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ASSESSMENT OF THE CONCENTRATIONS AND HUMAN EXPOSURE TO HEAVY METALS IN BATHING SOAPS IN NIGERIA

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ABSTRACT

The presence of heavy metals in consumer products, particularly in personal care items like soaps, poses potential health risks to consumers. This study aimed to determine the concentrations and risks of Pb, Ni, Zn, Co, Cd and Cr in commonly used bathing soaps available in the Nigerian market. A total of seventeen bathing soaps comprising of medicated, moisturizing, toilet and skin whitening soaps were obtained for this study. Analytical procedures under satisfactory conditions were harnessed to determine the various concentrations and the results revealed varying concentrations of Pb (0.08 to 0.39 mg/kg), Ni (0.05 to 0.33 mg/kg), Zn (0.10 to 6.42 mg/kg), Co (0.04 to 1.93 mg/kg), Cd (0.02 to 0.09 mg/kg), and Cr (0.01 to 0.19 mg/kg) across the different soap categories. The systemic exposure dosage (SED) values for these metals obtained from the use of these bathing soaps were below their respective provisional tolerable daily intake or recommended daily intake values. The margin of safety (MoS) values obtained were greater than 100 which indicated that the concentrations of the metals in these soaps do not present considerable risk to the users. The findings underscore the importance of regular monitoring and regulation of heavy metal content in consumer products, particularly personal care items like soaps. As prolonged exposure to these metals, even in trace amounts, may have adverse effects on human's health and long-term toxicity. Therefore, stringent quality control measures and regulatory standards are imperative to safeguard public health and ensure the safety of consumers in Nigeria.

Keywords: Bathing soaps, Heavy metals, Human health

INTRODUCTION

When cleaning and washing surfaces, soap, an anion-like surface active agent, is utilized in combination with water. (Abdullah and Ibrahim, 2013). Varieties of soaps are technically synthesized by the reaction of plant or animal oils with Lyle (a strong solution of NaOH/KOH) to form glycerine and sodium/potassium salt of the fatty acid, a process known as saponification (Paula, 2007). Heavy metals are not introduced during the soap-making process; instead, they gain access through contamination, with the possible exception of using heavy metal hydroxide. In this instance, the soap may be used for reasons other than skin care (Robert and Linda, 2010).

Trace metals classified as heavy have a density at least five times higher in comparison to the density of water. While some, may be essential to the nutrition of humans, animals, or plants, others known as hazardous metals are not known to have a beneficial effect on nutrition. (Spiegel, 2002). The body's immunological, neurological, circulatory and endocrine systems are all adversely affected by the bioaccumulation of heavy metals by means of ingestion, inhalation, or even skin absorption. (Samara *et al.*, 2009). The high content levels of heavy metals in cosmetics have significant implications as these metals can penetrate the skin and be systematically absorbed (Saadatzadeh *et al.*, 2019). In soap production, a wide variety of fats and oils such as tallow, lard, palm kernel oil, coconut oil, marine oil and other ingredients are employed. Fats and oils, the major raw materials in soap production do not contain toxic metals, this implies that toxic metals found in soaps could have emanated from contaminant either from raw materials processing stage or during the production process. Having established that these soaps could have been contaminated with toxic metals, it is also important to note that many of these carcinogenic metals including chromium, nickel, cobalt, zinc and lead have been discovered to be the cause of some skin diseases such as dermatitis and eczema.

Because metals are able to accumulate in the body as time passes with some of them linked to several kinds of long-term health issues, human exposure to metals in soaps is of great concern to human health. (Bocca *et al.*, 2014). According to a list released by Annex II of the European Council Directive 76/768/EEC, certain metals, including Cd, Co, Cr, Ni, and Pb, as well as their derivatives are banned from being added intentionally to personal care products because of their hazardous properties (Iwegbue *et al.*, 2017). Nevertheless, because of interference during the production process, these metals continue to exist as contaminants in personal care goods like soaps. Therefore, this study determines the concentrations of selected medicated, moisturizing, toilet and skin whitening soaps in Nigeria.

MATERIALS AND METHODS

Sample Collection

Samples of soaps were randomly purchased from supermarkets in Abraka in Delta State, Nigeria. A total of 17 soaps comprising of medicated, moisturizing, toilet and skin whitening soaps were obtained. Every sample that was gathered was within its shelf life. Table 1 presents details about the samples that were gathered, including brand names, country of origin, and colour.

Table 1: Information on medicated, beauty, bathing and toilet soap samples

Brand	Colour	Country of Origin
Medicated Soaps		
Delta	White	Nigeria
Tetmosol	Yellow	Nigeria
Premier Cool	Blue	Ghana
Dettol	Yellow	UK
Tura	Blue	Nigeria
Moisturizing Soaps		
Dove	White	USA
Freshglow	Pink	Nigeria
DuduOsun	Black	Nigeria
OjaUrhobo	Dark brown	Nigeria
Lux	White	South Africa
Joy	White	Nigeria
Toilet Soaps		
Supreme	Yellow	Nigeria
Irish Spring	Green	USA
Eva Classic	Pink	UAE
Skin Whitening soaps		
Extract	Orange	Philippines
Hawaii	Orange	Nigeria
Visita	Pink	Nigeria

Reagents

Nitric acid (HNO_3, 69%) (Trace SELECT, Fluka), Hydrochloric acid (HCl, 65%) (Trace SELECT, Fluka), Perchloric acid ($HClO_4$65%) (Trace SELECT, Fluka) were of exceptionally pristine quality. The 1000 mg/L commercially available standards of Cd, Pb, Ni, Cr, Co, and Zn (Merck, Demstaldt, Germany) were diluted with 0.25 mol/L HNO_3 to generate the calibration standards.

Sample Preparation and Analysis

A beaker containing 1.0 g of each sample was filled with 3 mL of concentrated nitric acid, 3 mL of perchloric acid, and 9 mL of hydrochloric acid. The mixture was then allowed to stand for the entire night. The following day, the sample was heated to 125 ℃ for two hours. After letting the sample solution cool, it was filtered and diluted with 0.25 mol/L HNO_3 to a volume of 25 mL. The three blanks were made in the same manner, but without the samples. The digested samples were analyzed in triplicate for Cd, Pb, Ni, Cr, Co, and Zn by using flame atomic absorption spectrophotometry (Perkin Elmer, Analyst 200, and Norwalk CT, USA). Calibration standards and blank solutions were analyzed in similar way as the samples. Statistical analysis was carried out after deducting the average blank signal from the sample's analytical signal.

Quality Control and Assurance

All reagents used were ultra-pure. All glassware used were previously soaked in 10% (v/v) HNO_3 solution for 24 hrs and rinsed with deionized water. The instrument was calibrated after every five runs. The accuracy of the analytical procedure was determined by using spike recovery methods. A known concentration of the test metal was introduced into an already analyzed sample and the sample was reanalyzed. The percent spike recoveries for metals were between 89.5 and 98.8 %.

Statistical Analysis

Analysis of variance (ANOVA) was employed to find out if there were any notable differences in the metal concentrations across the various soap brands.

Health Risk Evaluation of Metals in Soaps

The health risk assessment of metals in the soaps was carried out using the Margin of Safety (MoS). Margin of Safety (MoS) is the magnitude by which the NOAEL of the critical toxic effect exceeds the estimated exposure dose, calculated according to the formula:

$$MoS = \frac{NO(A)EL}{SED}$$

Where SED stands for Systemic Exposure Dosage and NOAEL stands for No Observed Adverse Effect Level.

The link between the oral reference doses (RFDs) (which are defined as estimates of the daily exposure to the human population including sensitive sub-groups that is likely to be without a significant risk of adverse effects during lifetime) and the studied metals was used to derive the NOAEL values.

$$NOAEL = RFD \times UF \times MF$$

Where MF is the modifying factor (based on the applied scientific judgment) and UF the uncertainty factor (indicating the overall confidence in the distinct data sets). In this instance, UF and MF have default values of 100 and 1. The RFDs (in mg/kg/day) used were Pb (4×10^{-3}) (Storelli, 2008), Cd (1×10^{-3}), Cr (3×10^{-3}), Co (3×10^{-4}), (Zn (3.0×10^{-1}) and Ni (2×10^{-2}) (US EPA, 1989).

The Systemic Exposure Dose (SED) of a contaminant is the amount expected to enter the blood stream daily (and therefore be systemically available) per kg body weight. The systemic exposure dosage (SED) is shown by the expression (Iwegbue, 2015);

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

Where Cs is the concentration of metal in the soaps (mg kg^{-1}); AA is the amount of soap applied per day. SSA is the skin surface area in which the soap is applied (in cm^2), RF is the retention factor, F is the frequency of application per day; BF is the bioaccessibility factor; 10^{-3} is unit conversion factor; BW is the body weight (kg). A default body weight of 60 kg was used in this study. The values of AA, SSA, F and RF used in this study were 18.67 g, 17500 cm^2, 1.43 per day and 0.01 respectively which are standard values established by the Scientific Committee on Consumer Safety (SCCS, 2012). It is widely acknowledged that the MoS should be at least 100 to determine whether a substance is safe for usage, as suggested by the World Health Organization (WHO). (SCCS, 2012). The SCCS also pointed out that the oral bioavailability of the substance is assumed to be 100% in many convection computations of MoS if oral absorption statistics are available. Still, it is deemed reasonable to presume that the systemic availability of an oral dose is limited to no more than 50%. (SCCS, 2012). For the purpose of this study, the two scenarios were considered i.e. oral bioavailability of the investigated metals at 50%, and 100% of the measured concentrations of metals in the personal care products for the purpose of comparison with reference exposure dosage values. Margin of safety values greater than 100 indicates that there is no health risk while the margin of safety values less than 100 indicates there is health risk

RESULTS AND DISCUSSION

Metal concentrations in soaps

Table 2 displays the measured metal concentrations in the examined soaps. The results of the analysis of variance (ANOVA) showed that the amounts of the metals under study differed considerably ($p < 0.05$) both within the same soap category and between different soap categories. The differences could be linked to variations in the types of raw materials, formulations, and manufacturing techniques employed in the course of production (Iwegbue *et al.*, 2015).

Table 2: Concentrations (mg/kg) of the metal in the individual soaps

Category	Samples	Pb	Ni	Zn	Co	Cd	Cr
Medicated	SP1	0.10	0.19	0.40	0.56	0.03	0.07
	SP2	0.16	0.22	0.61	0.89	0.05	0.07
	SP3	0.08	0.12	1.03	1.93	0.02	0.04
	SP4	0.09	0.15	0.18	0.47	0.03	0.03
	SP5	0.11	0.20	0.22	0.33	0.03	0.03
Moisturizing	SP6	0.11	0.19	6.42	0.69	0.03	0.04
	SP7	0.10	0.20	0.12	0.59	0.04	0.02
	SP8	0.12	0.24	0.10	0.95	0.04	0.01
	SP9	0.12	0.18	1.05	1.01	0.05	0.01
	SP10	0.15	0.09	0.73	0.82	0.04	0.07
	SP11	0.21	0.05	0.63	0.62	0.02	0.03
Toilet	SP12	0.14	0.13	0.57	0.66	0.04	0.07
	SP13	0.18	0.21	0.61	0.73	0.05	0.07
	SP14	0.28	0.19	0.41	0.80	0.05	0.09
Skin Whitening	SP15	0.12	0.11	0.32	0.42	0.02	0.04
	SP16	0.21	0.11	0.30	0.37	0.03	0.07
	SP17	0.18	0.21	0.61	0.73	0.05	0.07
	Minimum	**0.08**	**0.05**	**0.10**	**0.33**	**0.02**	**0.01**
	Maximum	**0.28**	**0.24**	**6.42**	**1.93**	**0.05**	**0.07**

Table 3: Summary statistics metal concentrations in soaps (mg/kg)

Soaps	Statistics	Pb	Ni	Zn
Medicated	Mean±SD (Median)	0.108 ± 0.031 (0.10)	0.176 ± 0.04(0.19)	0.488 ± 0.348(0.4)
	Range	(0.08-0.16)	(0.12-0.22)	(0.18-1.03)
Moisturizing	Mean±SD (Median)	0.135 ± 0.040(0.12)	0.204 ± 0.073(0.2)	1.660 ± 2.434(0.61)
	Range	(0.10-0.21)	(0.05-0.24)	(0.10-6.42)
Toilet	Mean±SD (Median)	0.200 ± 0.072(0.18)	0.177 ± 0.042(0.19)	0.530 ± 0.106(0.57)
	Range	(0.14-0.28)	(0.13-0.21)	(0.41-0.61)
SkinWhitening	Mean±SD (Median)	0.170 ± 0.046(0.18)	0.143 ± 0.058(0.11)	0.410 ± 0.173(0.32)
	Range	(0.12-0.21)	(0.11-0.21)	(0.30-0.61)
		Co	**Cd**	**Cr**
Medicated	Mean±SD (Median)	0.836 ± 0.645(0.56)	0.032 ± 0.011(0.03)	0.048 ± 0.02(0.04)
	Range	(0.33-1.93)	(0.02-0.05)	(0.03-0.07)
Moisturizing	Mean±SD (Median)	0.794 ± 0.175(0.73)	0.042 ± 0.010(0.04)	0.028 ± 0.023(0.02)
	Range	(0.59-1.01)	(0.02-0.05)	(0.01-0.07)
Toilet	Mean±SD (Median)	0.730 ± 0.070(0.73)	0.047 ± 0.006(0.05)	0.077 ± 0.012(0.07)
	Range	(0.66-0.80)	(0.04-0.05)	(0.07-0.09)
Skin Whitening	Mean±SD (Median)	0.507 ± 0.195(0.42)	0.033 ± 0.015(0.03)	0.060 ± 0.017(0.07)
	Range	(0.37-0.73)	(0.02-0.05)	(0.04-0.07)

Cadmium

The concentration of Cd in these soaps ranged from 0.02 to 0.05 mg/kg. The descending order of toilet soaps, moisturizing soaps, skin-whitening soaps, and medicinal soaps indicated the concentration of Cd in the soaps. As of 2012, Health Canada determined a maximum acceptable level of 3 mg/kg for the presence of cadmium in cosmetic products as an impurity. In Germany, however, 5 mg/kg is the highest permitted limit (BfR, 2006). Cd concentrations in all samples investigated were discovered to be below the German and Canadian standards. These soaps had Cd concentrations that were lower than those previously documented in various Nigerian soap varieties by Iwegbue et al. (2017) and Umar and Caleb (2012). Application of Cd topically has resulted in skin lesions and tumour in rats' scrotum., keratosis and acanthosis with occasional ulcerative changes (Fasanya-Odewumi *et al.,* 1998). Also, percutaneous absorption has been revealed by elevated concentrations of Cd in the blood, liver and kidney of rats (Larsdown and Sampson, 1996). The induction or complexation of Cd to the metallothionein or the molecular interaction of free Cd with the sulfurhydroxyl radical of cysteine in the epidermal keratins (Alquadami *et al.*, 2013; Health Canada, 2012; Volpe *et al.*, 2012).

Lead

The concentrations of Pb in the soaps ranged from 0.08 to 0.28 mg/kg. The concentrations of Pb in the soaps was in the order of toilet soaps > skin whitening soaps > moisturizing soaps > medicated soaps. In 2013, the USFDA established a 20 mg/kg limit for lead contaminants in colourants utilized as materials in making cosmetic goods. Health Canada set a limit of 10 mg/kg for Pb in cosmetic products applied to the skin (Health Canada-Santé Canada, 2012). In this study, the concentration of Pb in the investigated soaps were less than the Health Canada and USFDA limits. Iwegbue *et al.* (2017) reported Pb levels ranging from <0.09 to 26.5 mg/kg in bathing soaps and shower gels used in Nigeria. Umar and Caleb (2013) reported Pb levels ranging from 1.13 to 1.14 µg/g in specific soap varieties in Nigeria. Abulude *et al.* (2007) reported Pb levels of less than LOQ to 5.80 µg/g in certain soaps and cleaning products in Nigeria.

Chromium

Chromium, cobalt and nickel are among the metals that may cause allergies. The Cr concentrations in the soaps ranged from 0.01 to 0.07 mg/kg. The concentration of Cr in the soaps was in the order of toilet soaps > skin whitening soaps > medicated soaps > moisturizing soaps. <LOQ to 43.0 µg/g. Chromium concentrations found in this study were lower than those reported in soaps in Nigeria (Iwegbue *et al.*, 2017; Umar and Caleb, 2012, Ayenimo *et al.*, 2010) and somewhere else (Chanchan *et al.*, 2010). The amounts of Cr present in these soaps suggest that there is no risk to the consumers of these soaps from Cr. About 5 % of contact allergy cases in Europe have been linked to chromium and the frequency of these cases increases as one ages and is commonly seen in men than in women (Aguilar-Bernier *et al.*, 2012; Uter *et al.*, 2012). Chromium in form of Cr (III) and Cr (VI) can act as potential haptens in the development of contact allergy (Thyssen *et al.*, 2007) and Cr (VI) has demonstrated a higher skin penetration rate compared to Cr (III) as a result of its high solubility. (Larese *et al.,* 2007). The duration of contact, the use of cleaners, and artificial sweeteners with low pH are other variables that affect how much Cr is absorbed via the skin (Iwegbue *et al.*, 2017).

Nickel

The concentration of Ni in the soaps ranged from 0.05 to 0.24 mg/kg. The concentrations of Ni in the soaps was in the order of medicated soaps > moisturizing soaps > toilet soaps > skin whitening soaps. These soap samples' Ni concentrations were lower than those of several Nigerian soap varieties. (Iwegbue *et al.*, 2017; Umar and Caleb, 2014; Ayenimo *et al.*, 2010). It has been shown that at concentrations of 5 to 10 mg/kg, adult patients with healthy skin may experience contact dermatitis while Ni concentrations of 0.5 mg/kg can induce contact dermatitis in pre-sensitized skin (Iwegbue *et al.*, 2017; Gawkrodger, 1996). Though Basketter *et al*. (1983) recommended that personal care products ought not to have nickel concentrations above 5 mg/kg, defined for good manufacture or even better, the final target limit for improved skin protection being less than 1 mg/kg, international regulations for Ni impurities in cosmetics are presently non-existent. (Bocca *et al*., 2014). Most of the brands under investigation had Ni concentrations lower than those considered acceptable for quality production practices or at levels that are technically avertable.

Cobalt

The concentrations of Co in the soaps ranged from 0.33 to 1.93 mg/kg. The concentrations of Co in the soaps was in the order of medicated soaps >moisturizing soaps >toilet soaps >skin whitening soaps. Two samples had Co values above 1 mg/kg, which may be of concern to pre-sensitized subjects. In the 2008 patch test comprising of 25,000 European individuals, cobalt was found to be the cause of positive results in 7.9% of the instances recorded (Uter *et al.*, 2012). The permeation of Co through the skin depends on the ability of sweat to oxidize Co into Co ions.

Zinc

The concentration of Zn varied from 0.10 to 6.42 mg/kg. The concentrations of Zn in the soaps followed the order: moisturizing soaps > toilet soaps > medicated soaps > skin whitening soaps. A wide range of Zn concentrations in personal care products has been reported in the literatures. For examples, Iwegbue *et al.* (2017) recorded values between 25.5 to 1000 mg/kg in soaps and cleansing creams in Nigeria. Ayenimo *et al.* (2010) recorded zinc concentrations of 0.201 to 0.886 mg/kg in medicated and non-medicated soaps in Nigeria.

Systemic Exposure Dosage

The systemic exposure dosage at 50% and 100% bioaccessibility are displayed in Tables 4. The systemic exposure dosage (SED) at 50% and 100% bioaccessibility for Cd varied between 0.001 to 0.002 µg kg^{-1}bw day^{-1} and0.002 to 0.004 µg kg^{-1}bw day^{-1} respectively. The provisional tolerable daily intake (PTDI) of Cd was set at 1 µg kg^{-1}bw day^{-1}(WHO, 2008), while the European Food Safety Authority set the provisional tolerable intake of Cd at 0.25 µg kg^{-1}bw day^{-1}. The SED of Cd from the usage of these soaps were below the WHO and EFSA PTDI values. The maximum systemic exposure dosage at 50% and 100 % bioaccessibility constituted 1.6% and 2.8% of the EFSA tolerable daily intake. This indicate no significant risk from Cd in the soaps.

Table 4: Systemic Exposure Dosage of metals in soaps using 50 % and 100 % bioaccesibility factors

		SED based on 50 % bioaccessibility						SED based on 100 % bioaccessibility					
Category	**Codes**	**Cd**	**Pb**	**Cr**	**Co**	**Ni**	**Zn**	**Cd**	**Pb**	**Cr**	**Co**	**Ni**	**Zn**
Medicated	SP1	0.001	0.004	0.003	0.022	0.007	0.016	0.002	0.008	0.005	0.044	0.015	0.031
	SP2	0.002	0.006	0.003	0.035	0.009	0.024	0.004	0.012	0.005	0.069	0.017	0.048
	SP3	0.001	0.003	0.002	0.075	0.005	0.040	0.002	0.006	0.003	0.150	0.009	0.080
	SP4	0.001	0.004	0.001	0.018	0.006	0.007	0.002	0.007	0.002	0.037	0.012	0.014
	SP5	0.001	0.004	0.001	0.013	0.008	0.009	0.002	0.009	0.002	0.026	0.016	0.017
Moisturizing	SP6	0.001	0.004	0.002	0.027	0.007	0.250	0.002	0.009	0.003	0.054	0.015	0.500
	SP7	0.002	0.004	0.001	0.023	0.008	0.005	0.003	0.008	0.002	0.046	0.016	0.009
	SP8	0.002	0.005	0.000	0.037	0.009	0.004	0.003	0.009	0.001	0.074	0.019	0.008
	SP9	0.002	0.005	0.000	0.039	0.007	0.041	0.004	0.009	0.001	0.079	0.014	0.082
	SP10	0.002	0.006	0.003	0.032	0.004	0.028	0.003	0.012	0.005	0.064	0.007	0.057
	SP11	0.001	0.008	0.001	0.024	0.002	0.025	0.002	0.016	0.002	0.048	0.004	0.049
Toilet	SP12	0.002	0.005	0.003	0.026	0.005	0.022	0.003	0.011	0.005	0.051	0.010	0.044
	SP13	0.001	0.009	0.002	0.019	0.004	0.025	0.002	0.017	0.004	0.038	0.007	0.051
	SP14	0.002	0.011	0.004	0.031	0.007	0.016	0.004	0.022	0.007	0.062	0.015	0.032
Skin Whitening	SP15	0.001	0.005	0.002	0.016	0.004	0.012	0.002	0.009	0.003	0.033	0.009	0.025
	SP16	0.001	0.008	0.003	0.014	0.004	0.012	0.002	0.016	0.005	0.029	0.009	0.023
	SP17	0.002	0.007	0.003	0.028	0.008	0.024	0.004	0.014	0.005	0.057	0.016	0.048
	Min	**0.001**	**0.003**	**0.000**	**0.013**	**0.002**	**0.005**	**0.002**	**0.006**	**0.001**	**0.026**	**0.004**	**0.008**
	Max	**0.002**	**0.011**	**0.004**	**0.075**	**0.007**	**0.250**	**0.004**	**0.022**	**0.007**	**0.150**	**0.019**	**0.500**
	Mean	**0.001**	**0.006**	**0.002**	**0.028**	**0.006**	**0.033**	**0.003**	**0.011**	**0.004**	**0.057**	**0.012**	**0.066**

The systemic exposure dosage of Pb from the use of these brands of soaps ranged from 0.003 to 0.011 µg kg^{-1}bw day^{-1}at 50 % oral bioaccessibility and 0.006 to 0.022 µg kg^{-1}bw day^{-1} at 100 % oral bioaccessibility. The FAO/WHO revoked the provisional tolerable daily intake of 3.6 µg kg-1bw day-1 in 2011 due to cumulative effects that made it no longer regarded health protective (FAO/WHO, 2011), but in this study, the 3.6 was adopted as the indicative value for comparison of the results. The maximal systemic exposure dosage at 50 % and 100 % oral bioaccessibility constituted 0.42 % and 0.83 % of the tolerable daily intake. This indicates no significant risk from Pb in the soaps.

The systemic exposure dosage (SED) at 50 % and 100 % oral bioaccessibility for Cr ranged from 0.0 to 0.004 µg kg^{-1}bw day^{-1} and0.001 to 0.007 µg kg^{-1}bw day^{-1} respectively. The provisional tolerable daily intake (PTDI) of Cr was set at 3.3 µg kg^{-1}bw day^{-1} (WHO, 2013). The SED of Cr from the usage of these soaps were below the WHO PTDI value. The maximum systemic exposure dosage at 50 % and 100 % oral bioaccessibility constituted 0.21 % and 0.45 % of the PTDI. This indicates no significant risk from Cr in the soaps.

The systemic exposure dosage (SED) at 50% and 100% oral bioaccessibility for Co ranged from 0.013 to 0.075 µg kg^{-1}bw day^{-1} and 0.026 to 0.15 µg kg^{-1}bw day^{-1} respectively. The provisional tolerable daily intake (PTDI) of Co was set at 1.7 µg kg^{-1}bw $day^{-1}$for a 60 kg adult (WHO, 2013). The SED of Co from the usage of these soaps was below the WHO PTDI value. The maximum systemic exposure dosage of Co at 50 % and 100 % oral bioaccessibility constituted 0.76 % and 8.82 % of the PTDI. This indicates no significant risk from Co in the soaps. The systemic exposure dosage of Ni from the use of these soaps products varies from 0.002 to 0.007 µg kg^{-1}bw day^{-1} at 50 % oral bioaccessibility and from 0.004 to 0.019 µg kg^{-1}bw day^{-1} at 100 % bioaccessibility. The tolerable daily intake of Ni is 12 µg kg^{-1}bw day^{-1} (WHO, 2008). The maximum systemic exposure dosage of Ni at 50 % and 100 % oral bioaccessibility constituted 0.11% and 0.22% respectively.

The systemic exposure dosage of Zn from the use of these soaps products varies from 0.005 to 0.250 µg kg^{-1}bw day^{-1} at 50 % oral bioaccessibility and from 0.008 to 0.500 µg kg^{-1} bw day^{-1} at 100% bioaccessibility. 12,000 µg of Zn and Fe per day is the recommended daily intake (RDI) (National Research Council, 1989). At 50% and 100% oral bioaccessibility, the systemic exposure dosage of zinc was much less than the RDI value.

Margin of Safety

The calculated margin of safety values at 50% and 100% oral bioaccessibility are shown in Table 5. Each of the metals under investigation had calculated margin of safety values more than 100 at both 50% and 100% bioaccessibility. This implies that using these soaps has no risk to users. While it may not be feasible to obtain 100% bioaccessibility of the metals in reality, the knowledge may be useful in optimizing manufacturing procedures and raw material selection to achieve little to no exposure to metals while using these soaps. The duration of exposure, the type of metals and the availability of counter ions (sulphate, acetate, chloride, and nitrate), applying cleansing fluid Larese et al., 2008), sweat's ability to oxidize, the anatomic location (Hostynek, 2003; Larese et al., 2007), gender, and the unique characteristics of the skin all affect how metals in soaps are absorbed through the skin. Furthermore, the age of the skin affects how well metals are absorbed via the skin. For instance, with respect to children, their body mass to surface area ratio is over three fold higher compared to that of adults and their skin's barrier qualities are less developed. (Paller *et al.*, 2011). This suggests that for the same topical exposure, children will therefore be exposed to more metals systemically than adults. However, for the elderly, due to their history of exposure and the fact that the skin acts as a storage system which stores metals, they are more vulnerable (Franken *et al.*, 2015).

Table 5: Margin of Safety of metals in soaps using 50 % and 100 % bioaccesibility factors

		MoS based on 50 % bioaccessibility						MoS based on 100 % bioaccessibility					
		Cd	**Pb**	**Cr**	**Co**	**Ni**	**Zn**	**Cd**	**Pb**	**Cr**	**Co**	**Ni**	**Zn**
Medicated	SP1	85613	102736	110074	1376	270358	1926301	42807	51368	55037	688	135179	963150
	SP2	51368	64210	110074	866	233491	1263148	25684	32105	55037	433	116746	631574
	SP3	128420	128420	192630	399	428067	748078	64210	64210	96315	200	214033	374039
	SP4	85613	114151	256840	1639	342453	4280668	42807	57076	128420	820	171227	2140334
	SP5	85613	93396	256840	2335	256840	3502365	42807	46698	128420	1167	128420	1751183
Moisturizing	SP6	85613	93396	192630	1117	270358	120019	42807	46698	96315	558	135179	60009
	SP7	64210	102736	385260	1306	256840	6421003	32105	51368	192630	653	128420	3210501
	SP8	64210	85613	770520	811	214033	7705203	32105	42807	385260	406	107017	3852602
	SP9	51368	85613	770520	763	285378	733829	25684	42807	385260	381	142689	366914
	SP10	64210	68491	110074	940	570756	1055507	32105	34245	55037	470	285378	527754
	SP11	128420	48922	256840	1243	1027360	1223048	64210	24461	128420	621	513680	611524
Toilet	SP12	64210	73383	110074	1167	395139	1351790	32105	36691	55037	584	197569	675895
	SP13	85613	46698	154104	1572	570756	1185416	42807	23349	77052	786	285378	592708
	SP14	51368	36691	85613	963	270358	1879318	25684	18346	42807	482	135179	939659
Skin Whitening	SP15	128420	85613	192630	1835	466982	2407876	64210	42807	96315	917	233491	1203938
	SP16	85613	48922	110074	2082	466982	2568401	42807	24461	55037	1041	233491	1203938
	SP17	51368	57076	110074	1056	244610	1263148	25684	28538	55037	528	122305	631574
	Min	**51368**	**46698**	**85613**	**399**	**214033**	**120019**	**25684**	**18346**	**20277**	**200**	**77830**	**60009**
	Max	**128420**	**128420**	**770520**	**2335**	**1027360**	**7705203**	**64210**	**64210**	**385260**	**9632**	**513680**	**3852602**
	Mean	**80074**	**78592**	**245581**	**1263**	**386515**	**2331478**	**40037**	**39296**	**122790**	**631**	**193258**	**1161017**

CONCLUSION

This concentrations and risks of metals in medicated, moisturizing, toilet and skin whitening soaps were investigated in this study. The results showed that the soaps were contaminated with the studied metals and varied significantly within a given soap category and among the different soap categories. The concentration of Pb in the investigated soaps were below the Health Canada and USFDA limits. The systemic exposure dosage (SED) of investigated metals at 50% and 100% oral bioaccessibility were generally lower than their provisional tolerable daily intake (PTDI) values, and each of the examined metals' 50% and 100% bioaccessibility margin of safety values was larger than100, indicating the usage of these soaps has no detrimental consequences to consumers.

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