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ORIGINAL ARTICLE

POTENTIAL HAZARDS OF TOXIC METALS FOUND IN TOOTHPASTES COMMONLY USED IN NIGERIA

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ABSTRACT

Background. Toothpastes have multi-functional configurations as oral care products. They can however constitute a possible source, amongst others, of toxic metal exposure in public health. Indeed, the public health impact of personal hygiene and consumer products is largely unknown.

Objective. To determine the level of toxic metals (lead, cadmium, cobalt, chromium, nickel) in toothpastes available in Nigeria, (home produced and imported), and assess the potential risk to the people.

Material and Method. The samples of toothpastes commonly used in Nigeria were tested. Using a market basket protocol thirty five different brands of toothpaste were used. Samples were digest by addition of 10 mL mixture of conc. nitric and hydrochloric acids ($HCl:HNO_3$, 3:1), followed by heating to dryness. 20 mL deionized water was added, stirred and filtered. The filtrate was made up in standard volumetric flask and lead, cadmium, chromium, cobalt and nickel concentrations were determined using the atomic absorption spectrophotometry 205A. The daily intake of metals and target hazard quotient (THQ) were then calculated.

Results. Pepsodent and Flodent had the highest levels of lead at respectively 23.575 and 18.092 mg/kg while Colgate Herbal had the highest nickel of 18.535 mg/kg. The daily intake estimates of all imported toothpaste samples were below the stated upper limits (UL). All target hazard quotients were also found to be below one.

Conclusions. Although the UL, THQ and daily intake rates were all normal, the high levels of lead in some of the toothpastes an important concern to public health suggesting that pre-marketing safety studies of toothpastes may be worthwhile for the regulatory authorities.

Key words: *toothpaste, risk for health, determination of metals in toothpastes*

INTRODUCTION

Toothpaste has multi-functional configuration as an oral care product. These functions which include cleaning teeth, fighting tartar, providing fluoride protection, freshening breath and whitening teeth have made their demand and use very high [13]. Adverse health outcomes due to poor-quality products have been reported [11]. Although no serious health conditions were reported from use of adulterated toothpaste, there was a cautionary note to consumers to avoid using toothpaste made in China after contaminated toothpaste was seized in some countries. The determination of potential toxic metals in personal hygiene and consumer products especially lead and cadmium which have no known biological function is crucial for the safety appraisal and sources classification of human and environmental exposures. The public is generally unaware of these types of everyday exposure from chemical constituents of consumer products and their health consequences. *Zolaly* et al. [31] included the use of toothpaste as one of the possible sources of lead exposure.

Environmental contamination by lead and cadmium is a matter of concern in many countries including Nigeria for several decades [28]. In view of

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the trade liberalisation and the lax in enforcement of importation regulations, the Nigerian market has been inundated with all manners of personal care and oral hygiene products. The public health impact of these products is largely unknown due to poor record keeping. In this risk assessment, we have investigated the potential toxic metal hazards of imported and Nigerian manufactured toothpastes by comparing levels of lead, cadmium, chromium, cobalt, and nickel with permissible limits given by World Health Organisation (WHO) and United States Environmental Protection Agency (USEPA). The daily intake of metals approach by *Richards* et al. [20], *Kobayashi* et al. [14] and *Garcia-Rico* et al. [10] the total hazard quotient (THQ) of *Singh* et al. [25] have been adapted in the risk assessment of these toothpastes.

MATERIAL AND METHODS

Using basket market protocol thirty five different brands of toothpastes purchased from supermarkets/shopping malls in Port Harcourt, Rivers State, Nigeria, in March 2013, were used for this study. The toothpaste samples were divided into two groups: (1) local - manufactured in Nigeria and (2) foreign or imported. The samples were ashed and digested in Teflon laboratory ware that had been cleaned in a high-efficiency particulate air (HEPA) filtered (class 100), trace-metal-clean laboratory to minimize contamination. This protocol involved sequential cleaning of the lab ware in a series of baths in solutions (1 week each) and rinses (five per solution) in a three-step order, namely a detergent solution and deionized water rinses, then 6 N HCl (reagent grade) solution and ultra-pure water rinses, finally 7.5 N HNO_3 (trace metal grade) solution and ultra pure water rinses. The lab ware was then air dried in a polypropylene laminar air flow-exhausting hood. Dry ashing method was used by adding 30mL of each sample into a conical flask and heated on a hot plate at 200^{o}C, for 45mins, then in a furnace at 500^{o}C until the volume was drastically reduced to near dryness. Digestion was done by addition of 10 mL conc. aqua regia ($HCl:HNO_3$, 3:1), it was then heated to dryness. 20 mL de-ionised water was added, stirred and filtered. The filtrate was made up in standard volumetric flask. Lead, cadmium, nickel, chromium and cobalt were determined with flame Atomic Absorption Spectrophotometry 205A. The limit of detection (LOD) for Cd, Cr, Co and Ni was 0.001 mg/kg, whereas for Pb was 0.01 mg/kg, with blank values reading as 0.00 mg/kg for all the metals in deionised water with electrical conductivity value of lower than 5 μS/cm. Samples were analysed in triplicate. Replicate analyses of several samples indicate the range of error to be ± 2% for all the metals in the toothpaste samples presented.

Data analyses

Daily metal intake (DMI) estimate

Toothpaste ingestion is highest in children and the mean amount of toothpaste loaded onto the toothbrush per brushing episode is around 0.55 g [14, 20]. Since it has been estimated that a mean of 48% of this amount is ingested, 0.264 g/person/day toothpaste was adapted in this study [14, 20].

$$\text{DMI (mg/day)} = C_{metal} \times D_{intake} / B_{weight}$$

Where:

C_{metal} is the metal concentration in sample taken for analysis (in mg/kg).

B_{weight} is the body weight (60 kg in this study).

D_{intake} is the daily intake (0.264 g/person/day) [14, 20]

Target hazard quotients (THQ)

Target hazard quotients (THQ) were developed by the Environmental Protection Agency (EPA) in the US for the estimation of potential health risks associated with long term exposure to non-carcinogenic chemical pollutants [27]. These include not only intake of metals but another significant data as exposure frequency and duration, body weight, oral slope cancer factor and the oral reference dose (RfD). The THQ is a ratio between the measured concentration and the oral reference dose (RfD), weighted by the length and frequency of exposure, amount ingested and body weight. The metals of concern have been recorded to be potential carcinogenic substances [12]. The THQ <1 means the exposed population is assumed to be safe and 1 < THQ < 5 means that the exposed population is in a level of concern interval. THQ parameter is a dimensionless index and THQ values are additive, but not multiplicative.

The Target Hazard Quotients for non-carcinogens was determined based on the modified formulae of *Chien* et al. [4].

$$\text{THQ} = (\text{EFr} \times \text{ED}_{tot} \times \text{TIR} \times \text{C} / \text{RfD}_o \times \text{BW}_a \times \text{AT}_n) \times 10^{-3}$$

Where the parameter values are the following:

EFr = Exposure Frequency = 365 days/year

ED_{tot} = Exposure Duration = 35 years (chronic exposure)

TIR = Toothpaste Ingestion Rate = 0.264 g/person/day [14, 20]

C = Concentration of metal in toothpaste = mg/kg

RfD_o = oral Reference Dose = mg/kg/day

BW_a = average body weight, adult = 60 kg, children = 15 kg

AT_n = average exposure time for non-carcinogens in days (EFr(365 days/year) x ED_{tot}(number of exposure years, assuming 35 years in this study)

10^{-3} = the unit of conversion

The total THQ (TTHQ) of heavy metals for the individual parameter assayed was calculated according to *Chien* et al. [5] as the sum of the individual THQ of the potential toxic metals.

The total THQ is the sum of the following compositions:

Total THQ (TTHQ) = THQ (toxicant 1) + THQ (toxicant 2) + ... + THQ (toxicant *n*).

RESULTS AND DISCUSSION

The different concentrations of the metals lead, cobalt, chromium, nickel, and cadmium in the local tooth paste samples is summarised in Table 1. Pepsodent had the highest levels of lead cobalt and nickel, 23.58, 12.71 and 18.63 mg/kg respectively. Oral B Pro-Expert Dent Fresh had the lowest lead level of 4.51 mg/kg, while Red Oil Gel had highest amount of cadmium 1.28 mg/kg.

Table 2 presents the different concentrations of the potential toxic metals lead, cobalt, chromium, nickel, and cadmium in the imported tooth pastes. Flodent had the highest values for lead, cobalt, chromium, and cadmium as 18.09, 16.34, 10.85 and 2.49 mg/kg respectively, while Colgate Herbal had the highest amount of nickel, 18.54 mg/kg.

The used oral reference doses (RfD) and upper tolerable daily intakes for metals (UL) are presented in Table 3. No UL for chromium and cobalt has been set yet. The potential toxic metal intake through the daily consumption of the various local toothpaste is shown on Figure 1. Both chromium and cadmium had negligible daily intakes. For lead, all daily intake values were below the UL as established by *Garcia-Rico* et al. [10]. This was also true for nickel. For cadmium, Sensodyne (Tooth Care F) value for daily intake exceeded the UL established by *Garcia-Rico et al.* [10]. Figure 2 shows daily intake of potential toxic metals from use of the imported toothpaste. The daily intake estimates of all the imported toothpaste samples were found to be below the stated upper limits by *Garcia-Rico* et al. [10].

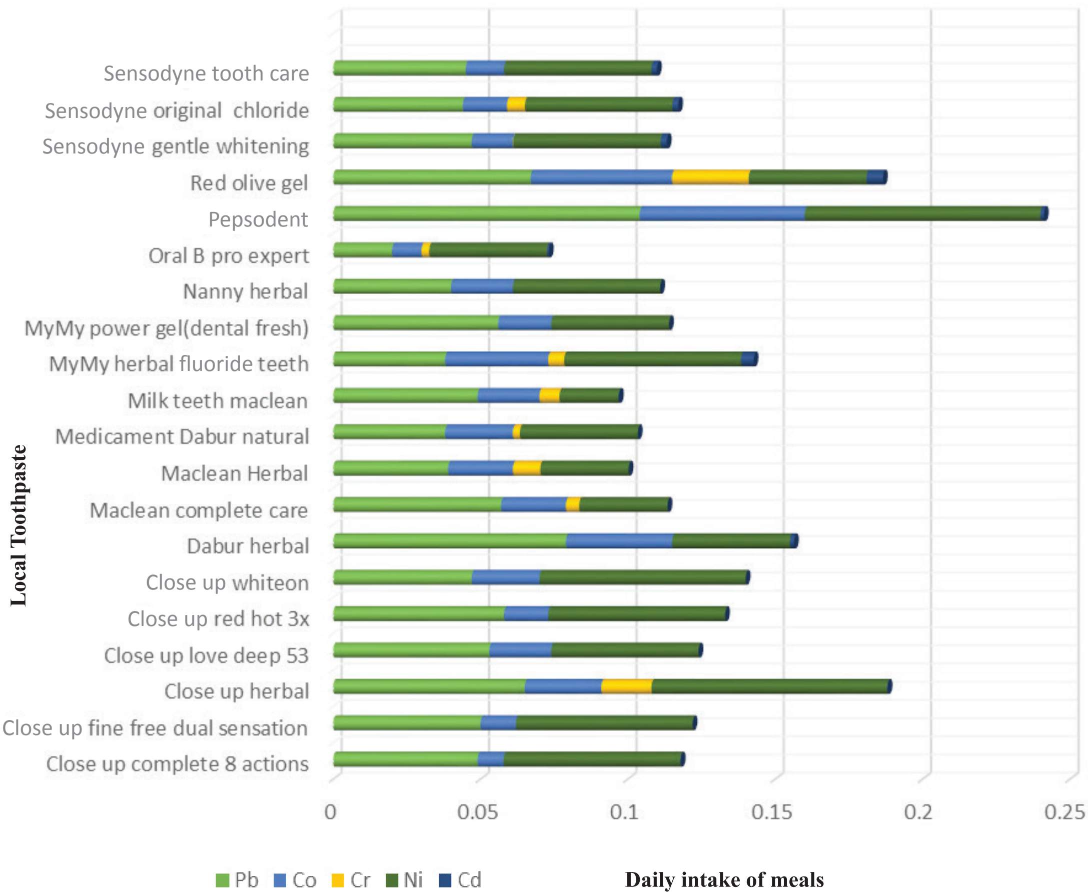

Figure 1. Daily intake of potential toxic metals (Pb, Co, Cr, Ni, Cd) from the use of toothpastes manufactured in Nigeria

Table 1. The levels (mg/kg) of potential toxic metals in the local toothpastes manufactured in Nigeria

Local toothpastes	Lead	Cobalt	Chromium	Nickel	Cadmium
Close Up Complete 8 Actions	11.033	1.989	<0.001	14.505	0.043
Close Up Fine Free Dual Sensation	11.412	2.869	0.001	14.312	<0.001
Close Up Herbal (Family Teeth)	14.871	5.992	3.897	17.050	0.043
Close Up Loves Deep (53)	12.116	4.769	<0.001	12.101	<0.001
Close Up Red Hot (3X)	13.103	3.428	0.002	13.789	<0.001
Close Up White On	10.689	5.137	<0.001	15.121	0.001
Dabour Herbal (Mint x Lemon)	17.888	8.178	<0.001	8.573	0.329
Macleans Complete Care	13.004	5.108	1.024	6.798	<0.001
Macleans Herbal	8.768	5.032	2.211	7.024	<0.001
Medicamente Dabour Natural	8.699	5.328	0.542	9.302	<0.001
Milk Teeth Macleans 1 – 6	11.103	4.865	1.543	5.472	0.043
MyMy Herbal Flouride Teeth	8.718	7.997	1.231	13.554	0.978
MyMy Power Gel (Dental Fresh)	12.672	4.197	0.001	9.692	<0.001
Nanny Herbal	9.321	4.672	<0.001	11.169	0.001
Oral B Pro-Expert Dent Fresh	4.514	2.283	0.596	7.979	0.144
Pepsodent	23.575	12.712	<0.001	18.631	0.284
Red Olive Gel	15.369	10.891	5.968	8.421	1.284
Sensodyne Gentle Whitening	10.794	3.101	0.031	12.235	0.484
Sensodyne Original St. Chloride	9.973	3.412	1.385	10.897	0.456
Sensodyne (Tooth Care F)	10.321	2.978	<0.001	11.872	0.453

Table 2. The levels (mg/kg) of potential toxic metals in the imported toothpastes

Imported toothpastes	Lead	Cobalt	Chromium	Nickel	Cadmium
Aqua Fresh Mink Mint	13.694	5.172	0.032	14.179	0.342
Aqua Fresh Minty	15.650	13.157	10.706	18.219	2.238
Close Up Complete	6.329	2.698	4.116	11.821	<0.001
Close Up Fine Breeze	6.365	1.055	<0.001	10.655	<0.001
Colgate Fresh Confidence (External Red)	12.234	3.324	0.024	10.520	0.249
Colgate Fresh Confidence (Main Gate)	11.439	4.123	0.012	11.253	0.543
Colgate (Great Regular Flavour)	13.482	3.431	<0.001	8.975	1.316
Colgate Herbal	16.314	11.554	3.217	18.535	2.218
Colgate Junior	13.130	2.742	<0.001	9.992	0.363
Colgate Strengthen, Teeth Freshen	10.842	2.114	0.010	13.863	0.331
Colgate Total	9.401	3.102	<0.001	9.013	0.292
Colgate Triple Action	11.369	2.341	0.019	12.023	0.214
Flodent	18.092	16.336	10.854	18.146	2.490
Meriadent P Protection	14.443	4.476	0.022	11.986	0.034
Oral B	10.438	4.031	5.324	13.142	0.412

Table 3. Oral reference doses (RfD) and upper tolerable daily intakes (UL) for investigated metals

Element	RfD (mg/kg/day) [26]	UL (mg/day) [6, 14]
Pb	0.004	0.240
Cd	0.001	0.064
Cr	1.5	-
Ni	0.020	1
Co	0.043	-

Figure 3 shows the Target Hazard Quotients (THQ) of potential toxic metals from the use of locally manufactured toothpastes. These THQs were calculated using the oral reference doses (mg/kg/day) (Cr – 1.5; Ni – 2.0×10^{-2}; Pb – 4.0×10^{-3}; Cd – 1.0×10^{-3} and Co – 4.3×10^{-2}) of the individual metal as stipulated by USEPA [26] and Food and Nutrition Board [7]. The THQ values were less than one for all the toothpaste manufactured in Nigeria. The Target Hazard Quotients (THQ) of the potential toxic metals from the use of imported toothpastes is shown on Figure 4. All target hazard quotients were also found to be below one. Similarly the DMI and THQ values for children (not shown in the figures) were even lower than adults.

The sulfhydryl-reactive toxic metals like cadmium, lead and mercury have no beneficial biological function and their accumulation in the body has serious adverse health effects. These metals burden tax nutritional status, which impact negatively on anti-oxidative and detoxification processes. The present study is a risk assessment of toothpaste commonly used in Nigeria. In Nigeria there is indiscriminate use of toothpaste (flavoured or regular) across the ages. Moreover most children start brushing as early as two years. The percentage of toothpaste ingested diminish significantly as the children's age increase, regardless of the amount of toothpaste used [14, 20]. Some studies have reported increase in the amount of toothpaste ingested for toothpastes flavoured for children [1, 14, 18] but others showed no difference in amount ingested between these and flavoured toothpastes [15].

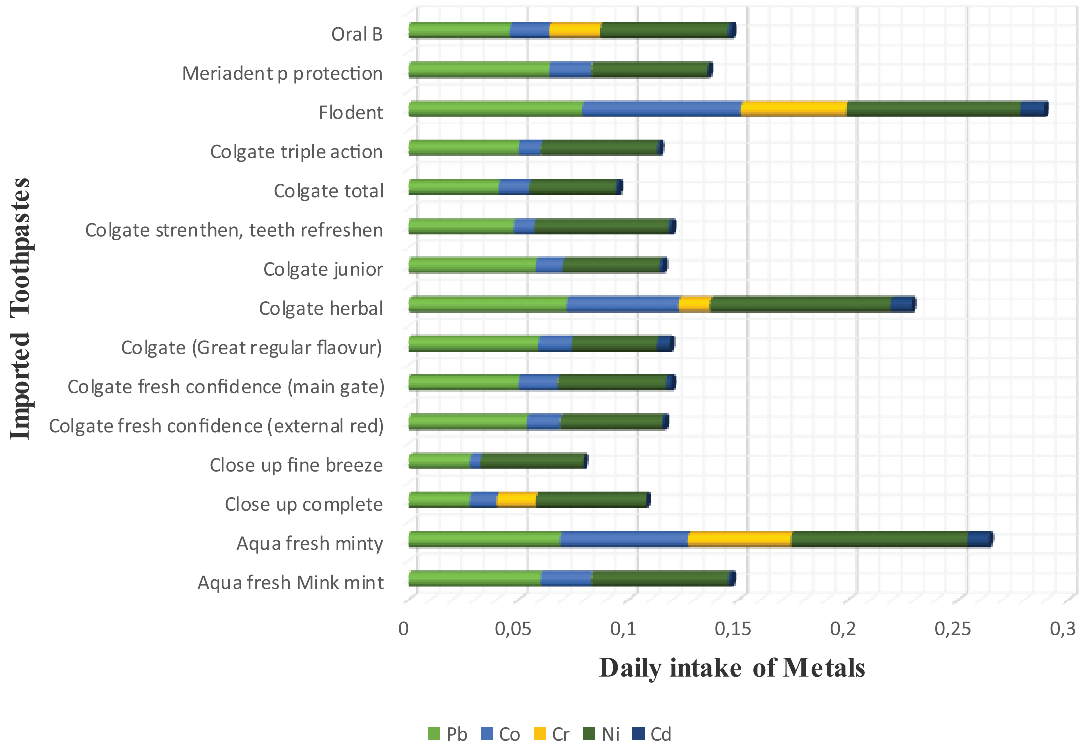

Figure 2. Daily intake of potential toxic metals (Pb, Co, Cr, Ni, Cd) from the use of the imported toothpastes

Although all the THQ values were less than one for all the local toothpaste samples suggesting no potential health risk associated with their use. It is however important to note the high levels of lead, cobalt and nickel, 23.58, 12.71 and 18.63 mg/kg respectively in one of the commonest used toothpastes like Pepsodent especially in children. Although the magnitude of the amount of potential toxic metal ingested from the toothpaste appears small, it must be remembered that this quantity is "in addition to" the potential toxic metal ingested from other sources like, water, beverages and food prepared with water, etc. It should be emphasized again that total potential toxic metal ingestion is the most important consideration. According to the work of *Zolaly* et al. [31] on the association between blood lead levels (BLL) and environmental exposure among Saudi school children in some districts of Al-Madinah, 95.8% that had BLL above 10 µg/dl used toothpaste. Since caries cause the minerals to diffuse through the enamel surface in the process known as demineralization, the high level of lead in this study is of notable public health importance given the increasing incidence of caries in Nigeria [2]. *Baranowska* et al. [3] found a positive correlation between age and lead level in human teeth. *Shirasawa* et al. [24] found that lead levels in modern teeth in Japan were higher than those obtained from teeth from the human remains of earlier periods, indicating that the pollution from lead is now greater than it was in the remote past. Reports from three dermatitis clinics, show that cheilitis, an inflammatory condition of the lips, is often caused by toothpastes [8, 9, 16]. The daily intake of lead and nickel were below the UL, whereas the daily intake of cadmium from Sensodyne (Tooth Care F) exceeded the UL established by *Garcia-Rico* et al. [10].

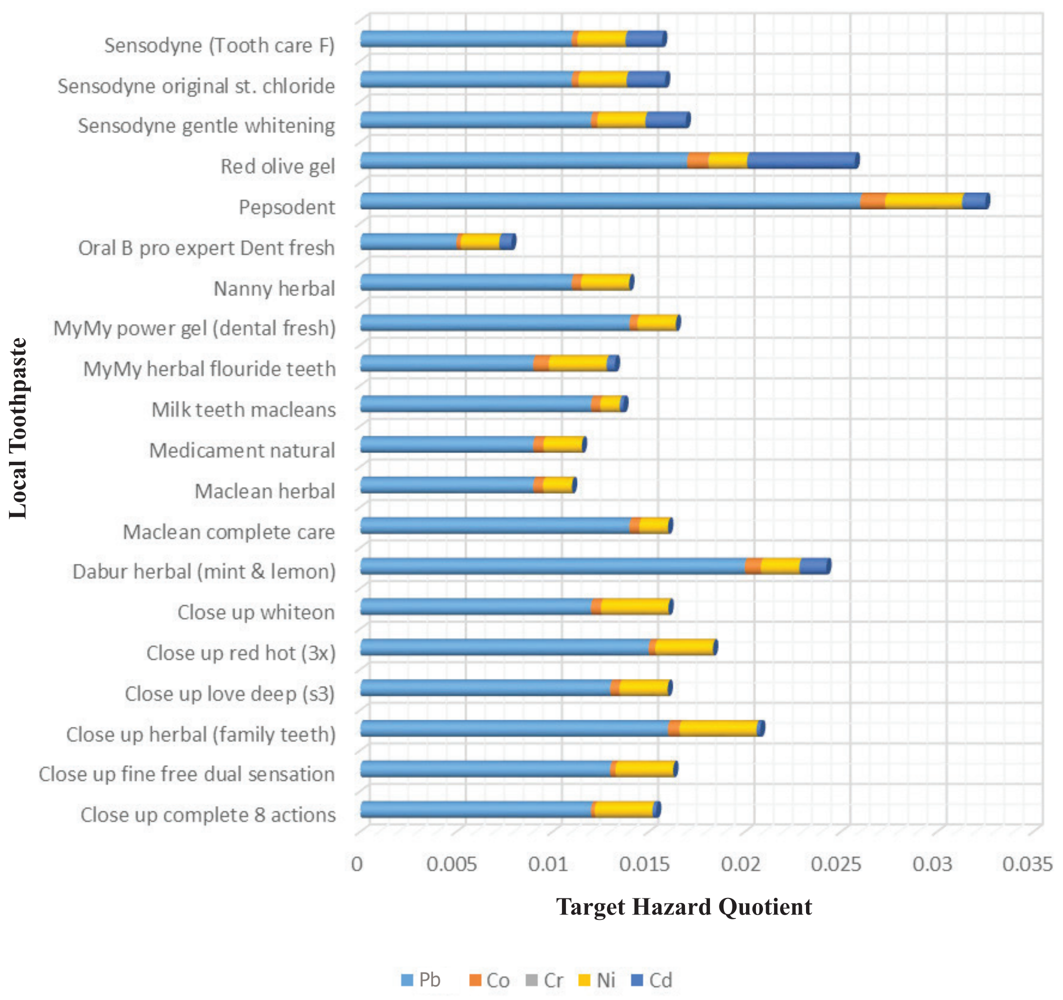

Figure 3. Target Hazard Quotients (THQ) of potential toxic metals from use of toothpastes manufactured in Nigeria

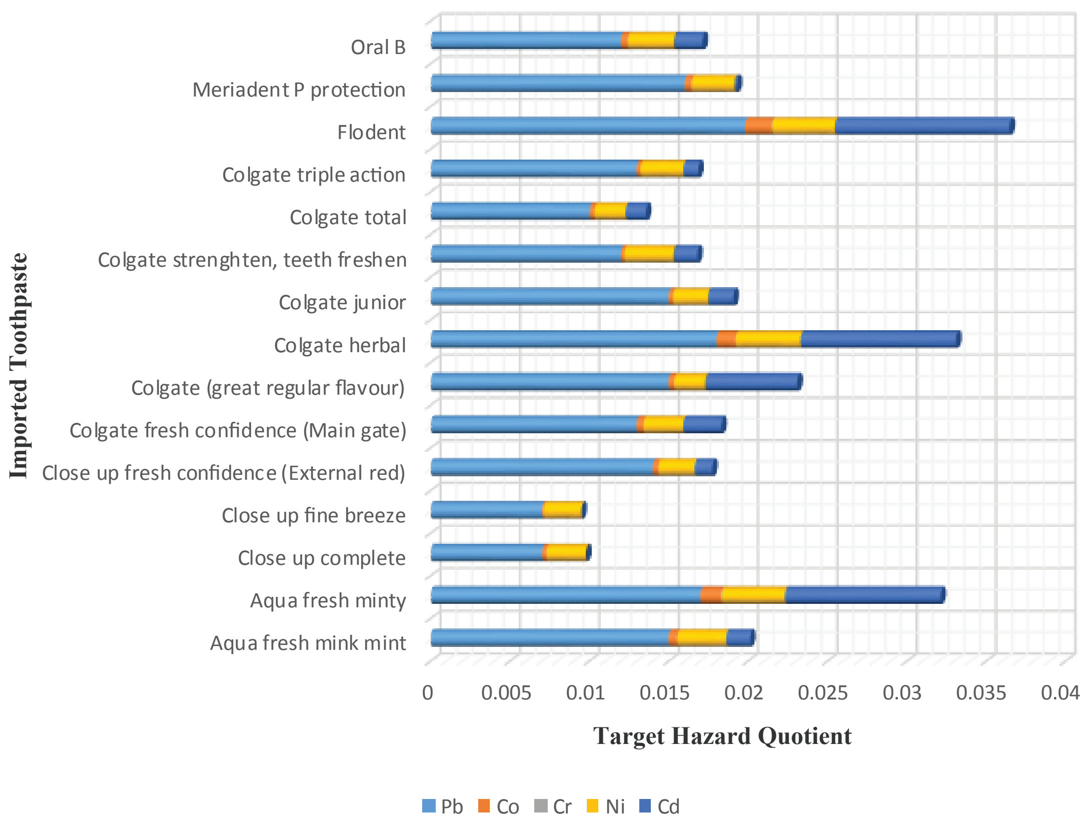

Figure 4. Target Hazard Quotients (THQ) values from the use of imported toothpastes

The daily intake estimates of all the imported toothpaste samples were found to be below the stated upper limits by *Garcia-Rico* et al. [10]. Human exposure to cadmium from consumables can reach up to 60% of PTWI in some regions of the world and the possible contribution from these consumables may be significant [23]. Renal dysfunction for instance is expected in sensitive population groups at cadmium exposure levels of half of the present PTWI. Cadmium is a non-essential trace element with deleterious effects on cardiovascular, gastrointestinal, neurological, renal, and respiratory systems [22]. Lead exposure is causally related to a modest increase in both blood pressure and hypertension [4]. Evidence suggests that the consequences of this effect are substantial, because hypertension is the leading cause of mortality resulting from cardiovascular disease. An association between bone lead and mortality as a result of cardiovascular disease has been reported. Men with the highest levels of bone lead had more than five times the risk of dying of cardiovascular disease compared to men with the lowest levels of bone lead [30].

Subchronic and chronic oral exposure of cobalt in man has been associated with effects on the hematological, thyroid and cardiovascular systems. Some case reports have also indicated the occurrence of reversible neurological responses. Cobalt crosses the placenta, produces dose-dependent maternal toxicity and was found to be embryotoxic with increased frequency of fetuses with lower bodyweight or skeletal retardation and embryo-lethality. In chronic studies, cobalt affects fertility in a time- and dose-dependent manner. There is a decrease in sperm motility, testicular weight, epididymal sperm concentration and fertility [17, 19].

Exposure to nickel was linked with genotoxic, immunotoxic, reproductive toxic, neurotoxic and carcinogenic effects [29]. *Sainio* and *Kanerva* [21] described the need for improving regulation and labelling of toothpastes, and forecast the creation of an international standard.

CONCLUSION

The results of our study confirm that pre-marketing safety studies for the toothpastes may be worthwhile for the regulatory authorities.

Conflict of interest

The authors declare no conflict of interest.

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