Contamination and health risks from heavy metals (Cd and Pb) and trace elements (Cu and Zn) in dairy products

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Abstract

Background and Purpose: Dairy products are known as an important food source in human diet. This study was carried out to analyze the content of metals (Cd, Cu, Pb, and Zn) in butter and cheese, and evaluates the potential health risks of metals to humans through the consumption of dairy products.

Materials and Methods: In this analytical observational study, a total of 32 samples of butter and cheese were collected from the market basket of Hamadan City in 2016. After preparing and processing the samples in the laboratory, the content of metals were determined using inductively coupled plasma-optical emission spectrometer (ICP-OES). Also, all statistical analyses of the collected data were performed using SPSS version 19.0 statistical package according to Shapiro-Wilk test for normality, One Way ANOVA (Duncan Multiple Range Test), Pearson’s correlations, and Independent t-test.

Results: The results of the current study showed that the mean concentrations (µg kg⁻¹) of Cd, Cu, Pb and Zn in butter samples were 0.83 ± 0.15, 6.25 ± 1.76, 21.75 ± 10.94, and 131.35 ± 9.24, respectively, while in cheese samples, they were 0.70 ± 0.11, 39.43 ± 40.26, 12.85 ± 2.41, and 198.08 ± 10.97, respectively. Also, the Target hazard quotient (THQ) values in adults and children through the consumption of butter and cheese were within the safe limits (THQ < 1).

Conclusion: Considering the serious contamination of some brands of butter and cheese by Cu and Pb, a control of heavy metals and trace elements levels during the whole production processing of dairy products must be applied.

Key words: Food safety; Metal contamination; Health risk index; Milk

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1. Introduction

Heavy metals are typically released into the environment from natural and anthropogenic activities. Since they are persistent in the environment, they can cause serious health and environmental effects. Some heavy metals like Cu, Fe, and Zn are essential in maintaining proper metabolic activity in living organisms; while, others like As, Cd, Hg, and Pb are non-essential, and they have no important role in biological systems. At the same time, they can cause toxicity to living organisms at high contents (1-5). According to, dairy products, such as milk, are good sources of fats, proteins, macro and micro elements (Ca, K, P, Cu, Fe, Zn, and Se), and vitamins, therefore, they are known as important components of human diets, and are widely consumed by children and adults, and especially elderly people around the World (3, 6). Nowadays, entering toxic metals to milk and other dairy products via foodstuff, water, as well as manufacturing and packaging processes are serious concerns due to the fact that they can cause adverse health effects to humans (3). Milk and dairy products also become contaminated with heavy metals (2, 7). Cadmium, as a non-essential and very toxic element for human health, accumulates principally in the kidneys and liver organs (8, 9). Copper, on the other hand, is an essential element, but at high amounts, it is very toxic and causes adverse health problems. A maximum intake limit of Cu was set to be at 30 mg/day (10, 11). Lead is also known as one most commonly distributed environmental metal poison, the poisoning of which is considered as the most common environmental health hazard (12, 13), whereas Zinc is one of the important elements for normal growth and development in the human body (14, 15).

Health risk assessment as part of risk analysis process includes some steps, such as hazard identification, dose-response analysis, exposure assessment, and risk characterization, the results of which are quantitative or qualitative explanations of the likelihood of harm associated with exposure to synthetic chemicals. In this regard, the assessment of human health risk requires identification, collection, and integration of information on the health hazards of chemicals, exposure of human to toxins in polluted environmental media, and relationships between exposure duration, dose, and adverse health effects (16). In the current study, for the purpose of safe consumption of dairy products, the presence of trace and toxic heavy metals in the mentioned products and the associated health risks were studied. Since, there has so far been no health risk assessment of the existence of heavy metals in dairy products in Iran, the present study was conducted to determine the potential health risk of Cd, Cu, Pb and Zn concentrations of some popular brands of cheese and butter which were marketed in Hamedan City.

2. Material and Methods

In the current study, for analyzing the content of heavy metals (Cd and Pb) and tracing the elements (Cu and Zn) in dairy products consumed in Hamedan City, a total of 16 pasteurized butter products from four major brands and 16 pasteurized cheese products from four major brands were collected from dairy shops in 2016. The samples were then immediately transported to the laboratory in a cooler with ice packs, and were stored at -20 °C until analysis. Dairy product samples (2 g) were digested with the mixture of HNO3 and HClO4 (4:1 v/v) and heated at 70 °C for 2 hours until a transparent solution was
obtained (17-19). After digestion, the samples were filtered through Whitman filter paper No. 42, and diluted to a suitable concentration. Three blank samples, substituted by de-ionized distilled water, were run simultaneously with each batch of digestion (18). Working standard solutions of Cd, Cu, Pb, and Zn were also prepared by dilution of certified standard solutions to desired content. The heavy metals and trace elements content in the digested samples were then measured using inductively coupled plasma-optical emission spectrometry (710-ES Varian, Australia) at wavelengths (nm) of 226.50 for Cd, 324.75 for Cu, 196.03 for Pb and 206.20 for Zn with three replications.

The statistical analysis of the collected data were performed using SPSS version 19.0 statistical package consisted of a first Shapiro-Wilk test for normality, followed by one-way ANOVA, which was conducted to examine the statistical significance of differences in the mean concentration of Cd, Cu, Pb, and Zn analyzed in dairy samples. Also, the concentration of the analyzed metals in butter and cheese samples was compared through independent sample t-test. Finally, to observe if there was a correlation between the metals in the different dairy samples, the 2-tailed test of Pearson correlation was performed.

The daily intake of metals depends on both the metal content in food and the daily food consumption. In addition, the body weight of a human being can influence the tolerance of contaminants. The EDI (mg kg⁻¹ day⁻¹) of metals was computed according to Equation 1 (18, 20).

\[ EDI = \frac{C_{metal} \times W_{food}}{BW} \]  

, here \( C_{metal} \) represents the content of heavy metals in contaminated foods (mg kg⁻¹), \( W_{food} \) indicates that the daily average consumption of food (g per day) and \( BW \) represent the body weight (70000 g for adults and 15000 g for children) (21-23). Hence, the average daily consumption of dairy products in Iran was considered to be 139 g (24).

The Target Hazard Quotient for the local inhabitants via the consumption of contaminated dairy products was evaluated based on the food chain and the reference oral dose (RfD) for each metal (0.001, 0.04, 0.0035, and 0.30 mg kg⁻¹ day⁻¹ for Cd, Cu, Pb, and Zn, respectively) (25-28). In this regard, the THQ < 1 meant that the exposed population was assumed to be safe (18, 29). The THQ of metals was calculated by Equation 2 (18).

\[ THQ = \frac{EDI}{RfD} \]  

The total THQ (TTHQ) of heavy metals for the dairy products was also calculated according to Equation 3:

\[ TTHQ = THQ (\text{toxicant 1}) + THQ (\text{toxicant 3}) + \ldots + THQ (\text{toxicant n}) \]  

3. Results

The concentrations of Cu, Cd, Pb and Zn in the analyzed butter and cheese samples are presented in Table 1. Among the analyzed butter samples, Cd was detected in a range of 0.60 to 0.90 µg kg⁻¹, while Cu was in a range of 4.70 to 8.70 µg kg⁻¹, and Pb was observed to be in a range of 14.70 to 38.00 µg kg⁻¹. Zn was also found to be in the range of 123.00 to 142.70 µg kg⁻¹. Also, among the analyzed cheese samples, Cd was detected in a range of 0.60 to 0.80 µg kg⁻¹. Cu was in a range of 17.00 to 99.70 µg kg⁻¹, Pb was in a range of
10.00 to 15.00 µg kg\(^{-1}\), and Zn was in a range of 189.30 to 212.00 µg kg\(^{-1}\).

Comparing the heavy metal concentrations in the studied dairy products with the maximum permissible limits (µg kg\(^{-1}\)) (2.60, 10.0, 20.0, and 328.0 for Cd, Cu, Pb, and Zn, respectively) established by Codex Alimentarius Commission and International Dairy Federation(18, 30), showed that only the mean content of Cu in cheese samples was higher than MPL.

The results presented in Table 2 also indicated that the THQ values in adults and children via the consumption of both butter and cheese were lower than 1 (safe limits).

The Pearson's correlations analyses were then performed between metal concentrations in dairy product samples to understand the relationships between them. The results showed that in butter samples, there were found positive correlations between Cu and Zn (r = 0.738, P < 0.01), and negative correlations between Pb and Zn (r = -0.610, P < 0.05). While, in cheese samples, there were positive correlations found between Cu and Zn (r = 0.762, P < 0.01) and also between Pb and Zn (r = 0.870, P < 0.01).

At the same time, the results of independent t-test showed that there were significant differences (p < 0.05) in the contents of Cu, Pb, and Zn between butter and cheese samples. While, the content levels of Cd did not differ significantly (p > 0.05) between the samples of dairy products.

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**Table 1.** Heavy metals and trace elements concentration (mean ± SD) of the butter and cheese samples (µg kg\(^{-1}\))

| Brand | Metal Concentration | Metal | Concentration (µg kg\(^{-1}\)) |
|-------|---------------------|-------|-------------------------------|
|       |                     | Cd    | Cu                            | Pb                            | Zn                            |
|       |                     | 1     | 2                             | 3                             | 4                             |
|       | Butter              | 0.90±0.12a | 5.30±1.50a  | 38.00±1.73c    | 123.00±0.00a   |
|       | 1                   | 0.90±0.15a | 6.30±0.50b  | 18.30±0.58b    | 135.00±4.00b   |
|       | 2                   | 0.90±0.23a | 4.70±1.50a  | 16.00±1.00a    | 124.70±3.51a   |
|       | 3                   | 0.60±0.17a | 8.70±1.50c  | 14.70±0.58a    | 142.70±1.53c   |
|       | 4                   | 0.60±0.12a | 5.30±1.50a  | 38.00±1.73c    | 123.00±0.00a   |
|       | Min.                | 0.90   | 4.70                         | 14.70                        | 123.0            |
|       | Max.                | 0.60   | 8.70                         | 38.0                         | 142.70           |
|       | Mean                | 0.83   | 6.25                         | 21.75                        | 131.35           |
|       | S.D.                | 0.15   | 1.76                         | 10.94                        | 9.24              |
|       | Cheese              | 0.80±0.25a | 17.00±2.00a  | 11.70±0.58b    | 189.30±5.13a    |
|       | 1                   | 0.60±0.10a | 18.30±1.53a  | 14.70±0.58c    | 201.70±2.08b    |
|       | 2                   | 0.60±0.15a | 9.70±8.39b   | 15.00±0.00c    | 212.00±5.30c    |
|       | 3                   | 0.80±0.21a | 22.70±5.13a  | 10.00±0.00a    | 189.30±1.15a    |
|       | 4                   | 0.60    | 17.00                        | 11.70                        | 189.30           |
|       | Min.                | 0.60   | 9.70                         | 15.0                         | 212.00           |
|       | Max.                | 0.80   | 39.43                        | 12.85                        | 198.08           |
|       | Mean                | 0.70   | 40.26                        | 2.41                         | 10.97             |
|       | S.D.                | 0.11   | 40.26                        | 2.41                         | 10.97             |

* The letters (a, b, and c) as presented in Table 1, represent the statistical differences (statistical grouping) among different brands of dairy products based on the mean concentration of metals according to Duncan multiple range test (p = 0.05)
Before the intervention, the mean of adherence to exercise programs, drug treatment, and diabetic diet were calculated to be 15.53, 23.92, and 48.20, respectively, in Podcast group, while the mean of adherence to the same factors in Pamphlet group were equal to 14.48, 24.04, and 46.54, respectively. The independent t-test showed no significant difference between adherence to exercise programs, drug treatment, and diabetic diet in aural training and pamphlets groups before the intervention (P = 0.265, P = 0.936, and P=0.523). After the intervention, the mean of adherence to exercise programs, drug treatment and diabetic diet increased as follows: Podcast group (20.00, 23.95 and 57.12); Pamphlet group (21.26, 25.40 and 55.59).

However, the results of independent t-test showed no significant difference between the adherence rate to exercise programs, drug treatment, and diabetic diet in Podcast and Pamphlet groups (P = 0.371, P= 0.319 and P = 0.378), as shown in Table 2.

Table 2. Estimated Daily Intake of metals (EDI, mg kg\(^{-1}\) day\(^{-1}\)) and Target Hazard Quotient (THQ) for individual heavy metal caused by butter and cheese

|        | Cd    | Cu    | Pb    | Zn    |
|--------|-------|-------|-------|-------|
|        | Butter|       |       |       |
| Adults | EDI   | 1.65E-06 | 1.24E-05 | 4.32E-05 | 2.61E-04 |
|        | THQ   | 1.65E-03 | 3.10E-04 | 1.23E-02 | 8.70E-04 |
| Children | EDI      | 7.69E-06 | 5.79E-05 | 2.01E-04 | 1.22E-03 |
|         | THQ   | 7.69E-03 | 1.45E-03 | 5.76E-02 | 4.06E-03 |
|        | Cheese|       |       |       |
| Adults | EDI   | 1.39E-06 | 7.83E-05 | 2.55E-05 | 3.95E-04 |
|        | THQ   | 1.39E-03 | 1.96E-03 | 7.29E-03 | 1.32E-03 |
| Children | EDI      | 6.49E-06 | 3.65E-04 | 1.19E-04 | 1.84E-03 |
|         | THQ   | 6.49E-03 | 9.13E-03 | 3.40E-02 | 6.12E-03 |

4. Discussion

Cadmium is a non-essential trace element that gradually accumulates inside human body, and especially in kidneys. Thus, in people affected by Cd poisoning, the occurrence of kidney stones is increased. The toxicity of Cd may lead to acute pulmonary edema, acute gastroenteritis, hypertension, and may also cause a case called Itai-Itai disease (31). Natural or anthropogenic origins, such as atmospheric deposition in soils, and chemical fertilizers are the major resources of the presence of Cd in milk and dairy products (18). In the present study, the Cd levels in butter and cheese samples were in the ranges of 0.60-0.90 µg kg\(^{-1}\), and 0.60-0.80 µg kg\(^{-1}\).
with an average concentration of 0.83 ± 0.15 µg kg\(^{-1}\) and 0.70 ± 0.11 µg kg\(^{-1}\), respectively. These findings come against with the level obtained by Abdulkhaliliq et al. for white cheese consumed in West Bank, Palestine (29.78 ± 19.60 µg kg\(^{-1}\)) (4), Meshref et al. for butter (57.0 ± 5.0 µg kg\(^{-1}\)), kareish cheese (90.0 ± 9.0 µg kg\(^{-1}\)) consumed in Egypt (18), and Al-Ashmawy et al. for kareish cheese (87.0 µg kg\(^{-1}\)) (20). Ayar et al. reported that the mean content of Cd for butter and white cheese consumed in Turkey were 15.0 and 12.0 µg kg\(^{-1}\), respectively (2). On the contrary, higher levels of Cd contamination in kinds of cheese and butter consumed in Egypt were reported 10.0-1120 and 439 µg kg\(^{-1}\), respectively (31, 32). Copper as an essential trace element is necessary for the integrity of cardiovascular system, adequate growth, neuronendocrine function, elasticity of the lungs, and Fe metabolism. It is also mentioned in the literature review that milk and dairy products are considered a very poor source of Cu; however, except in conditions with severe malnutrition, Cu deficiency is uncommon (18). The results of the current study showed that Cu concentrations in butter and cheese samples were found in the ranges of 4.70-8.70 µg kg\(^{-1}\) and 17.0-99.7 µg kg\(^{-1}\) with an average content (µg kg\(^{-1}\)) of 6.25 ± 1.76 and 39.43 ± 40.26, respectively. This reported Cu level was much lower than those observed in kinds of cheese consumed in Egypt (90.0-1030.0 µg kg\(^{-1}\)) (31), 2.0-530.0 µg kg\(^{-1}\) for kareish cheese marketed in Egypt (18), and 610-1230 µg kg\(^{-1}\) for white cheese consumed in West Bank, Palestine (4). Regarding Cu (1500-3300 µg kg\(^{-1}\)) for kareish cheese, a higher level was also reported by Deeb (33). On the other hand, Meshref et al. and Enb et al. reported that the mean levels of Cu for butter were 600.0 and 1472 µg kg\(^{-1}\), respectively (18, 32). Also, the mean levels of Cu for butter consumed in Brazil and Egypt were determined to be 32.0 ± 12.0 µg kg\(^{-1}\) and 907.0 µg kg\(^{-1}\), respectively (32, 34).

Due to its low rate of elimination, lead has a cumulative and severe toxic effect. The major resources for the presence of Pb in milk and dairy products may be due to environmental sources, such as waste disposal, atmospheric deposition, urban effluent, and vehicle exhausts (18). The important symptoms of Pb toxicity include ulcerative stomatitis, decreases in sexual drive, abnormalities in sperm number, a blue gingival, unpotance, and sterility. Also, women exposed to Pb poisoning may suffer from menstrual disorders with spontaneous abortion and abnormal ovarian cycle (31). The obtained results of the current study showed that the mean concentrations of Pb in butter and cheese samples were found in the ranges of 14.70-38.0 µg kg\(^{-1}\) and 10.0-15.0 µg kg\(^{-1}\), with an average content (µg kg\(^{-1}\)) of 21.75 ± 10.94, and 12.85 ± 2.41, respectively. Lead levels in the literature have also been reported in the mean of 80.0 ± 16.0 µg kg\(^{-1}\) in the butter consumed in Brazil (34), 430.0 ± 29.0 µg kg\(^{-1}\) and 490.0 ± 21.0 µg kg\(^{-1}\) for kareish cheese and butter marketed in Egypt (18), 224 µg kg\(^{-1}\) for butter marketed in Egypt (32), and in the range of 80-1480 µg kg\(^{-1}\) for the Kaireish cheese consumed in Egypt (31). On the other hand, the Pb levels of Italian fresh cheese were recorded to be 470.0 µg kg\(^{-1}\) (7). In one other study, Ayar et al. reported that Pb contents in butter and white cheese were 116.0 µg kg\(^{-1}\) and 920.0 µg kg\(^{-1}\), respectively (2). Zinc is necessary for the functional performance of the immune system and physiological processes, and it may also be involved in the activity and the structure of about 300 enzymes responsible for protein
synthesis and nucleic acid, cellular differentiation and replication, sexual maturation, and insulin secretion. Also, it has been proved that chronic Zn exposure resulted in leucopenia, anemia, diarrhea, and gastrointestinal diseases (18, 35). It should be noted that Zinc contents in butter and cheese samples were found in the ranges of 123.00-142.70 µg kg\(^{-1}\), and 189.30-212.00 µg kg\(^{-1}\), with an average content of 131.35±9.24 µg kg\(^{-1}\), and 198.08±10.97 µg kg\(^{-1}\), respectively. In this regard, Fahmy and Abdel-Fattah (36) reported that Zn content in butter samples was 86.0 µg kg\(^{-1}\), which was lower than those obtained in the current study. Also, these values were lower than the levels obtained by Leggli et al. (34), Meshref et al. (18), and Enb et al. (32) who determined the mean levels of Zn (µg kg\(^{-1}\)) 1360.0, 5980.0, and 19086 for butter, respectively. Inversely, higher contents of Zn in cheese (33660-63410 µg kg\(^{-1}\)) were reported by Maas et al. (37). Regarding kareish cheese, higher levels of Zn equal to 3402-17570 µg kg\(^{-1}\) and 24900-35900 µg kg\(^{-1}\) were reported by Meshref et al. (18) and Deeb (33), respectively.

The target hazard quotient has also been recognized as a useful parameter for the assessment of risks associated with the consumption of metal contaminated food (29). According to the results of the present study, the Total THQ values (TTHQ) of heavy metals for adults and children through the consumption of butter were found to be 1.51E-02 and 7.10E-02, respectively, which were below the safe limit (TTHQ < 1) for both age groups. Also, the TTHQ values for adults and children through the consumption of cheese were documented to be 1.20E-02 and 5.57E-02, respectively, which were below the safe limit (TTHQ < 1) similar to butter samples for both groups of consumers. Thus, it could be concluded that all consumers including adults and children have no potential health risk through consuming dairy products (butter and cheese) from the study area. Similarly, Meshref et al. (18) reported that the THQ for daily exposure of Cd, Cu, Pb and Zn through the consumption of Kareish cheese and butter marketed in Egypt were below the safe limit (THQ < 1).

Conflict of Interests
The authors have no conflict of interest.

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References
1. Li Y, McCrory DF, Powel JM, Saam H, Jackson-Smith D. A survey of selected heavy metal concentrations in Wisconsin Dairy Feeds. J Dairy Sci 2005; 88(8):2911-22. PMID: 16027206 doi: 10.3168/jds.S0022-0302(05)72972-6
2. Ayar A, Sert D, Akin N. The trace metal levels in milk and dairy products consumed in middle Anatolia-Turkey. Environ Monit Assess 2009; 152(1-4):1-12. PMID: 18478348 doi:10.1007/s10661-008-0291-9
3. Qin LQ, Wang XP, Li W, Tong X, Tong WJ. The minerals and heavy metals in cow’s milk from China and Japan. J Health Sci 2009; 55(2):300-05. doi:10.1248/jhs.55.300
4. Abdulkhaliq A, Swaileh KM, Hussein RM, Matani M. Levels of metals (Cd, Pb, Cu and Fe) in cow’s milk, dairy products and hen’s eggs from the West Bank, Palestine. Int Food Res J 2012; 19(3):1089-94.
5. Sobhanardakani S, Mohammadi Roozbahani M, Sorooshnia R, Karimi H. Assessment of heavy metal contamination in surface soils of Ahvaz IV industrial estate, Khuzestan province, Iran. Iran J Health Sci 2016; 4(1):53-61.
6. Buldini PL, Cavalli S, Sharana, JL. Matrix removal for the ion chromatographic determination of some trace elements in milk.
Microchem J 2002; 72(3):277-84. doi: 10.1016/S0002-265X(02)00039-5

7. Anastasio A, Caggiano R, Macciato M, Paolo C, Ragosta M, Paino S, et al. Heavy metal concentrations in dairy products from sheep milk collected in two regions of southern Italy. Acta Vet Scand 2006; 47(1):69-74. PMCID: PMC1698924 doi: 10.1186/1751-0147-47-69

8. Özcan MM, AL Juhaimi FY. Determination of heavy metals in bee honey with connected and not connected metal wires using inductively coupled plasma atomic emission spectrometry (ICP-AES). Environ Monit Assess 2012;184(4):2373-5. PMID: 21573852 doi:10.1007/s10661-011-2123-6

9. Sobhanardakani S, Kianpour M. Heavy metal levels and potential health risk assessment in honey consumed in the west of Iran. Avicenna J Environ Health Eng 2016; 3(2): e7795.

10. Hussein A, Khaled A. Determination of metals in tuna species and bivalves from Alexandria, Egypt. Egypt J Aquat Res 2014; 40(1):9-17. doi: 10.1016/j.jaqr.2014.02.003

11. Sobhanardakani S, Talebian S, Maanijou M. Evaluation of As, Zn, Pb and Cu concentrations in ground water resources of Toyserkan Plain and preparing the zoning map using GIS. J Mazandaran Univ Med Sci 2014; 24(114):120-30. (Persian)

12. Şireli UT, Gönçüoğlu M, Yıldırım T, Gürkoğlu A, Çakmak O. Assessment of heavy metals (cadmium and lead) in vacuum packaged smoked fish species (mackerel, Salmo salar and Oncorhynchus mykiss) marketed in Ankara (Turkey). Ege J Fish Aquat Sci 2006; 23(3-4):353-6.

13. Sobhanardakani S, Razban SS, Maanijou M. Evaluation of concentration of some heavy metals in ground water resources of Qahavand Plain-Hamedan. J Kermanshah Univ Med Sci 2014; 18(6):339-48.

14. Narin I, Tuzen M, Sari H, Soyak M. Heavy metal content of potato and corn chips from Turkey. Bull Environ Contam Toxicol 2005; 74(6):1072-7. PMID: 16158843 doi: 10.1007/s00128-005-0690-3

15. Öztürk E, Atsan E, Polat T, Kara K. Variation in heavy metal concentrations of potato (Solanum tuberosum L.) cultivars. J Anim Plant Sci 2011; 21(2):235-9.

16. Sobhanardakani S. Health risk assessment of As and Zn in canola and soybean oils consumed in Kermanshah City. J Adv Environ Health Res 2016; 4(2):62-7.

17. Patra RC, Swarup D, Kumar P, Nandi D, Naresh R, Ali SL. Milk trace elements in lactating cows environmentally exposed to higher level of lead and cadmium around different industrial units. Sci Total Environ 2008; 404(1):36-43. PMID: 18657303 doi: 10.1016/j.scitotenv.2008.06.010

18. Meshref AMS, Moselhy WA, El-Houda N, Hassan Y. Heavy metals and trace elements levels in milk and milk products. J Food Meas Charact 2014; 8(4):381-8. doi: 10.1007/s11694-014-9203-6

19. Sobhanardakani S, Tizhosh M. Determination of Zn, Pb, Cd and Cu contents in raw milk from the Khorram Abad dairies. J Food Hyg 2016; 6(2):43-50. (Persian)

20. Al-Ashmawy MAM, Prevalence and public health significance of aluminum residues in milk and some dairy products. J Food Sci 2011; 76(3):T73-6. PMID: 21535864 doi: 10.1111/j.1750-3841.2011.02064.x

21. Falco G, Ilobet J, Bocio A, Domingo JL. Daily intake of arsenic, cadmium, mercury, and lead by consumption of edible marine species. J Agric Food Chem 2006; 54(16):6106-12. PMID: 16881724 doi:10.1021/jf0610110

22. Omar WA, Zaghoul KH, Abdal-Khaled AA, Abo-Hegab S. Risk assessment and toxic effects of metal pollution in two cultured and wild fish species from highly degraded aquatic habitats. Arch Environ Contam Toxicol 2013;65(4):753-64. PMCID:PMC3830742 doi:10.1007/s00244-013-9935-z

23. Tang W, Cheng J, Zhao W, Wang W. Mercury levels and estimated total daily intakes for children and adults from an electronic waste recycling area in Taizhou, China: Key role of rice and fish consumption. J Environ Sci 2015; 34:107-15. PMID: 26257353 doi.org/10.1016/j.jes.2015.01.029

24. Abdi F, Atarodi kashani Z, Mirmiran P, Esteki T. Surveying global and Iranian food consumption patterns: A review of the literature. J Fasa Univ Med Sci 2015; 5(2):159-67.

25. Xue ZJ, Liu SQ, Liu YL, Yan YL. Health risk assessment of heavy metals for edible parts of...
vegetables grown in sewage-irrigated soils in suburbs of Baoding City, China. Environ Monit Assess 2012; 184(6):3503-13. PMID: 21769562 doi: 10.1007/s10661-011-2204-6
26. Liang Q, Xue ZJ, Wang F, Sun ZM, Yang ZX, Liu SQ. Contamination and health risks from heavy metals in cultivated soil in Zhangjiakou City of Hebei Province, China. Environ Monit Assess 2015; 187(12):1547-0. doi: 10.1007/s10661-015-4955-y
27. Zeng X, Wang Z, Wang J, Guo J, Chen X, Zhuang J. Health risk assessment of heavy metals via dietary intake of wheat grown in Tianjin sewage irrigation area. Ecotoxicol 2015; 24(10):2751-6. PMID: 26433741 doi: 10.1007/s11356-015-0550-x
28. Guo J, Yue T, Li X, Yuan Y. Heavy metal levels in kiwifruit orchard soils and trees and its potential health risk assessment in Shaanxi, China. Environ Sci Pollu Res 2016; 23(14):14560-8. PMID: 27068913 doi: 10.1007/s11356-015-6620-6
29. Zhuang P, McBride MB, Xia H, Li N, Li Z. Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, south China. Sci Total Environ 2009; 407(4):1551-61. doi: 10.1016/j.scitotenv.2008.10.061
30. Malhat F, Hagag M, Saber A, Fayz AE. Contamination of cow’s milk by heavy metal in Egypt. Bull Environ Contam Toxicol 2012; 88(4):611-3. PMID: 22323048 doi: 10.1007/s00128-012-0550-x
31. Ibrahim EMA. Cadmium, copper and lead in some kinds of cheeses. Benha Vet Med J 2004; 15(2):55-64.
32. Enb A, Abou Donia MA, Abd-Rabou NS, Abou-Abd AAK, El-Senaity MH. Chemical composition of raw milk and heavy metals behavior during processing of milk products. Glob Vet 2009; 3(3):268-75.
33. Deeb AMM. Trace metals concentrations in cheese collected from Kaf El-Sheikh governorate, Egypt. Assiut Vet Med J 2010; 56(127):75-84.
34. Leggli CVS, Bohrer D, Do Nascimento PC, De Carvalho LM. Flame and graphite furnace atomic absorption spectrometry for trace element determination in vegetable oils, margarine and butter after sample emulsification. Food Addit Contam A 2011; 28(5):640-8. PMID: 21424962 doi: 10.1080/19440049.2011.555843
35. Vahcic N, Hruskar M, Markovic K, Banovic M, Baric IC. Essential minerals in milk and their daily intake through milk consumption. Mljekarstvo 2010; 60(2):77-85.
36. Fahmy BG, Abdel-Fattah SA. Mycological and heavy metals incidence in butter with a trial of these metals elimination. J Egypt Vet Med Assoc 2008; 68(2):179-88.
37. Maas S, Lucot E, Gimbert F, Crini N, Badot P-M. Trace metals in raw cow’s milk and assessment of transfer to Comté cheese. Food Chem 2011; 129(1):7-12. doi: 10.1016/j.foodchem.2010.09.034