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Heavy Metal Exposure from Personal Care Products

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Abstract Numerous studies have described human exposure to heavy metals from diverse sources in Nigeria, but little is known about the exposure from personal care products, and few or no report is available on the personal care product concentrations of cadmium, chromium, copper and zinc, which have biotic effects. The levels of these elements were determined in 74 samples of 5 different classes of personal care products commonly used in Nigeria using atomic absorption spectrophotometry. Significant levels of Cd, Cr, Cu and Zn were found in all the products. The highest values of Cd (0.553 ppm) and Cu (0.783 ppm) were observed in hair cream, while medicated cream was mostly implicated for Cr (0.383 ppm) and Zn (0.793 ppm). Since no limit relating to cosmetic products is available, it is difficult to ascertain if the values of metals obtained in this study are too high or low; but Cd and Cr are prohibited in any amount in cosmetics. Prolonged use of soaps and creams containing these elements may pose threat to human health and the environment.

Keywords Heavy metals · Personal care products · Health effects · Dermal contact · Environment

The toxic effects of heavy metals on human health and ecosystem are well documented (Turkdogan et al. 2003; Gheorghiu et al. 2007; Kawata et al. 2007; Liu et al. 2009. At low concentration, some of these elements cause internal body organ damage in animals and humans. Various forms of mammalian cancers, respiratory diseases, organ failures and retardation of the intellect had been traced to metal poisoning (Hall 2002; Davydova 1999; Brams et al. 1989). For instance, an increase incidence of certain forms of cancer, possibly as a result of direct inhibition of DNA mismatches remediation by cadmium (Mc Murray and Trainer 2003) has been reported in the literature (El-Safty et al. 2007). Cadmium also causes kidney damage and bone degradation because it affects calcium metabolism (Waalkes 1991). Zinc has been reported to cause the same signs of illness as does lead, and can easily be mistakenly diagnosed as lead poisoning (McCluggage 1991). Although individual metals exhibit specific signs of their toxicity, the following have been reported as general signs associated with cadmium, copper and zinc poisoning: gastrointestinal disorders, diarrhoea, stomatitis, tremor, ataxia, paralysis, vomiting and convulsion, depression, and pneumonia when vapours and fumes are inhaled (McCluggage 1991).

Human exposures to these xenobiotics from diverse sources have been widely investigated. These usually involve industrial and medical wastes (Dorigo et al. 2004), pesticide, petroleum by-products (Mowat and Bundy 2001) beverages (Maduabuchi et al. 2008), snacks and confectioneries (Narin et al. 2005; Gopalani et al. 2007) and foods (Mahaffey et al. 1975). These reports generally discussed the potential health implications of heavy metals through ingestion and inhalation of contaminated air, foods or drinks. Information on the exposure to metal toxins through dermal contact is very scanty, and few or no data exists on the personal care products‘ concentration of cadmium, chromium, copper and zinc in the world. These metals are

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cumulative poisons, which have been reported to be exceptionally toxic (Ellen et al. 1990).

However, few investigations have been carried out on the domestic and household sources of metal exposure in developed countries (Friberg et al. 1986; Storr-Hansen and Rastogi 1988; Alloway 1995; Brooks et al. 2003; Fiala 2006; Lin et al. 2009). The findings were based on corrosion of metal plumbing fittings, galvanized roofs, health care products, saucepans, utensils, recycled papers, children ski helmets and housing paint as significant sources of metal exposure. No attempts have been made to investigate personal care products, which impact directly on human body. The belief is that human exposure to heavy metals is usually from contaminated air, soil, water or food. The presence of trace organic compounds such as polychlorinated biphenyls (Storr-Hansen and Rastogi 1988) and organosilicone compounds (Horii and Kannan 2008) in personal care and house hold products is some indirect evidence of possible heavy metals in these products. Heavy metals and trace organic compounds have been identified as common pollutants in diverse environmental matrices (Storr-Hansen and Rastogi 1988; Malawska and Wilkomirski 2000).

A number of good examples of these items include various types of medicated and non-medicated soaps and creams that are used regularly in our daily lives. Many of them contain heavy metals like Cd, Cr, Ag and Zn (Schwartz et al. 2004). The liberal use of soaps and creams containing these elements can cause harm to our health, skin and environment. It has been reported that prolonged use of some skin lightening soaps can damage nerves, or even lead to skin cancer and liver toxicity, proving to be fatal (Bangha et al. 1997). Rubber foot wears, leather, necklaces and bracelets have been implicated as common sources of contact dermatitis in Nigeria (Olumide 1985). Recent studies also revealed significant levels of heavy metals in facial cosmetics such as eyeliners, eyes-pencils and lipsticks (Nnorom et al. 2005). Similarly, traditional eye make-ups used among rural people in Nigeria have been reported to have high contents of heavy metals (Ajayi et al. 2002).

Disposal down the drain of personal care products containing heavy metals may also lead to ground water contamination via septic tank. Therefore, determination of heavy metals in the products is important for the evaluation and characterization of sources of human and environmental exposure. This study determined the levels of Cd, Cr, Cu and Zn in some frequently used personal care-products in Nigeria. The valuable data generated will create awareness about risks associated with indiscriminate use of personal care products and also provide baseline information for further research on epidemiological Studies.

Materials and Methods

Samples of commonly used personal care products were purchased from some local stores in western part of Nigeria. The samples include medicated soaps and cream, non-medicated soaps and cream and hair cream. The items were transferred to the laboratory for analysis.

All reagents used were of analytical grade of BDH chemicals. 1,000 ppm of each of the metals analysed were prepared by dissolving their salt in appropriate volume of water and made up to 1 dm^3 in a volumetric flasks, using dilution factor. The appropriate volume of the stock solution was diluted with distilled water to give concentration of the working ranges (Bruce and Whiteshide 1984).

Solid samples were dried in an oven at 105°C to constant weight and then stored in a desiccator. Creamy samples liable to charring were dried at 70–80°C. About 0.2 g of each of the dried samples was weighed into a porcelain crucible and dry-ashed in a muffle furnace by stepwise increase of the temperature up to 550°C over a few hours (Crosby 1977). A few drops of concentrated nitric acid were added to the solid as an ashing aid before ashing was commenced. The ash was dissolved with IM HNO_3. Sample such as cream and lotions, which could not be conveniently processed by dry-ashing, were wet digested with a 4:1 mixture of nitric acid and perchloric acid. The digest was evaporated to almost dryness and then made up with distilled water to 100 mL. The sample solutions were subsequently analysed for Cd, Cr, Cu and Zn, using a flame atomic absorption spectrophotometer available at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria. The instrument working condition and parameters for the determinations are shown in Table 1. Each sample was analysed in triplicate, and reagent blank determination was performed to ascertain that no impurity was introduced during the extraction procedure.

Results and Discussion

Heavy metal exposure from soaps, body and hair creams have largely been overlooked. This study is the first to evaluate Cd, Cr, Cu and Zn concentrations in personal care products like soaps, body and hair creams, which have direct contact with human body. Table 2 indicates the different classes of samples analysed. The contents of heavy metals in the investigated samples as a mean of triplicate determination are described in Table 3. The determination was based on quantification by standard addition methods (Fig. 1). We treated values lower than the detection limit as not detectable (ND). The results are not corrected for the recoveries. All the personal-care products in this study were found to

Table 1 Working conditions of buck scientific atomic absorption spectrophotometer for the determination of heavy metals

Element	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Gain	Oxidant	Acetylene flow	Burner height	Detection limit (ppm)
Cd	228.8	3	2	7	Air	2.1	7	0.002
Cr	357.9	1	5	5	Air	4.7	5	0.002
Cu	324.7	2	4	5	Air	1.8	7	0.001
Zn	213.9	2	4	8	Air	13.5	7	0.006

contain substantial levels of cadmium, chromium, copper and zinc. Results indicate a wide range of concentrations for these elements within each class as evidenced by the high coefficient of variation (CV). The mean values of the heavy metals vary from class to class, and the differences are significant at 95% confidence interval ($p < 0.05$). To our knowledge, there is no report available on the analysis of Cd, Cr, Cu and Zn in personal care products like body and hair creams. Hence, data obtained in this study are compared to similar study elsewhere.

The mean levels of Cd were ranged from 0.024 to 0.553 ppm. The highest amount was found in hair cream and the lowest in non-medicated cream. The abundance of cadmium in these products is in this order: Hair cream > medicated soap > medicated cream > non-medicated cream > non-medicated soap. The study revealed that the maximum content (0.553 ± 0.194 ppm) of cadmium in the personal care products under study is lower than those obtained by Nnorom et al. (2005) for eyeliners (1.3 ± 0.7 μg/g), eye pencils (0.8 ± 0. 2 μg/g) and lipsticks (1.1 ± 0.6 μg/g). Conversely, the value was 8–9 fold greater than those obtained by Storr-Hansen and Rastogi (1988) for household products like recycled papers (0.066 ppm). Maximum concentration of Cr (0.383 ppm) was detected in medicated cream and minimum concentration (0.064 ppm) in non-medicated cream. The order of content of Cr in the personal care products was determined as medicated cream > medicated soap > hair cream > non-medicated soap > non-medicated cream. Highest level of Cu (0.783 ppm) was observed in hair cream followed by medicated cream (0.745 ppm) while the lowest value was detected in non-medicated soap. The mean concentration of Zn ranged from 0.250 ppm in non-medicated cream to 0.793 ppm in medicated cream. These values are more than 100 times lower than those reported for similar personal care products (Nnorom et al. 2005). The abundance of Zn under the present study is in this order: medicated cream > hair cream > medicated soap > non-medicated soap > non-medicated cream.

Table 2 Classes of samples analysed

Usage class	Sample name	n
Medicated soaps (n = 20)	Tura	5
	Meriko	5
	Asepso	3
	Dettol	4
	Skin solution	3
Non-medicated soaps (n = 18)	Premier	2
	Swift	4
	Joy	5
	Canoe	3
	S.T.	4
Medicated cream (n = 14)	G and G	3
	Movate	4
	Emeron	4
	Tura	3
Non-medicated cream (n = 9)	Peras	2
	Jet	3
	Skin complexion	1
	Nivea	3
Hair cream (n = 13)	Soulmate	5
	Royal crown	3
	Dollas	3
	Apple	2

All the heavy metals were detected in the investigated samples. The regulations relating to cosmetic products give no limit values for heavy metals in cosmetic products except of 1 ppm for Hg (ACSB 2007). It is therefore, difficult to ascertain if the values of metals obtained in this study are too high or low. However, Cd and Cr are listed as one of the substances that are prohibited in any amount in cosmetics (Council Directive 76/768/EEC of 27 July 1976). Prolong use of soaps and creams containing these elements may pose threat to human health and the environment. Several reports have since shown that kidney damage and/or bone effects are likely to occur at lower kidney cadmium levels. European studies have shown signs of cadmium induced kidney damage in the general population at urinary cadmium levels around 2–3 μg Cd/g creatinine (Buchet et al. 1990; Jarup et al. 2000).

Investigation has also revealed that the effects of the low concentrations of cadmium were similar to those of the high concentrations (Iger et al. 1994). This implies that cadmium levels found in this study could cause systemic toxicological effects in people using those personal care products. Little research has been done on dermal

Table 3 Concentrations (ppm) of heavy metals in personal-care products

Product class	Statistic	Cd	Cr	Cu	Zn
Medicated soap	Mean	0.252	0.274	0.596	0.682
	SD	0.146	0.072	0.257	0.402
	CV (%)	57.9	26.3	43.1	29.9
	Range	0.090–0.440	0.020–0.392	0.185–0.871	0.422–0.886
Non-medicated soap	Mean	0.024	0.118	0.264	0.540
	SD	0.021	0.107	0.163	0.344
	CV (%)	87.5	90.7	61.7	63.7
	Range	ND–0.05	0.01–0.295	0.103–0.516	0.201–1.104
Medicated cream	Mean	0.215	0.383	0.745	0.793
	SD	0.108	0.130	0.177	0.249
	CV (%)	50.2	33.9	23.8	31.9
	Range	0.063–0.361	0.192–0.474	0.571–0.933	0.539–1.104
Non-medicated cream	Mean	0.038	0.064	3.740	0.249
	SD	0.031	0.039	2.327	0.093
	CV (%)	81.6	65.0	62.2	37.2
	Range	0.016–0.082	0.027–0.119	1.829–6.847	0.136–0.355
Hair cream	Mean	0.553	0.135	0.783	0.725
	SD	0.194	0.198	0.261	0.131
	CV (%)	39.2	146.7	33.3	18.1
	Range	0.279–0.781	0.013–0.426	0.525–0.810	0.531–0.811

* *SD* Standard deviation of the mean of triplicate determinations, *CV* Coefficient of variation

ND Not detected

absorption of cadmium, but report by Wester et al. (1992) has demonstrated a penetration of 12.7% (water) of the applied cadmium dose into the human skin. In similar way, Cd from body and hair creams could be absorbed into human body through dermal contact. Details about possible health problems due to Cd absorption have been published (Godt et al. 2006).

This study also revealed that the soaps, body and hair creams are potential sources of Cr in human body and environment. The maximum value of Cr obtained in this study is several orders of magnitude lower than those reported elsewhere Nnorom et al. (2005). This does not imply that continuous use of these products on human body could not result to detrimental effects. The values of Cr obtained in this study are a cause for alarm because the element is forbidden in cosmetics (Council Directive 76/768/EEC of 27 July 1976). Chromium may be intentionally added to cosmetics as dyes. Exposure to chromium can cause skin rashes, kidney and liver damage, lung cancer, respiratory problems and even death (http://www.lenntech.com/periodic-chart-elements/cr-en.htm). However, the health hazards associated with exposure to chromium are dependent on its oxidation state. The metal form of chromium as it was determined in this product is assumed to be of low toxicity. Further research is required to investigate the speciation of Cr in other to ascertain if it is present in the personal care products in the toxic form.

Cu compound can be used as biocides in medicated cream and soap and this may be responsible for the high values obtained in this study. The effects of copper are manifesting at low concentrations (http://www.lenntech.com/periodic-chart-elements/Cu-en.htm). The present study revealed that the investigated personal care products could serve as significant sources of human exposure to Cr through dermal contact. Exposure to copper compound dusts can cause dermatitis, discolouring of the skin, and irritation of the nose and throat. (http://www.environmentwriter.org/resources/backissues/chemicals/cupric_acetate.htm). Chronic exposure to copper can produce numerous physiological and behavioural disturbances, which include brain damage and progressive demyelination, psychiatric disturbances–depression, suicidal tendencies and aggressive behaviour–haemolytic anaemia, cirrhosis of the liver, motor dysfunction and corneal opacities (U.S. EPA 1987; ATSDR 1990a; Goyer 1991). Some patients may also experience poor coordination, tremors, disturbed gait, muscle rigidity, and myocardial infarction (ATSDR 1990a).

Fine powders of zinc oxide have characteristics ideal for use as a broad-spectrum inorganic ultraviolet (UV) radiation blocking material in personal-care products (Masui

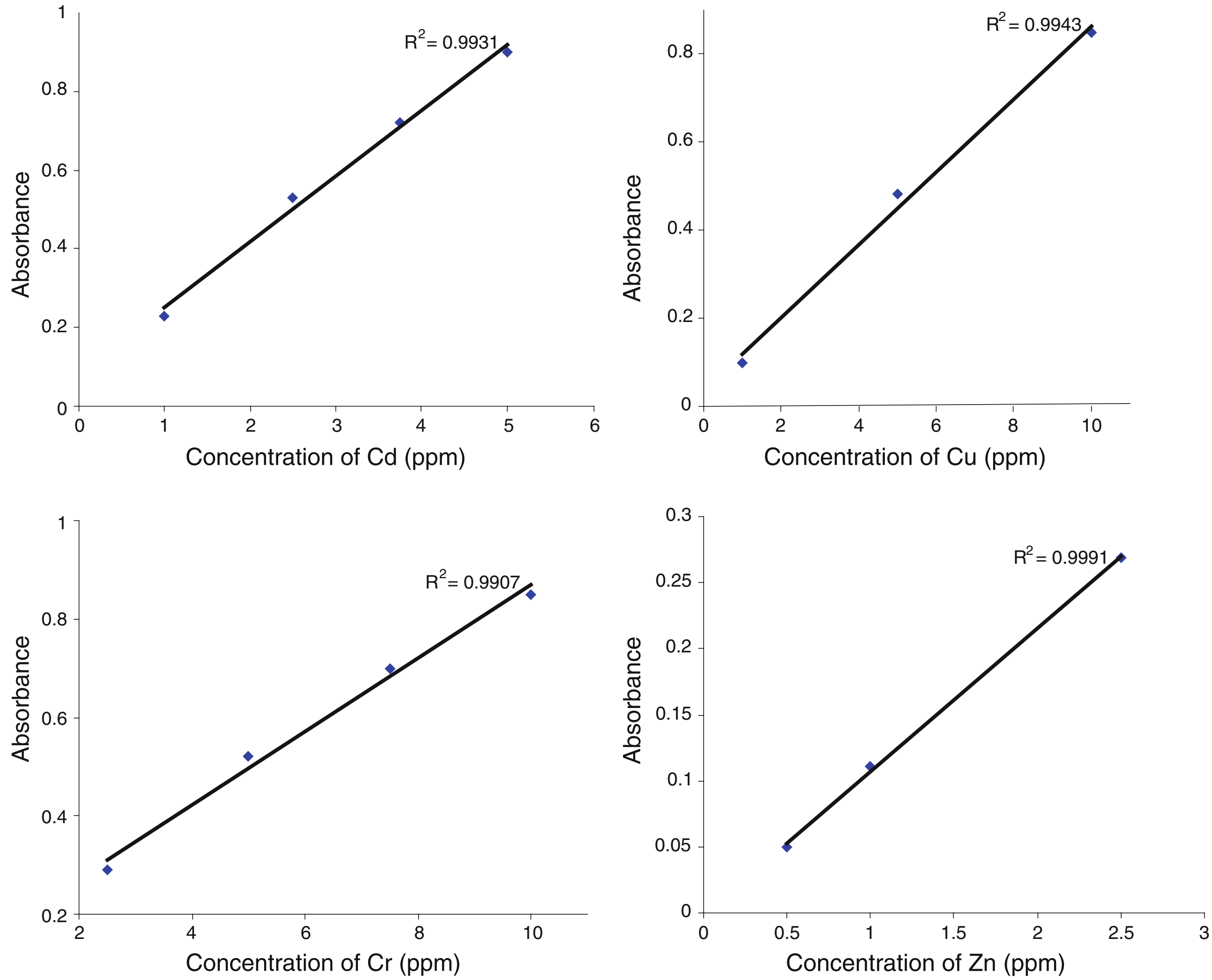

Fig. 1 Calibration curves for the heavy metals analysed in personal care products

et al. 1997; Yabe et al. 2001) and this may be responsible for the high content of Zn in present study. The high refractive index of zinc can make the skin look unnaturally white when incorporated into body cream (Yabe et al. 2001). Since the demand for skin lightening cream is very high, especially in developing countries, this also can prompt the manufacturers of the investigated products to add zinc intentionally to boost their markets. Excessive zinc intake in humans indicates possible effects on the pancreas. The literature on the spectrum of health effects of zinc status, ranging from symptoms of zinc deficiency to excess exposure is available (Walsh et al. 1994). Despite the fact that zinc is essential in the body, the values obtained in this study deserves safety concerns due to cumulative effect, arising from incessant exposure.

Generally, the highest values of Cd (0.553 ppm) and Cu (0.783 ppm) were observed in hair cream. Petrolatum, the main ingredient of hair cream could be responsible for the high value of Cd and Cu in the hair cream. Petroleum contain significant amount of cadmium (Cd), zinc (Zn), copper (Cu) and chromium (Cr) (Stigter et al. 2000). Similarly, medicated cream is mostly implicated for Cr (0.383 ppm) and Zn (0.793 ppm) in this study. The frequent use of soap and body cream containing these elements could be responsible for various skin diseases such as allergic skin, follicular and pigmentary disorders, which are common among the users (exposed groups) of these products in Nigeria.

The present study has showed that the use of personal care products like soap, body and hair creams can expose users to significant levels of heavy metals. Ideally, exposure assessment involves three phases: sources of pollutants, concentrations of pollutants and doses of pollutants absorbed into the body using biomarkers like blood, skin and urine. This study has only demonstrated that personal care products are notable sources of cadmium, chromium, copper and zinc in human body as well as in the environment. Further study is required on the absorbed level and the number of persons exposed should be determined for different groups of the general population, in particular susceptible groups and highly exposed group. In other words, the health implication of these metals can only be properly assessed by monitoring the levels of these toxic metals in the blood and urine sample of the group engaged in the practice.

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