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Geophagy and Heavy Metals (Pb, Cd and Hg) Content of Local Kaolin Varieties in the Cameroon Market: Assessment Indices for Contamination and Risk of Consumption or Toxicity to the Population

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This study was conducted to profile the mining distribution, sale and consumption of most common kaolin in Cameroon, to determine the levels of Pb, Cd and Hg in local kaolin varieties at the sale points and to observed contamination possibilities. Preliminary questionnaires were administered to 1102 individuals from cosmopolitan cities, to determine some anthropometric parameters and consumption rate. A more detailed questionnaire was also administered to 122 vendors in the markets visited. Information requested included: Market situation of kaolin and consumption rate, source of procurement, awareness of the ban passed on kaolin, reasons for kaolin consumption, quantity consumed per day and most common variety. Results show that varieties (pink, white, yellow, grey, green and multicoloured) of kaolin are contaminated with Pb, Cd and Hg in a disproportionate manner, with the grey kaolin being the commonest and the most widely consumed variety. Additional contamination occurs for Pb and Cd as the grey variety is conveyed from the mining sites to the markets. Differences in Pb, Cd and Hg contents amongst the mining sites of kaolin were statistically insignificant. These differences were statistically significant for markets ($p = 0.0007$). Differences between Pb and Cd mean values at mining sites and markets are significant while that for Hg were insignificant. Post mining contamination, health risk and potential toxicity indices revealed that grey kaolin is contaminated by Pb and Cd after mining and consumers of kaolin will have high risk to toxicity of Pb, Cd and Hg.

Key words: Kaolin varieties, geophagy, heavy metals, potential toxicity, consumption risk

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INTRODUCTION

Geophagia or geophagy is a specific disorder due to clay or kaolin-eating (Grigsby *et al*., 1999). In many communities, kaolin is consumed by pregnant women to reduce symptoms of hyperemesis gravidarum which is severe form of nausea and vomiting during pregnancy and probably to prevent cramp or tetany which may be due to hypocalcaemia (Dreyer *et al*., 2004). Kaolin consumption is therefore, a habit in a population sector that is large and vulnerable.

Meanwhile, an alert notification from European Commission to the Cameroon Ministry of Public Health (Alert Notification, 2002) stated that kaolin carried from Cameroon to Europe had abnormally high amount of lead (Pb) at levels a 100 times higher than the maximum permissible level. After this notification, local clay or kaolin from Cameroon market was confirmed to contain not only Pb but Cd and Hg as well (Bonglaisin *et al*., 2011). An increased consumption of such kaolin or clay contaminated by these heavy mineral elements or the consumption of contaminated pottery produced from clay (Phipps *et al*., 2012) would normally results in their accumulation in body tissues and organs and with an eventual consequent defect on health.

This study continues to examine kaolin consumption after the ban from the Ministry of public Health as revealed by authors (Bonglaisin *et al*., 2011), investigating the most abundant and most widely consumed local kaolin variety. It is through this most consumed variety that the extent of the damage kaolin is causing to the consumers can be estimated. This study has also tried to describe possible reasons that could be attributed to kaolin contamination and if the need for contamination to be curbed down is raised, findings from this study can be applied. Secondly, if cleansing of the mined kaolin needs to be done to avoid hazard, then the most consumed or most abundant kaolin should be the target.

Based on the foregoing, the present investigation was carried out to:

- Determine the heavy metals (Pb, Cd and Hg) content of local kaolin varieties in the Cameroon market
- Determine kaolin mining sites of most orally consumed local kaolin in markets varieties
- Determine the level of Pb, Cd and Hg in the most consumed local kaolin at the mined and sale points
- Assess contamination and the potential toxicity of the consumption of kaolin to the Cameroon population

MATERIALS AND METHODS

In order to carry out this objective a questionnaire was designed and administered to 1102 individuals from cosmopolitan cities (Douala, Yaounde and Bamenda) to represent the country's population. In view of getting target groups that reflect these cities, communities such as Liberty church International (Douala), Etoug Ebe Baptist church (Yaounde), Hope/Menda Baptist churches (Bamenda) and Navigators women of Cameroon were selected to obtain consumption rate, age, weights and heights of kaolin consumers. A more detailed questionnaire was then designed, tested and eventually administered to a total of 122 individuals identified through informal discussions as consumers and vendors of local kaolin in each of the markets visited in the following towns: Douala, Yaounde, Bafoussam, Bamenda and Ngaoundere to get information that reflects the entire territory. The second questionnaire was designed to provide information on: Market situation of kaolin and confirmation of consumption rate, source of procurement, awareness of ban passed on kaolin by the Ministry of Public Health (MPH), type mostly consumed (orally), reasons for kaolin consumption and quantity consumed per day (estimated from the amount of money used to purchase kaolin consumed).

Six samples of approximately 1 kg each were then purchased from the randomly selected vendors in each of the markets.

In addition to samples collected from sale points, other samples were collected directly from 3 mining sites in Onitsha (in Nigeria), Mbengwi and Balengou (in Cameroon). The choices of these mining sites were selected based on tracking information on the source of the most orally consumed variety samples earlier purchased from the market. In each mining sites 4 separate samples were collected from 4 equidistant cardinal points (15 m apart) and at a depth of about 2 m.

In all 42 kaolin samples were collected. All samples collected were packaged in waterproof papers and transported to the laboratory for analyses.

Water content was determined according to the International Soil Reference and Information Centre method (Van Reeuwijk, 2002).

Standard solutions (Fisher chemicals) of Lead (Pb), Cadmium (Cd) and Mercury (Hg) were prepared from stock solutions of 1000 μg L^{-1} (ppm) by following appropriate dilutions using 10% nitric acid. Glassware was cleaned by overnight soaking in HNO_3:H_2O (1:1) followed by repeated rinsing with de-ionized water. De-ionized water was used throughout this work and acids were all of analytical grade.

The different varieties of kaolin samples were ground using a mortar and sieved with the USA Standard Testing sieve N°120, opening in micrometer 125 (Tyler Equivalent 115 mesh). Mineralization of kaolin samples was carried out in a humid medium for 30 min in a mixture of hot perchloric acid (2 mL), nitric acid (10 mL) and sulphuric acid (2 mL) (AOAC., 1984). This was filtered through acid washed filter paper (Whatman 42) into a 25 mL flask.

The heavy metal analysis was done using Perkin 311 model Atomic Absorption Spectrophotometer (Burtis and Ashwood, 2001) as stipulated by Bonglaisin *et al*. (2011). Heavy metal concentrations were derived using linear regression equations of the standard values and their absorbance readings.

The Earth Science laboratory of IRAD where all the heavy metal analyses were carried out is amongst the laboratories accredited by TUNAC (Tunisian Accreditation Council) in Africa. The Centre also receives, analyses and sends the result of soil samples from ITC (International Institute for Geo-Information Science and Earth Observation), Enschede, The Netherlands for quality assurance.

Advantage of this External Quality Assessment (EQA) program was exploited by introducing soil samples of known heavy metal concentrations as Internal Quality Controls (IQC) during analyses, so as to provide accurate results. This technique helped to ensure scientific validity of the results as well as the reliability of all operations.

Statistical analysis: Data was analyzed by Statgraphic 5.0. The data obtained was subjected to a one-way Analysis of Variance (Steel and Torrie, 1980). Significantly different means were separated using appropriate methods (Duncan, 1955). The values obtained were presented as Least Significance Differences (LSD) of means at $p<0.05$ compared to those which did not differ significantly ($p>0.05$).

RESULTS AND DISCUSSION

Field survey: From a total of 1102 men and women that participated in the first questionnaire at the population level, 1042 were women (94.6%) kaolin consumption rate amongst women corresponds to 31.6% while that amongst the few men who participated stands at 10%. Mean body weight and average Body Mass Index (BMI) for kaolin consumer women were 69.8±13.3 kg and 26.5±5.1 kg m^{-2} compared to 71.6±13.4 and 27.4±5.3 kg m^{-2} for non consumers, respectively with an age range of 15-78 years. Mean body weight and mean BMI for kaolin consumer men was 71.5±13.9 kg and 24.8±7.8 kg m^{-2} with an age range of 15-42 years.

Grey kaolin or clay is the commonest and the only variety available in the all markets visited and the most widely consumed directly like food. Other varieties like the white, yellow and green, called locally in French as ‘argile blanc’, ‘argile jaune’ and ‘argile vert’ respectively are mostly used for therapeutic purposes because they are believed to have medicinal virtues. Grey kaolin in the Cameroon market comes from three sources: Mbengwi (4.9%), Balengou (11.5%) and Nigeria (83.6%). The pink variety comes from Balengou and Nigeria and is only available in few markets. Exactly 68.9% of the vendors met in the market consumed kaolin while 31.1% were only vendors and never consumed kaolin. The reasons for consumption of grey kaolin varied from the appreciation of taste and odor (flavor), to beliefs or simply no reasons at all, as some women state that grey kaolin was their kola-nut. The health problem encountered mostly amongst kaolin consumers was constipation. Of the 122 people who filled the questionnaire at the vendor level, 86.9% were aware of the ban passed on kaolin consumption. Exactly 40.2% consumed the product in pregnancy, 9.0% could not remember while 10.7% never consumed kaolin in pregnancy. Daily consumption of one or more times a day was 29.5% while weekly consumption of one or two times a week was only 6.6%. Casual consumers dominated with 32.8%. Estimated average consumption per day was approximately the same as obtained in the previous research work (Bonglaisin *et al*., 2011) while consumption range was 26.0-120 g.

Pb, Cd and Hg content of other kaolin varieties: According to colour or variety, Table 1 illustrates that the green variety attracts Pb significantly more than all the other varieties ($p\leq 0.05$). The white, the pink, the yellow and the multicolour varieties attract more lead in a statistically significant manner compared to the grey variety ($p = 0.000$). High ANOVA (11.02) however, shows great variation of Pb between the varieties. No statistical significant difference exists for Cd contamination with respect to kaolin varieties ($p = 0.918$), low variation of Cd occurs between the different varieties (ANOVA = 0.29). As for the case of mercury, there also exists a statistical significant difference between the different varieties ($p = 0.013$). F-ratio for Hg (3.07) indicates variation of Hg amongst the varieties.

Colour in soils is due primarily to two factors, humus content and the chemical nature of the iron compounds. Iron is an important colour material which stains mineral particles. Ferrous or iron (II) oxide gives grey colour. Ferric or iron (III) oxide gives red colour. Hydrated ferric oxide gives yellow colour (Valanciene *et al*., 2010). Valanciene *et al*. (2010) also revealed that the yellow coloured kaolin is often due to limonite made up of ferric oxide principally, the green colour is due to micaceous minerals that are made of chlorite, biotite and illite or even due to abundant ferric oxide (hematite). But the reason for which Pb, Cd and Hg contaminate the different varieties differently has not been understood.

Pb, Cd and Hg in grey kaolin: The average concentrations of Pb, Cd and Hg in different samples of grey colour kaolin, observed to be the most abundant and most available type in all the markets under study are presented in Table 2. These results reveal that grey kaolin

Table 1: Heavy metals concentration as a function of colour of kaolin

		Pb (μg g^{-1})		Cd (μg g^{-1})		Hg (μg g^{-1})	
Varieties	Numbers	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Grey	13	98.80±65.9[a]	0.12-229.9	11.2±6.4[a]	0.00-19.60	3.94±1.54[a]	0.00-6.90
White	3	161.30±74.4[b]	3.85-229.1	9.9±8.6[a]	0.60-24.00	4.91±0.62[b]	4.25-6.25
Pink	4	161.40±35.7[b]	120.6-231.6	10.8±9.1[a]	0.12-26.31	4.80±0.64[b]	3.88-5.75
Yellow	4	156.40±35.4[b]	129.5-236.1	10.5±6.8[a]	2.26-23.30	4.76±1.01[ab]	3.88-6.25
Green	3	260.59±51.1[c]	218.8-335.1	8.9±8.4[a]	0.48-18.93	5.78±0.54[b]	5.25-6.25
Multicolour	3	186.50±44.9[b]	121.9-289.5	9.2±6.7[a]	0.36-23.30	4.61±1.14[b]	1.13-6.40
ANOVA		11.02		0.29		3.07	
p-value		0.000		0.918		0.013	

Values in the same column having the same superscripts are not significantly different from each other (p>0.05)

Table 2: Variation of heavy metal content of grey coloured kaolin in Cameroonians markets

Markets	Numbers	Pb (μg g^{-1}) Mean (Average)	Cd (μg g^{-1}) Mean (Average)	Hg (μg g^{-1}) Mean (Average)
Yaounde	9	94.1±64.2[b]	11.4±7.3[a]	3.40±1.9[a]
Douala	9	79.9±76.0[b]	7.6±7.4[a]	2.90±1.3[a]
Bafoussam	6	105.7±25.7[b]	13.4±3.9[a]	3.50±1.0[ab]
Bamenda A	1	173.2±35.2[c]	13.4±6.6[a]	4.80±0.91[bc]
Bamenda B	1	22.3±3.3[a]	11.9±6.3[a]	4.20±0.68[ab]
Ngaoundere	6	129.3±48.1[bc]	11.5±5.7[a]	5.77±0.76[c]
ANOVA		5.6	0.84	4.8
p-value		0.0007	0.532	0.002

Values in the same column having the same superscripts are not significantly different (p>0.05), values are taken as Mean±SD

Table 3: Heavy metal concentration of grey kaolin sampled at mining site

		Pb (μg g^{-1})		Cd (μg g^{-1})		Hg (μg g^{-1})	
Mine	Numbers	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Achala-Agu	6	65.4±47.2[a]	18.7-129.4	12.0±9.5[a]	0.00-20.4	5.8±1.9[a]	2.6-7.6
Balengou	6	86.4±58.1[a]	4.9-137.7	7.5±8.5[a]	0.24-22.0	4.4±2.5[a]	0.38-6.5
Mbengwi	6	99.4±64.6[a]	27.5-213.7	8.9±9.8[a]	0.12-21.1	6.0±2.6[a]	2.13-10.25
ANOVA		0.54		0.36		0.95	
p-value		0.592		0.7035		0.410	

Values in the same column having the same superscripts are not significantly different from each other (p>0.05)

is contaminated with Pb, Cd and Hg. The difference between Pb contents at market levels is statistically significant (p = 0.0007) and an ANOVA of 5.6 value indicates that there is great variation between the markets under study. The difference between Hg contents at market levels is also statistically significant (p = 0.002), with great variation between the markets (ANOVA = 4.8). On the contrary, no significant difference exists for Cd (p = 0.532). The F-ratio of 0.84 for Cd shows that there is no variation in the values of Cd amongst the markets under study. The various ranges or standard deviations (Table 3) reveal that heavy metals are not evenly distributed in kaolin samples.

There has been a lot of attention paid to heavy levels in soil because they are well-known to cause adverse health effects and are relatively widespread. Mean values of Pb that range from 22.3 μg g^{-1} in Bamenda B (Mbengwi kaolin) to 173.2 μg g^{-1} in the Bamenda A (Nigeria kaolin) don't pose any problem if compared to 300 μg g^{-1} considered as maximum permissible concentration for Pb in agricultural soil recommended by the European Soil Bureau. However, mean values of Cd and Hg in kaolin that range from 7.6-13.4 and 2.9-5.7 μg g^{-1}, respectively are far above the maximum permissible concentration of 0.3 μg g^{-1} recommended by the same institution (Lacatusu, 2000). Except for 22.3 μg g^{-1}, mean values of Pb are observed to be far above 37.6 μg g^{-1} found in one agricultural soil in china (Wei and Yang, 2010).

Pb, Cd and Hg contents of grey kaolin at the mining sites: Table 3 shows Pb, Cd and Hg contents of kaolin (grey) at the mining site. Differences in Pb, Cd and Hg contents as regards these mining sites (Nigeria, Balengou or Mbengwi) for kaolin are not statistically significant (p = 0.592, 0.7035 and 0.41, respectively). Low F-ratios for Pb, Cd and Hg (0.54, 0.36 and 0.95, respectively) indicate great variations of these heavy metals within the respective mining sites.

The mean values of Pb that range from 65.4-99.4 μg g^{-1} are within the acceptable range for agricultural soil, though high when compared to those obtained elsewhere (Wei and Yang, 2010). Those for Cd and Hg that range from 7.5-12.0 and 4.4-6.0 μg g^{-1}, respectively are not within the acceptable limit of 0.3 μg g^{-1} as stated above. The heavy metals contamination of kaolin or clay material could be due to agronomic practices above the mining sites. Lead (Pb) and Cd have been found predominantly in applied fertilizers like urea, triple super phosphate, muriate of potash (Shakya and Pradhananga, 2013). The passing of a stream through cultivated farm fields like in Achala-Agu village near Onitsha (Nigeria) can carry leached or washed heavy metals from these farms into the mining sites. Many Nigerian rivers and streams have been observed to be loaded with heavy metals (Asonye *et al*., 2007; Amadi, 2012) and will contaminate the mining site proportionate to the load of heavy metals that is being conveyed in them.

The relatively higher concentrations of Hg in the kaolin samples may be attributed also to the agricultural use of fungicides and seed preservatives that have been shown to have this heavy metal (Zhang and Wong, 2007). Mercury contamination might also originate from diverse sources such as day to day using and dumping of pharmaceuticals, thermometers, electronic materials and batteries etc., as the population has not been educated on waste disposal (especially electronic waste) in our communities. This will be true for Mbengwi where the mining site is located on the slope below human settlement with possibility of washing or leaching of Hg from settlement to mining site. This same logic is true for Pb and Cd contamination when fertilizers are applied on cultivated pieces of land within the settlement area, since the possibility of spillage and or leakage into the soil and the passage into the water bodies by run-off activities is inevitable. This view points are supported by evidence presented by Zhang and Wong (2007). Zeng and Zhang (2001) have also showed evidence of heavy metal mobility in soil horizon from highland to lowland, proving that contamination by this pathway of washing or leaching plays a greater role. Pieces of evidence of these heavy metals resulting from herbicides, pesticides and sewage have also been reported (Wei and Yang, 2010). It is obvious that these heavy metals will remain in the kaolin mining site immediately they access these areas and will not be washed off because kaolin is known to attract heavy metals. Clay particles are usually negatively charged. This is a very important factor influencing sorption properties of the soil or clay. It is because of this reason that soils having more kaolin or clay minerals can enrich higher heavy metals (Chen *et al*., 2011; Dube *et al*., 2011) due to their positively charged nature.

Rahman *et al*. (2012) revealed variation with an increased accumulation of heavy metals during the dry season compared to the wet or rainy season. This means there is more room for heavy metals to fit together when moisture departs from clay or kaolin during the dry season. A more convincing reason for variation could be that sediments that reach the mining site from the neighborhood contaminate disproportionately depending on the heavy metal load that varies due to alternation of fertilizing and non fertilizing periods. The quantities of heavy metals that come in from pesticides and domestic waste to contaminate kaolin at the mining site will depend on their load in them at any particular time. This is the same for any other human contaminating activity above the mining site like the case of Hg. Also sediments will hardly be evenly distributed at the mining site during run-off from rain water. This is certainly the reason for differential accumulation or variation of heavy metals at the mining sites revealed by the ranges and standard deviations presented in Table 3.

Table 4: Heavy metal (Pb, Cd, Hg) content of grey kaolin from mining site compared to that from the market in Bamenda

Sources	Pb	Cd	Hg
Nigeria			
Mine	65.4±47.2[a]	12.0±9.5[a]	5.8±1.9[a]
Market	173±35.2[b]	13.4±6.6[a]	4.77±0.91[a]
ANOVA	20.12	0.09	1.70
p-value	0.0012	0.772	0.222
Balengou			
Mine	76.2±58.6[a]	9.4±8.1[a]	5.1±1.82[a]
Market	142.4±19.4[b]	15.7±8.1[a]	4.73±0.89[a]
ANOVA	9.09	1.82	0.21
p-value	0.0118	0.2041	0.656
Mbengwi			
Mine	99.4±64.6[b]	8.9±9.8[a]	6.0±2.6[a]
Market	22.28±3.3[a]	11.9±6.3[a]	4.19±0.68[a]
ANOVA	8.52	0.39	2.87
p-value	0.015	0.546	0.121

Values in the same column having the same superscripts are not significantly different from each other (p>0.05)

Pb, Cd and Hg in grey kaolin at mining and Bamenda market sites: Table 4 presents Pb, Cd and Hg contents of grey kaolin with respect to the distances of their mining sites to the Bamenda market. Bamenda B (Mbengwi) is only about 45 km away, Balengou is about 120 km and Achala-Agu (Nigeria) more than 600 km corresponding, respectively to 65.4, 86.4 and 99.4 µg g^{-1} for Pb, compared to market values of 22.3, 142.4 and 173 µg g^{-1}, for Mbengwi, Balengou and Achala-Agu, respectively. Apart from the Mbengwi type that must have been mined from a section of the mine that is least contaminated by Pb, it seems seasonable to state that Pb contamination is linked to the distance from the mining site. Generally, Hg is observed to decrease as one passes from the mining site to the market while Cd on the contrary increases from the mining site to the market, with no specific logic or trends for closer mines. Standard deviations show great variation of heavy metals at both the mine and market levels (Table 4).

The findings by some authors that Hg is most pollutant in the transportation sector, due to traffic and anthropogenic activities is not verified in this study. High concentrations of Pb, Cd and Hg were equally found by the same authors in dust particles collected at the sides of a highway (Shakya and Pradhananga, 2013), indicating that transportation can contaminate kaolin especially during loading and off-loading.

During market visits it was remarked that some wholesale dealers used cement bags to transport kaolin. Cement is known to contain traces of heavy metals (VDZ., 2002) and any bag that has initially contained cement will harbour also traces of cement and thus heavy metals that would eventually contaminate kaolin if utilized. A Value as high as 106 ppm (Achternbosch *et al*., 2003) has been reported for Pb in cement from Portland that is sometimes on sale in the Cameroon local market. This cement also contains Cd and Hg at 0.4 and 0.07 ppm, respectively, indicating that cement bags are amongst the potential sources of kaolin contamination during transportation.

Post mining contamination index: Using the results (mean values) of heavy metal concentration found in the different grey kaolin samples in the Bamenda market, the values were compared to those of the mining site for each metal. Based on this logic, contamination indices for each of the metal analyzed after mining were calculated.

As such, post mining contamination index (PCI) of kaolin as it passes from the mine to the market (in Bamenda) is defined as:

$$PCI = \frac{OCm_a}{OCm_S}$$

where, OCm_a is observed concentration of heavy metal in the market and OCm_s is observed concentration of heavy metal at the mining site.

Based on this definition, kaolin samples for PCI lower than or equal to 1 are considered not to be contaminated during transportation from the mine to the market while PCI higher than 1 considered contaminated. The post mining contamination indices of the different kaolin analyzed are shown on the histograms (Fig. 1).

According to the values obtained for Pb, Achala-Agu and Balengou kaolin varieties are contaminated with this heavy metal as they pass from the mining sites to the market while kaolin from the Mbengwi mine that is closest to the Bamenda market is not contaminated. The values for Cd show that all kaolin is contaminated with more Cd as they are conveyed to the markets. On the contrary, there is no Hg contamination as kaolin evolves from the mining site to the market.

Potential toxicity index of heavy metal: Using the results of heavy metal concentration found in the different samples, the values were compared to the maximum acceptable limits for each metal.

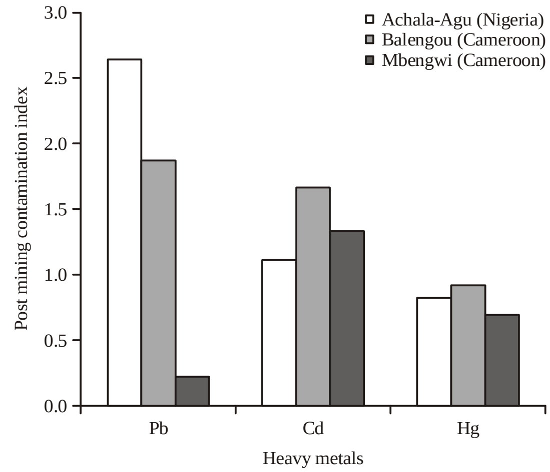

Fig. 1: Post mining contamination index for heavy metals

Given that heavy metal can be toxic to human health, FAO/WHO in 2006 has defined Maximum Permissible Limit (MPL) in food. These limits vary according to metal and concentrations higher than these limits in any food render the food potentially toxic. Based on this reasoning, the potential toxicity indices for each of the metal analyzed were calculated.

In this respect Potential Toxicity Index (PTI) in kaolin (or in the food) is defined as:

$$PTI = \frac{OCf}{PCf}$$

where, OCf is observed concentration in food material and PCf is permissible concentration in food material.

Based on this definition food samples for PTI lower than 1 are considered as potentially not toxic to the body while PTI higher than 1 considered toxic. The PTI of the different metals analyzed in each sample are shown on the histograms (Fig. 2a-c).

Health risks and hazards of exposure: The risk of intake of heavy metal-contaminated grey kaolin to human health was characterized by Health Risk Index (HRI). Calculated as follows:

$$\text{Daily intake of heavy metal (DIM)} = \frac{\text{Cmetal} \times \text{Cf} \times \text{Dkaolin intake}}{\text{B(average weight)}}$$

where, Cmetal is heavy metal concentrations in kaolin sample (μg g^{-1}), at the market level = 100.75 (average value for grey), Dkaolin intake is daily intake of kaolin (low = 30 g, medium = 60 g and high = 120 g), Cf is Conversion factor (average fraction of dry matter contained in kaolin from the market), B (average weight) is average body weight (70 kg); approximated from the

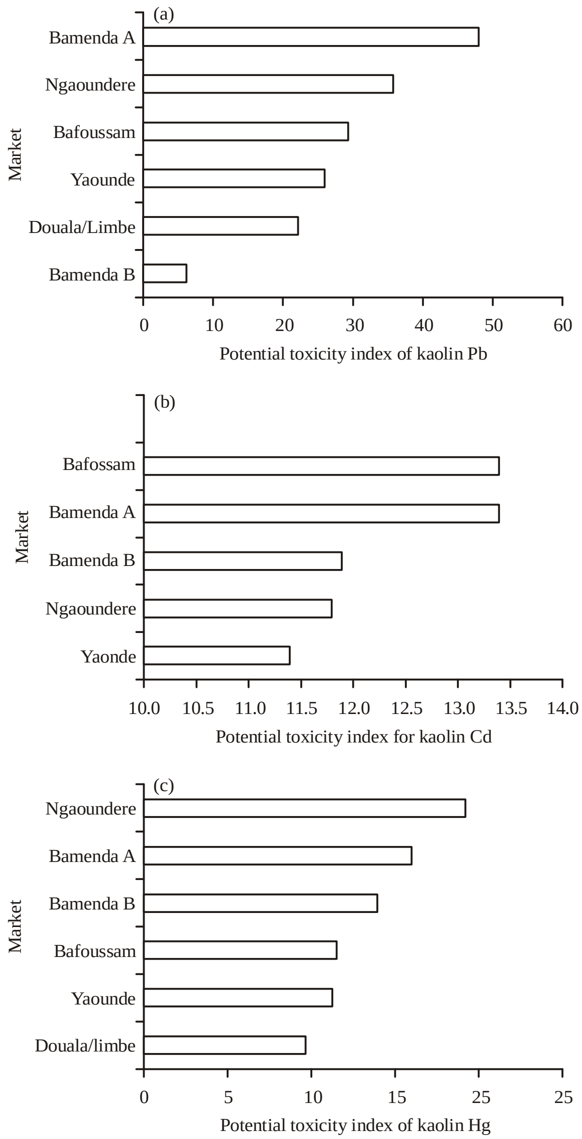

Fig. 2(a-c): Potential toxicity of kaolin in (a) Pb, (b) Cd and (c) Hg as a function of MPL

value of 69.8±13.3 for a total of 326 kaolin consumers obtained from the questionnaire that involved 31.6% of 1042 participants during field survey in this study.

Therefore:

$$\text{Daily intake of Pb for low consumption (DIM)} = \frac{100.75 \times 0.953 \times 30}{70}$$

where, Low DIM for lead = 41.15, Medium DIM = 82.30, High DIM = 164.60.

Health Risk Index (used to assess hazard exposure) was then calculated as follows:

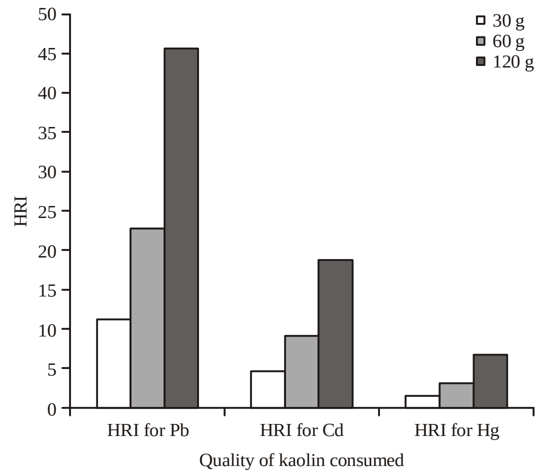

Fig. 3: HRI for Pb, Cd and Hg against kaolin consumed

Calculation of HRI for lead:

$$\text{Health Risk Index for Pb (HRI)} = \frac{\text{DIM}}{\text{RfD}}$$

$$\text{HRI (Pb)} = \frac{\text{DIM}}{\text{RfD}^{\mu g}/_{g}}$$

$$\text{HRI Pb (low)} = \frac{41.15}{3.6}$$

HRI for low consumption = 11.4; medium = 22.9; high = 45.6.

Considering the RfDos of 1 and 0.23 μg g^{-1} and average consumptions per market of 11.5 and 4.095 for cadmium and mercury, respectively (for grey kaolin), the same calculations were carried out for these metals.

Detailed results are presented on Fig. 3. The population will have no risk if the index is less than or equal to 1 and if the index is greater than 1 then population will experience health risk. Therefore, the values of HRI for Pb of 11.4 for low kaolin consumers, 22.9 for medium consumption and 45.6 for high consumption indicate factors that are multiplying risk at each level of consumption. Though the HRI values of 4.7, 9.4 and 18.79 for low, average and high kaolin consumption, respectively for Cd are not as high as those for Pb, they are also greater than 1 (Fig. 3).

The calculated HRI values of 1.67, 1.97 and 6.69 for low, average and high kaolin consumption, respectively for Hg are also presented in Fig. 3. These HRI values are lower when compared to those for Cd and Pb, indicating that this heavy metal is affecting the population less than Cd and Pb.

This HRI risk assessment method has been used by Wang *et al*. (2005), Khan *et al*. (2009) and Singh *et al*. (2010) and is useful illustration of the level at which the targeted population is exposed to a hazard. Local grey kaolin consumers are therefore pruned to develop diseases that come about as a result of exposure to these heavy metals.

CONCLUSION

This investigation shows that only three mining sites (Nigeria, Balengou and Mbengwi) are sources of grey kaolin that is commonest in the Cameroon market. Apart from Mbengwi that is closest to the Bamenda market, Pb concentrations increase significantly as kaolin passes from the mining sites to the market levels. Cadmium concentrations also increase significantly while concentrations in Hg generally drop as one passes from mine to market. The values of these metals are above the acceptable thresholds for edible matter, consequently people who are involved in the habit of consuming kaolin are exposed to toxicity of these heavy metals. Heavy metals are observed not to be evenly distributed in the various varieties found in the markets.

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