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Concentration of Some Selected Heavy Metals as Contaminants and Associated Potential Health Risks in Raw Milk in Birnin Kebbi Metropolis, Kebbi State, Nigeria

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Abstract

Raw milk is a vital component in the human diet due to its complete nutritional contents. This study was carried out to investigate the concentrations of cadmium, chromium, arsenic, mercury, lead and copper in the raw milk of camel, cow, goat and sheep from different dairy farms in Birnin Kebbi and environs and evaluate the potential health risks of metals to humans via consumption of raw milk. A total of two hundred (200) samples of raw milk 50 each of camel, cow, goat and sheep were collected from the dairy farms directly using the established protocol of random sampling and analysed using Atomic Adsorption Specctrophotometer. The concentrations (mg/kg wet weight) of Cd, Cr, As, Hg, Pb and Cu detected in raw milk were in the range: 0.001 - 0.038, 0.022 – 0.314, ND – 0.00002, 0.001 – 0.005, 0.021 – 0.330 and 0.021 – 1.077 respectively. The prevalence of the metals in the various samples are in the order: Cu > Pb > Cr > Cd > Hg > As. Cow milk has the highest number of samples (52%) above the Maximum Permissible Limit (MPL), sheep milk has the least number of samples above the MPL. It was concluded from this study that although the maximum limit of Cu, Pb and Cr have been exceeded by 52%, 48% and 42% respectively in the dairy products tested, the health risk assessment indices comprising Estimated Daily Intakes, Provisional Tolerable Daily Intakes, Target Hazard Quotient, and Hazard Index indicated no potential health risk upon consumption of such dairy products analyzed.

Key words: Daily intake. Health risk. Heavy metals. Hazard index. Milk.

Introduction

Milk is one of the natural foods secreted by the mammary glands of mammals and is widely consumed by the public to meet nutritional needs. With a complete nutritional content, milk plays an important role as food for health, intelligence, and growth, especially the growth and development of children [1]. For instance, fresh cow milk is a kind of milk that is often consumed by the public. This is because besides being easy to obtain and having high nutritional content, fresh cow's milk is also relatively affordable. In a study conducted by Umar *et al*. [2], cow milk was reported to be a rich source of protein, fat, carbohydrates, minerals, and vitamins.

The overall quality of food and food ingredients in nature cannot be separated from various influences, such as environmental conditions which are the benchmark needed for food to obtain eligibility for consumption [3]. The ultimate quality of milk will decrease if there are contaminants in it. Raw milk can be contaminated with heavy metals from the environment, such as Cr, As, Hg, Pb and Cd. Milk contamination can be caused by several things, such as microbes, pesticide residues, and heavy metals accumulation. Research by Pilarczyk *et al*. [4], reported that consuming meat and milk from heavy metal contaminated environment is very dangerous for the consumers. Heavy metal contamination of the animal can occur due to organic rearing because heavy metals can come from feed or drinking water that contains a lot of heavy metals.

One of the animal-based food ingredients that contain a good nutritional value for human consumption is milk [5]. Mammalian milk has quite a potential opportunity in product development. Milk is popular with the wider community because of its beneficial nutritional content in it. Fresh raw milk is a liquid produced from the udders of healthy and clean animals from proper milking, its natural content is still pure without being reduced or adulterated with anything. Foodstuffs must be free from the possibility of biological, chemical, and other contamination that can interfere with, harm, and threaten human health, and do not conflict with religion, beliefs, or community customs, so they are suitable and safe for consumption [6].

Heavy metals are often described as metallic and metalloid chemical components with high atomic weights and specific gravity, which can be toxic to living things. Heavy metals such as cadmium (Cd), mercury (Hg) and lead (Pb) are not essential elements and have no biological role, but at very low concentrations they can cause toxic effects [7]. Heavy metals can enter foods such as milk and processed products and bioaccumulate in vital organs causing disturbances in kidney function, anemia, the reproductive system, and the nervous system [8,9].

Immense environmental pollution has elevated the problems of milk contamination and uncertainties about milk qualities [10]. The worldwide milk contamination through environmental pollutants and xenobiotic compounds via cattle feeds like toxic metals, mycotoxin, dioxin and other pollutants are considered to have tremendous influence on public health [11]. Intake of these contaminated milk acts like an additional source of heavy metal exposure [12]. The main sources of metal contamination are industrial or domestic effluents, combustion, bushfires, decomposition of chemical fertilizers, pesticides etc. [13].

Over exposure of humans to heavy metals could lead to abdominal pain, hepatotoxicity, neurotoxicity, vomiting [14], decreasing of intelligence quotient (IQ) level, Alzheimer's disease, behavioral disorders [15], tissue injury, irritation of lungs, cancer [16] etc. Furthermore, heavy metals are known to be highly resistant to bacteria and environmental degradation in nature and become accumulated in the food chains via bio-transformation, bio-accumulation and biomagnifications [17]. Complete elimination or prevention of chemical contaminants cannot be achieved from raw milk because the lipophilic contaminants will always find their way into the persistent fat compounds from where heavy metals cannot be readily removed [18]. The contamination of food stuffs due to metals and other environmental pollutants are the most important issues in developing countries. Several studies have been conducted around the world with reference to the health risks of metals in environmental matrices, for example; arsenic in cultivated rice in Srilanka [19], trace metal and aflatoxin in cassava flour in west Africa [20], metals contaminated mushroom in Ethiopia [21], also health risk for contamination of foods and soils in China [22] and India [23]. However, it was observed that continuous long-term exposures of consumers to heavy metal through the consumption of raw milk get less emphasis in developing countries particularly in Nigeria. Considering the aforementioned challenges in terms of public health hazard of Nigerians, this study was carried out to investigate the concentration of selected heavy metals contaminating raw milks in Birnin Kebbi areas, Kebbi State. The results from this study is expected to provide a baseline information on the level of pollution in this catchment.

Materials and Methods

Collection of Samples

A total of 200 samples of raw milk (50 each of cow, camel, goat and sheep) were collected from March 2024 to August 2024 from various dairy farms in Birnin Kebbi and environs, Kebbi State, Nigeria.

All samples were collected in nitric acid-washed polyethylene containers. The samples were immediately transported to the laboratory in a cooler with crushed ice packs and were stored in deep freezers at -20^{0}C prior to analysis.

Sample Preparation

All the laboratory glassware and working surfaces were washed well with deionized water and diluted HNO_3 (10%) then rinsed with deionized water followed by drying. The digestion vessels were soaked in water and detergent for about 3hours with subsequent several rinsing with distilled water and then with a mixture of (80 mL H_2O_2 200 mL HCl 37%, and 250 mL of deionized water) again one more time with 10% diluted HNO_3. And finally, all the equipment were washed at least three times using deionized water and air-dried [24].

Samples Digestion

The samples were digested by the wet digestion technique according to the method reported by Sallam and Mohammed, [24]. Two mL of the raw milk samples were homogenized well and transferred quantitatively to a 20-mL screw- capped tube containing 10 mL HNO_3 97% and 2 mL HClO and was heated at 53 °C in a water bath until complete digestion, followed by cooling at room temperature. After cooling, the digested mixture was placed in a 50 mL volumetric flask containing distilled water to be diluted and then filtrated using Whatman filter paper (No. 42, Merck, Darmstadt, Germany) into clean Pyrex glass tubes and kept at room temperature (35 °C) till analysis for their metals content (Hg, As, Pb, Cd, Cr and Cu) [24].

Standard or blank solutions were also prepared in the same manner as the wet digestion technique but without adding any sample. The blank solutions were analyzed to determine any contamination of the chemicals with heavy metals and to be subtracted from the final results.

Validation of the Method

Standard solutions of 0.005, 0.01, 0.05, 0.25, 1.0, and 2.5 mg/L of each metal were prepared and used for the metal analysis. The instrumental precision, as well as the digestion method and Certified Reference Material precisions for heavy metal determination were achieved by measuring the limits of detection (LOD), limits of quantification (LOQ), precision (repeatability; CV%), and spiking recoveries percentage [24].

Heavy Metals Analysis

Collected filtrates were analyzed for their mercury, arsenic, lead, cadmium, chromium, and copper at the Central Laboratory, Faculty of Science, Usmanu Dan-fodiyo University, Sokoto. Heavy metals analysis was carried out with the use of an Atomic Absorption Spectrophotometer (AAS; Buck scientific 210 VGP, Inc.), which has an autosampler, digital absorbance, and concentration readout capable of analyzing under lamp wavelength (nm) of 217.0, 228.8, 324.7, 357.9, 253.7, 193.7; and lamp current (mA) of 5, 4, 4, 7, 4, 10 for lead, cadmium, copper, chromium, mercury, and arsenic, respectively. Analysis of As and Hg was conducted by flameless AAS equipped with arsenic and mercury hydride system (MHS) "cold vapor technique", while lead, cadmium, copper, and chromium were determined by air acetylene flow flame AAS [24].

The concentration of heavy metals (mg/kg wet weight) was estimated according to Eq (1).

$$C = R \times (D/W) \qquad (1)$$

where C = Concentration of the element (wet weight), *R* = Reading of digital scale of AAS, *D* = Dilution of the prepared samples, while *W* = Weight of the samples.

Health Risk Assessment

The EDI, THQ, and HI of heavy metals were calculated to appreciate the non-carcinogenic risks associated with the consumption of heavy metals in dairies. The EDI was calculated according to Eq. (2).

$$EDI = \frac{C \times D}{BW} \text{ mg/kg bw / day} \qquad (2)$$

where, C = the mean concentration of heavy metals in raw milk samples (mg/kg), *D* = dairy intake is the daily consumption of milk for each kg BW of an adult person, while BW = average body weight for an adult person = 70 kg. The average daily consumption per adult person was recorded to be 58.97 mL/g of milk [25].

The THQ was affirmed by the Environmental Protection Agency (EPA) in the USA to determine the non-carcinogenic health risks linked to the consumption of heavy metal-contaminated food, frequency and duration of metal, body weight, and other parameters [26].

The THQ was calculated according to Eq. (3).

$$THQ = \frac{EDI}{RfD} \qquad (3)$$

where, RfD is the reference doses (mg/kg/day) = 0.0001, 0.001, 1.5, 0.04 (mg/kg/day) for Hg (MeHg), Cd, Cr, and Cu, respectively [26]. If the results of THQ are more than 1, it indicates that the risks of non-carcinogenic potential hazards for human health may occur, but if THQ is less than 1, there won't be any health risk. Yet, if the individual THQ is less than 1, the non-carcinogenic adverse hazards might happen due to the cumulative effect of such heavy elements.

Furthermore, the HI was also calculated to estimate the non-carcinogenic health hazards correlated with the ingestion of more than one toxic element in dairy samples. HI is known to be the sum of individual hazard quotients of all examined elements in the same sample. If the revealed HI data are more than 1, it denotes the possibility of occurring non-carcinogenic potential hazards for consumers. It was calculated according to USEPA [26], by applying Eq. 4.

$$HI = \sum THQ_{Hg} + \sum THQ_{As} + \sum THQ_{Pb} + \sum THQ_{Cd} + \sum THQ_{Cr} + \sum THQ_{Cu} \qquad (4)$$

Statistical Analysis

Heavy metals analysis was done in triplicates. All data obtained were analyzed via the Vassar Stats website for statistical computation (http://vassarstats.net). Metal concentrations were expressed as Mean ± standard error (SE). One-way ANOVA was used to estimate the significant difference in the levels of heavy metals among different milk samples. concerning the experimental study, the average of triplicate measurements either from treated or control samples were analyzed by t -test for statistical differences ($p < 0.05$).

Results and Discussion

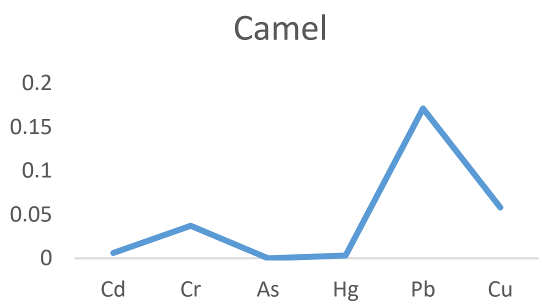

Fig. 1: Mean Conc. of metals in Camel Milk [mg/L]

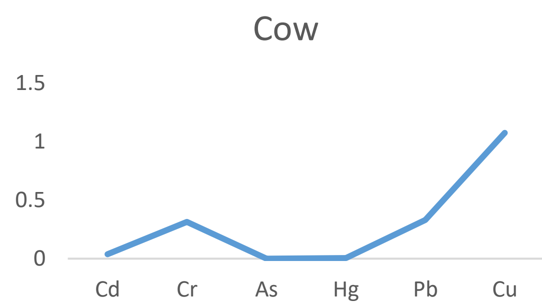

Fig. 2: Mean Conc. of metals in Cow Milk [mg/L]

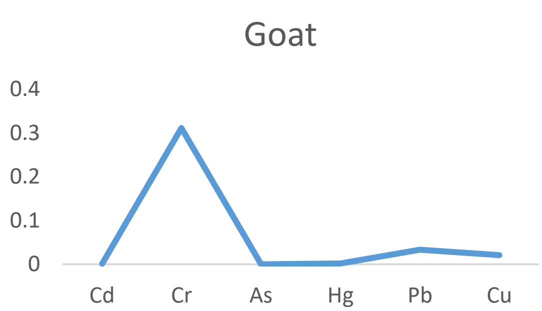

Fig. 3: Mean Conc. of metals in Goat Milk [mg/L]

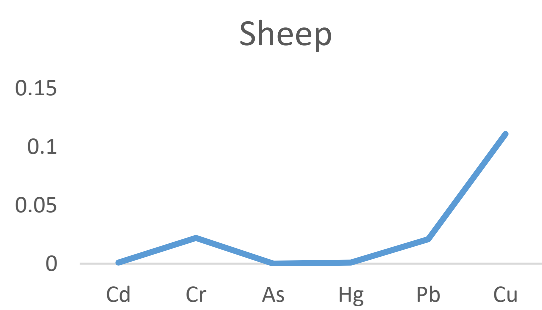

Fig. 4: Mean Conc. of metals in Sheep Milk [mg/L]

The mean concentrations of toxic elements (Cd, Cr, As, Hg, Pb and Cu) in the raw milk samples of camel, cow, goat and sheep are shown in Figures 1-4. All six metals were detectable in the samples and their concentrations were in the order of Cu > Pb >Cr > Cd > Hg > As. And the prevalence of the metals in the raw milk was in the order: cow milk > camel milk > goat milk > sheep milk.

The presence of Cd in raw milk may be due to either natural or anthropogenic origins (fertilizers, pesticides, and atmospheric deposition in soils). It is considered to be the most important contaminant of raw milk in modern times. In this study, the mean concentrations of Cd in the raw milk samples were in the range of 0.001 mg/L in goat and sheep milk to 0.038 mg/l in cow milk. This is largely due to contamination of the environment due to intensive use of agrochemicals. This findings are in complete agreement with the levels reported by AlAshmawy *et al*. [27], for raw milk (0.052 mg/kg) and higher than those obtained by Hafez and Kishk [28] for cow's milk (0.0018 mg/kg); Ayar *et al*. [29] for milk (0.0017 mg/kg); El-Sayed *et al*. [30] for milk collected from different regions of Egypt (0.002–0.039 mg/kg). Several other researchers reported higher levels of Cd contamination in milk, [31;32;33;34] as they observed that the Cd concentrations were 0.07, 0.086, 0.076, 0.416 and 0.2–0.288 mg/kg respectively.

In their study of heavy metals in ruminant animals in Nigeria, Adepoju-Bello *et al*. [35]; Emgwa *et al*. [36]; Magomya *et al*. [37]; Salako *et al*. [39], reported that cadmium in ewe and goat milk were below the permissible limits, though, ewe milk showed higher levels than goat milk. This they attributed to different locations of feeding of the animals. Cadmium is ranked among the most toxic heavy metals. In human body, Cadmium accumulates in liver and kidney and causes renal damage and dysfunction [39]. Prolonged and continuous consumption of milk or milk products with high level of Cadmium by humans lead to bioaccumulation of the metal and major health hazards. Cadmium is more known by its toxicity and metabolic antagonism with Zn and other elements [40]. The result of this study indicated that the mean concentration of cadmium in camel and cow are above the maximum permissible levels of 0.003 mg/L stipulated by WHO and Standard Organisation of Nigeria [41].

Mean chromium concentration in the samples were in the range 0.022 mg/L - 0.311 mg/L. The highest chromium concentration was detected in the raw milk of cow, while the lowest concentration was observed in the milk from sheep. The highest levels of chromium observed in this study is higher than the Maximum Permitted of 0.05mg/l by the WHO and SON. Adegbola *et al.* [42], reported similar trend in their studies. Again, Yabrir *et al.* [43] reported low levels of Chromium in ewe milk but higher values than the stipulated permissible levels in goat milk. Trivalent chromium are considered to be essential trace element, but the hexavalent molecule can be a poison at higher level [44]. Chromium compounds are mutagenic and carcinogenic in variety of test systems [45].

The mean arsenic level (mg/kg wet weight) levels ranged from 0.0 to 0.00002 mg/L, in raw milk, A significant difference ($P < 0.01$) was observed in As level among the milk samples tested, with cow milk containing the highest As level. Higher arsenic concentration (0.12 –0.97 mg/ L), was reported in raw milk distributed in an area adjacent to leather-processing plants in China [46]. Again, higher mean levels of 0.12 and 0.16 mg/kg were reported for As in milk and cheese, respectively in Mexico [47]. Similarly, lower As concentrations of 0.0049 mg/kg were reported for milk, in India [46]. The mean concentration (mg/kg wet weight) of Hg in raw milk ranged from 0.001 to 0.005. The highest level 0.005mg/L was detected in cow milk and the lowest level of 0.001 mg/Kg in sheep. Significant higher ($P < 0.01$) Hg level was detected in cow milk when compared with its level in the other four dairy products. Similar Hg concentrations 0.0033 to 0.0072 mg/kg were reported for milk in India [46]. A higher mean value (0.0073 – 0.0150 mg/L) than our findings was recorded in raw cow's Milk from Iran [48]. On the other hand, Hg was not detected in milk powder tested in Nigeria [49].

The mean level of Pb ranged from 0.021 to 0.330 mg/L wet weight in the raw milk samples. Lower levels of Pb were determined in milk (0.009–0.126 mg/kg) in France [50].
Conversely, higher mean concentrations of lead (2.68 ± 0.94 mg/L) were detected in raw cow milk from the I gd i r region in Turkey [51]. Again, higher lead level contamination of 2.98 ± 2.43 and 3.08 ± 2.32 mg/kg was detected in milk and cheese in Nigeria, respectively [52].

Both raw milk samples from cow and camel analyzed exhibited higher significant differences ($P < 0.01$) in Pb, Cd, and Cr levels when compared with raw milk from other samples. Copper mean concentrations in the samples analyzed ranged from 0.021 mg/L in goat to 0.077 mg/kg wet weight. Significant differences ($P < 0.01$) were determined for Cu concentrations among the different milk products tested; with the cow milk showing the highest value. Copper was detected in raw milk from Bangladesh in the mean range from 0.012 to 0.480 mg/L [46] which seems much lower than the level determined in the present study for raw milk. Similar, mean Cu contamination of 0.59 ± 0.01 mg/L was recorded in milk analyzed in Nigeria [49;50].

The data obtained from this study showed clearly that copper and lead are the predominant heavy metals among all the examined samples and cow milk retained the highest maximum level of all analyzed heavy metals; this could be ascribed to the way these heavy metals are excreted into the raw milk and the persistent nature aside their non-biodegradable properties after being absorbed and accumulated in the tissues of the animals [53].

Moreover, it has been demonstrated that heavy metals especially, lead, cadmium, chromium, and copper preferentially bound to milk caseins [46] necessitating their accumulation in milk samples. The existence of heavy metals in raw milk could also be attributed to the contaminated drinking water served to dairy animals and/ or contaminated animal feed which absorbed the heavy metals from soil that has been irrigated with industrial wastewater or sewage water. Furthermore, the indiscriminate use of fertilizers and other agrochemicals may influence the uptake of heavy metals by the plants, which in turn are consumed by the dairy animals.

Table 1: Comparison of the heavy metals detected in the samples (*n* = 50) with their maximum permissible limits (MPL).

Heavy metals	MPL (mg/Kg)	Camel milk	Cow milk	Goat milk	Sheep milk
Cd	0.003[a]	14% (7/50)	28% (14/50)	18% (9/50)	6% (3/50)
Cr	0.3[b]	18% (9/50)	42% (21/50	14% (7/50)	6% (3/50)
As	0.00001[c]	4% (2/50)	8% (4/50)	2% (1/50)	2% (1/50)
Hg	0.01[c]	2% (1/50)	6% (3/50)	0% (0)	0% (0)
Pb	0.02[b]	18% (9/50)	48% (24/50)	34% (17/50)	16% (8/50)
Cu	0.01[b]	20% (10/50)	52% (26/50)	24% (12/50)	14% (7/50)

a Commission Regulation (EU), [54]. http://data.europa.eu/eli/reg/2021/488/oj.
b USDA, [55]. https://www.fas.usda.gov/data/china-china-releases-standard-maximum-levels-contaminants-foods.
C Commission Regulation (EU) [56]. http://data.europa.eu/eli/reg/2022/1005/oj.

According to the maximum permissible limit of heavy metals established by USDA [55], commission regulation [54;56] and the Standard Organisation of Nigeria [41] the percentages of unacceptable contaminated samples by Hg and As were low, followed by Cd and Cr, while Cu and Pb exhibited the highest percentages of the samples exceeding the permissible limit (Table 1). The percentages of unacceptable metals are in the order: Cu > Pb > Cr > Cd > As > Hg and their prevalence in the samples in the order: cow milk > goat milk > camel > sheep milk (Table 1).

The higher concentrations of Cu and Pb in the samples could result from their high anthropogenic concentrations owing to the traffic density especially in urban areas, and the indiscriminate and excessive use of fertilizers and pesticides in agricultural practices [57]. All these factors contributed to the substantial existence of Cu and Pb in the raw milk samples above the maximum residue limits (MRL) [57]. The Agency for Toxic Substances and Diseases Registry (ATSDR) in the USA made a priority list for heavy metals in which As and Pb occupied the first and second position, while Cd and Cr were ranked 7th and 17th. On the other hand, the Standard Organisation of Nigeria listed the maximum residue levels (MRLs) for As, Cr, and Pb as 0.1, 0.3, and 0.05 mg/kg, respectively [57].

Table 2: Estimated Daily Intakes (EDI) of the heavy metals detected in dairy products samples (mg/kg bw/day) in comparison to their Provisional Tolerable Daily Intakes (PTDI) or their Bench Mark Dose Levels (BMDL).

Heavy metals	PTDI BMDL mg/Kg/day	Mean concentration of heavy metals (mg/kg) Raw Milk											
						Camel milk		Cow milk		Goat milk		Sheep milk	
		Camel Milk	Cow milk	Goat milk	Sheep milk	EDI mg/Kg/day	%PTDI/BMDL	EDI mg/Kg/day	%PTDI/BMDL	EDI mg/Kg/day	%PTDI/BMDL	EDI mg/Kg/day	%PTDI/BMDL
Cd	8.3 E-04a	0.006	0.038	0.001	0.001	5.05 E-05	0.61	0.03 E -05	0.36	8.42 E-06	1.01	8.42 E -05	1.01
Cr	3 E01a	0.037	0.314	0.311	0.022	3.12 E-05	0.10	0.26 E -05	8.67	2.62 E-04	0.87	18.53 E-05	6.18
As	3 E-03b	0.00	0.00002	ND	0.00001	0.00	0.00	1.68 E- 04	5.60	0.00	0.00	8.42 E -06	2.81
Hg	2.3 E-04c	0.003	0.005	0.002	0.001	2.53 E-06	1.11	0.004 E -05	0.17	1.68 E -05	7.30	0.84 E -03	3.65
Pb	6.3 E-04d	0.171	0.330	0.033	0.021	1.44 E-04	2.29	0.28 E -04	0.44	0.25 E -04	4.00	1.77 E -05	2.81
Cu	0.5e	0.058	1.077	0.021	0.111	4.89 E-05	0.98	0.91 E -06	0.18	1.77 E -05	0.04	0.94 E -04	0.19

a JECFA [58]
b EFSA [59]
c JECFA [60]
d EFSA [61]
e FAO/WHO [62]

Cytotoxicity Results

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The EDI compared with the TDI for the metals Cd, Cr, As, Hg, Pb and Cu have been assessed in order to appraise the health risk correlated to the ingestion of heavy metals contaminated milk products (Table 2). The percentage of the Estimated Daily Intakes (EDI) of the heavy metals detected in the milk samples (mg/kg/day) in comparison to their Provisional Tolerable Daily Intakes (PTDI) or their Bench Mark Dose Levels (BMDL) ranged between < 1% to 8.67% , which indicated no potential health risk from the metals investigated upon consumption of such milk product.

Table 3: Target Hazard Quotient (THQ) and TTHQ (Total Target Hazard Quotient) of heavy metals due to consumption of milk products examined.

Heavy Metals	RfD mg/Kg/day	Camel milk		Cow milk		Goat milk		Sheep milk	
		EDI mg/Kg/day	THQ	EDI mg/Kg/day	THQ	EDI mg/Kg/day	THQ	EDI mg/Kg/day	THQ
Cd	1 E-03	5.05 E-05	5.05 E-02	0.03 E-05	3.00 E-04	8.42 E-06	8.42 E-03	8.42 E-05	8.42 E-02
Cr	1.5	3.12 E-05	2.08 E-05	0.26 E-05	1.73 E-06	2.62 E-04	1.74 E-04	18.53 E-05	12.28 E-05
As	-	-	-	1.68 E-04	-	-	-	8.42 E-06	-
Hg	1 E-04	2.53 E-06	2.53 E-02	0.004 E-05	4.00 E-08	1.68 E-05	1.68 E-01	0.84 E-03	8.40 E-04
Pb	3.5 E-03	1.44 E-04	4.11 E-02	0.28 E-04	8.00 E-02	0.25 E-04	7.14 E-03	1.77 E-05	5.06 E-04
Cu	4 E-02	4.89 E-05	1.22 E-03	0.91 E-06	2.28 E-05	1.77 E-05	4.43 E-04	0.94 E-04	2.35 E-03

THQ = EDI/RfD. RfD = the oral reference dose (mg/kg/day); RfD for Hg (MeHg), Cd, Cr and Cu were established by USEPA [26]; there was no RfD proposed for organic As such as AsB (arsenobetaine) and AsC (arsenocholine).

The THQ has been recognized as a useful parameter for evaluation of risks associated with the consumption of metal contaminated food. The THQ is a ratio of determined dose of a pollutant to a reference oral dose (RfD) for that substance. Table 3 showed the THQ results obtained in this study. Perusal of the table revealed that all the values obtained are less than one. The less than unity values suggest that the consumers would not be exposed to potential health risks upon dairies consumption. But it is imperative to pay attention to limiting the expected sources of heavy metal contamination as much as possible in order to avoid the problem of bio-accumulation of these toxic elements in human tissues. The THQ of As was not detected because there was no reference oral dose (RfD) for it [26].

Conclusion

The study concluded that large numbers of the dairy samples analyzed are contaminated with heavy metals, particularly lead, copper and chromium which exceeded the maximum permissible limit (MPL) in 48%, 52% and 42% of samples tested, respectively. The cow milk has the highest prevalence of samples above the MPL, followed by camel milk and then the goat milk while sheep milk has the least contaminated milk above the MPL. Hg and As showed the least contamination level having less than 10% of the samples exceeding the MPL. Despite the fact that this present results revealed that a substantial number of the raw milk tested exceeded the MPL for the heavy metals analyzed, the Health risk assessment indices comprising the Estimated Daily Intakes (EDIs), Target Hazard Quotient (THQ), Total Target Hazard Quotient (TTHQ), and Hazard Index (HI) indicated no potential health risk upon consumption of such dairy products at the time of analysis.

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