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Toxic effects of selected trace elements contained in make-ups on female university students in Nigeria

Onyenekenwa Cyprian Eneh

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Abstract Arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), beryllium (Be), nickel (Ni), selenium (Se), and thallium (Tl) are reportedly notorious toxic contents of make-ups, with potential to cause cancer and chronic kidney disease, warranting investigation on their toxic effects. One hundred female university students were randomly selected as consistent users of make-ups for upward of 3 years. The serum/urine levels of the 8 elements were regressed against the kidney functions (estimated glomerular rate, eGFR) of the subjects. At coefficient of − 0.009, As had insignificant (0.518) level. The coefficient for Cd was − .155 and insignificant (0.423). At coefficient of − 039, Pb level was insignificant (0.595). The coefficient, 0.061, for Hg was insignificant (0.462). At − 1.585, the coefficient of Be was insignificant (0.292). The coefficient for Ni, 1.384, was insignificant (0.354). At − .002, the coefficient of Se was insignificant (0.635). The coefficient, 0.039, for Tl was significant at 5% (0.015). This finding internally validated the mean serum Tl level, 201.4900 ± 20.63316 µg/L, which was much higher than the normal level of < 2 µg/L and within the toxic range of > 200 µg/L. A policy is needed to address the use of make-ups containing Tl.

O. C. Eneh (✉)
Institute for Development Studies, University of Nigeria, Enugu Campus, Enugu, Nigeria
e-mail: onyenekenwa.eneh@unn.edu.ng

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Introduction

Trace metals and their toxicity in make-ups

Mercury (Hg), arsenic (As), lead (Pb), cobalt (Co), antimony (Sb), cadmium (Cd), nickel (Ni), and chromium (Cr) are prohibited in cosmetics because of their exceptional toxicity (SCOOPWHOOP, 2017). Yet, Indian herbal cosmetics have predominance of Hg and Pb that exceeds the permissible limit set by the World Health Organization (WHO). Similarly, Nigerian local facial make-ups have high levels of trace metals (Sani et al., 2016). Unacceptable levels of As in lipsticks, eye shadows, and eyebrow pencils have been reported in Germany (Saadatzadeh et al., 2019). Talcum powder contains Pb and Cr (Gondal et al., 2012). In Canada, all cosmetics have Ni. Pb and beryllium (Be) as well as at least 4 of the 8 metals of environmental health concern (As, Cd, Pb, Hg, Be, Ni, selenium and thallium) are contained in over 90% of cosmetics (Orisakwe & Otaraku, 2013). Sunscreens contain titanium, Ti (regulated), in addition to other heavy metals (not regulated) (Aldayel et al., 2018; Capelli et al., 2014).

The use of make-ups in pregnancy is responsible for prenatal Pb exposure which is associated with a greater risk of premature delivery, reduced postnatal growth, lower child mental growth, schizophrenia, and

dementia in adulthood (Wang et al., 2016). Intrauterine growth retardation occurs as a result of heavy metal exposure in pregnancy (Bruzzoniti et al., 2017). Even at a low level, Cd exposure may avert neurodevelopment (Henn et al., 2016). Prenatal exposure to As is linked to low fetal growth, low birth weight, poor head and chest development in infants, atherosclerotic disease, and inflammation in adults (Li et al., 2019).

Common colorants in eye shadows, blushes, and concealers are iron oxides (Brown, 2013). Lip glosses, lipsticks, and nail polishes contain aluminum (Al) compounds as colorants (Klotz et al., 2017). Al is contained in antiperspirants, sun creams, and toothpaste. Al exposure is linked to chronic disorders, including Alzheimer's disease and breast cancer (Becker et al., 2016). Skin bleaching agents contain a significant level of As and Hg in the Caribbean region (Mohiuddin, 2019a; Sneyers et al., 2009), leading to skin problems, lung cancer, circulatory and peripheral neuropathy, and increased risk of gastrointestinal and urinary tract malignancies (Chan et al., 2019; Lavilla et al., 2009), and nephrotic syndrome (Qin et al., 2019; Mohiuddin, 2019b; Doshi et al., 2018; Orr & Bridges, 2017; Zhang et al., 2014). The toxic legacy of Hg dental amalgam continues for decades after use, because of pervasive bioaccumulation of Hg in the environment (Tibau & Grube, 2019). Cumulative exposure to mixtures of heavy metals is associated with obesity and chronic hypertension and type 2 diabetes (T2DM) (Wani et al., 2015). Zinc oxide (ZnO) is an ingredient in sunscreens (Martin et al., 2004), yet zinc (Zn) exposure causes the same symptoms as Pb poisoning (Piao et al., 2003).

Twelve heavy metals most often associated with environmental toxicity are Cd, Cr, Co, Cu, Fe, Pb, Hg, Ni, As, Be, selenium (Se), and thallium (Tl). There is an increasing concern about the toxic effects of trace elements contained in make-ups used on daily basis mostly by young women. As, Cd, Pb, Hg, Be, Ni, Se, and Tl have been identified as the notorious daredevils (Mohiuddin, 2019c). Hence, this study investigated their toxic effects on the regular users of make-ups containing them. Obviously, the empirical study will benefit users of make-ups who are possible victims of their toxic effects and health policy-makers as well as enrich the literature.

Kidney function as a measure of toxicity of trace metals contained in make-ups

Kidney is a filter of blood that removes toxins and regulates fluid, molecules, and by-products of metabolic processes. A gradual loss of this function has been linked to trace elements circulating in the human body. Exposure to toxic elements has nephrotoxic effects. Heavy metal exposure colludes with other environmental hazards to cause kidney and liver dysfunction. The cumulative effect of toxic elements for 3 months or longer is linked to chronic kidney disease (CKD) and potentiates complications (Fevrier-Paul et al., 2018; Hall & Hall, 2011).

Study aim and objectives

The study sought the relationship between serum concentrations of Cd, Pb, Hg, Ni, Se, and Tl and urine level of As and Be in make-ups and the kidney functions (estimated glomerular rate, eGFR) of users with a view to ascertaining the potential for poisoning that could lead to cancer by exposure to Be or CKD and its complications by exposure to As, Cd, Pb, Hg, Ni, Se, and Tl. Preliminary observations had shown that university female students form a significant group of make-ups patrons and could justifiably be targeted for a study on toxic effects of trace elements contained in make-ups. Make-up is used in this study to represent cosmetics applied on the skin mostly by females. They include lipstick, eye shadow/lash pencil, talcum powder, antiperspirant, sun cream, and lightening cream, among others.

Delimitations of the study

Age, sex, and race influence eGFR values. Average eGFR value of 116 mL/min./1.7 3 m is associated with age bracket of 20–29. Average eGFR value of 107 mL/min/1.73 m is associated with 30–39 age bracket. Average eGFR value of 99 mL/min./1.73 m is associated with 40–49 age range. But, in Nigerian climes, asking a woman to divulge her age almost always prompted her to lie, especially to strangers, such as the researchers. All respondents were women of black race. Therefore, age, sex, and race were left out of the study.

Materials and methods

Design

University female students were subjects for the study. Students of any first generation federal university are representative of the targets because the university is not tribal, faith-based, and is for the rich and the poor. Withholding the name of the university is deliberate for anonymity as a necessary part of the condition for informed consent of the subjects.

The cross-sectional study used convenience sampling method to select 100 female university students based on suitability and relevance (of user of make-ups) and availability for and willingness to participate in the study. Besides, the subject consented to allowing the research findings to be published with anonymity (of subject and institution) as academic resource. The subjects, thus, met the inclusion criteria and fell out of the exclusion criteria (*vide ultra*).

Inclusion and exclusion criteria

Inclusion criteria were habitual use of make-ups for a minimum of three consecutive years; willingness to participate in, and availability for, the study; and willingness to allow study results to be published with anonymity for academic purposes.

Exclusion criteria were non-habitual use or non-use of make-ups for a minimum of three consecutive years; unwillingness to participate in, and unavailability for, the study; and unwillingness to allow study results to be published with anonymity for academic purposes.

Sample collection

The study procedure was explained to the prospective subjects, from who informed consent for participation in the study and allowing academic publication/s of the results of the study with anonymity were sought and obtained. Fresh and sterile needles, syringes, and blood sample bottles were obtained from a teaching hospital (tertiary health institution) that had imported pharmaceuticals and medical equipment from recognized pharmaceutical manufacturing companies in Europe, USA, and South Africa. They were, therefore, trace elements-free. A phlebotomist working with the teaching hospital used the fresh (sterile) needle/syringe and blood sample bottles to collect the blood samples, with swab cotton wool and methylated spirit. A sterilized sample bottle was given to each subject to supply early morning urine, with instruction to store the sample in the fridge between collection and delivery to the laboratory. The samples were analyzed by a Medical Laboratory Scientist working in the Medical Diagnostic Laboratory Unit of the Teaching Hospital for serum levels of Cd, Pb, Hg, Ni, Se, and Tl and urine levels of As and Be (independent variables) and the kidney functions (dependent variables) of the make-ups users. The two sets of data were subjected to regression to determine the relationship between the variables. Analysis was performed using Statistical Package for Social Sciences (SPSS) Version 23.0.

Ethical committee approval

Since the study involved human samples, an appropriate Health Research and Ethical Review Committee gave the ethical approval. All the methods were performed in accordance with the relevant guidelines and regulations.

Quantitative determination of the trace elements

Arsenic, lead, and cadmium

Arsenic, lead, and cadmium were determined by Environmental Protection Agency (EPA) of the USA method-200_13-trace element determination via atomic absorption graphite furnace spectrometer using Buck scientific atomic absorption spectrophotometer (GFAAS, made in USA). Pd-Mg mixture was served as the matrix modifier for As, while Ni was used as matrix modifier for Pb and Cd (Bakırdere et al., 2013).

Mercury (Hg)

Total mercury was determined by absorption spectrometry (dithizone colorimetry), neutron activation analysis or cold vapor atomic absorption spectrometry of the EPA of the USA method-200_13-trace element determination via atomic absorption graphite furnace spectrometer using Buck Scientific atomic

absorption spectrophotometer (GFAAS, made in USA) (Bakırdere et al., 2013).

Beryllium (Be)

Beryllium was determined by EPA of the USA method-200_13-trace element determination via atomic absorption graphite furnace spectrometer using Buck Scientific Atomic Absorption Spectrophotometer (GFAAS, made in USA) (Bakırdere et al., 2013).

Nickel (Ni)

Nickel was determined by using 2-[(2-mercaptophenylimino)methyl]phenol (MPMP) to form a brown 1:2 MPMP-nickel(II) complex at pH > 10, which was extracted into chloroform. The complex had a maximum absorption at 421 nm. The relative standard deviation at 0.018 μg mL^{-1} is 1.1% ($n = 8$) (Shabani et al., 2008).

Selenium (Se)

Selenium was determined by digesting the sample by wet-ashing procedure and finally analyzing it using inductively coupled plasma-mass spectrometry (ICP-MS). The mean Se value was obtained (Moatkhef et al. 2020).

Thallium (Tl)

Urine samples were subjected to quantitative 24-h-urinary-thallium-level (QT) analysis. Independent-samples t test and Spearman's coefficient were applied for analytical purposes. SPSS software 16 was used to conduct statistical analyses with P values less than 0.05 regarded as significant (Ghaderi et al., 2017).

Procedure for eGFR

Based on the sample blood creatinine level and/or blood cystatin C level, the estimated glomerular filtration rate (eGFR) was a calculated estimate of the actual glomerular filtration rate of the blood sample drawn from a vein.

Results and discussion

Table 1 shows the serum/urine levels of selected trace elements and kidney functions, while Table 2 shows the means and standard deviations for serum/urine levels of the selected trace elements and for kidney functions (eGFR ml/min in 1.73 m^3). From Table 2, the mean kidney function (eGFR ml/min in 1.73 m^3) was 56.9800 ± 3.22860. This fell within the range, eGFR < 60 ml/min in 1.73 m^3, which indicates kidney function affected by trace elements (Fevrier-Paul et al., 2018). The mean urine As level of 106.0108 ± 23.83840 fell outside the normal range of ≤ 50 μg/L and high normal range of > 50 to < 200 μg/L (ATSDR, 2000). The mean serum Cd level of 3.7864 ± 1.76790 ng/mL was within the normal range of < 5.0 ng/mL (Agency for Toxic Substances and Disease Registry, ATSDR, 2000).

The mean serum Pb level of 17.2548 ± 4.63788 exceeded the normal serum Pb levels in adults of up to 10 μg/dL. It fell within the range, 10 and 25 μg/dL, for regular exposure to Pb. A consistent and regular use of make-ups by subjects confirmed the literature claim of regular exposure to Pb (Agency for Toxic Substances and Disease Registry, ATSDR, 2000). The mean serum Hg was 25.9482 ± 4.14231. This value exceeded the normal level, < 10–20 μg/L, and 35 μg/L level caused by long-term exposure to Hg vapor. Hg is a highly toxic element, and there is no known safe blood level of Hg (Agency for Toxic Substances and Disease Registry, ATSDR, 2000). The mean urine Be level of 0.5574 ± 0.22715 μg/L exceeded the minimum acceptable level of 0.28 μg/L but was within the normal range of 0.28–1 μg/L. Levels in excess of this range can cause cancer (Agency for Toxic Substances and Disease Registry, ATSDR, 2002).

The mean serum Ni of 0.6237 ± 0.23037 was within the healthy range, 0.14–0.65 μg/L, but above 0.2 μg/L, which is the most reliable value in adults (Agency for Toxic Substances and Disease Registry, ATSDR, 2000). The mean serum Se level of 103.8950 ± 88.80677 μg/L was within the average range of 100.6 ± 12.9 μg/L for adults (over 16 years), 93.9 ± 13.6 μg/L for adult women, and 102.1 ± 12.3 μg/L for adult men (Safaralizadeh et al., 2005). The mean serum Tl level of

Table 1 Serum/urine levels of selected trace elements and kidney functions

S.N	Kidney function (eGFR ml/min in 1.73 m^3)	As Level (µg/L)	Cd Level ng/mL	Pb Level (µg/dL)	Hg Level (µg/dL)	Be Level (µg/L)	Ni Level (µg/L)	Se Level (µg/L)	Tl Level (µg/L)
1	51	166.10	8.08	9.09	21.49	0.31	0.97	99.1	202
2	53	171.17	3.01	10.01	19.31	0.29	0.93	98.2	201
3	56	180.92	7.10	19.01	20.34	0.33	0.23	93.4	201
4	59	161.88	2.08	16.02	21.08	0.41	0.79	94.4	201
5	59	150.11	9.39	19.03	29.09	0.55	0.37	95.1	203
6	59	159.19	2.49	17.01	31.03	0.69	0.23	94.6	203
7	58	153.18	8.08	14.01	28.04	0.32	0.33	94.2	202
8	55	157.72	2.17	11.04	22.09	0.44	0.98	95.2	202
9	56	155.18	2.03	18.06	27.03	0.42	0.57	983	202
10	54	152.42	9.09	14.92	23.59	0.34	0.33	94.4	204
11	58	157.14	2.09	12.08	26.71	0.71	0.45	97.3	204
12	59	152.00	6.07	13.01	24.76	0.98	0.58	94.8	204
13	57	156.17	2.02	20.01	30.01	0.76	0.59	93.2	202
14	57	171.10	8.03	24.91	33.09	0.37	0.38	93.9	201
15	57	194.62	2.05	20.08	24.17	0.68	0.41	94.8	203
16	48	190.98	9.07	20.07	25.11	0.46	0.29	94.9	204
17	57	183.87	3.04	20.06	20.00	0.65	0.31	95.6	202
18	59	190.76	3.03	21.05	29.01	0.62	0.68	93.8	202
19	56	163.77	1.08	22.09	23.99	0.81	0.42	96.1	203
20	55	152.89	4.08	23.09	34.82	0.97	0.33	95.4	204
21	58	189.82	5.03	24.53	34.29	0.37	0.57	96.7	202
22	58	177.78	5.00	24.89	22.18	0.29	0.61	94.3	201
23	56	171.34	3.08	19.00	26.52	0.28	0.62	95.2	201
24	56	199.54	4.04	18.04	29.48	0.83	0.69	93.6	201
25	57	167.67	5.09	12.02	20.88	0.94	0.39	93.5	203
26	58	181.19	4.09	19.09	22.76	0.63	0.34	97.3	203
27	58	190.82	5.00	21.01	28.67	0.29	0.43	93.8	202
28	56	191.02	2.05	18.01	28.28	0.33	0.58	93.1	202
29	57	190.15	5.05	14.02	31.90	0.41	0.41	97.5	202
30	57	193.13	4.74	16.03	32.89	0.55	0.23	94.5	204
31	58	189.17	1.63	15.01	26.68	0.69	0.44	96.3	203
32	59	152.10	3.73	12.01	21.98	0.32	0.58	97.5	203
33	59	158.13	4.63	10.04	23.91	0.44	0.54	96.6	202
34	59	151.15	3.57	22.26	25.88	0.42	0.42	94.6	202
35	49	155.11	2.44	22.12	27.66	0.34	0.41	95.3	023
36	48	156.88	3.53	24.30	29.75	0.71	0.48	93.7	202
37	48	167.90	2.62	24.17	23.73	0.98	0.41	94.3	203
38	49	188.72	2.98	12.03	22.24	0.76	0.23	93.8	201
39	54	166.14	2.19	23.71	34.11	0.37	0.25	95.4	203
40	54	190.00	2.75	19.18	32.08	0.68	0.41	95.7	201
41	53	189.34	2.83	13.17	20.79	0.46	0.50	94.9	202
42	56	176.19	2.42	23.51	22.79	0.65	0.27	95.4	201

Table 1 (continued)

S.N	Kidney function (eGFR ml/min in 1.73 m^3)	As Level (µg/L)	Cd Level ng/mL	Pb Level (µg/dL)	Hg Level (µg/dL)	Be Level (µg/L)	Ni Level (µg/L)	Se Level (µg/L)	Tl Level (µg/L)
43	57	184.16	2.58	11.07	33.03	0.62	0.41	95.1	201
44	57	168.19	2.93	14.14	20.12	0.81	0.59	96.4	201
45	58	179.34	2.74	14.01	22.31	0.97	0.22	96.8	203
46	59	187.09	4.83	14.03	28.22	0.37	0.71	94.3	203
47	57	182.28	5.81	15.20	29.27	0.29	0.33	93.8	202
48	58	182.00	3.44	10.20	24.71	0.28	0.58	94.2	202
49	62	179.66	4.73	17.04	28.34	0.83	0.98	95.4	202
50	59	120.45	1.95	11.11	25.88	0.91	0.68	95.6	204
51	62	198.78	3.58	21.09	22.87	0.41	0.68	97.2	203
52	63	139.13	4.81	19.01	24.98	0.29	0.72	98.5	202
53	54	146.33	5.19	11.01	27.78	0.33	0.79	93.7	203
54	57	101.98	4.67	17.02	19.67	0.41	0.89	94.3	204
55	58	156.86	3.67	16.03	26.23	0.55	0.31	94.7	302
56	58	165.25	3.97	12.11	28.09	0.69	0.68	94.2	203
57	59	171.67	4.93	14.09	29.16	0.32	0.80	94.1	203
58	59	178.99	1.97	13.14	22.51	0.44	0.43	94.0	201
59	63	188.06	5.24	18.01	25.87	0.42	0.81	93.9	201
60	66	190.00	2.30	11.22	24.81	0.34	0.53	94.8	202
61	52	160.18	2.71	16.38	18.01	0.71	0.84	94.9	202
62	52	170.82	2.94	14.28	17.22	0.98	0.68	96.4	201
63	51	189.52	2.86	21.42	23.07	0.76	0.81	96.4	201
64	51	159.17	2.89	20.11	35.09	0.37	0.71	94.3	201
65	63	151.13	2.72	24.28	20.31	0.68	0.91	95.4	203
66	62	168.19	2.96	12.17	23.11	0.46	0.52	95.9	203
67	61	159.62	2.48	22.16	29.02	0.65	0.39	94.6	202
68	58	167.70	2.52	24.05	21.21	0.62	0.82	95.3	202
69	58	172.00	2.75	25.01	28.13	0.81	0.94	93.6	202
70	58	166.55	2.89	22.01	22.33	0.97	0.31	94.3	204
71	59	178.19	2.61	23.43	27.17	0.37	0.781	93.9	202
72	55	189.24	2.49	21.02	25.11	0.29	0.98	94.9	201
73	59	171.65	2.76	10.00	24.00	0.28	0.74	95.3	204
74	59	167.08	2.92	16.04	27.01	0.83	0.83	94.7	203
75	58	117.42	2.94	13.02	31.63	0.91	0.91	93.8	202
76	58	119.09	2.97	18.09	34.13	0.38	0.73	94.9	202
77	57	198.08	2.95	24.01	32.01	0.29	0.71	94.8	202
78	59	142.89	2.92	13.01	29.32	0.33	0.97	93.6	201
79	59	143.38	2.83	18.02	22.14	0.41	0.79	94.4	201
80	59	153.12	2.96	19.03	28.41	0.55	0.91	94.7	201
81	58	163.05	2.98	16.21	28.31	0.69	0.83	94.6	202
82	56	178.37	2.87	15.73	22.23	0.32	0.99	94.1	201
83	57	182.78	2.97	12.51	25.13	0.44	0.88	94.8	201
84	56	158.89	2.88	24.56	28.44	0.42	0.98	95.8	201

Table 1 (continued)

S.N	Kidney function (eGFR ml/min in 1.73 m^3)	As Level (µg/L)	Cd Level ng/mL	Pb Level (µg/dL)	Hg Level (µg/dL)	Be Level (µg/L)	Ni Level (µg/L)	Se Level (µg/L)	Tl Level (µg/L)
85	58	199.10	2.98	23.01	22.32	0.34	0.90	95.4	203
86	56	107.17	2.74	21.83	29.31	0.71	0.78	96.3	203
87	59	133.68	3.70	25.01	26.19	0.98	0.39	93.8	202
88	59	196.66	5.09	10.30	23.01	0.76	0.81	94.7	202
89	58	157.92	1.96	21.00	29.01	0.37	0.82	94.6	202
90	58	165.09	4.90	17.03	20.51	0.68	0.70	96.7	204
91	57	114.23	5.93	11.67	20.11	0.46	0.56	94.0	203
92	59	196.67	3.94	22.12	29.01	0.65	0.77	95.3	202
93	54	179.44	2.88	12.07	23.02	0.62	0.87	93.7	201
94	54	173.54	5.83	18.14	21.02	0.81	0.95	93.8	202
95	56	194.67	2.78	14.03	24.11	0.97	0.78	96.1	204
96	56	146.72	2.99	13.03	27.02	0.37	0.61	95.1	207
97	59	163.88	4.81	19.02	27.03	0.29	0.91	95.0	201
98	58	124.76	3.81	15.30	29.31	0.28	0.83	96.2	203
99	57	87.74	6.71	13.02	27.22	0.83	0.88	93.8	201
100	59	97.02	7.91	10.02	26.02	0.97	0.73	94.2	205

201.4900 + 20.63316 µg/L was much higher than the normal level of < 2 µg/L and within the toxic range of > 200 µg/L (National Institute for Occupational Safety and Health, NIOSH, Center for Disease Control, CDC, 2003).

Table 3 shows the model summary of the serum levels of selected trace elements and kidney functions. The *R* square value of 0.100 means that 10% of the variation in the dependent variable is explained by the variation in the independent variables. Table 4 shows the ANOVA of the serum levels of the selected trace elements and kidney functions. The *R* square value of 0.100 (see model summary table) was not significant (0.271) at 1%, 5% and 10% (see ANOVA table).

Table 5 shows the regression coefficients of the serum/urine levels of selected trace elements and kidney functions. At − 0.009, the coefficient for As showed that for every 1% rise in urine As level, kidney function decreased by 0.9%. This was, however, not significant (0.518) at 1%, 5%, and 10%. The coefficient of − 0.155 for Cd showed that for every 1%

Table 2 Means and standard deviations for serum/urine levels of trace elements and for kidney functions (eGFR ml/min in 1.73 m^3)

	Number	Minimum	Maximum	Mean	Std. deviation
Descriptive statistics					
Kidney function (eGFR ml/min in 1.73 m^3)	100	48.00	66.00	56.9800	3.22860
As	100	87.74	199.54	166.0108	23.83840
Cd	100	1.08	9.39	3.7864	1.76790
Pb	100	9.09	25.01	17.2548	4.63788
Hg	100	17.22	35.09	25.9482	4.14231
Be	100	.28	.98	.5574	.22715
Ni	100	.22	.99	.6237	.23037
Se	100	93.10	983.00	103.8950	88.80677
Tl	100	23.00	302.00	201.4900	20.63316
Valid N (listwise)	100				

Table 3 Model summary[a] of the serum/urine levels of selected trace elements and kidney functions

Model	R	*R* square	Adjusted *R* square	Std. error of the estimate
1	.317[a]	.100	.021	3.19437

[a]Predictors: (constant), Tl, Se, Ni, Be, Hg, Pb, Cd, As

rise in serum Cd level, kidney function decreased by 15.5%. This was, however not significant (0.423) at the three levels of 1%, 5%, and 10%.

At − 0.039, the coefficient for Pb showed that for every 1% rise in serum Pb level, kidney function decreased by 3.9%. This was, however, not significant (0.595) at 1%, 5%, and 10%. The coefficient of 0.061 for Hg showed that for every 1% rise in serum Hg level, kidney function increased by 6.1%. This was, however, not significant (0.462) at 1%, 5%, and 10%.

The coefficient of Be, − 1.585, showed that for every 1% rise in urine Be level, kidney function decreased by 158.5%. This was, however, not significant (0.292) at 1%, 5%, and 10%. At 1.384, the coefficient for Ni showed that for every 1% rise in serum Ni level, kidney function increased by 138.4%. This was, however, not significant (0.354) at 1%, 5%, and 10%.

The coefficient, − 0.002, for Se showed that for every 1% rise in serum Se level, kidney function decreased by 0.2%. This was, however, not significant (0.635) at 1%, 5%, and 10%. At 0.039, the coefficient for Tl showed that for every 1% rise in serum Tl level, kidney function increased by 3.9%. This was significant (0.015) at 5%. This finding internally validated the finding on the mean serum Tl level of 201.4900 + 20.63316 which was much higher than the normal level of < 2 µg/L and within the toxic range of > 200 µg/L.

Table 4 ANOVA[a] of the serum/urine levels of selected trace elements and kidney functions

Model		Sum of squares	Df	Mean square	*F*	Sig
1	Regression	103.394	8	12.924	1.267	.271[a]
	Residual	928.566	91	10.204		
	Total	1031.960	99			

Dependent variable: kidney function (eGFR ml/min in 1.73 m^3)

[a]Predictors: (constant), Tl, Se, Ni, Be, Hg, Pb, Cd, As

Table 5 Coefficients[a] (regression) of the serum levels of selected trace elements and kidney functions

Model		Unstandardized coefficients		Standardized coefficients	*t*	Sig
		B	Std. error	Beta		
1	(Constant)	50.551	5.195		9.731	.000
	As	− .009	.014	− .069	− .649	.518
	Cd	− .155	.193	− .085	− .804	.423
	Pb	− .039	.074	− .056	− .533	.595
	Hg	.061	.082	.078	.740	.462
	Be	− 1.585	1.497	− .112	− 1.059	.292
	Ni	1.384	1.485	.099	.932	.354
	Se	− .002	.004	− .048	− .477	.635
	Tl	.039	.016	.250	2.473	.015

Dependent variable: kidney function (eGFR ml/min in 1.73 m^3)

Conclusions

Against the backdrop of increasing concern for the toxicity of trace elements in make-ups, 8 such elements (As, Cd, Pb, Hg, Be, Ni, Se, and Tl), described as notorious daredevils, have been investigated. The study was aimed at ascertaining the potential for poisoning from make-ups use that could lead to cancer by exposure to Be or CKD and its complications by exposure to As, Cd, Pb, Hg, Ni, Se, and Tl. Female university students who consistently used make-ups for upwards of 3 years were the subjects. The serum/urine levels of these trace elements were regressed against the kidney functions of the subjects. Only the level of Tl in the body was significant (0.015) at 5%. This finding internally validated the finding on the mean serum Tl level of 201.4900 + 20.63316, which was much higher than the normal level of < 2 μg/L and within the toxic range of > 200 μg/L. This finding warrants concerns for the toxicity of Tl contained in make-ups used in Nigeria.

Author's contribution Not applicable; single author, who did all the work.

Data Availability Materials and data embedded in this work are transparently available.

Code availability Materials and data are in Microsoft Word with custom code.

Declarations

Ethical approval The Health Research and Ethical Review Committee of the University of Nigeria Teaching Hospital (UNTH), Ituku-Ozalla, Enugu approved the study.

Consent to participate All subjects gave informed consent to participate in the study.

Consent for publication All the subjects gave informed consent for academic publishing of the results of the study with anonymity.

Competing interests The author declares no competing interests.

References

Agency for Toxic Substances and Disease Registry, ATSDR. (2002). Public health statement for beryllium. https://www.atsdr.cdc.gov/phs/

Agency for Toxic Substances and Disease Registry, ATSDR. (2000). *Toxicological profile for arsenic*. Public Health Service, U.S. Department of Health and Human Services.

Aldayel, O., Hefne, J., Alharbi, K. N., & Al-Ajyan, T. (2018). Heavy metals concentration in facial cosmetics. *Natural Products Chemistry & Research, 6*, 303.

Bakırdere, S., Yaroğlu, T., Tırık, N., Demiröz, M., Fidan, A. K., Maruldalı, O., Karaca, A. (2013). Determination of As Cd, and Pb in Tap Water and Bottled Water Samples by Using Optimized GFAAS System with Pd-Mg and Ni as Matrix Modifiers, *Journal of Spectroscopy,* https://doi.org/10.1155/2013/824817

Becker, L. C., Boyer, I., Bergfeld, W. F., Belsito, D. V., Hill, R. A., et al. (2016). Safety assessment of alumina and aluminum hydroxide as used in cosmetics. *International Journal of Toxicology, 35*(3 suppl), 16S-33S.

Brown, V. J. (2013). Metals in lip products: a cause for concern? *Environmental Health Perspectives, 121*(6), A196.

Bruzzoniti, M. C., Abollino, O., Pazzi, M., Rivoira, L., Giacomino, A., et al. (2017). Chromium, nickel, and cobalt in cosmetic matrices: an integrated bioanalytical characterization through total content, bioaccessibility, and Cr (III)/Cr (VI) speciation. *Analytical and Bioanalytical Chemistry, 409*(29), 6831–6841.

Capelli, C., Foppiano, D., Venturelli, G., Carlini, E., Magi, E., et al. (2014). Determination of arsenic, cadmium, cobalt, chromium, nickel, and lead in cosmetic face-powders: optimization of extraction and validation. *Analytical Letters, 47*, 7.

Chan, T. Y. K., Chan, A. P. L., & Tang, H. L. (2019). Nephrotic syndrome caused by exposures to skin-lightening cosmetic products containing inorganic mercury. *Clinical Toxicology (philadelphia, PA), 17*, 1–7.

Doshi, M., Annigeri, R. A., Kowdle, P. C., Subba Rao, B., & Varman, M. (2018). Membranous nephropathy due to chronic mercury poisoning from traditional Indian medicines: report of five cases. *Clinical Kidney Journal, 12*(2), 239–244.

Fevrier-Paul, A., Soyibo, A., Mitchell, S., & Voutchkov, M. (2018). Role of toxic elements in chronic kidney disease. *Journal of Health and Pollution, 8*(20), 181–202. https://doi.org/10.5696/2156-9614-8.20.181202

Ghaderi, A., Banafshe, H.R., Khodabandehlo, S., Mehrzad, F., Mehrpour, O., & Afshar, R. (2017). *Electron Physician*, 9(4), 4190–4194. https://doi.org/10.19082/4190

Gondal, M. A., Dastageer, M. A., Naqvi, A. A., Isab, A. A., & Maganda, Y. W. (2012). Detection of toxic metals (lead and chromium) in talcum powder using laser induced breakdown spectroscopy. *Applied Optics, 51*(30), 7395–7401.

Hall, J., & Hall, J. (2011). *Guyton, Hall Textbook of Medical Physiology* (12th ed.). Elsevier.

Henn, C. B., Ettinger, A. S., Hopkins, M. R., Jim, R., Amarasiriwardena, C., et al. (2016). Prenatal arsenic exposure and birth outcomes among a population residing near a mining related superfund site. *Environmental Health Perspectives, 124*(8), 1308–1315.

Klotz, K., Weistenhöfer, W., Neff, F., Hartwig, A., Van Thriel, C., et al. (2017). The health effects of aluminum exposure. *Deutsches Ärzteblatt International, 114*(39), 653–659.

Lavilla, I., Cabaleiro, N., Costas, M., de la Calle, I., & Bendicho, C. (2009). Ultrasound- assisted emulsification of cosmetic samples prior to elemental analysis by different atomic spectrometric techniques. *Talanta, 80*(1), 109–116.

Li, H., Zheng, J., Wang, H., Huang, G., Huang, Q., et al. (2019). Maternal cosmetics use during pregnancy and risks of adverse outcomes: a prospective cohort study. *Science and Reports, 9*(1), 8030.

Martin, C. J., Werntz, C. L., 3rd., & Ducatman, A. M. (2004). The interpretation of zinc protoporphyrin changes in lead intoxication: a case report and review of the literature. *Occupational Medicine (london), 54*(8), 587–591.

Moatkhef, F., Ismail, H., Agamy, N., & Aborhyem, S. (2020). Quantitative determination of selenium in the most common food items sold in Egypt. *The Journal of the Egyptian Public Health Association, 95*, 15. https://doi.org/10.1186/s42506-020-00044-z

Mohiuddin, A. K. (2019a). Cosmetics in use: a pharmacological review. *Journal of Dermatology & Cosmetology, 3*(2), 50–67.

Mohiuddin, A. K. (2019b). Skin lighteners, hyperpigmentation management. *ASIO Journal of Pharmaceutical, Herbal Medicines Research* (ASIO-JPHMR) Volume, 5, 1.

Mohiuddin, A. K. (2019c) Heavy Metals in cosmetics: the notorious daredevils and burning health issues. *American Journal of Biomedical Science and Research,* 4, 332–337. AJBSR.MS.ID.000829. https://doi.org/10.34297/AJBSR.2019.04.000829

National Institute for Occupational Safety and Health (NIOSH), *Center for Disease Control (CDC).* (2003). Thallium: Systemic agent. https://www.cdc.gov/niosh/ershdb/emergencyresponsecardThalliumbloodconcentrationlevels

Orisakwe, O. E., & Otaraku, J. O. (2013). Metal concentrations in cosmetics commonly used in Nigeria. *The Scientific World Journal, 5*, 959637.

Orr, S. E., & Bridges, C. C. (2017). Chronic kidney disease and exposure to nephrotoxic metals. *International Journal of Molecular Sciences, 18*(5), E1039.

Piao, F., Yokoyama, K., Ma, N., & Yamauchi, T. (2003). Subacute toxic effects of zinc on various tissues and organs of rats. *Toxicology Letters, 145*(1), 28–35.

Qin, A. B., Su, T., Wang, S. X., Zhang, F., Zhou, F. D., et al. (2019). Mercury-associated glomerulonephritis: a retrospective study of 35 cases in a single Chinese center. *BMC Nephrology, 20*(1), 228.

Saadatzadeh, A., Afzalan, S., Zadehdabagh, R., Tishezan, L., Najafi, N., et al. (2019). Determination of heavy metals (lead, cadmium, arsenic, and mercury) in authorized and unauthorized cosmetics. *Cutaneous and Ocular Toxicology, 38*(3), 207–211.

Shabani, A. M. H., Dadfarnia, S., Shahbaazi, Z., & Jafari, A. A. (2008). Extraction-spectrophotometric determination of nickel at microgram level in water and wastewater using 2-[(2-mercaptophenylimino)methyl]phenol. *Bulletin of the Chemical Society of Ethiopia, 22*(3), 323–329.

Safaralizadeh, R., Kardar, G. A., Pourpal, Z., Moin, M., & Zare, A. (2005). Teimourian S (2005) Serum concentration of selenium in healthy individuals living in Tehran. *Nutrition Journal, 4*, 32. https://doi.org/10.1186/1475-2891-4-32

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

SCOOPWHOOP. (2017). Not just Virat Kohli, here are other celebs who said no to endorsements on ethical grounds.

Sneyers, L., Verheyen, L., Vermaercke, P., & Bruggemann, M. (2009). Trace element determination in beauty products by k0-instrumental neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry, 281*, 259–263.

Tibau, A. V., & Grube, B. D. (2019). Mercury contamination from Dental Amalgam. *Journal of Health and Pollution, 9*(22), 190612.

Wang, Y., Chen, L., Gao, Y., Zhang, Y., Wang, C., et al. (2016). Effects of prenatal exposure to cadmium on neurodevelopment of infants in Shandong, China. *Environmental Pollution, 211*, 67–73.

Wani, A. L., Ara, A., & Usmani, J. A. (2015). *Lead Toxicity: a Review. Interdisciplinary Toxicology, 8*(2), 55–64.

Zhang, L., Liu, F., Peng, Y., Sun, L., & Chen, C. (2014). Nephrotic syndrome of minimal change disease following exposure to mercury-containing skin-lightening cream. *Annals of Saudi Medicine, 34*(3), 257–261.