RESEARCH
O&G Forum 2024; 34-3s: 2533-2538

HEAVY METAL ASSESSMENT IN POWDER MILK SAMPLES FOR CHILDREN IN KERBELA GOVERNORATE

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Abstract
In this research, six heavy metals such as cobalt (Co), chromium (Cr), selenium (Se), zinc (Zn), lead (Pb), and cadmium (Cd) in children's powder milk used by children at three age-old; first from 1 to 6 month, second from 6 to 12 month, and third from 1 to 2 year. Powder milk samples were collected from local markets in Karbala Governorate, Iraq. Heavy metals were measured using atomic absorption spectrometry. Alas, some of the health risk parameters due to heavy metals in the present study such as Estimation of daily intake, Target Hazard Quotient, Hazard Index, and cancer risk were calculated. The results showed that the average values of Co, Cr, Se, Zn, Pb, and Cd concentration for all samples of powder milk in parts per million (µg/kg) were 100.25±16.69, 32.73±3.66, 79.62±11.38, 78±1.11, 63.92±7.72, and 1.11±0.16, respectively. While, the average values of the Target Hazard Quotient for all samples in the current work were 0.069±0.013, 0.228±0.031, 0.336±0.05, 0.005±0.0003, 0.338±0.052, and 0.021±0.002, respectively. Moreover, the average values of cancer risk due to Pb and Cd in all samples of the present study were 1.13E-05±7.43E-6 and 7.46E-6±8.15E-7, respectively. According to the safe limits of heavy metals recommended by WHO and EPA, the results of Pb concentration in most samples were high. While, the values of health risk parameters did not exceed the permissible limits.
Keyword: heavy metals, powder milk, children, cancer risk, and Iraqi markets.

1. Introduction

Milk is considered one of the main and most important foodstuffs for the growth of children because it contains essential and very important elements and contributes to building bones in children and greatly strengthening bones in people because of the vitamins it contains such as A, B1 and B12, minerals, amino acids, and healthy and essential fats for building the body. Milk can be affected by the presence of some heavy elements that negatively affect the health of children and adults through packaging, such as the precipitation of some elements. Heavy metals in milk, like most food contamination, is heavy metals that are usually toxic when mixed with milk [1]. Heavy metals are of great interest to scientists because their presence in the environment has negative effects on the health of man, animals, and crops. Heavy metals are in food and come from various sources, the most important of which are: contaminated soil in which food for humans and animals is produced; waste sludge, chemical fertilizers and pesticides used in agriculture, the use of materials during milking, storage, and transportation of milk, as well as heavy metal contamination of the food and water ingested by cattle affect the quality of milk [2]. The presence of heavy metals in foods particularly in industrial products is a current issue due to the contamination of the food chain involved and the damage they cause to public health. It is necessary to emphasize that the health risks of the child population need to be evaluated comprehensively, considering the chronic exposure to heavy metals in foods that usually present asymptomatic for a long time of life. some metals, copper, and zinc are necessary at low levels for the normal functioning of living organisms, however, in high concentrations, they can be very toxic [3, 4]. Although the mother's milk is the ideal source of nutrition for infants, there are cases in which mothers must give their children powdered milk for special cases that may affect the mothers, forcing the child to be artificially breastfed [5]. Herein lie the problems if the manufacturing of milk powder does not meet the specifications of international health organizations. In particular, in Iraq, powdered milk is provided to infants as an alternative to breast milk or as a supplement to it due to living conditions, or as an aid and supplement to breast milk, as it is manufactured from animal and plant sources, especially soybeans [6]. Heavy metals are essentially persistent pollutants in the environment that can be harmful to human health. As a result of direct human exposure to toxic metals due to urbanization, industrialization, and increasing population emissions, all of this causes the presence of toxic heavy metals in infant milk, endangering children's health. Symptoms that accompany an increase in heavy metals in children's bodies include low infant body weight, immaturity of the kidneys and liver, decreased ability to remove toxins, and a weak central nervous system, which makes infants particularly vulnerable to toxic pollutants [7]. Several studies of heavy metals in milk in the world [8-10]. This study aims to determine heavy metals (Co, Cr, Se, Zn, Pb, and Cd) and some health risk parameters in powder milk used by children in three categories ages old, 1 month, 6 months, and 12 months.

2. Materials and Methods

2.1. Sample Collection

Fifteen different samples of powdered children's formula were collected from the three ages such as 1-6 months, 6-12 months, and 1-3 years. They were collected from the markets of Karbala Governorate / Iraq from various existing sources, and then the samples were prepared to examine the concentrations of heavy metals within them at the University of Karbala in a laboratory. Faculty of Medicine, Chemistry Branch. Table 1 represents the name of the powdered milk samples used, the symbol for each sample, and the origin of each sample. Shows the age of children for each type of powdered milk sample used.

Table 1. Powder milk samples in the present study

No.	Type of milk	Sample name	Sample code	Origin	Age
1	1	Dialac1	PM1	Vietnam	1-6 month
2		Kikuz1	PM2	philippic	
3		Novalak1	PM3	German	
4		Dovelac1	PM4	France	
5		S26 1	PM5	Singaporean	
6	2	Nido2	PM6	France	6-12 month
7		Evolac2	PM7	Sudia	
8		Eptamil 2	PM8	Singaporean	
9		Babilac2	PM9	France	
10		Dialac2	PM10	Vietnam	
11		Kikuz2	PM11	France	
12		Liptomil2	PM12	Swears	
13		Nutrimilk2	PM13	France	
14	3	Dialac3	PM14	Vietnam	1-3 year
15		S26 3	PM15	Singaporean	

2.2. Samples digestion

Work was done to measure the heavy elements by taking (5) grams of powdered milk for each type separately using an accurate balance and adding it to (5) ml of ionized water. They were mixed well using a vortex device, then taking (1) ml of the solution, (1) ml of the modified solution was added to the milk solution and left for (24) hours in a special tube. Then the solution was shaken well through the vortex device again for (30) seconds, and then the solution was filtered through a filter with a diameter of (45%) microns, then put an amount of (20) microns using a pipette, then take the filtered solution and placed in an atomic absorption spectrometer, through which the concentration of the following heavy elements (Co, Cr, Se, Zn, Pb, and Cd) was measured for each type of milk.

2.3. Analysis of the heavy metals

Instrumental analysis of Co, Cr, Se, Zn, Pb, and Cd was conducted by air acetylene Flame Atomic Absorption Spectrophotometer (Shimadzu model AA-6300). The values of wavelength in nm for Co, Cr, Se, Zn, Pb, and Cd were 240.73, 422.7, 196.03, 360.12, 217.00, and 228.80, respectively.

2.4. Health risk assessment

The Estimation daily intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI) of heavy metals were calculated to appreciate the non-carcinogenic risks associated with the consumption of heavy metals in powder milk. The EDI was calculated according to Eq. (1-3) [11-14].

$$EDI\ (\mu g/kg\ per\ day) = \frac{C(\frac{\mu g}{kg}) \times D(\frac{kg}{day})}{BW(kg)} \quad (1)$$

$$THQ = \frac{EDI\ (\frac{\mu g}{kg}\ per\ day)}{RfD(\frac{\mu g}{kg}\ per\ day)} \quad (2)$$

$$HI = \mathrm{THQ}_1 + \mathrm{THQ}_2 + \cdots + \mathrm{THQ}_n = \sum_1^n \mathrm{THQ}_n \quad (3)$$

Where, C is the concentration of heavy metals in powder milk (μg/kg), D is the daily consumption of powder milk for each kg, BW is the average body weight, and RfD is the oral reference dose in μg/kg per day. The values of D in 1-month-old, 6-month-old, and 12-month-old were 120 g/day, 140 g/day, and 105 g/day, respectively, while the values of BW were 4.2 kg, 7.5 kg, and 10 kg, respectively [15]. Moreover, the values of RfD for each heave metal were Co =30, Cr = 3, Se = 5, Zn = 300, Pb = 4, and Cd = 1 [16].

The Cancer risk over time and cumulative cancer risk of heavy metals were calculated to appreciate the carcinogenic risks associated with the consumption of heavy metals in powder milk. The EDI was calculated according to Eq. (4) [17,18].

$$CR = EDI\left(\frac{\mu g}{kg}\ per\ day\right) \times CSF\ (\frac{\mu g}{kg} per\ day)^{-1} \quad (4)$$

Where, CSF is the cancer slope factor. Pb and Cd had oral cancer slope factors of 8.5E-06 and 3.8E-04, respectively [17]. The cumulative cancer risk from exposure to numerous carcinogenic heavy metals through canned milk consumption was considered the total of the individual heavy metal incremental hazards and calculated as indicated in the following equation using a constructed Eq. (5) [17,18]:

$$\text{Total cancer risks} = \mathrm{CR}_1 + \mathrm{CR}_2 + \cdots + \mathrm{CR}_n = \sum_1^n \mathrm{CR}_n \quad (5)$$

3. Result and discussion

Table 2 shows the results of six heavy metals (Co, Cr, Se, Zn, Pb, and Cd) of a sample of powder milk for the age of children who consume this type, according to the age of the children for each type of milk. From Table 2, It showed that the average values of Co, Cr, Se, Zn, Pb, and Cd concentrations (ppb or μg/kg) in the first age group (1-6 months) were 101.88, 33.24, 84.52, 78.10, 70.90, and 0.76, respectively, for the second age group (6-12 months) were 83.24, 33.21, 70.84, 77.67, 62.69, and 1.37, respectively. While, the average concentrations in the third age group (1-3 years) were 109.55, 32, 77.85, 78.65, 67.4, and 1.45, respectively. Also, it is found that (Table 2), the maximum values of concentration for Co, Cr, Se, Zn, pb, and Cd in all samples of powder milk in the present study were 192 μg/kg ,61 μg/kg ,140 μg/kg,83 μg/kg ,125 μg/kg , and 2.6 μg/kg, respectively, while, the minimum values were 12 μg/kg, 9 μg/kg, 16 μg/kg, 66 μg/kg, 5 μg/kg, and 0.2 μg/kg, respectively. Moreover, the average value with stander error of concentration (in unit μg/kg) for Co, Cr, Se, Zn, pb, and Cd in all samples in the present study were100.25±16.69, 32.73±3.66, 79.62±11.38, 78±1.11, 63.92±7.72, and 1.11±0.16, respectively. The maximum permissible limit (safe limit) value according to the World Health Organization for the concentrations of Co, Cr, Se, Zn, Pb, and Cd in unit ppb (μg/kg) were 190, 300, 500, 920, 20, and 2.6, respectively [19, 20]. Therefore, the results of the concentrations of Co, Cr, Se, Zn, Pb, and Cd in powder milk samples of the present research were within the safe limit value according to the World Health Organization, except the results of Co element in sample (M13) and Pb concentration for most samples. Several reasons contribute to the high recorded values of Co and Pb in some powder milk samples, such as transferring through water and food to animals, contamination during manufacturing, and chemistry affinity towards particular ingredients.

Table 2. Results of heavy metals Concentration in milk powder samples.

No.	Sample code	Age	Concentrations of heavy metals (ppb or µg/kg)					
			Co	**Cr**	**Se**	**Zn**	**pb**	**Cd**
1	PM1	1-6 months	157	13.4	59.5	78.7	55.4	1
2	PM2		23	28.5	21.4	76.9	27.3	0.2
3	PM3		166.7	39.1	132.2	81.1	92.2	0.5
4	PM4		12.3	32.1	69.4	78.4	106.7	1.1
5	PM5		150.4	53.1	140.1	75.4	72.9	1
6	PM6	6-12 months	109.5	61.7	50.2	82.7	125.5	1.8
7	PM7		49.4	32.2	117.2	82.4	48.1	1
8	PM8		29.4	9.8	68.2	66.8	50.9	1.2
9	PM9		41.4	16	27.8	75.3	5.9	1.4
10	PM10		44.7	49.3	49.2	83.5	86.1	2.1
11	PM11		127.8	34.1	51	79.7	60.6	0.9
12	PM12		180.5	29.4	132.3	73.3	61.7	1.2
13	PM13		192.6	28.3	120.1	78.5	30.8	0.4
14	PM14	1-3 years	43.4	21.4	16.3	82.7	74.8	0.3
15	PM15		175.7	42.6	139.4	74.6	60	2.6
Average		1-6 months	101.88	33.24	84.52	78.10	70.90	0.76
Average		6- 12 months	83.24	33.21	70.84	77.67	62.69	1.37
Average		1-3 years	109.55	32	77.85	78.65	67.4	1.45
Average±S.E		All	100.25±16.69	32.73±3.66	79.62±11.38	78±1.11	63.92±7.72	1.11±0.16
Safe limit [19,20]			190	300	500	920	20	2.6

Table 3 shows the results of the estimation of daily intake due to the amount of heavy metals in powdered milk in the present study consumption by children. Table 3, Shows that the average values of estimation daily intake due to Co, Cr, Se, Zn, Pb, and Cd concentrations (µg/kg per day) in the first age group (one month) were 2.911, 0.950, 2.415, 2.231, 2.026, and 0.022, respectively, for the second age group (6 months) were 1.55, 0.62, 1.32, 1.45, 1.17, and 0.03, respectively. While, the average concentrations in the third age group (12 months) were 1.1505, 0.336, 0.8175, 0.8255, 0.7075, and 0.015, respectively. While, the average value with stranded error of estimation daily intake due to Co, Cr, Se, Zn, Pb, and Cd concentrations (µg/kg per day) in all samples of the present study were 2.088±0.40, 0.685±0.095, 1.680±0.281, 1.628±0.12, 1.354±0.21, and 0.021±0.002, respectively. It noted that the results of the estimation of daily intake (µg/kg/day) due to heavy elements present in the children's powder milk used in this research, and according to the weight of the child and the amount that the children eat, is within the permissible limits of world toxic heavy metals of Co, Cr, Se, Zn, Pb, and Cd which are 30, 3, 5, 300, 4, and 1, respectively [21], which means that all powder samples are safe.

Table 3. Results of Estimation daily intake milk powder samples

No.	Sample code	Age	Estimation daily intake (µg/kg per day)					
			Co	**Cr**	**Se**	**Zn**	**pb**	**Cd**
1	PM1	1	4.486	0.383	1.700	2.249	1.583	0.029
2	PM2		0.657	0.814	0.611	2.197	0.780	0.006
3	PM3		4.763	1.117	3.777	2.317	2.634	0.014
4	PM4		0.351	0.917	1.983	2.240	3.049	0.031
5	PM5		4.297	1.517	4.003	2.154	2.083	0.029
6	PM6	6	2.044	1.152	0.937	1.544	2.343	0.034
7	PM7		0.922	0.601	2.188	1.538	0.898	0.019
8	PM8		0.549	0.183	1.273	1.247	0.950	0.022
9	PM9		0.773	0.299	0.519	1.406	0.110	0.026
10	PM10		0.834	0.920	0.918	1.559	1.607	0.039
11	PM11		2.386	0.637	0.952	1.488	1.131	0.017

12	PM12		3.369	0.549	2.470	1.368	1.152	0.022
13	PM13		3.595	0.528	2.242	1.465	0.575	0.007
14	PM14	12	0.456	0.225	0.171	0.868	0.785	0.003
15	PM15		1.845	0.447	1.464	0.783	0.630	0.027
Average		1	2.911	0.950	2.415	2.231	2.026	0.022
Average		6	1.55	0.62	1.32	1.45	1.17	0.03
Average		12	1.1505	0.336	0.8175	0.8255	0.7075	0.015
Average±S.E		All	2.088±0.40	0.685±0.095	1.680±0.281	1.628±0.12	1.354±0.21	0.021±0.002
Safe limit [22]			**30**	**3**	**5**	**300**	**4**	**1**

Table 4 shows the results of the Target Hazard Quotient and Hazard Index due to the amount of heavy metals in powdered milk in the present study consumption by children. Table 4, shows that the average values of Target Hazard Quotient due to Co, Cr, Se, Zn, Pb, and Cd concentrations in the first age group (one month) were 0.097, 0.317, 0.483, 0.007, 0.507, and 0.022, respectively, for the second age group (6 months) were 0.05, 0.21, 0.26, 0.00, 0.29, and 0.03, respectively. While, the average concentrations in the third age group (12 months) were 0.038, 0.112, 0.1635, 0.003, 0.177, and 0.015, respectively. While, the average value with the stranded error of Target Hazard Quotient due to Co, Cr, Se, Zn, Pb, and Cd concentrations in all samples of the present study were 0.069±0.013, 0.228±0.031, 0.336±0.05, 0.005±0.0003, 0.338±0.052, and 0.021±0.002, respectively. The average value of the Hazard Index in the first age group (one month), the second age group (6 months), the third age group (12 months), and all age groups were 0.526, 0.32, 0.19, and 0.358 ±0.053, respectively. It noted that the results of the Target Hazard Quotient and Hazard Index due to heavy elements present in the children's powder milk used in this research were within the permissible limits of world toxic heavy metals, which is equal to or higher than 1 [23].

Table 4. Results of Target Hazard Quotient and Hazard Index in milk powder samples.

No.	Sample code	Month old	Target Hazard Quotient						Hazard Index
			Co	**Cr**	**Se**	**Zn**	**pb**	**Cd**	
1	PM1	1	0.150	0.128	0.340	0.007	0.396	0.029	0.42
2	PM2		0.022	0.271	0.122	0.007	0.195	0.006	0.20
3	PM3		0.159	0.372	0.755	0.008	0.659	0.014	0.67
4	PM4		0.012	0.306	0.397	0.007	0.762	0.031	0.79
5	PM5		0.143	0.506	0.801	0.007	0.521	0.029	0.55
6	PM6	6	0.068	0.384	0.187	0.005	0.586	0.034	0.62
7	PM7		0.031	0.200	0.438	0.005	0.224	0.019	0.24
8	PM8		0.018	0.061	0.255	0.004	0.238	0.022	0.26
9	PM9		0.026	0.100	0.104	0.005	0.028	0.026	0.05
10	PM10		0.028	0.307	0.184	0.005	0.402	0.039	0.44
11	PM11		0.080	0.212	0.190	0.005	0.283	0.017	0.30
12	PM12		0.112	0.183	0.494	0.005	0.288	0.022	0.31
13	PM13		0.120	0.176	0.448	0.005	0.144	0.007	0.15
14	PM14	12	0.015	0.075	0.034	0.003	0.196	0.003	0.20
15	PM15		0.061	0.149	0.293	0.003	0.158	0.027	0.18
Average		1	0.097	0.317	0.483	0.007	0.507	0.022	0.526
Average		6	0.05	0.21	0.26	0.00	0.29	0.03	0.32
Average		12	0.038	0.112	0.1635	0.003	0.177	0.015	0.19
Average±S.E		All	0.069±0.013	0.228±0.031	0.336±0.05	0.005±0.0003	0.338±0.052	0.021±0.002	0.358 ±0.053
Safe limit			**1**	**1**	**1**	**1**	**1**	**1**	**1**

Table 5 shows the results of cancer risk due to Pb and Cd concentration as well as total cancer risk for three types of powdered milk used and for each age group selected. Table 5, shows that the average values of cancer risk due to Pb, Cd concentrations, and total elements (Pb+Cd) in the first age group (one month) were 1.74E-05, 7.40E-06, and 2.58E-05, respectively, for the second age group (6 months) were 9.56E-06, 8.71E-06, and2.00E-05, respectively. While, the average concentrations in the third age group (12 months) were 0.038, 6.00E-06, 5.50E-06, and 1.40E-05, respectively. While, the average value with the stranded error of cancer risk due to Pb, Cd concentrations, and total elements (Pb+Cd) in all samples of the present study were 1.13E-05±7.43E-6, 7.46E-6±8.15E-7, and 2.03E-5±9.68E-6, respectively. It noted that the results of the cancer risk and total cancer risk due to Pb and Cd elements present in the children's powder milk used in this research were within the permissible limits of world toxic heavy metals, which is equal to the range 1.00E-06 to 1.00E-04 [24].

Table 5. Results of Cancer risk and total Cancer risk in milk powder samples.

No.	Sample code	Month old	Cancer risk		Total cancer risk
			pb	Cd	
1	PM1	1	1E-05	1E-05	2E-05
2	PM2		7E-06	2E-06	9E-06
3	PM3		2E-05	5E-06	3E-05
4	PM4		3E-05	1E-05	4E-05
5	PM5		2E-05	1E-05	3E-05
6	PM6	6	2E-05	1E-05	3E-05
7	PM7		8E-06	7E-06	1E-05
8	PM8		8E-06	9E-06	2E-05
9	PM9		9E-07	1E-05	1E-05
10	PM10		1E-05	1E-05	3E-05
11	PM11		1E-05	6E-06	2E-05
12	PM12		1E-05	9E-06	2E-05
13	PM13		5E-06	3E-06	8E-06
14	PM14	12	7E-06	1E-06	8E-06
15	PM15		5E-06	1E-05	2E-05
Average		1	1.74E-05	7.40E-06	2.58E-05
Average		6	9.56E-06	8.71E-06	2.00E-05
Average		12	6.00E-06	5.50E-06	1.40E-05
Average±S.E		All	1.13E-05±7.43E-6	7.46E-6±8.15E-7	2.03E-5±9.68E-6
Safe limit [24]			1.00E-06-1.00E-04		

Ensuring the safety of milk production is vital to promote increased consumption. Heavy metals like Co, Cr, Se, Zn, Pb, and Cd must be closely monitored due to their adverse impact on organ functions. Elevated lead levels during pregnancy are linked to low birth weight and reduced physiological indicators in newborns, affecting long-term neurological development in children. The International Agency for Research on Cancer classifies cadmium as a Group 1 carcinogen, while inorganic lead is a Group 2 carcinogen and is considered a priority contaminant in food [25]. Given the persistent nature of lead and cadmium, their potential transfer into the food chain poses significant risks, necessitating ongoing evaluation of their presence in milk and associated consumption risks. Excessive consumption of milk that contains high levels of heavy metals hurts the health of children. This interpretation agreed with a previous study [8-10].

4. Conclusion

The results of the concentrations of chromium (Cr), selenium (Se), zinc (Zn), and cadmium (Cd) in all of the powder milk samples for each age-old group in the present study in Kerbala governorate were within the safe limit allowed by World Health Organization and European Regulation limits, while the most of the samples had lead (Pb) concentrations were high. Also, the cobalt (Co) concentrations in the sample (M13) witnessed an increase in the percentage of cobalt by (192.6) µg/kg above the normal limit, which was (190) µg/kg, which was specified by the World Health Organization, and this is very worrying because cobalt is a toxic substance if its concentration exceeds the normal limit in the body which it is equal one. The health risk parameters due to heavy metals in the present study such as Estimation daily intake, Target Hazard Quotient, Hazard Index, and cancer risk of milk samples of the present study for each age within the corresponding oral reference dose in all samples. Therefore, it can be concluded from the results of this research that the health risk due to the concentration of heavy metals in children's powder milk in Iraqi markets in Kerbela city was safe.

References

1. *Manoj Kumar, C. T., Chauhan, O. P., Sathish Kumar, M. H., & Devaraja, H. C. (2022). Chemistry of Milk and Milk Products. In Advances in Food Chemistry: Food Components, Processing and Preservation (pp. 471-495). Singapore: Springer Nature Singapore.*
2. *Bánfalvi, G. (2011). Cellular effects of heavy metals (pp. 3-28). New York, NY, USA:: Springer.*
3. *Taher, F. A., & Abojassim, A. A. (2023). Assessment of Heavy Metals in Biscuit Samples Available in Iraqi Markets. Biological Trace Element Research, 1-9.*
4. *Abojassim, A. A., & Munim, R. R. (2020). Chapter-4 Hazards of Heavy Metal on Human Health. MULTIDISCIPLINARY, 51.*
5. *Koller, M., & Saleh, H. M. (2018). Introductory chapter: Introducing heavy metals. Heavy metals, 1, 3-11.*
6. *Bharti, R., & Sharma, R. (2022). Effect of heavy metals: An overview. Materials Today: Proceedings, 51, 880-885.*
7. *Muneam, R., & Abojassim, A. A. (2023). Assessment of Health Risks for Heavy Metals in Iraqi, Iranian and Turkish of Cheese Samples Available of Iraqi Markets. Jordan Journal of Physics, 16(4), 491-500.*
8. *Aggarwal, A., Verma, T., & Ghosh, S. (2022). Heavy Metal Residues in Milk and Milk Products and Their Detection Method. In Trends and Innovations in Food Science. IntechOpen.*
9. *Boudebbouz, A., Boudalia, S., Bousbia, A., Gueroui, Y., Boussadia, M. I., Chelaghmia, M. L., ... & Symeon, G. K. (2023). Determination of heavy metal levels and health risk*

assessment of raw cow milk in Guelma Region, Algeria. Biological Trace Element Research, 201(4), 1704-1716.

10. Movassaghghazani, M., & Shabansalmani, N. (2024). Assessment of Aflatoxin M1 in human breast and powdered milk in Tehran, Iran. Toxicon, 237, 107530.

11. Elafify, M., Marwa, E. T., Sallam, K. I., Sadoma, N. M., Abd-Elghany, S. M., Abdelkhalek, A., & El-Baz, A. H. (2023). Heavy metal residues in milk and some dairy products with insight into their health risk assessment and the role of Lactobacillus rhamnosus in reducing the lead and cadmium load in cheese. Food Chemistry Advances, 2, 100261.

12. Abojassim, A. A., & Muneam, R. R. (2023). Assessment of health risk due to Pb, Cd, and Cr concentrations in imported cheese samples in Iraq markets. Kuwait Journal of Science, 50(3B).

13. US EPA, & IRIS. (2021). Chemical search |IRIS|US EPA. https://cfpub.epa. gov/ncea/iris/searc h/index.cfm.

14. US EPA. (2021). NATA glossary of terms. https://www.epa.gov/natio nal-air-toxics-asses sment/ nata-gloss ary-terms.

15. Elaridi, J., Dimassi, H., Al Yamani, O., Estephan, M., & Hassan, H. F. (2021). Determination of lead, cadmium and arsenic in infant formula in the Lebanese market. Food Control, 123, 107750.

16. USEPA (United States Environmental Protection Agency). Risk-BasedConcentrations Table. USEPA (2014). Available online at: http://www.epa.gov/reg3hwmd/risk/human/index.htm.

17. Okpashi, V. E. (2022). Health Risk of Ingested Heavy Metals in Fluidized Canned Milks: Are We Drinking Heavy Metals?. Journal of Food Quality, 2022:1-8.

18. Liu, X., Zhang, A., Ji, C., Joseph, S., Bian, R., Li, L., ... & Paz-Ferreiro, J. (2013). Biochar's effect on crop productivity and the dependence on experimental conditions—a meta-analysis of literature data. Plant and soil, 373, 583-594.

19. FAO/WHO, 2012. In: Organization FaAOWH (Ed.), Joint FAO/WHO Food Standards Program:Codex Committee on Contaminants in Foods (Editorial Amendments to the General Standard for Contaminants and Toxins in Food and Feed) CX/CF 12/6/11.

20. FAO/WHO Jo int Food Standards Programme, Codex Committee e on Contaminants in Foods, Eighth Session The Hague, The Netherlands, 31 March – 4 April 201 4 (Prepared by Japan and the Netherlands.

21. EC, (2001). COMMISSION REGULATION," Off. J. Eur. Communities, 466.

22. Tripathi, R. M., Raghunath, R., Sastry, V. N., & Krishnamoorthy, T. M. (1999). Daily intake of heavy metals by infants through milk and milk products. Science of the total environment, 227(2-3), 229-235.

23. Islam, M.S., Ahmed, M.K. (2014). Habibullah-Al-Mamun, M., and Masunaga, S., Environ. Monit. Assess., 186 (12) 8727.

24. EPA (1989), "Risk-assessment Guidance for Superfund", Volume 1, Human health evaluation manual, Part A, Interim report (Final) (No. PB-90-155581/XAB; EPA-540/1-89/002), (Environmental Protection Agency, Washington DC, USA, Office of Solid Waste and Emergency Response, 1989).

25. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Radiation. IARC Monogr Eval Carcinog Risks Hum. 2012;100(Pt D):7-303. PMID: 23189752; PMCID: PMC4781534.