Assessment of Dietary Exposure and Health Risk to Multiple Heavy Metals amongst Some Workers in Yaoundé, Cameroon

Angèle N. Tchana¹, Nina D. Kamnang¹, Arielle T. Maliedje¹, Faustin T. Manfo², Frederic N. Njyou¹, Wilfred A. Abia¹, Edouard A. Nantia³ and Paul F. Moundipa¹

1. Laboratory of Pharmacology and Toxicology, Department of Biochemistry, Faculty of Science, University of Yaoundé I, Yaoundé P.O. Box 812, Cameroon

2. Department of Biochemistry and Molecular Biology, Faculty of Science, University of Buea, Buea P.O.Box 63, Cameroon

3. Department of Biochemistry, Faculty of Science, University of Bamenda, Bamenda P.O.Box 39, Cameroon

Abstract: This study reports on the dietary exposure of people in Yaoundé, Cameroon to heavy metals: lead (Pb), cadmium (Cd), mercury (Hg), copper (Cu) and zinc (Zn). One hundred and fifty table-ready food, water and soft drink samples were collected from households and street restaurants in Yaoundé and analyzed for heavy metals contents using atomic absorption spectrophotometer. Lead (93%, range 0.019-1.77 ppm), Cd (70%, range 0.01-4.68 ppm), Hg (81%, range 0.03-10.56 ppm), Cu (90%, range 0.004-40.32 ppm) and Zn (87%, range 0.014-2,447.04 ppm) were detected in studied samples. Maximum level of each metal exceeded its corresponding European Commissions legislative limits. Samples from street restaurants were most tainted with heavy metals. The highest average daily intakes (ADIs) of Pb (0.96 mg/day) and Hg (1.84 mg/day) were through tap water, while Cd (1.15 mg/day), Cu (5.42 mg/day) and Zn (601.6 mg/day) were through rice/peanut sauce mixed food. The ADI for Cd and Hg was each higher than its respective PTDI (provisional tolerable daily intake) as defined by JECFA (Joint FAO/WHO Expert Committee on Food Additives) and EVM (Expert Group on Vitamins and Minerals). The estimated average daily exposure dose of each detected metal significantly ($p = 0.001$) exceeded its corresponding PTDI. However, the health risk index was < 1 for all studied samples and it was found to be safe, indicating there is a relative absence of health risks associated with the ingestion of contaminated foods, water and soft drinks. Notwithstanding, the detected levels and ADI being higher than legislative limits and PTDI respectively speculates need for awareness raising towards reducing exposure levels to heavy metals in Cameroon.

Key words: Dietary exposure, food, water and soft drink contamination, heavy metals, Cameroon.

1. Introduction

Heavy metals are environmental pollutants prevalent in the surroundings as a result of natural and anthropogenic activities. Human exposure to heavy metals occurs through industrial activities, water supplies, automobile exhausts, disposal current, consumer products, application of fertilizers in soil, pesticides, urban effluents, and food [1, 2]. Some heavy metals (Zn and Cu) are essential for normal cell

physiology when present in low amounts, but exhibit toxicity to living organisms when taken up in high quantity, or if the mechanisms of elimination are impaired. Other heavy metals such as Pb, Cd, and Hg have no known benefit to human physiology, and are essentially referred to as toxicants or “toxic metals”. Heavy metals enter the food chain where they tend to bioaccumulate particularly because of the ability of plants to uptake the chemicals [3-5].

The presence of heavy metals in the animal production chain can result from consumption of contaminated agricultural commodities and/or related products. Animal feed can also be intentionally

Corresponding author: Paul F. Moundipa, Ph.D., professor, research fields: biochemistry.

supplemented with mineral raw materials during breeding [6, 7]. Heavy metals have also been reported in commercially available foods [8], given the likelihood of contamination of some commonly used raw materials (meat, plants).

They can enter the body by inhalation, dermal absorption, or ingestion [9]. Once into the organism they slowly accumulate in target organs such as the kidneys, lungs, liver, teeth, bones, brain and keratinized tissues such as hair and nails [4, 10, 11]. Heavy metals can form metal ion and induce reactive oxygen species (ROS) production, with subsequent lipid peroxidation, DNA damages and protein denaturation [12, 13]. These toxicity mechanisms are common in some pathologies such as the reproductive system and development disorders, neurodegenerative diseases, metabolic diseases, kidney disorders and respiratory problems [4, 14-16]. Being ubiquitous and not easily biodegradable, heavy metals can persist in the environment and notably in the food chain with important human health risks. Indeed, many health implications such as cancer [17, 18], Alzheimer's disease, Parkinson's disease [15, 19] caused by consumption of food contaminated with Hg, Pb, Cd, etc., have been reported.

Previous studies also highlighted sources, potential human health risks and high concentrations of heavy metals in commonly consumed foods and items in some developing countries like Bangladesh [20, 21], Ghana [2, 6, 22], Nigeria [6, 23], Uganda [24], Cameroon [25, 26]. Considering the susceptibility of to heavy metals exposure and insufficient data related to exposure levels, there is need to get information on the heavy metals dietary exposure levels amongst Cameroonians. The aim of this study was to determine the extent to which the population of Yaoundé in Cameroon is exposed to heavy metals in their diets, water and/or soft drinks commonly prepared at homes and/or bought from small road-side restaurants for direct consumption.

2. Materials and Methods

2.1 Reagents and Equipment

The reagents used in the experiment were high grade and purchased from Sigma Aldrich (USA), Prolabo (France), Merck (Germany). Demineralized water was used wherever needed. Working standard solutions (100 ppm in 1% nitric acid) of Pb, Cd, Hg, Cu and Zn were prepared from the stock solutions having 1,000 ppm followed by appropriate dilution. Atomic absorption spectrophotometer (Buck Scientific, In., Fort Point St., USA) was used for metals determination. Glassware and tubes were pre-washed with 10% nitric acid solution to avoid additional metal contamination of samples.

2.2 Study Site and Study Population

A descriptive cross-sectional survey was conducted in 2013 among the population (age between 21 and 65 years) in all the 23 districts of Yaoundé, Center region of Cameroon. Yaoundé is the administrative capital of Cameroon, and the second cosmopolitan city in the country after Douala (the economic capital). Yaoundé is characterized by wide diversified individually owned small road-side restaurants that attempting to provide foods and related services to the busy population of Yaoundé, working in diversity of jobs life and in Yaoundé sorely to fend for themselves and families. Thus, the study population was essentially people leaving and working in the city of Yaoundé, regardless of their occupations, e.g., students, employees, informal sectors workers (traders, mechanics, sheet metal workers, welders, taxi drivers ...), and/or unemployed.

2.3 Survey on Foods/Snacks, Water and Soft Drinks Consumptions

Semi-structured (and food frequency) questionnaires were used to collect information on lifestyle, nutritional habits, the origin of various foodstuffs,

food preparation method, food consumption intake/amounts and frequency (per day/week/month), amount ingested, storage behavior, medical background from each participants (those who had signed the informed consent form).

2.4 Sampling

One hundred and fifty (150) samples consisted of mixed food dishes, food items and beverages (Table 1) were randomly collected or purchased from households and/or small road-side restaurants in Yaoundé from February to March 2013. Solid and liquid samples that were not pre-packaged e.g., tap water, foods in plates ready for consumption, were mixed thoroughly prior to sample collection. Pre-packaged samples e.g., soft drinks in cocked bottles, sardine in cans, sachet/bottled water, were collected in their natural packaging as found in the

study households and/or small road-side restaurants (i.e., in plastic bags, cans). Both non- and pre-packaged samples collected were immediately placed into an ice cooler, and transferred to the Laboratory of Pharmacology and Toxicology of the University of Yaoundé I, where samples were pre-processed before analysis. Each solid sample was weighed, meanwhile, mixed food dishes such as paste with sauce commonly eaten in combination were mixed to make a single sample of the final consumed food. Each of the weighed solid samples was then milled, and after thorough mixing, a sub-sample (100 g) was placed in sterile glass container, sealed and preserved at -20 °C until analysis of heavy metals. Similarly, each liquid sample (beverages) was mixed thoroughly and a sub-sample (100 mL) was placed in sterile glass bottle, sealed and preserved at -20 °C until analysis of heavy metals.

Table 1 Sample types collected from all 23 districts in Yaoundé, Centre Region of Cameroon.

Sample type	Number of samples	Food-base	Cooking method /Storage material
Corn paste + (Okra soup, cabbage sauce, “djama-djama”, “ndolè ^a ” sauce)	12	Cereals (corn)	Boiling/Plastic
Cassava paste + (egusi sauce ^a , “eru ^a ”)	8	Tuber (cassava flour)	Boiling/Plastic
Cocoyam paste + peanut sauce ^a	7	Tuber (cocoyam), leguminous (peanut)	Boiling/Plastic
Rice + (stew soup, peanut sauce)	22	Cereals (rice)	Boiling/Plastic
Doughnut	12	Cereals (wheat, corn)	Frying/Plastic
Porridge	6	Cereals (corn, rice), leguminous (peanut, beans)	Boiling/Plastic
Beans	3	Leguminous (beans), tuber (sweet potato)	Boiling, frying/Plastic
Fish + cassava paste	5	Fish, tuber (cassava)	Roasting/Plastic
Sausage/pie meat	4	-	Preserved/Can
Sardine	4	-	Preserved/Can
Tomato	7	-	Preserved//Plastic, Can
Milk [†]	6	-	Bottled/Plastic
Refined oil/Palm oil	6	-	Bottled/Plastic
Soft drink [†]	11	-	Bottled/Plastic
Mineral water [†]	4	-	Bottled/Plastic
Sachet water [†]	15	-	Package/Plastic
Spring water [†]	3	-	Package/Plastic
Water-well ^{a†}	8	-	-/Plastic
Tap water ^{a†}	7	-	-/Plastic
Total	150		

^a: Samples originating from households; [†]: liquid samples.

2.5 Heavy Metals Analysis

Wet digestion was conducted on 2 g of food or soft drink samples introduced in a flask, except water samples, with 20 mL of aqua regia (nitric acid (75%)/hydrochloric acid (36%): 1:3 v/v). The flask was placed in a reflux device and heated at 80 °C for 2 to 3 hours until the solution become clear [27]. The digest was allowed to cool and transferred into a measuring flask using specific Whatman filter paper for metals. The filtrate was then made up to 50 mL using demineralized water and stored at the same time with 50 mL each water sample at 4 °C. Samples were mineralized in duplicate for Cd, Pb, Hg, Cu and Zn determination by atomic absorption spectrophotometry [28]. Briefly, 25 mL of mineral deposit of the test sample was introduced into the air-acetylene flame (lamp current of 4 mA) of the spectrophotometer in which it was vaporized and atomized. Wavelengths of 288.8 nm, 217 nm, 253.7 nm, 324.8 nm, and 213.9 nm were used respectively for Cd, Pb, Hg, Cu and Zn. Concentration (ppm) of metal was read after calibration of the instrument with known concentrations of the metals solutions: 2.5, 5.0, 10, 15, 20 ppm and reagent blank for Pb; 5.0, 10, 15, 20 ppm and reagent blank for Cd and Hg; and 1, 2.0, 3.0, 4.0, 5.0 ppm and reagent blank for Cu and Zn.

2.6 Exposure Assessment Calculations

2.6.1 Calculating the Average Daily Intake (ADI) of Heavy Metals

The studied samples were broadly categorized into food, water and soft drink. The ADI of a metal in a food was determined by multiplying the average content of the metal in food by the averaged consumed amount of food and frequency of consumption [29], using the following formula:

$$ADI = \Sigma (T \text{ food or beverages} \times Q \text{ ingested} \times F \text{ food}) / 30$$

where, ADI = average daily intake of metal (mg/day); T = heavy metal content in the food ingested (mg/kg

or mg/L); Q ingested = weight of the food consumed (g) and F = frequency of consumption of a food over 30 days.

2.6.2 Estimation of Daily Exposure to Heavy Metals in the Study Population

Average daily exposure dose (ADED). The daily exposure dose of heavy metals (DED) was calculated using the following formula [29] and the survey data:

$$ADED = ADI/bw$$

where ADED = the average daily exposure dose to heavy metal ($\mu\text{g/kg bw/day}$) and bw = body weight of individual (kg). The average body weight of 60.7 kg for African (adult) as established by WHO [30] was used in this study.

Contribution rate of metal exposure. The contribution rate of metal exposure from collected samples was determined as followed:

$$\text{Food contribution rate of metal exposure} = (\text{metal exposure of the sample} / \text{total dietary metal exposure}) \times 100\%$$

Health risk index (HRI). The potential HRI to consumers which refers to the ratio of the daily exposure dose of metals to the oral reference dose was determined according to EPA [31] as followed:

$$HRI = (ADED/PTDI) \times 10^{-3}$$

where PTDI is the provisional tolerable daily intake reference dose of the metal and 10^{-3} factor of uncertainty (conversion factor). $HRI > 1$ indicates a reason for health concern.

2.7 Statistical Analyses

The software statistical package for social sciences (SPSS 20.0) was used for data analysis. Data were presented as mean $\pm$ standard deviation. Mann-Whitney *U*, Kruskal-Wallis for non-normally distributed data, analysis of variance (ANOVA) and Student *t*-tests for parametric data were used to compare groups. Correlation analysis was done using Chi-square test. A *p*-value < 0.05 was considered statistically significant.

2.8 Ethical Statement

The experimental procedure was approved by the Cameroon National Ethics Committee of Research for Human Health (No. 2013/05/252/CNERSH/SP).

3. Results

3.1 Characteristics of the Population

The studied population (251 individuals) was mostly informal sector workers (70%) followed by students (16%), employees (12%) and others (3%). About 67% of participants used to eat both in small road-side or street restaurants and households, while 22% and 11% eat in households, small road-side restaurants, respectively (Fig. 1). There was a significant correlation between the catering and status of participants ($p = 0.001$), with people involved in small businesses feeding mainly in the small road-side or street restaurant (Fig. 1).

3.2 Levels of Heavy Metals in Food and Foodstuff Samples

The contamination profile of samples as well as the mean concentrations of heavy metal in broader groups regarded to guidelines is summarized in Table 2. Lead was detected in 93% of samples (range 0.019-1.77 ppm), Cd in 70% (range 0.01-4.68 ppm), Hg in 81% (range 0.03-10.56 ppm), Cu in 90% (range

0.004-40.32 ppm) and Zn in 87% of samples (range 0.014-2,447.04 ppm). Highest levels of metals were recorded in samples from the small road-side restaurants and were 8 to 105.6 folds more than permitted [32, 33]. Differences in Pb, Cu and Zn values were significant ($p = 0.001$) between the studied household and small road-side restaurant foods.

The average concentrations of metals in water samples varied from 0.019 to 0.9 ppm for Pb, 0.01 to 0.58 ppm for Cd, 0.03 to 1.13 ppm for Hg, 0.004 to 2.02 ppm for Cu and 0.014 to 0.41 ppm for Zn with no significant difference ($p > 0.05$). The concentrations of Pb, Cd and Hg in 100% positive samples were higher than recommended [32, 33]. and were in the following respective ranges in specify samples: sachet water (0.019-0.83 ppm, 0.02-0.58 ppm and 0.03-1.13 ppm); tap water (0.02-0.48 ppm, 0.07-0.27 ppm and 0.27-0.92 ppm); water from wells (0.02-0.38 ppm, 0.02-0.38 ppm and 0.24-0.89 ppm); spring water (0.06-0.42 ppm, 0.07-0.13 ppm and 0.1-0.51 ppm); and mineral water (0.02-0.9 ppm, 0.01-0.16 ppm and 0.06-0.83 ppm).

The average concentrations of metals in soft drink samples were not significantly different ($p > 0.05$). The concentrations of metals in bottled soft drink and sachet soft drink ranged respectively as followed: Pb (0.54-1.28; 0.18-1.34 ppm), Cd (1.24-4.68; 0.6-2.35 ppm),

Fig. 1 Distribution of participants ($n = 251$) by feeding milieu.

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Table 2 Occurrence and mean concentrations of heavy metals in samples groups.

	Heavy metal	Pb	Cd	Hg	Cu	Zn
Sample analyzed (<i>n</i> = 150)	Positive (%)	139 (93)	105 (70)	122 (81)	135 (90)	131 (87)
	Mean range (ppm)	0.019-1.77	0.01-4.68	0.03-10.56	0.004-40.32	0.014-2,447.04
Feeding milieu						
Household (<i>n</i> = 22)	Positive (%)	20 (91)	18 (82)	18 (82)	19 (86)	18 (82)
	Mean range (ppm)	0.02-1.22	0.02-0.97	0.04-0.92	0.02-17.64	0.02-557.2
	Mean $\pm$ SD	0.21 $\pm$ 0.21	0.18	0.36 $\pm$ 0.01	1.95 $\pm$ 0.26	27.44 $\pm$ 0.21
Street or small road-side restaurant (<i>n</i> = 128)	Positive (%)	115 (90)	87 (68)	104 (81)	116 (91)	113 (88)
	Mean range (ppm)	0.019-1.77	0.01-4.68	0.03-10.56	0.004-40.32	0.014-2,447.04
	Mean $\pm$ SD	0.5	0.76 $\pm$ 0.18	0.46 $\pm$ 0.22	9.51 $\pm$ 3.06	143.12 $\pm$ 49.73
	<i>p</i> -Value	0.001	0.054	0.559	0.001	0.001
Sample group						
Water (<i>n</i> = 37)	Positive (%)	37 (100)	34 (91.9)	31 (83.8)	30 (81)	34 (91.9)
	Mean range (ppm)	0.019-0.9	0.01-0.58	0.03-1.13	0.004-2.02	0.014-0.41
	Mean $\pm$ SD	0.19 $\pm$ 0.23	0.14 $\pm$ 0.12	0.38 $\pm$ 0.32	0.13 $\pm$ 0.34	0.1 $\pm$ 0.11
	(%) Above guideline	100	100	100	-	-
	Guidelines (ppm)	0.01*	0.003*	0.001*	2*	3*
	<i>p</i> -Value	0.334	0.184	0.198	0.116	0.247
Soft drinks (<i>n</i> = 11)	Positive (%)	11 (100)	9 (81.81)	10 (90.9)	11 (100)	8 (72.72)
	Mean range (ppm)	0.18-1.34	0.6-4.68	0.03-0.83	2.29-40.32	3.31-16.71
	Mean $\pm$ SD	0.85 $\pm$ 0.4	1.71 $\pm$ 1.42	0.35 $\pm$ 0.28	18 $\pm$ 12.41	7.36 $\pm$ 6.11
	(%) Above guideline	100	100	100	90.9	63.63
	Guidelines (ppm)	0.05*	0.4-0.5*	0.01*	5*	5*
	<i>p</i> -Value	0.361	0.408	0.522	1	0.357
Food (<i>n</i> = 102)	Positive (%)	91 (89.21)	62 (60.78)	81 (79.41)	94 (92.15)	89 (87.25)
	Mean range (ppm)	0.02-1.77	0.13-3.5	0.03-10.56	0.03-38.56	1.73-2,447.04
	Mean $\pm$ SD	0.54 $\pm$ 0.43	0.76 $\pm$ 0.95	0.49 $\pm$ 1.14	10.36 $\pm$ 8.02	184 $\pm$ 432
	(%) Above guideline	100	100	72.54	-	16.66
	Guidelines (ppm)	0.1*	0.05*	0.1*	100*	300*
	<i>p</i> -Value	0.001	0.582	0.488	0.033	0.001

SD: Standard deviation, *: Permissible limits [32, 33]. Analysis of variables was done by Kruskal-Wallis and Mann-Whitney *U* tests. Significance at *p*-value < 0.05

Hg (0.04-0.83; 0.03-0.67 ppm), Cu (5.37-40.32; 2.29-35.5 ppm) and Zn (9.66-16.71; 3.31-10.61 ppm). The levels of Pb, Cd and Hg in samples exceeded the allowances [32, 33].

In food group samples, the concentrations ranged from 0.02 to 1.77 ppm for Pb, 0.13 to 3.5 ppm for Cd, 0.03 to 10.56 ppm for Hg, 0.03 to 38.56 ppm for Cu and 1.73 to 2,447.04 for Zn, and differed significantly (*p* < 0.05) for Pb, Cu and Zn. The maximum levels for Pb, Cd, Hg, Cu and Zn were found respectively in refined oil, corn paste/vegetable sauce mixed food, cocoyam paste/peanut sauce mixed food, cassava paste/egusi

sauce mixed food and cassava paste/vegetable mixed food (water “fufu/eru”).

3.3 Heavy Metal Contents according to Storage Behaviour

The concentrations varied significantly (*p* < 0.05) depending on the natural packaging of samples collected as found in the field (Table 3), as far as Pb, Cu and Zn were concerned. Levels of heavy metals were generally higher in samples stored in plastic bags relative to those in can, the two storage material mostly encountered in the feeding areas.

Table 3 Levels of heavy metals (ppm) according to storage behavior.

Heavy metal	Storage material	Number of positive samples	Mean $\pm$ SD (range)	<i>p</i> -Value
Pb	Plastic (<i>n</i> = 133)	119	0.43 (0.19-1.77)	0.027*
	Can (<i>n</i> = 17)	16	0.74 (0.02-1.7)	
Cd	Plastic (<i>n</i> = 133)	95	0.69 $\pm$ 0.75 (0.1-4.67)	0.845
	Can (<i>n</i> = 17)	10	0.57 $\pm$ 0.75 (0.19-1.82)	
Hg	Plastic (<i>n</i> = 133)	110	0.47 $\pm$ 0.42 (0.03-10.56)	0.325
	Can (<i>n</i> = 17)	12	0.30 $\pm$ 0.41 (0.03-1.7)	
Cu	Plastic (<i>n</i> = 133)	118	7.64 $\pm$ 7.12 (0.004-40.32)	0.001*
	Can (<i>n</i> = 17)	17	14.32 $\pm$ 7.12 (2.93-30.73)	
Zn	Plastic (<i>n</i> = 133)	114	119.31 $\pm$ 178.96 (0.14-2,447.04)	0.001*
	Can (<i>n</i> = 17)	17	179.72 $\pm$ 178.9 (16-670)	

Mean $\pm$ SD: Mean $\pm$ Standard deviation, *: significantly different for $p < 0.05$.

Fig. 2 Contribution of sample types lead exposure.

3.4 Estimated ADI of Heavy Metals in Sample Groups

Daily intake of heavy metals was estimated and presented in Table 4 below. A significant difference ($p < 0.05$) was observed between the ADI of Hg (0.19 mg/d) through water consumption and Pb (0.09 mg/d), Cd (0.07 mg/d), Cu (0.07 mg/d), Zn (0.07 mg/d). There was no such significant difference with regard to soft drink and food group samples. Dietary intake of Cd, Cu and Zn through soft drink consumption (0.14; 1.34 and 0.59 mg/d respectively) and food consumption (0.1; 1.11 and 29.45 mg/d respectively) were significantly different ($p < 0.05$) when compared

to those of Pb (0.07 and 0.06 mg/d) and Hg (0.03 and 0.07 mg/d).

3.5 Exposure Level of Participants to Heavy Metals

Considering an average body weight of 60.7 kg adult Cameroonian, and on the basis of the food survey questionnaire data, the estimated daily heavy metal exposures in the studied population are presented in Figs. 2-6. The average exposure dose of Pb, Cd, Hg, Cu and Zn in the population was estimated to be 18.37 $\mu\text{g/kg.bw/d}$; 23.10 $\mu\text{g/kg.bw/d}$; 21.74 $\mu\text{g/kg.bw/d}$; 210 $\mu\text{g/kg.bw/d}$ and 2,830 $\mu\text{g/kg.bw/d}$ and were significantly different ($p = 0.001$),

meanwhile, their health risk indexes (HRIs) were all below one (Table 4) and relative contribution rates of sample are presented in Table 5. The exposure doses in the categorized groups of participants presented in

Table 6 showed a positive association ($p < 0.05$) between professional status and exposure levels of Pb and Hg. Individuals working in small business and others were the most exposed.

Fig. 3 Contribution of sample types to cadmium exposure.

Fig. 4 Contribution of sample types to mercury exposure.

Fig. 5 Contribution of sample types to copper exposure.

Fig. 6 Contribution of sample types to zinc exposure.

Table 4 ADI of metals in samples group and estimated average daily intake and exposure dose to heavy metals in the study population.

Heavy metal	Sample groups						Estimated daily exposure dose in the study population (<i>n</i> = 251)				
	Water (1)		Soft drink (2)		Food (3)		ADI (mg/d)	ADED (µg/kg.bw/d) (range)	<i>p</i> -Value *	PTDI (µg/kg.bw/d)	HRI
	ADI (mg/d) (range)	Contribution rate (%)	ADI (mg/d) (Range)	Contribution rate (%)	ADI (mg/d) (Range)	Contribution rate (%)					
Pb	0.09 ± 0.18 (0.003-0.96)	40.91	0.07 ± 0.37 (0.01-0.12)	31.82	0.06 ± 0.77 (0.001-0.38)	27.27	1.1 ± 0.49 (0.22-4.23)	18.37 ± 8.30 (3.75-70.57)	0.001	3.6*	0.0051
Cd	0.07 ^d ± 0.12 (0.002-0.58)	1.58	0.14 ^b ± 0.14 (0.032-0.44)	45.16	0.1 ^c ± 0.19 (0.005-1.15)	32.26	1.4 ± 0.81 (0.31-8.09)	23.10 ± 13.62 (5.2-133.33)	0.001	1*	0.0231
Hg	0.19 ^{ad} ± 0.34 (0.005-1.84)	65.52	0.03 ± 0.23 (0.002-0.08)	10.34	0.07 ± 0.19 (0.001-1.72)	24.14	1.32 ± 0.65 (0.11-3.83)	21.74 ± 10.91 (1.83-63.13)	0.001	0.23*	0.0945
Cu	0.07 ^d ± 0.34 (0.001-0.8)	2.78	1.34 ^b ± 0.99 (0.12-3.76)	53.17	1.11 ^c ± 1.21 (0.047-5.42)	44.05	12.85 ± 8.93 (2.27-81.10)	210 ± 140 (30-1,350)	0.001	160**	0.0013
Zn	0.06 ^d ± 0.13 (0.002-0.6)	0.2	0.59 ^{bd} ± 0.58 (0.017-1.56)	1.96	29.45 ^{cd} ± 116.3 (0.097-601.6)	97.84	170.28 ± 93.01 (12.60-534.88)	2,830 ± 1,550 (210-8,810)	0.001	700**	0.004

Mean ± SD: Mean ± standard deviation, significantly different at $p < 0.05$ in samples analyzed, ^a: Different when compared to values of (1); ^b: Different when compared to values of (2); ^c: Different when compare to values of (3); ^d: Different when comparing values of (1), (2) and (3); ADI: average daily intake, ADED: average daily exposure dose, PTDI: provisional tolerable daily intake,* PTDI established by the Joint FAO/WHO Expert Committee on Food Additives [34], ** safe upper level recommended by the Expert Group on Vitamins and Minerals (EVM) [35]; HRI: Health Risk Index.

Table 5 Mean heavy metal daily exposure (mg/d) and relative contribution rate (%) of samples.

Sample type	Food-base	Pb (mg/d)	Contribution rate	Cd (mg/d)	Contribution rate	Hg (mg/d)	Contribution rate	Cu (mg/d)	Contribution rate	Zn (mg/d)	Contribution rate
Corn paste + (Okra soup. cabbage sauce. “djama-djama”, “ndolè” sauce	Corn food-base	0.47	13.17	0.361	14.38	0.24	10.4	7.671	26.92	86.913	17.9
Cassava paste + (egusi sauce ^a . “eru” ^a	Tuber (cassava flour)	0.062	1.74	0.273	10.87	0.205	8.9	3.864	13.56	197.48	40.68
Cocoyam paste + peanut sauce ^a	Tuber (cocoyam)	0.111	3.11	0.311	12.39	0.462	20	2.034	7.14	0.427	0.088
Rice + (stew soup. peanut sauce)	Cereals (rice)	0.189	5.3	0.296	11.79	0.132	5.71	2.38	8.35	109.62	22.6
Doughnut	Cereals (wheat, corn)	0.095	2.7	0.177	7.05	0.07	3.1	1.318	4.62	28.215	5.81
Porridge	Cereals (corn, rice). leguminous (peanut, beans)	0.043	1.21	0.124	4.94	0.024	1.04	1.201	4.21	15.167	3.12
Beans	Leguminous (beans), tuber (sweet potatoes)	0.039	1.1	0.17	6.77	0.064	2.8	1.933	6.78	3.489	0.72
Fish + cassava paste	Fish. tuber (cassava)	0.023	0.65	0.025	0.99	0.022	0.96	0.625	2.19	12.308	2.53
Sausage/pie meat		0.033	0.92	0.016	0.63	0.001	0.043	0.333	1.17	7.283	1.5
Sardine		0.017	0.48	0.017	0.67	0.021	0.91	0.333	1.17	6.879	1.41
Tomato		0.017	0.48	0.037	1.47	0.012	0.519	0.480	1.68	2.414	0.497
Milk (liquid)		0.075	2.1	0.036	1.43	0.025	1.1	2.042	7.17	12.247	2.52
Refined oil/Palm oil		0.109	3.1	0.058	2.31	0.055	2.4	1.325	4.65	1.59	0.33
Soft drink		0.129	3.61	0.263	10.47	0.050	2.19	2.616	9.18	1.13	0.233
Mineral water		0.068	1.9	0.015	0.59	0.019	0.83	0.002	0.007	0.008	0.0016
Sachet water		0.035	0.98	0.032	1.27	0.077	3.34	0.035	0.13	0.025	0.005
Water-well ^a		0.026	0.73	0.04	1.59	0.151	6.54	0.010	0.035	0.042	0.008
Spring water		0.025	0.7	0.010	0.39	0.028	1.22	0.003	0.01	0.005	0.001
Tap water ^a		2	56.02	0.251	10	0.646	28	0.293	1.03	0.226	0.047
Dietary exposure		3.57		2.51		2.31		28.5		485.5	
			100		100		100		100		100

^a: Sample type from households.

Table 6 Estimated average daily exposure dose of heavy metals in the studied population.

Professional status	ADED in the study population ($\mu\text{g/kg bw/d}$) (range)				
	Pb	Cd	Hg	Cu	Zn
Employees	16.83 $\pm$ 15.32 (7.63-33.32)	20.94 $\pm$ 21.02 (5.1-70.75)	18.51 $\pm$ 18.02 (4.55-57.03)	0.2 $\pm$ 0.1 (0.05-1.35)	2.46 $\pm$ 2.55 (0.21-6.83)
Students	14.79 $\pm$ 15.55 (3.75-70.57)	19.84 $\pm$ 20.45 (5.2-133.33)	14.94 $\pm$ 14.24 (1.83-43.64)	0.2 $\pm$ 0.5 (0.04-0.74)	2.37 $\pm$ 2.15 (0.7-8.81)
Informal Sector Workers	19.31 $\pm$ 16.69 (5.04-51.91)	23.97 $\pm$ 19.58 (5.38-69.05)	23.82 $\pm$ 24 (4.9-63.13)	0.22 $\pm$ 0.2 (0.04-1.08)	2.97 $\pm$ 3.25 (0.33-7.41)
Others	20.85 $\pm$ 19.52 (9.69-24.75)	27.52 $\pm$ 26.23 (10.12-36.23)	23.6 $\pm$ 23.10 (11.67-28.68)	0.25 $\pm$ 0.28 (0.08-0.33)	3.76 $\pm$ 3.3 (1.77-4.24)
<i>p</i> -Value	0.044	0.378	0.001	0.776	0.153
PTDI	3.6*	1*	0.23*	160**	700**

Values are presented as mean $\pm$ standard deviation, significantly different at $p < 0.05$; ADED: average daily exposure dose; PTDI: provisional tolerable daily intake; *: PTDI established by the Joint FAO/WHO Expert Committee on Food Additives [34]; ** safe upper level recommended by the Expert Group on Vitamins and Minerals (EVM) [35].

4. Discussion

The present study investigated the exposure of the population ($n = 251$) from all 23 districts in the capital city of Cameroon, Yaoundé, to heavy metals originating from foods/snacks, water and/or soft drinks. Hazardous naturally occurring heavy metals (Cd, Pb and Hg) which are toxic at low concentrations, as well as trace elements or essential metals (Cu and Zn) which are useful to the body at low concentrations, were concerned. The procedure was used for exposure/health risk assessment, included food survey, chemicals determination in popularly table-ready foodstuffs and estimation of dietary exposure dose of the population.

From the food survey, 33% of students, 20% of employees and 5% of others fed mainly in households probably due to their request programme. The observation that covers 70% of studied participants (Fig. 1) either get their foods, water and/or soft drinks from small-road-side restaurants (70%) or from both household and small-road side restaurants (76%) may be partly explained by the proximity to, the affordability and flexibility of the small road-side restaurants-foods, water and/or soft drinks in addition to the nature of their activities and location of these restaurants which are generally around their workplaces. Similarly, considering the busy nature of

city life (each person working hard to meet up with city demands—bills, rents, family), it is obvious that many people will go in for fast foods and/or lunch bowls. This may be part of the influential factors towards the continuous expose of studied participants to heavy metals in their diets, water and/or soft drinks. Additionally, the observed high levels of contamination by heavy metals may partly be due to the generally inadequate knowledge on basic food safety and foods hygiene by the small road-side-food sellers especially as their restaurants are exposed along the major runways. This can be supported by the findings from the study conducted in Spain [36], that revealed an increased content of lead (from 0.5400 to 2.1000 $\mu\text{g/g}$) and cadmium (from 0.1431 to 0.2398 $\mu\text{g/g}$) in small road-side vended foods after 2 hours exposure to environment. Furthermore, exposure to the metals could be accentuated by the poor quality of the final-consumed foods considering local restaurant sellers generally wrap the foods, even while still hot, with wrapping papers, which are plastic in nature and may further contaminate the foods.

The average contents of Pb, Cd and Hg in 100% contaminated water samples (sachet water, tap water, water from wells, spring water and mineral water) were 19-380 times higher than the permissible limits [32, 33] (Table 2), with the exception of Zn and Cu

contents. Maximum levels of Cu, Zn, Hg and Cd in water were provided by sachet water and Pb by mineral water. Metals levels in this study were higher than reported in Nigeria [37] and Uganda [24]. Sachets water currently sold and consumed by the majority of small road-side business people or sachet water vendors in the streets of Yaoundé is from doubtful origins. This sachet water speculatively may likely be produced in households from tap water and/or groundwater. As such, contamination of the sachet water could originate from multiple sources, including contaminated soil, the use of heavy metals in the domestic drinking water supply systems [38], the manufacturing process of plastic material into which some analyzed samples were packaged [1, 39]. Runoff from urban storms and leaching of metals from household waste and soluble metal residues could also bring in heavy metals into the ground waters (spring and well water) [40].

The average contents of heavy metals in bottle soft drink samples and sachet soft drink were 1.4 to 350 times higher than the standards of 0.05 mg/kg for Pb, 0.4-0.5 mg/kg for Cd, 0.001 mg/kg for Hg, 5 mg/kg for Cu and Zn recommended [32, 33]. With the exception of lead, the significantly ($p > 0.05$) high levels of heavy metals revealed in bottled soft drink samples could be due to their uptake and accumulation at any point of the production chain: soil contamination, handling of raw materials and state of water utilized, storage conditions, processing and/or packaging [39, 41]. A similar observation was reported in Nigeria [42] where Pb (0.17 to 3.39 mg/L), Hg (0.29 to 11.32 mg/L) and Cd (0.149 mg/L) were detected in soft drink with highest levels found in bottled samples.

When considering food samples, the average heavy metal contents of 100% contaminated samples with Pb and Cd, 72.54% with Hg and 16.66% with Zn exceeded from 0.6 to 15.2 folds the standards [33] excepted Cu (Table 2). The wide handling of foods and applications of heavy metals, incineration and/or

the presence of garbage dumps, one may speculate high accumulations of heavy metals in food chains, in other food commodities, in water utilized during cooking process or production, and likelihood that, atmospheric pollution, urban wastes, vehicle emissions, poor packaging of meals may have contributed to extending the level of contamination recorded in some samples [22, 36, 43]. Heavy metals including Pb, Cd, Hg and Zn are reported to be used in the manufacturing process of plastics, kitchen utensils, preserved and cans coating [1, 44]. It resulted from the survey sheets that artisanal aluminum cookware and ladles, tap water and water from wells were commonly used in cooking process and plastic materials for storage. Findings from this present study indicate a significant variation ($p < 0.05$) between samples levels of Pb and Cd and the storage material used (Table 3). The metals may have migrated into food. In addition, investigation on these kitchen utensils in Cameroon [44] revealed that substantial amounts of Pb, Cd and other metals can migrate from artisanal cookware during cooking and enter the food. Furthermore, the repeated re-heating of food packaging in plastics, or through or through the cookware as recorded during the survey may also increase the potential for metals build-up in the food.

Daily estimated intake of metals from analyzed samples showed that, water was the most dietary source of Pb and Hg (40.91% and 65.52% respectively). Soft drink contributed for 45.16% and 53.17% to Cd and Cu intake respectively while food contributed for 97.84% to zinc intake (Table 4). Despite the fact that refined oil, soft drink, cocoyam paste/peanut sauce and cassava paste (water “fufu”)/“eru” provided highest concentrations of Pb, Cd and Cu, Hg, Cu and Zn respectively, the main source of dietary exposure to lead and mercury was tap water (contribution rate 56.02 and 28%, respectively), followed respectively by corn-rice-food-bases and cocoyam-corn food-bases. The main source of dietary cadmium exposure was

corn food-base followed by cocoyam-rice food-bases; corn food-base for copper followed by cassava food-base and soft drink; cassava food-base for zinc followed by rice-corn food-bases (Table 5, Figs. 2-6). Taken all together, tap water was likely to have provided highest daily intake of Pb, Cd, Hg, Cu and Zn due to its most frequent usages such as intake as drinking water, use in preparation/processing and cooking and the high content of metals recorded in the analyzed samples.

The daily exposure dose of the study population was derived from ADI, and showed significant ($p < 0.05$) variations between different heavy metals (Table 4) and some participants (informal sector workers and others) (Table 6). The daily exposure values of Pb, Cd and Hg were up to 5.1; 23.1 and 94.5 times respectively higher than the regulated provisional tolerable daily intake (PTDI) [34] (Table 4). The daily exposure doses of Cu and Zn were 1.3 and 4 times respectively than the safe upper levels recommended [35]. Despite these observations, the health risk index indicated no level of concern for Pb, Cd, Hg, Cu and Zn ($HRI < 1$). However, regular consumption of such contaminated food may lead to bioaccumulation of the heavy metals in the body at levels exceeding the PTDI, which may have negative health implications. The adverse effects of heavy metals as endocrine disruptors and/or inducers of serious long-term illnesses such as cancer, metabolic diseases, neurodegenerative diseases, infertility, etc., is well documented [4, 15, 16].

5. Conclusions

This investigation showed high occurrence frequencies of heavy metals in foods (food items, ready-to-eat foods), water from different sources (tap, mineral, spring, wells) and soft drinks commonly consumed by individuals in Yaoundé-Cameroon. Those from street restaurants infatuated by workers from informal sector were the most contaminated. They are sufficient evidence to suggest through this

pilot study that, Cameroonians are exposed to heavy metals at levels above the acceptable PTDI thresholds. The main source of exposure to Pb and Hg was tap water, and the staple cereals and tubers food-base for Cd, Cu and Zn. The health risks levels of the population towards these metals were found to be safe (< 1). However, further or continuous exposure may lead to health implication. A correlation study of heavy metals and other environmental toxicants in food to levels of suitable biomarkers to accurately estimate the degree of human exposure via urine, educational intervention to control foods contamination in order to reduce human exposure including susceptible populations, such as children to these toxic substances is necessary.

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