentrations exceeding the American Conference of Government Industrial Hygienist's (ACGIH) threshold limit value (TLV) of 0.05 mg/l for inorganic lead and lead chromate and 0.1 mg/l for lead tetraethyl as well as the USEPA's action level for lead in drinking water, which is put at 0.0015 mg/l (18). Bio Claire Body Lightening Lotion[®] had lead content of 0.1 mg/kg, which is exactly the TLV for lead tetraethyl; while the other 23 cosmetics had lead contents above the TLV, with Boalish Eyeliner[®] and Black Opal Crème Stick Foundation[®] having an exceptionally high lead content of 42.12 and 11.50 mg/kg, respectively. The use of these cosmetics may be of public health concern because of likely dermal absorption. Lead can be absorbed through the skin (8,9) and although studies on the dermal absorption of lead in humans are still scarce, damaged skin, pH, and metallic chemical structure are likely factors that could enhance percutaneous penetration of metals (9–19).

All the cosmetics in this study had manganese concentrations above the ACGIH's TLV of 0.2 mg/kg with Tura Medicated Soap[®] having the highest concentration of manganese at 1.49 mg/kg. Trace amounts of manganese are essential for animals; however, in large quantities the metal can cause acute and chronic poisoning.

Table VIII
Total Noncancer Risk [Chronic Hazard Index (HI)] and Total Cancer Risk of
Cosmetics Manufactured Outside Nigeria

Cosmetics	Chronic HI $\sum_{k=1}^n \text{CDE}_k / \text{RFD}_k$	Total cancer risk $\sum_{k=1}^n \text{CDE}_k \text{SF}_k$
Fem Tight Antiseptic Vaginal Wash Soap	2.40E-08	2.37E-11
Face to Face Facial Mask	8.86E-09	4.40E-12
St. Ives Apricot Facial Scrub	1.36E-07	ND
Palmer's Cocoa Butter Body Cream	1.49E-07	2.60E-13
Cucumber Extract Facial toner	7.98E-08	1.17E-12
Fantasy Body Spray (Rapsberry)	1.59E-07	5.21E-13
Chris Adams Active Woman Perfume	4.45E-08	ND
Veet Hair Removing Cream	7.51E-07	3.90E-12
Sleek Concealer Powder	ND	ND
Black Opal Crème Stick Foundation	3.59E-07	2.29E-10
Fruity Lip Balm (Strawberry)	ND	ND
Baolishi Eyeliner	7.78E-07	4.77E-09
Mary Kay Crème-to-Powder	ND	ND
Far Away Body Shimmering Powder	6.54E-08	2.23E-10
Island Beauty Lipstick	7.15E-08	5.95E-11
St. Ives Body Cream	2.79E-07	4.17E-12
Vovi Milk Complex Cream	2.37E-07	2.60E-13
Empire Fade Cream Lotion	1.23E-07	3.90E-13
Fair and White Exfoliating Soap	1.08E-06	9.37E-12
Clear Essence Maxi-tone	2.18E-07	ND
Ushas Eye Shadow	3.93E-06	7.81E-13
Bouquet Roll-on Deodorant	3.01E-07	1.30E-13
Sally Hansen Nail Color	1.60E-07	3.90E-13
Jordana Loose Powder	1.16E-07	ND
Pop Facial Cream	ND	ND
Jennifer Lopez Secret	5.02E-07	4.95E-11
Eden Apricot Scrub Soap	3.15E-08	2.47E-11
Crusader Medicated Soap	8.68E-07	ND
Lentheric Anti-perspirant Roll-on	3.06E-08	3.04E-11
Swiss Luxury Bath Shower Gel	4.48E-07	3.38E-12
Dove Body Fairness Lotion	2.08E-07	ND
Mac Waterproof Mascara	ND	ND
Dark and Lovely Compact Powder	5.03E-06	2.47E-12
Bio Claire Body Lightening Lotion	2.27E-07	4.17E-12
Absolute Juicy Lip Shimmer	1.12E-07	ND

ND: Not detected.

Manganese is a powerful neurotoxin that causes learning disabilities and deficits in intellectual function in children (20) and manganism and manganese-induced parkinsonism in adults (21) and children (22) as well as compulsive behaviors, emotional lability,

hallucinations, and attention disorders (23). In addition, high maternal manganese levels are associated with low fetal birth weight (24) and increased infant mortality (25).

Some of the cosmetics manufactured outside Nigeria have nickel contents below the recommended exposure limit (REL) of 1 mg/kg (26). The lead content in 37.14% of cosmetics manufactured outside Nigeria exceeded the REL, with Black Opal Crème Stick Foundation® having the highest lead level of 17.34 mg/kg. About 28.57% contained nickel below the REL set by the National Institute for Occupational Safety and Health (NIOSH) as 1 mg/kg (26). Tura Medicated Soap® had a nickel content of 4.53 mg/kg, which is higher than the 1 mg/kg REL (26). Skin contact by nickel can cause dermatitis and a type of chronic eczema known as “nickel itch” resulting from hypersensitivity reactions of nickel on the skin. Also, nickel and certain of its compounds are listed by the International Agency for Research on Cancer (IARC) under group 2B carcinogens as possibly carcinogenic to humans (13). Chromium and mercury were not detected in any of the cosmetics manufactured in Nigeria. Royal Gold Cortex Remover® had an arsenic content of 0.002 mg/l, which is below the 10 µg/l drinking water standard. However, increased levels of skin cancer have been associated with arsenic exposure, even at levels below the 10 ppb (10 µg/l) drinking water standards (27).

Cadmium levels were all under the permissible limits of 3 mg/kg (26) and within the TLV. Cadmium in cosmetics may be from one of the inorganic base materials used in the manufacturing process rather than as ingredients employed in the manufacture of these cosmetics since the metal is found in the environment (5). Cadmium, chromium, and arsenic have been shown to be carcinogenic (17). The most predominant cancer-causing metal found in this study analyzed was cadmium whereas the least occurring carcinogenic metal was arsenic. Hitherto, cadmium has no known physiologic function and no known mechanism for its selective transport and homeostasis has been documented. Cadmium has been recognized as an endocrine disruptor because of adverse effects on reproduction (28), disruption of steroidogenesis and spermatogenesis in vivo and in laboratory animals (29), and ability to bind to androgen and estrogen receptors (30). Clinical studies have associated cadmium exposure with prostate toxicity (31), testicular toxicity, and infertility (32). Biological half-life in humans is estimated at 20–30 years (14).

Chromium was not detected in 80% of the cosmetics, however 20% had chromium concentration ranging from 0.11 to 9.81 mg/kg, which exceeded the permissible exposure limit of 0.05 mg/kg, set by the NIOSH for chromium (33). Although chromium metal or trivalent chromium (Cr^{3+}) is not very toxic, hexavalent chromium (Cr^{6+}) is carcinogenic and moderately toxic; as it is corrosive to the skin and causes denaturation and precipitation of tissue proteins (14). Chromium is a transition metal and a known sensitizer of the human skin. Dermatological and epidemiological researchers have shown that chromium is responsible for most adverse skin reactions (34). Although chromium is not a primary cause of allergic dermatitis, its presence in cosmetics even at very low concentration could be of pathological importance (35). Our observation is similar to the report by Hepp *et al.* (36) except lead that has a high value of 42 mg/kg compared to 14 mg/kg given in the published article and that chromium value is much higher in the published article.

The use of mercury-containing cosmetics calls for caution as case studies have shown effects such as tremors, impaired cognitive skills, and sleep disturbance in workers with

chronic exposure to mercury vapor even at low concentrations in the range 0.7–42 $\mu\text{g}/\text{m}^3$ [equivalent of 7.0×10^{-10} mg/l (kg) to 4.2×10^{-8} mg/l (kg)] (37,38). Similarly, NAFDAC's Directorate of Registration and Regulatory Affairs Guidelines for Registration of Imported Cosmetics in Nigeria states that mercury and its compounds are not permitted in cosmetic products because mercury is reported to cause dermatitis and its cumulative toxicity causes damage to kidneys, which could manifest as hypertension and fatal kidney failure (39). Arsenic was not detected in most of the cosmetics manufactured outside Nigeria.

The total noncarcinogenic HIs for both the cosmetic manufactured in and outside Nigeria fall below the hazard threshold value of 1 set by the USEPA (16). This confers a measure of safety and no toxicological concern. Similarly, the total cancer risk value for both the cosmetic products manufactured in and outside Nigeria was less than the acceptable or tolerable risk level of 10^{-6} – 10^{-4} set by USEPA (16). This implies that the amount of these carcinogenic metals to which users of these cosmetics are exposed to from a single day use is unlikely to cause cancer but chronic exposure may however be of public health concern. In this study, the values for total cancer risk and HI subsist entirely of the risk contributed by the heavy metals and do not contain any risk that may be contributed by other hazardous substances. Actual risk indices may be higher if possible additional factors are included.

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