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Heavy Metal Dietary Intake and Potential Health Risks for University Hostel Students

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Abstract The study was conducted to determine the residual concentration of Cd, Pb, Asand Hg in some foodstuffs served to university students living at hostels of Beni-Suef University (BSU), Egypt, and to estimate the dietary intake of such metals, as well as to assess the potential health risks associated with the consumption of such foods. Therefore, a total of 200 samples, 50 each of, soft cheese, UHT milk, raw broiler carcasses and canned tuna, were periodically collected from university hostels of BSU and examined for the residual levels of these metals using atomic absorption spectrophotometer. The obtained results revealed that the mean residual levels of Cd in soft cheese, UHT milk, broiler's meat and canned tuna samples were 0.37, 0.26, 0.089 and 0.093 mg/kg, respectively, while those of Pb were 0.187, 0.20, 0.181 and 0.164 mg/kg, respectively. Regarding As, they were 0.196, 0.24, 0.14 and 0.201 mg/kg, respectively, and Hg mean residual concentration accounted for 0.05, 0.05, 0.117 and 0.235 mg/kg, respectively. Some of the examined food samples had heavy metals' concentrations above the international standards. The total weekly dietary intakes of Cd, Pb, As and Hg were 4.99, 5.38, 4.77 and 2.76 μg/kg bw/week, respectively, that were comparable to the provisional tolerable weekly intake recommended by the Joint Expert Committee on Food Additives (JECFA). The total target hazard quotient (TTHQ) of broiler's meat was over 1 (1.686), thus indicating possible health risks in contrast to the TTHQs of other foodstuffs that were below one.

Keywords Heavy metals · UHT milk · Cheese · Tuna · Poultry meat · Dietary intake

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Introduction

Cadmium (Cd), lead (Pb), arsenic (As) and mercury (Hg) are widely distributed heavy metals in the environment. They have neither beneficial effects for human beings nor known homeostasis mechanism [1, 2]. These metals are considered the most toxic heavy ones to animals and humans, and the risks associated with them are numerous and diverse including neurotoxic and carcinogenic effects (Agency for Toxic Substance and Disease Registry, ATSDR) [3–9]. It was reported that the presence of Pb, Cd, As and Hg at low concentrations leads to metabolic disorders that cause many health problems such as weakness and heart/kidney failure [10, 11].

Heavy metals are increasingly being introduced into the environment through several natural and anthropogenic sources, which include, but not limited to, natural weathering of the earth's crust, mining, soil erosion, industrial wastes, urban runoff, sewage effluents, pesticides, fungicides, air pollution fallouts and/or any other disease control agents applied to plants [12].

People are mainly exposed to heavy metals in the workplace. However, ingestion (food and water) is the main route of exposure accounting for more than 90 % compared to other routes such as inhalation and skin contact [13]. Although toxicity and public health risks of any contaminant are a function of concentration, it is well known that prolonged exposure to these heavy metals at relatively low concentrations can also lead to adverse results [3–7]. Recently, the accumulation of heavy metals in the environment acquired an increasing concern due to the food safety issues and the associated potential public health risks [14].

The release of dangerous pollutants into the environment persistently increases heavy metal levels entering the food chain. Food contamination with heavy metals can take place during their handling, transportation and processing. Many factors may contribute to food contamination with metals such as growth of plants in highly contaminated areas, watering of plants using polluted water and rearing of animals on feeds containing toxic metals and contaminated pasture. Contact between food and metals, such as processing equipments and utensils, food stores, food packaging containers and food cans is another important source of food contamination with heavy metals. Once metals reach food, their levels are seldom decreased by traditional preparation and processing techniques. In some occasions, washing may slightly decrease the food metal content, while their concentration could be increased by water evaporation [15].

To evaluate potential health hazards to consumers, it is necessary to determine the dietary intake of each metal and to compare it with the toxicologically acceptable limits set by regulatory agencies [16]. It is well known that there are clear differences in both food consumption and food contamination with different heavy metals among different countries of the world [17].

The FAO/WHO stated that is the responsibility of national authorities to ensure that food products do not contain toxic chemical residues (heavy metals, pesticides, aflatoxins) in levels susceptible to cause health risks to the consumers. Therefore, a continuous surveillance system of contaminants concentrations in food is crucial for consumer safety that facilitates international trade. Thus, three different methods can be used to estimate the dietary intake of a specific substance: the total diet study (TDS "market basket"), the duplicate-meal study (DMS) and the selective analysis of individual food items [18].

Several approaches have been proposed for assessment of the potential health risks of heavy metals intake. One of them is the target hazard quotient (THQ), which is the ratio between the estimated dose of a contaminant and the reference dose below which there will not be any noticeable risk [19]. If such ratio exceeds unity, there may be a potential health risk.

There is a scarcity in surveillance studies estimating the concentrations of heavy metals in food and a lack of data concerning heavy metals dietary intake of university hostel students in Egypt. This in addition to the expected potential health risks to students increase the interest of choosing this item as a subject of study in Beni-Suef, Egypt, with the objectives of investigating the concentrations of Cd, Pb, As and Hg in soft cheese, ultra-heat-treated (UHT) milk, canned tuna and broiler's meat served for students at hostels of Beni-Suef University (BSU), estimating the weekly dietary intakes of those metals and comparing the results with the provisional tolerable weekly intake (PTWI) recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA), in order to assess the potential health risks using the THQ method.

Materials and Methods

Collection of Samples

A total of 200 random samples (50 each of UHT cow's milk, soft cheese, raw broiler's meat and canned tuna) were collected periodically (on a monthly basis) from two food stores of BSU student hostels, Beni-Suef, Egypt, during one academic year (2013/2014). BSU student hostels host about 3200 undergraduate students of 17–23 years old of both sexes. All samples were apparently sound at time of collection. The soft cheese, UHT milk and canned tuna samples were collected in their original packages, while the raw broiler's meat samples were taken in sterile polyethylene bags. Samples were identified and transported in a sterile icebox with a minimum of delay to the laboratory for further preparation and examination.

Digestion Procedures

Two grams/milliliter from each sample were placed in a digestion flask and digested with a mixture of 10 ml of nitric acid (HNO3) 65 % (supra-pure, MerkDarmastadt, Germany) and 2 ml of perchloric acid ($HClO_4$) 70 % (extra-pure-Merk, D-6100 Darmastadt, Germany) [20]. Flasks were tightly closed and the content was vigorously shaken and allowed to stand overnight at room temperature. Flasks were heated for 3 h in water bath adjusted at 70 °C to ensure complete digestion of samples. They were further vigorously shaken at 30-min intervals during the heating period. Finally, flasks were cooled at room temperature and then diluted with 20 ml de-ionized water and filtered via Whatman filter paper no. 42. The filtrate was collected in glass tubes that were capped with polyethylene films and kept at room temperature until analysis [21].

Preparation of Blank and Standard Solutions

Blank solution, consisted of 10 ml of nitric acid 65 % and 2 ml of perchloric acid 70 %, was prepared. Standard solutions of Cd, Pb, As and Hg were prepared using pure certified atomic absorption spectrophotometer metals standard. Both blank and standard solutions were treated as samples by the wet digestion procedure and then diluted with 20 ml de-ionized water.

Instrument

Quantitative determination of heavy metals was carried out by Buck scientific 210VGP Atomic Absorption Spectrophotometer (AAS) at Central Laboratory of Faculty of Veterinary Medicine, Zagazig University, Egypt.

Measurement

The digest, blank and standard solutions were aspirated by AAS and analysed for heavy metal content. Analysis was conducted by air/acetylene flow (5.5/1.11/m) flame in case of Cd, Pb and As, with hydride generation was used for As determination using sodium borohydride to reduce As into arsine, while cold vapour technique was used for Hg determination [22]. The analytical detection limits of Cd, Pb, As and Hg for the used instrumentation were 0.005, 0.02, 0.01 and 0.005 ppm, respectively.

Calculation

Cd, Pb, As and Hg levels were recorded from the digital scale of AAS and calculated according to the following equation:

$$\text{Metal concentration(ppm)} = \text{R} \times \text{D} \Big/ \text{W}$$

where *R* is reading of AAS, *D* dilution of the sample and *W* weight of the sample.

The concentration or the absorption values of heavy metals in blank solutions were also calculated and subtracted from those of each sample.

Estimation of Weekly Dietary Intake of Metals

The weekly consumption rate of each food item/student was used in calculation of the dietary intakes of heavy metals. Consumption rates were obtained from the official reports released by the food sector in BSU student hostels (Table 1). Weekly dietary intake of each heavy metal for each studied food item was calculated according to the following equation [18]:

$$\text{Dietary metal intake} \left(\mu\text{g} \big/ \text{kg bw} \big/ \text{week}\right) = \frac{\text{Concentration}\left(\mu\text{g} \big/ \text{kg}\right) \times \text{Consumption}\left(\text{kg} \big/ \text{day}\right) \times n}{\text{Average body weight}}$$

where n = times of consumption per week.

Student average body weight = 62 kg (the average weight of a total of 50 students of different ages).

The total dietary intake/student of each metal was computed by summing up the intakes from the studied foodstuffs.

Estimation of Target Hazard Quotients (THQs) and Total Target Hazard Quotients (TTHQ)

The methodology for estimation of THQ was displayed in US Environmental Protection Agency Region III Risk-based concentration table [19] as in the following equation:

$$\text{THQ} = \frac{\text{EF} \times \text{ED} \times \text{FIR} \times \text{C}}{\text{RDo} \times \text{BW} \times \text{TA}} \times 10^{-3}$$

where EF is the exposure frequency (n days/year), ED is the exposure duration (70 years; equivalent to the average lifetime), FIR is the food ingestion rate (g/person/day), as in Table 1, C is the metal concentration in examined food (μg/g), RDo is the oral reference dose (Cd = 1×10^{-3} μg/g/day, Pb = 4×10^{-3} μg/g/day, As = 3×10^{-4} μg/g/day, Hg = 3×10^{-4} μg/g/day) [19, 23], BW is the average body weight (62 kg), and TA is the average exposure time for non-carcinogenic foods (365 days/year × ED).

The TTHQ of the studied metals for an individual food item was calculated as the following:

$$\begin{aligned}\text{TTHQ(individual food item)} = {} & \text{THQ(cadmium)} \\ & + \text{THQ(lead)} \\ & + \text{THQ(arsenic)} \\ & + \text{THQ(mercury)}.\end{aligned}$$

Statistical Analysis

All the data were analysed using SPSS/PCT [24]. Independent *T* test was performed to evaluate significant differences at $P < 0.05$.

Results and Discussion

Heavy Metal Concentrations in Examined Food Samples

Cadmium

From the data illustrated in Fig. 1a, it is evident that the mean values of Cd residual concentrations in soft cheese, UHT milk,

Table 1 Consumption rates of the examined food items/student

Foodstuffs	Weight or volume/diet/student	Times/week	Exposure frequency (n days/year)[a]
Soft cheese	65 g	6	216
UHT milk	120 ml	Twice	72
Broiler's meat (cooked)	250–275 g	4	144
Canned tuna	85 g	Once	36

[a] The academic year in BSU includes 9 months

broiler's meat and canned tuna were 0.37, 0.26, 0.089 and 0.093 ppm, respectively. Nearly similar results in milk and cheese samples were detected by [25]; however, lower results were reported by [26–28]. Besides, lower values of Cd (0.003–0.022 and 0.009 ppm) were demonstrated by [29] in broiler's meat and tuna samples, respectively.

The results of examination of selected foodstuffs for residual level of Cd showed that none of the examined samples was below the limit of detection by AAS (0.005 ppm). Regarding the permissible limits of Cd, it was clear that 31 out of 50 broiler's meat samples (62 %) exceeded the maximum acceptable limits in poultry meat (0.05 mg/kg) recommended by [30, 31]. While 21 out of 50 canned tuna samples (42 %) exceeded the limit (0.1 mg/kg) recommended by the same authorities in tuna muscle meat. With referring to the permissible limits of Cd in milk and dairy products recommended by International Dairy Federation Standard [32], it was found that 100 % of both UHT milk and soft cheese samples exceeded such limit (0.006 mg/kg). These elevated values of Cd in Egyptian foods are attributed to the high level of Cd in the Egyptian environment and consequently in plants and animal tissues and products which could be attributed to the increasing emission of Cd into atmosphere from mining and smelting industries, the contamination of River Nile with the industrial wastes especially plastic industries, cadmium escapes into the air from iron and steel production industries and the high usage of phosphate fertilizers [33].

The mean value of Cd in soft cheese was significantly higher than that of UHT milk at $p < 0.05$. In addition, the mean value of UHT milk was significantly higher than those of broiler's meat and canned tuna, while there was no significant difference between broiler's meat and canned tuna mean

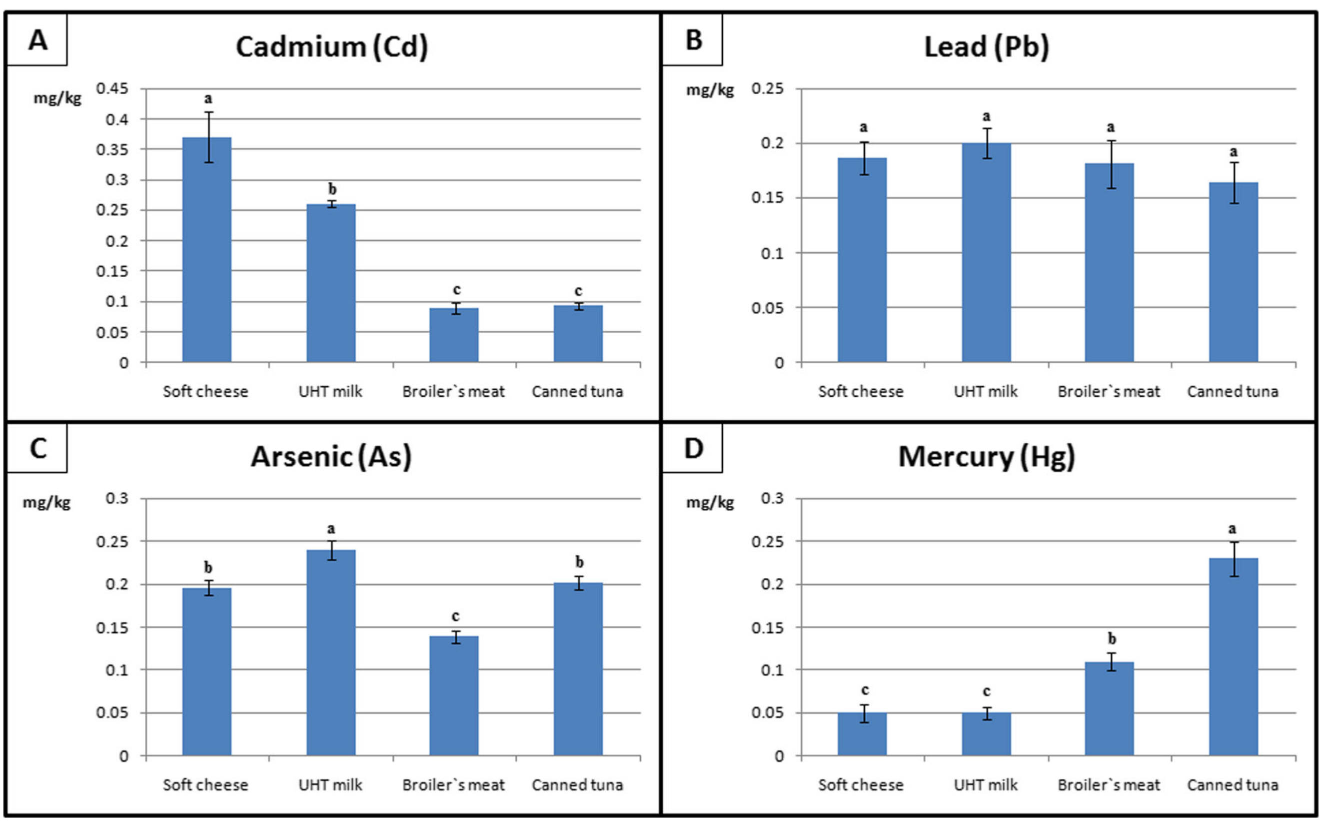

Fig. 1 Residual concentrations of Cd (**a**), Pb (**b**), As (**c**) and Hg (**d**) in examined food samples represented by means ± standard error (mg/kg). Different *a*, *b* and *c* within each metal indicate statistically significant difference between means at $p < 0.05$

values at $p < 0.05$. Such results can be explained in light of the study of Cabrera [34] who indicated that raw or heat-treated milk and dairy products usually have low concentrations of cadmium, except if dairy animals are reared on contaminated pastures, feed and water. Furthermore, contamination during marketing, storage and leaching from food packages is an additional source of Cd in milk and other dairy products.

The obtained results are not consistent with the report of the JECFA [35] that low Cd concentrations are found in milk, meat, eggs and fruits; medium levels are found in cereals and potatoes, whereas high levels are present in molluscs, crustacean and animal kidneys. Nevertheless, they revealed that finfish contain low values of Cd as observed in the present study.

Lead

The results illustrated in Fig. 1b clarify that the mean values of Pb were 0.187, 0.2, 0.181 and 0.164 mg/kg, in examined soft cheese, UHT milk, broiler's meat and canned tuna, respectively. No significant differences were detected at $p < 0.05$ between the four examined foods. Lower Pb values in broiler's meat and tuna were detected by [29] (0.025–0.056 and 0.021 ppm, respectively) and [36]. While Abdulkhaliq [37] reported similar values in milk samples and lower values in cheese samples.

According to the results of AAS, 46 (92 %), 43 (86 %), 38 (76 %) and 40 (80 %) out of 50 samples of soft cheese, UHT milk, broiler's meat and canned tuna, respectively, were above the LOD of Pb (0.02 ppm). Comparing to the permissible limits of Pb stated by official authorities, it could be concluded that 92, 86, 62 and 20 % of examined soft cheese, UHT milk, broiler's meat and canned tuna, respectively, were higher than the maximum acceptable limits of Pb recommended by [30, 31] which were 0.02, 0.02, 0.1 and 0.3 mg/kg, respectively. Pb could contaminate food upon release into the atmosphere in the form of metal fumes or suspended particles from smelting or fuel combustion and disposal of wastes [38], which then contaminate animal's feeds and water to be accumulated in their tissues.

Arsenic

The illustrated data in Fig. 1c shows that the mean values of total As in examined soft cheese, UHT milk, broiler's meat and canned tuna samples were 0.196, 0.24, 0.14 and 0.201 mg/kg, respectively. None of the examined samples from the four foodstuffs was below the limit of detection of As by AAS (0.01 ppm). UHT milk samples had a significantly higher As concentration ($p < 0.05$), followed by soft cheese and canned tuna samples, while broiler's meat samples had a significantly lower As concentration than other examined foods (at $p < 0.05$). On the contrary, Vahter and Concha [39] reported higher residual levels of As in cheese samples and attributed that increase to the elimination of water during the curdling process, where As is linked to casein during the main stages of curdling. Furthermore, arsenic residual levels in cow's milk could depend on many other factors including the rate of nutritional and environmental contamination, food packaging, heat treatment, exposure to UV light, and storage duration of the product [40].

The concentration of As in broiler's meat and canned tuna was previously investigated by [29] who found lower concentrations of As in broiler's meat (ND 0.018 ppm) and higher concentrations in tuna samples (0.516 ppm) than those reported in the current study. Higher concentrations of As in canned tuna samples (0.44–1.3 mg/kg) were also affirmed by [41], while lower As level (0.062 mg/kg) in fish samples was estimated by [42]. Elevated concentrations of As in canned fish, in such studies, was attributed to the high temperatures implemented during food processing which may induce a considerable solubilization of arsenic. This is in accordance with the concept of [43] that fish and other seafoods can accumulate sizeable quantities of arsenic from their environment and, consequently, the daily intake of arsenic by humans generally reflects the quantities of seafood in their diet.

Mercury

The mean values of Hg in soft cheese, UHT milk, broiler's meat and canned tuna are summarized in Fig. 1d. They accounted for 0.05, 0.05, 0.117 and 0.235 ppm, respectively. The highest levels (significantly at $p < 0.05$) of Hg were reported in canned tuna, followed by broiler's meat, while the residual concentrations in soft cheese and UHT milk were similar and significantly lower than values in canned tuna and broiler's meat without significant difference in between (at $p < 0.05$). Referring to the permissible limit of Hg in the muscle meat of tuna fish recommended by [30, 31] (1.0 mg/kg wet weight); it was clear that none of the examined canned tuna samples exceeded such limit.

The obtained results of mercury in broiler's meat and tuna samples are well in line with those reported by [29] who recorded 0.03 and 0.29 mg/kg in the same foods, respectively. Conversely, a lower value in fish samples (0.048 mg/kg) was recorded by [36], who considered that value non-exceeding the maximum permissible limit stated by the Chilean Food Health Regulation (0.5–1.5 mg/kg fish). The consumption of fish is an important route of exposure to methyl Hg [44]. Lipton and Gillett [45] reported that tuna were sufficiently high in Hg levels which warrant health concern for high-risk groups with very high consumption rates. Moreover, it was recorded by Dudka and Miller [46] that fish and shellfish tend to concentrate environmental Hg and marine organisms have a distinct capacity to convert inorganic Hg into organic compounds (MeHg), thus rendering Hg more easily transferable throughout the aquatic food chain, and therefore, marine seafood contains up to 5 mg/kg Hg. In addition, it was suggested that tuna and other large predatory fish species tend to bio-accumulate Hg in their tissues and may keep it in high concentrations. Hence, consumption of fish and other seafood is the main source of the Hg load in the human being [47].

Weekly Dietary Heavy Metal Intake

An important aspect in assessing risk to human health from potentially harmful chemicals in food is the knowledge of the dietary intake of such substances that must remain within determined safety margins. The weekly dietary intake of each heavy metal (Cd, Pb, As and Hg) from the examined foodstuffs per kilogram body weight/student is outlined in Table 2 and Fig. 2. The total dietary intake of each metal was compared with PTWI recommended by JECFA. The total weekly dietary intakes of Cd, Pb, As and Hg were 4.99, 5.38, 4.77 and 2.76 μg/kg body weight of student/week, respectively.

Concerning the provisional tolerable weekly intake (PTWI) recommended by JECFA, it was found that weekly dietary exposure of BSU students to Cd represented 71.37 % of PTWI (7 μg/kg body weight) stated by JECFA [48]. Several studies have established Cd intake estimates in various countries around the world. It was reported that the weekly dietary intakes of cadmium for some European countries varied between 70 μg/week (Spain) and 210 μg/week (Greece), thus representing 17–50 % of the PTWI, while in France represented 45 % of PTWI [21, 49, 50]. In a study reported by LegCo [51] in Hong Kong, weekly dietary intake of Cd by average eaters and high consumers' secondary school students reached 2.49 and 5.71 μg/kg body weight which represents 35.5 and 81.5 % of PTWI. Another study done by Chen et al. [52] in Hong Kong estimated the dietary exposure of adult population to Cd revealed that adult population in Hong Kong intake about 2.075 μg Cd/kg bw/week. The majority of Cd intake in the current study was caused by soft cheese (46 %) followed by broilers' meat (31.4 %), UHT milk (20.1 %) and canned tuna (2.4 %) (Fig. 2).

As regards to the weekly dietary intake of Pb, it represented 21.52 % of PTWI (25 μg/kg body weight/week) recommended by JECFA [46], and it was recorded that the dietary exposure of European population to Pb represented 17, 131, 83.5 and 56 % of PTWI in Spain, Italy, Belgium and Greece, respectively [49, 53–55], indicating that BSU students intake higher values of Pb than in populations Spain, while lower than populations in Italy, Belgium and Greece, as well as students exposure to Pb in our current study was dramatically higher than the adult population in Hong Kong which was 1.47 μg/kg bw/week by total diet study [52]. Furthermore, in a duplicate diet study performed by [56] in Catalonia, Spain, it was found that the dietary Pb intake by an adult person is 2.31 μg/kg bw/week. On the contrary, greatly higher Pb intake (3.05 μg/kg bw/day) was reported by [57] in Yaoundé, Cameroon. The major food contributor in Pb intake in the current study was broiler's meat (59.8 %) followed by soft cheese (21.7 %) and UHT milk (14.3 %), while canned tuna represented about 4 % of the total Pb intake (Fig. 2).

Regarding the PTWI of Arsenic, the provisional tolerable daily intake (PTDI) for total As has been set, in 1967, at 50 μg/kg body weight/day. The total As daily intake in European countries was found to be 1.5, 2, 4 and 9.5 % of PTDI (50 μg/kg body weight/day) in Belgium, UK, France and Spain, respectively [16, 49, 53, 58]. However, the JECFA has updated As level to be a PTWI of 15 μg/kg body weight/week for inorganic arsenic [59]. Nevertheless, this level is not suitable to be used as a reference for comparison

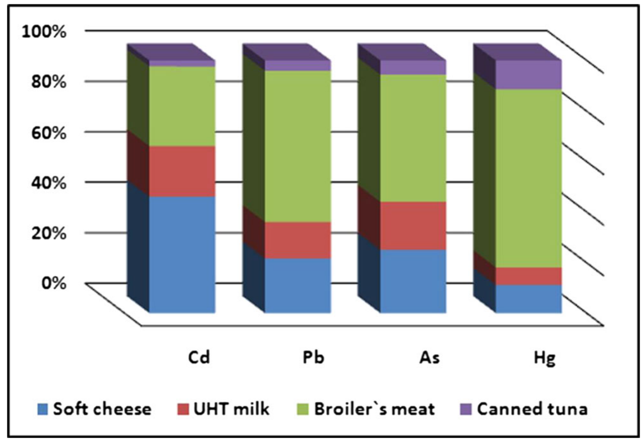

Fig. 2 Percentage of contribution of each examined foods to the weekly dietary intake of studied heavy metals

Table 2 Estimated weekly dietary intake of heavy metals by each student from the selected food items (μg/kg bw/week) comparing with PTWI

Samples Metals	Soft cheese	UHT milk	Broiler's meat	Canned tuna	Total dietary intake[a]
Cd	2.30	1.006	1.57	0.12	4.99
Pb	1.17	0.77	3.22	0.22	5.38
As	1.20	0.90	2.40	0.27	4.77
Hg	0.31	0.193	1.95	0.315	2.76

[a] Total weekly dietary intake = $WDI_{cheese} + WDI_{milk} + WDI_{broiler} + WDI_{tuna}$

intentions since most studies determine total rather than inorganic arsenic intake. Taking into consideration the previous studies on inorganic As in different foods [60–63], we can suggest that at least 50 % of the total As in our examined foodstuffs is inorganic. Accordingly, 50 % of student intake of As represents 2.38 μg/kg body weight/week which accounts for 15.9 % of PTWI of inorganic As. It is worth mentioning that inorganic arsenic forms are more hazardous to humans than the organic ones, such as arsenobetaine, which are generally of low toxicity [43].

A similar intake value (2.52 μg/kg body weight representing 16.8 % of PTWI of inorganic As) was demonstrated by LegCo [51] in average eaters' students in Hong Kong, who reported higher intake level than that in the current study in high consumers' secondary school students (6.77 μg/kg body weight representing 45.13 % of PTWI of inorganic As). A notable finding in the present study is that the large fraction of total As intake by students was correlated to broiler's meat consumption (50.3 %) followed by soft cheese (25.1 %) (Fig. 2), which could be attributed to the higher consumption rate of broiler's meat by students than other food items; this findings supports the previous observations of LegCo [51], although it does not confirm the concept of [43] that the daily intake of As by humans reflects generally the quantities of seafood in the diet in which arsenic occurs mainly in the organic form.

The JECFA [64] established a new PTWI for inorganic Hg of 4 μg/kg bw/week, while the previous PTWI of 5 μg/kg bw/week for total mercury, established at the 16th meeting, was withdrawn. The committee added that the new PTWI for inorganic Hg was considered applicable to dietary exposure to total Hg from foods other than fish and shellfish. For dietary exposure to mercury from fish and shellfish, the previously established PTWI for methyl Hg (3.3 μg/kg bw/week) should be used [64], due to the high capacity of seafood to convert inorganic Hg into methyl Hg, thus rendering Hg more easily transferable throughout the seafood chain.

Table 2 showed that the weekly dietary exposure of students to total mercury from examined food items other than fish and shellfish was 2.45 μg/kg bw/week which represents 61.32 % of PTWI of inorganic Hg (4 μg/kg bw/week) recommended by JECFA [59]. However, the dietary exposure to total Hg from canned tuna represents only 9.45 % of PTWI of methyl Hg (3.3 μg/kg bw/week) recommended by JECFA [64]. It was surprising that dietary exposure of students to total mercury from foods other than fish and shell fish exceeded the upper limits of estimates of average exposure of adults (1 μg/kg bw/week) and was below that recommended for children (4 μg/kg bw/week) [64]. Although the highest residual level of Hg was recorded in examined canned tuna samples, the largest part of Hg intake was associated with consumption of broiler's meat (Fig. 2), an observation which could be attributed to the high consumption rate of broiler's meat as compared with canned tuna. The dietary exposure of secondary school students to mercury was previously found to be 2.98 and 6.41 μg/kg bw/week (for average eaters and high consumers' students) representing 59.6 and 128 % of PTWI, respectively [51]. In other studies, it represented 9.3, 28 and 31 % of PTWI in UK, Spain and Belgium, respectively [49, 53, 58].

In conclusion, all metal dietary intakes recorded in this study fell within the recommended provisional tolerable intakes. It is important to take into account that such levels represent only a fraction of student exposure to these metals because the approach adopted in the present study was to estimate dietary intake by analysing of individual food items Besides, there are other several sources that could possibly contribute in rising the dietary intake of such metals, such as drinking water, other foodstuffs served to students inside the hostels and foods consumed outside the hostels.

Target Hazard Quotients

Table 3 summarizes the results of THQ for Cd, Pb, As and Hg caused by consumption of soft cheese, UHT milk, broiler's meat and canned tuna in BSU student hostels and the TTHQs. THQ is the ratio between the estimated dose of a contaminant and the reference dose; if the ratio is lower than 1, it will not be any appreciable risk, but if such ratio exceeds unity (one), there may be a concern for potential health risks. Although THQ does not provide a quantitative estimation on the probability of exposed population to health risks, it offers an indication about the risk level due to exposure [19]. THQ was assumed in our study in accordance with the guideline of US EPA [65] that the consumed dose is equal to the absorbed metal dose and that cooking has no effect on the heavy metals' concentration [66].

As shown in Table 3, none of THQ values of the studied heavy metals exceeded 1 through the consumption of soft cheese, UHT milk, broiler's meat and canned tuna, which theoretically indicates absence of potential health risks. The estimated THQ ranged from 0.012 to 0.22, 0.02 to 0.08, 0.09 to 0.81 and 0.063 to 0.641 for Cd, Pb, As and Hg, respectively.

Table 3 Estimated target hazard quotients (THQs) of heavy metals through consumption of examined foodstuffs

Metals Foodstuffs	Cd	Pb	As	Hg	TTHQ[a]
Soft cheese	0.22	0.03	0.40	0.103	0.753
UHT milk	0.099	0.02	0.30	0.063	0.482
Broiler's meat	0.155	0.08	0.81	0.641	1.686
Canned tuna	0.012	0.05	0.09	0.103	0.255

[a] TTHQ: Total target hazard quotient = (THQ_{Cd} + THQ_{Pb} + THQ_{As} + THQ_{Hg})

Concerning, TTHQs of studied food items, it was clear that TTHQ of only broiler's meat was over 1 (1.686) which indicates possible health risks, while the TTHQs of other food were below 1. However, the obtained results do not necessarily indicate the absence of potential health risks from soft cheese, UHT milk and canned tuna consumed in BSU student hostels, as it was assumed that the THQ is not a sharp line between safe and unsafe metal exposures, additionally, it is not clear that exposures below or at the references are without risks, or that exposures above it have great risks [67].

Conclusion

From the present study, it can be concluded that soft cheese, UHT milk, broiler's meat and canned tuna represent considerable sources of some heavy metals including Cd, Pb, As and Hg to students living at the hostels of BSU, Egypt. Although high percent of the examined food samples contains heavy metals (Cd, Pb, As and Hg) in higher values than the permissible limits recommended by the international authorities [30, 31], the total weekly dietary intakes of studied heavy metals through consumption of such foodstuffs lie within the PTWI recommended by JECFA. These intake values might be underestimated as they represent a part of the exposure because there are other several sources which could contribute in elevating the dietary intake of such metals by students; however, Cd intake was very close to the tolerable intake value (71.37 %). Referring to the potential health risks of studied food, it was estimated that TTHQ of only broiler's meat exceeded 1 (1.686) indicating possible health risks, while the TTHQs of other foodstuffs were below 1 as comparing with the reference doses; however, THQ is not a sharp line between safe and unsafe metal exposures. The levels of dietary exposure of students to heavy metals in our current study give us an alarm that the students could be under health risk so future study using total diet approach is recommended.

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