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Review Article

Review of Toxic Trace Elements Contamination in Some Animal Food Products in Different Countries

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Abstract

Meat, chicken, eggs and milk are all important foods worldwide because of their energetic and nutritious constituents beneficial to human health. This review aims to analyze the results of the studies carried out on the contamination of these foods (meat, chicken, eggs and milk) by the toxic trace elements As, Cd and Pb in different countries, and to compare their values with the international regulatory limits. According to the data of the various studies analyzed, all the studied matrices have been contaminated with these toxic metals. The concentrations reported differ for each matrix according to their analyzed tissues, their geographical location, their age and the food types chosen. The concentrations involved also are highly dependent on the studied trace element. Most of the reported concentrations in these foods exceed the international regulatory thresholds. Therefore, it is important to perform regular monitoring studies for all these foodstuffs along with corresponding health risk assessment estimates as well as carrying out studies to better identify the origin of the high levels of these contaminants and seek solutions to prevent major human poisonings and to ensure the safety of these foods.

Keywords: Environmental contaminants, Food, Heavy metals, Health risk assessment, Regulatory thresholds

Introduction

Food such as meat, poultry, eggs and milk are a fundamental source of high quality animal proteins with bioactive peptides, lipids, minerals and vitamins (vitamins B3, B6, B12, and D) which provide adequate energy for daily needs and are essential for the growth and well-being of human beings [1-4]. But these foods can be contaminated by several environmental contaminants such as toxic trace elements [1]. Trace elements are "metallic and non-metallic" chemical elements that are found in the environment in small quantities (less than 100 mg/kg) and are found in different chemical forms, they have a higher density than water [5,6]. Among these trace elements, some are essential and are required by the organism in small quantities to ensure its proper physiological functioning such as copper (Cu), nickel (Ni), zinc (Zn), iron(Fe) and manganese (Mn) [7-9]. In contrast to these essential trace elements, the toxic trace elements have no physiological role and are classified in the list of the most toxic substances known, i.e. arsenic (As), cadmium (Cd) and lead (Pb) [1,2,7,8]. These latter elements are a major health and food safety concern which pose a large threat to the environment and human health due to their toxicity, persistence and non-biodegradability in the environment as well as bioaccumulation in the food chain [10-13]. Trace element pollution can originate from natural sources such as soil erosion and volcanoes and from anthropogenic activities including mining, smelting, wastewater disposal, and industrial discharges *(Fig. 1)*. The means of transport that release the trace elements, and the application of pesticides and fertilizers are the major sources of exposition [2,6,7]. Once in the environment, they can readily be introduced into plants, animal tissue and humans *(Fig. 1)* [2]. Dietary intake is considered the primary route of human exposure to toxic trace elements (50%), compared to other exposure routes [2]. These toxic trace elements in the body can lead to undesirable chronic effects; e.g. arsenic typically causes nervous, gastro-intestinal, cardiovascular, renal, pulmonary, reproductive disorders, and keratosis, melanosis and other skin disorders as well as cancers of various organs (liver, kidney and intestines) [14-17]. Exposure to cadmium causes kidney, liver, lung, and neurological and bone damage (itai - itai diseases) [18,19]. Cd causes damage to the placenta which leads to infertility, congenital malformations and

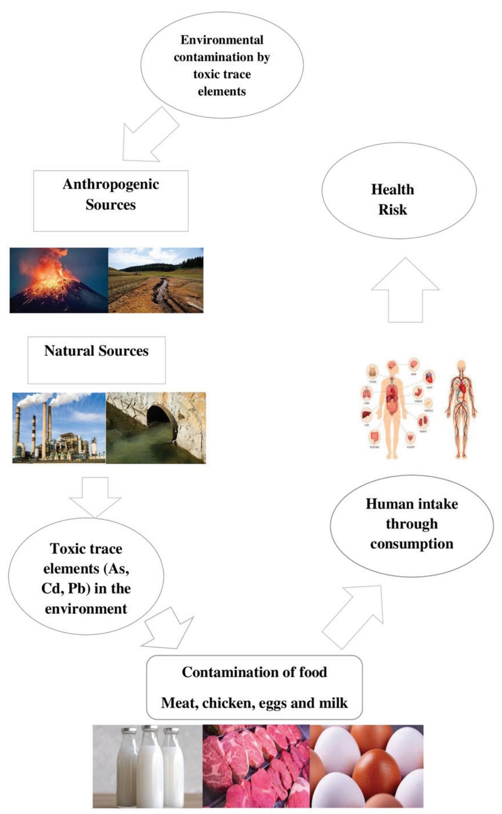

Fig 1. Sources of Toxic trace elements in the environment and contamination of food and their humain impact

abortion; in males, the damage caused by Cd has resulted in decreased sperm motility, testicular deformation and prostate cancer [19]. Exposure to Pb can cause neurological disorders that are expressed by symptoms such as learning and pronunciation problems, memory loss, depression and general fatigue [12,20,21]. It also causes other problems such as gastrointestinal disorders and anemia [21]. Thus, this review aims to analyze and evaluate the results obtained in different studies on the levels of trace element contamination of meat, chicken, eggs and milk by these three toxic elements As, Cd and Pb, and to compare concentrations with the regulatory limits to assess if they constitute a health risk for the consumer. The articles used in this study to analyze and evaluate previous studies are 55 research articles representing 10% of total papers collected from four main datavases which are Google Scholar, SNDL (National System of Online Documentation), PubMed, and ResearchGate. The 55 research articles were chosen since they precisely met our criterion of the analysis of critical toxic trace elements in foods from animal origin that we intended to examine. The period of download was from April 2023 to November 2023. These collected and analyzed articles come from different continents: Asia, Africa, Europe and America, with those from Asia being the most numerous.

Toxic Trace Elements in Food

Concentration of As, Cd and Pb in Different Tissues of Chicken

The results of the literature *(Table 1)* on the concentrations of As, Cd and Pb are very different in each tissue analyzed, in each species of chicken studied and also in each region of origin. For As, the highest concentration was reported by Bazzaz et al.[22] in the thigh and the breast meat of cock from Brazil (1.82 and 1.82 mg/kg w.w., respectively) and Türkiye (1.57 and 1.77 mg/kg w.w., respectively), respectively. The same authors showed that breast meat accumulates As more than thigh meat, which would support the observations that As concentrations vary according to muscle type for the same animal species Mottalib et al. [23]. reported that the highest concentrations of As in liver (0.94 mg/kg w.w.) in the broiler chicken from Bangladesh and the concentrations were not the same in the three species studied. The lowest concentration of As (0.06 mg/ kg w.w.) was measured by Uluozlu et al.[24] in kidney and liver of the cock chicken from Türkiye. These maximum concentrations in the liver of the majority of the results compared to other tissues could be related to the important role liver plays in trace element metabolism. In the case of Cd, Kamaly and Sharkawy [25] registered the highest concentrations in the meat of six brands of chicken (14; 13.01; 10.93; 10.15; 9.63; 5.87 mg/kg w.w.) which were higher than those in the liver (0.01; 0.02; 0.03; 0.05

Table 1. *Summary of the concentrations of trace elements in different parts of chicken*

Trace Elements	Type of Chicken (local names)	Tissues	Concentration (mg/kg wet weight)	Countries	References
As	Cock	Heart	0.06	Türkiye	Uluozlu et al.[24]
		Kidney	0.09		
		Liver	0.06		
		Meat	0.07		
		Breast	0.45	Bangladesh	Mottalib et al.[23]
		Liver	0.37		
	Broiler	Breast	0.63		
		Liver	0.94		
	Layer	Breast	0.21		
		Liver	0.24		
	Broiler	Meat	0.04	Bangladesh	Ullah et al.[28]
	Local		0.04		
	Sonali		0.04		
	Cock	Meat	0.19	Malaysia	Abduljaleel et al.[27]
		Liver	0.51		
		Tight	1.57	Türkiye	Bazzaz et al.[22]
		Breast	1.77		
		Tight Breast	1.82 1.82	Brazil	
		Meat	0.43	Bangladesh	Ahmed et al.[29]
		Meat	0.02	Brazil	Ng et al.[30]
		Meat	0.31	India	Das et al.[31]
		Meat	0.43	Bangladesh	Shaheen et al.[32]
Cd	Cock	Heart	0.25	Türkiye	Uluozlu et al.[24]
		Kidney	0.25		
		Liver	2.24		
		Meat	6.09		
		Heart	0.70	Türkiye	Yilmaz and Gecgel [33]
		Liver	0.05		
		Meat	0.01		
	Broiler	Meat	0.01	Bangladesh	Ullah et al.[28]
	Local		0.01		
	Sonali		0.01		
	Cock	Meat	0.23	Bangladesh	Shaheen et al.[32]
		Meat	0.15	Malaysia	Abduljaleel et al.[27]
		Liver	0.15		
	Brands 1 of poultry	Meat	5.87	Egypt	Kamaly and Shakawy [25]
		Liver	0.05		
	Brands 2 of poultry	Meat	0.63		
		Liver	0.01		
	Brands 3 of poultry	Meat	13.01		
		Liver	0.02		
	Brands 4 of poultry	Meat	14.00		
		Liver	10.93		
	Brands 5 of poultry	Meat	0.03		
		Liver	0.02		
	Brands 6 of poultry	Meat	10.15		
		Liver	0.03		
	White cornish	Meat	0.04	Egypt	Elsharawy [34]
	Layer	Liver	0.06	Egypt	El Bayomi et al.[26]
		Meat	0.06		
	Broiler	Liver	0.10		
		Meat	0.09		

Table 1. *Summary of the concentrations of trace elements in different parts of chicken (continued)*

Trace Elements	Type of Chicken (local names)	Tissues	Concentration (mg/kg wet weight)	Countries	References
Pb	Cock	Heart	0.04	Türkiye	Uluozlu et al.[24]
		Kidney	0.02		
		Liver	0.12		
		Meat	0.40		
		Heart	0.01	Türkiye	Yilmaz and Gecgel [33]
		Liver	0.03		
		Meat	0.02		
	Broiler	Meat	0.59	Bangladesh	Ullah et al.[28]
	Local		0.64		
	Sonali		1.02		
	Cock	Meat	0.37	Bangladesh	Shaheen et al.[32]
	Brand 1 of poultry	Meat	0.10	Egypt	Kamaly and Sharkawy [25]
		Liver	2.57		
	Brands 2 of poultry	Meat	0.03		
		Liver	3.15		
	Brands 3 of poultry	Meat	0.04		
		Liver	2.56		
	Brands 4 of poultry	Meat	0.04		
		Liver	2.58		
	Brands 5 of poultry	Meat	0.02		
		Liver	0.03		
	Brands 6 of poultry	Meat	0.30		
		Liver	5.55		
	White cornish	Meat	0.30	Egypt	Elsharawy [34]
	Cock	Tight	0.43	Türkiye	Bazzaz et al.[22]
		Breast	0.49		
		Tight	0.55	Brazil	
		Breast	0.50		
		Meat	0.21	Malaysia	Abduljaleel et al.[27]
		Liver	0.35		
	Layer	Liver	0.21	Egypt	El Bayomi et al.[26]
		Meat	0.10		
	Broiler	Liver	0.34		
		Meat	0.31		

As: Arsenic, Cd: Cadmium, Pb: Lead

mg/kg w.w.). Uluozlu et al.[24] also recorded the highest concentration of Cd in the meat of cock chicken from Türkiye (6.09 mg/kg w.w.). This could be a function of the strong assimilation of this metal in the muscle compared to that in the other organs (liver, kidney heart).

Regarding the levels of Pb, the authors reported different concentrations depending on the tissues and chicken species studied as well as the area of origin *(Table 1)*. Kamaly and Sharkawy[25] measured the highest concentration of Pb in the liver of the six brands of cock from Egypt. The liver accumulates more Pb than other tissues in cock [25-27]. This is linked to the role of the liveras an organ of metabolism, which is why it is the most important target for this metal.

Concentrations of As, Cd and Pb in Meat of Cattle and Sheep

The studies examined have found different concentrations of As in cattle meat *(Table 2)*, the highest of which (5.6 and 3.7 mg/kg w.w.) were recorded by Sathyamoorthy et al.[10] in India. Adjei et al.[35] registered a differences in values from four study sites where the highest was 0.28 mg/kg w.w. and the lowest 0.00 mg/ kg w.w. which was the lowest concentration recorded compared to the others results. For As in sheep, the highest concentration (0.34 mg/kg w.w.) was measured by Abd-Elghany et al.[36] in Kuwait and the lowest concentrations (0.00 mg/kg w.w.) were registered by Xiang et al.[37] from China. Regarding Cd concentrations in meat of cattle, Sathyamoorthy et al.[10] in India reported the highest concentrations (6.6 and 5.1 mg/kg w.w.) whereas the lowest concentration was recorded by Di Bella et al.[38] in Italy where the value was below the limit of detection (*ND*) *(Table 2)*. The highest concentration of Cd in the meat of sheep (0.23 mg/kg w.w.) was reported by Raeeszadeh et al.[39] in Iran and the lowest concentrations (0.00 mg/ kg w.w.) was obtained

Table 2. *Summary of the concentrations of trace elements in meat of cattle and sheep*

Trace Elements	Type of Meat		Concentrations (mg/kg wet weight)		Countries	References
As	Cattle		0.01		Italy	Di Bella et al.[38]
			2.73		Bangladesh	Chowdhury et al.[41]
			0.00		Ghana	Nkansah and Ansah [43]
			3.7	Site 1	India	Sathyamoorthy et al.[10]
			5.6	Site 2		
			0.28	Site 1	Ghana	Adjei et al.[35]
			0.00	Site 2		
			0.00	Site 3		
			0.01	Site 4		
			0.57		Bangladesh	Shaheen et al.[32]
	Sheep		0.23		Iran	Raeeszadeh et al.[39]
			0.01		Ghana	Nkansah and Ansah [43]
			0.34		Kuwait	Abd-Elghany et al.[36]
		Shoulder clod	0.00		China	Xiang et al.[37]
		Tenderloin	0.00			
		Neck	0.00			
		Rump	0.00			
		Mutton tripe	0.00			
		Intercostal meat	0.00			
			0.14		Bangladesh	Shaheen et al.[32]
Cd	Cattle		ND		Italy	Di Bella et al.[38]
			0.02		Thailand	Jankeaw et al.[44]
			0.00		Ghana	Adzitey et al.[45]
			0.01		Bangladesh	Kamal et al.[46]
			0.4		Uganda	Kasozi et al.[40]
			0.00		Bangladesh	Chowdhury et al.[41]
			0.07		Ghana	Nkansah and Ansah [43]
			0.00		Nigeria	Sabuwa and Nafarnda [48]
			6.6	Site 1	India	Sathyamoorthy et al.[10]
			5.1	Site 2		
			0.10		Site 1	Adjei et al.[35]
			0.05		Site 2	
			0.04		Site 3	
			0.00		Site 4	
			0.12		Bangladesh	Shaheen et al.[32]
	Sheep	Young	0.03		Egypt	Darwish et al.[42]
		Aged	0.06			
			0.23		Iran	Raeeszadeh et al.[39]
			0.01		Ghana	Nkansah and Ansah [43]
			0.30		Kuwait	Abd-Elghany et al.[36]
			0.14		Bangladesh	Shaheen et al.[32]
			0.01		Egypt	Abou-Arab [47]
		Shoulder clod	0.00		China	Xiang et al.[37]
		Tenderloin	0.00			
		Neck	0.00			
		Rump	0.00			
		Mutton tripe	0.00			
		Intercostal meat	0.00			

***Table 2.** Summary of the concentrations of trace elements in meat of cattle and sheep (continued)*

Trace Elements	Type of Meat		Concentrations (mg/kg wet weight)		Countries	References
Pb	Cattle		0.01		Italy	Di Bella et al.[38]
			0.04		Thailand	Jankeaw et al.[44]
			0.00		Ghana	Adzitey et al.[45]
			0.09		Bangladesh	Kamal et al.[46]
			5.4		Uganda	Kasozi et al. [40]
			4.62		Bangladesh	Chowdhury et al.[41]
			1.15		Ghana	Nkansah and Ansah [43]
			0.05		Nigeria	Sabuwa and Nafarnda [48]
			4.6	Site 1	India	Sathyamoorthy et al.[10]
			2.4	Site 2		
			0.09	Site 1	Ghana	Adjei et al.[35]
			0.01	Site 2		
			0.04	Site 3		
			0.00	Site 4		
			0.48		Bangladesh	Shaheen et al.[32]
	Sheep	Young	0.07		Egypt	Darwish et al.[42]
		Aged	0.25			
		Shoulder clod	0.00		China	Xiang et al.[37]
		Tenderloin	0.00			
		Neck	0.00			
		Rump	0.00			
		Mutton tripe	0.00			
		Intercostal meat	0.00			
			0.37		Ghana	Nkansah and Ansah [43]
			11.79		Iran	Raeeszadeh et al.[39]
			0.48		Kuwait	Abd-Elghany et al.[36]
			0.01		Egypt	Abou-Arab [47]
			0.15		Bangladesh	Shaheen et al.[32]

As: Arsenic, Cd: Cadmium, Pb: Lead, ND: Not Detected

in different areas of China by Xiang et al.[37]. For Pb in the meat of cattle, Kasozi et al.[40] measured the highest concentration (5.4 mg/kg w.w.) in meat from Uganda. Chowdhury et al.[41] in Bangladesh and Sathyamoorthy et al.[10] in India also recorded high concentrations of Pb with a similar value (4.6 mg/kg w.w.). The concentrations recorded in the other studies were negligible *(Table 2)*. For Pb in sheep meat from Iran, Raeeszadeh et al.[39] measured a significantly high concentration (11.79 mg/kg w.w.) which was higher compared to the results of all the other studies and the lowest concentrations were recorded by Xiang et al.[37] from different locations in China. Darwish et al.[42] showed that there is a difference in Pb concentration in sheep meat as a function of the animals' age, the concentration in meat of older sheep (0.25 mg/kg w.w.) was higher than that of younger individuals (0.07 mg/kg w.w.). The results of these different studies *(Table 2)* show that there are important variations in concentrations of the accumulation of trace elements (i.e. As, Cd and Pb) in cattle and sheep meat underscoring the importance of such regional studies on the contents of these elements in comestible species.

Concentrations of As, Cd and Pb in Eggs

The concentrations of the targeted trace elements (As, Cd and Pb) in eggs *(Table 3)* are quite different. For the same metal, the analyticle results differ depending on the type of egg and for the same type of egg the results are different depending on the method of breeding of the species producing these eggs and therefore on its food type and the animals' geographic location. For As, the higest concentrations were reported by Shaheen et al.[32] from Bangladesh in chicken and duck eggs (0.30 and 034 mg/kg w.w., respectively). Nisianakis et al.[49] in Greece found similar concentrations (0.01 mg/kg w.w.) in three types of eggs (chicken, duck and goose), a finding that is explained by the fact that these species of hens have the same rearing method and especially the same diet. These values were higher than those reported by the same

Table 3. Summary of the concentrations of trace elements in eggs of different poultry species

Trace Elements	Type of Eggs	Concentrations (mg/kg wet weight)		Countries		References
As	Chicken	0.01		Greece		Nisianakis et al.[49]
	Türkiye	0.00				
	Duck	0.01				
	Goose	0.01				
	Chicken	Balady eggs	0.14	Egypt		Saad Eldin and Raslan [50]
		Commerciel eggs	0.12			
		Organic eggs	0.04			
		Local 1	BDL	Bangladesh		Samad et al.[51]
		Local 2	BDL			
		Local 3	BDL			
		Local 4	BDL			
		Local 5	BDL			
		Local 6	BDL			
		0.30		Bangladesh		Shaheen et al.[32]
	Duck	0.34				
	Chicken	0.02		North	Egypt	Hashish et al.[56]
		0.03		Middle		
		0.02		South		
		0.02		Upper Egypt		
		0.00		France		Leblanc et al.[54]
		0.02		Egypt		Ferweez et al.[57]
		0.00		United Kingdom		Ysart et al.[55]
Cd	Chicken	0.00		Greece		Nisianakis et al.[49]
	Türkiye	0.00				
	Duck	0.00				
	Goose	0.00				
	Chicken	Balady eggs	0.18	Egypt		Saad Eldin and Raslan [50]
		Commerciel eggs	0.09			
		Organic eggs	0.04			
		0.30		Bangladesh		Shaheen et al.[32]
	Duck	0.34				
	Chicken	0.18		Iran		Sobhan Ardakani et al.[53]
		Local 1	< 0.001	Bangladesh		Samad et al.[51]
		Local 2	< 0.001			
		Local 3	< 0.001			
		Local 4	< 0.001			
		Local 5	< 0.001			
		Local 6	< 0.001			
		0.01		North	Egypt	Hashish et al.[56]
		0.01		Middle		
		0.00		South		
		0.00		Upper Egypt		
		0.00		France		Leblac et al.[54]
	Duck	0.93		Indonesia		Asnawi [52]
	Chicken	0.03		Egypt		Ferweez et al.[57]
		0.00		United Kingdom		Ysart et al.[55]

Table 3. *Summary of the concentrations of trace elements in eggs of different poultry species (continued)*						
Trace Elements	**Type of Eggs**	**Concentrations (mg/kg wet weight)**		**Countries**		**References**
Pb	Chicken	Balady eggs	0.34	Egypt		Saad Eldin and Raslan [50]
		Commercial eggs	0.18			
		Organic eggs	0.08			
		0.28		Bangladesh		Shaheen et al.[32]
	Duck	0.32				
	Chicken	0.29		Iran		Sobhan Ardakani [53]
		0.09		Egypt		Ferweez et al.[57]
		0.22		North	Egypt	Hashish et al.[56]
		0.30		Middle		
		0.17		South		
		0.17		Upper Egypt		
		0.01		France		Leblanc et al.[54]
		Local 1	0.37	Bangladesh		Samad et al.[51]
		Local 2	0.29			
		Local 3	0.51			
		Local 4	1.90			
		Local 5	0.50			
		Local 6	1.58			
		0.00		United Kingdom		Ysart et al.[55]

As: Arsenic, Cd: Cadmium, Pb: Lead, BDL: Below detection limit

authors for Türkiye. eggs (0.009 mg/kg w.w.). In Egypt, Saad Eldin and Raslan [50] reported high and almost similar concentrations for Ballady and comercial eggs (0.12 and 0.14 mg/kg w.w., respectively) the concentrations for which are much higher than that obtained for the organic eggs (0.04 mg/kg w.w.). Samad et al.[51] from Bangladesh reported the negligible and lowest recorded values of As in chicken eggs which were below the limit of detection (BDL).

For Cd, Asnawi [52] in Indonesia reported the highest value (0.93 mg/kg w.w.) in duck eggs followed by the results registered by Shaheen et al.[32] in Bangladesh in chicken and duck eggs (0.30 and 0.34 mg/kg w.w., respectively). Sobhan Ardakani et al.[53] in Iran also registered the highest concentration in chicken eggs (0.18 mg/kg w.w.). Nisianakis et al.[49] in Egypt, Leblanc et al.[54] in France, Ysart et al.[55] in United Kingdom, Hashish et al.[56] in upper and south Egypt and Samad et al.[51] in Bangladesh reported the lowest concentrations in chicken eggs. The highest concentrations in chicken eggs were reported by Shaheen et al.[32] in Bangladesh which recorded similar values in chicken and duck eggs. Hashish et al.[56] in Egypt reported different concentrations in chicken eggs from different regions for which the highest levels were found in the eggs from the north and middle regions of the country, and the lowest values were registered in those from the south and in Upper Egypt.

For Pb, the highest concentrations were registered in chicken eggs by Samad et al.[51] (1.9; 1.58; 0.51 mg/kg w.w.) from different sites in Bangladesh, followed by the results obtained by Hashish et al.[56] from Egypt (0.34 and 0.30 mg/kg w.w., respectively) in chicken eggs. Shaheen et al.[32] in Bangladesh also obtained a high concentration in duck eggs (0.32 mg/kg w.w.). Shaheen et al.[32] from Bangladesh and Sobhan Ardakani et al.[53] from Iran recorded similar levels in chicken eggs. Hashish et al.[56] also found similar concentrations in hens' eggs from southern and middle Egypt (0.17 mg/kg w.w.). Leblanc et al.[54] from France and Ysart et al.[55] from United Kingdom reported the lowest concentrations (0.011; 0.003 mg/kg w.w., respectively). The results of the various studies analyzed show that the study region and poultry species greatly influence the levels of these trace elements in eggs.

Concentrations of As, Cd and Pb in Milk

For each trace element; the concentrations in milk differ according to the type of milk (cow, Ewe, goat) and for the same type of milk, the concentrations also differ according to the region of study. For As, Castro-González et al.[58] from Mexico obtained a significantly high concentration (1.15 mg/kg w.w.). Sarkar et al.[59] from India and Shaheen et al.[32] from Bangladesh also reported high concentrations in cow milk (1 and 0.44 mg/kg w.w., respectively). Monteverde et al.[60] registered the lowest and negligible values in two groups of cow milk in Italy whish are below the detection limit.

Reagrding Cd in the cow milk *(Table 4)*, the highest concentration (1.24 mg/kg w.w.) was reported by Elatrash et al.[61] in Lybia. Monteverde et al.[60] in Italy; Ali et al.[62] in Tanzania; Ismail et al.[63] in Pakistan; Belete et al.[64] from Ethiopia and Bali from Algeria reported the lowest values of Cd. For Cd in goat milk, Balli et al.[65] registered different concentrations at three study sites in Algeria where the concentration recorded in site 1 was similar to that reported by Yabrir et al.[66] in goat milk (0.01 mg/kg w.w.). Yabrir et al.[66] also registered a low concentration in ewe milk (0.06 mg/kg w.w.).

For Pb; Malhat et al.[67] from the four sites in Egypt and Capcarova et al.[68] from Slovakia, and Elatrash et al.[61] in Lybia registered a high concentrations in cow milk while the highest values were reported by Malhat et al.[67] in Egypt *(Table 4)*. Ismail et al.[63] from Pakistan and Castro-González et al.[69] from Mexico registered the same value (0.03 mg/kg w.w.). The lowest concentrations of Pb in cow milk were registered by Belete et al.[64] from Ethiopia; Shaheen et al.[32] from Bangladesh; Ismail et al.[63] at site 3 from Pakistan; and Elsaim et al.[70] from Sudan. In Algeria, Yabrir et al.[66] registered different concentrations among which the value registered in the ewe milk was higher (1.18 mg/kg w.w.) than that measured in goat milk (0.07 mg/kg w.w.). For Pb in goat milk Balli et al.[65] recorded the highest values at three sites in Algeria. Homayonibezi et al.[71] found Pb values from the two Iranian sites that were different and low *(Table 4)*. The lowest values of Pb were registered by Ismail et al.[63] in four sites from Pakistan. All these results again show the importance of the animal species, study location and geographical area in the concentration of the toxic trace elements in milk.

Comparison of the Concentrations Obtained in Different Foodstuffs Reviewed with the Regulatory Limits

For As, there is no threshold limit set for this element in the foods analyzed. For Cd and Pb, the results of the studies were compared to the different regulatory limits set by the European Union (EU), Food Standards Australia New Zealand (FSANZ) and Joint FAO/WHO Expert Committee on Food Additives (JECFA), with

Table 4. *Summary of the concentrations of trace elements in milk*

Trace Elements	Type of Milk	Concentrations (mg/kg wet weight)	Contries		References
As	Cow milk	0.44	Bangladesh		Shaheen et al.[32]
		1.00	India		Sarkar et al.[59]
		0.12	Mexico		Castro-González et al.[69]
		1.15	Mexico		Castro-González et al.[58]
		BDL	Group 1	Italy	Monteverde et al.[60]
		BDL	Group 2		
Cd	Cow milk	0.03	Algeria		Bousbia et al.[72]
		0.27	Slovak		Capcarova et al. [68]
		0.44	Bangladesh		Shaheen et al.[32]
		0.08	Egypt		Enb et al.[73]
		0.28	Site 1	Egypt	Malhat et al.[67]
		0.27	Site 2		
		0.20	Site 3		
		0.22	Site 4		
		0.23	Site 5		
		0.00	Site 1	Sudan	Elsaim et al.[70]
		0.00	Site 2		
		0.00	Site 3		
		BDL	Group 1	Italy	Monteverde et al.[60]
		BDL	Group 2		
		ND	Tanzania		Ali et al.[62]
		1.24	Libya		Elatrash et al.[61]
		0.00	Site 1	Pakistan	Ismail et al.[63]
		BDL	Site 2		
		BDL	Site 3		
		0.00	Site 4		
		ND	Ethiopia		Belete et al.[64]
	Goat milk	0.01	Site 1	Algeria	Balli et al.[65]
		0.00	Site 2		
		0.03	Site 3		
		BDL	Site 1	Pakistan	Ismail et al.[63]
		BDL	Site 2		
		BDL	Site 3		
		0.001	Site 4		
	Ewe milk	0.06	Algeria		Yabrir et al.[66]
	Goat milk	0.01			

***Table 4.** Summary of the concentrations of trace elements in milk (continued)*

Trace Elements	Type of Milk	Concentrations (mg/kg wet weight)	Contries		References
Pb	Cow milk	3.8	Slovak		Capcarova et al.[68]
		0.26	Tanznia		Ali et al.[62]
		0.03	Site 1	Pakistan	Ismail et al.[63]
		0.02	Site 2		
		BDL	Site 3		
		0.01	Site 4		
		0.27	Bangladesh		Shaheen et al.[32]
		3.43	Libya		Elatrash et al.[61]
		0.03	Mexico		Castro-González et al.[69]
		0.03	Mexico		Castro-González et al.[58]
		ND	Ethiopia		Belete et al.[64]
		0.06	Egypt		Enb et al.[73]
		1.85	Site 1	Egypt	Malhat et al.[67]
		3.5	Site 2		
		2.9	Site 3		
		4.4	Site 4		
		3.05	Site 5		
		0.00	Site 1	Sudan	Elsaim et al.[70]
		0.00	Site 2		
		0.00	Site 3		
	Ewe milk	1.18	Algeria		Yabrir et al.[66]
	Goat milk	0.07			
	Cow milk	0.02	Group 1	Italy	Monteverde et al.[60]
		0.03	Group 2		
	Goat milk	0.42	Site 1	Algeria	Balli et al.[65]
		0.38	Site 2		
		0.33	Site 3		
		0.00	Site 1	Pakistan	Ismail et al.[63]
		0.00	Site 2		
		0.00	Site 3		
		BDL	Site 4		
		0.14	Site 1	Iran	Homayonibezi et al.[71]
		BDL	Site 2		

As: Arsenic, Cd: Cadmium, Pb: Lead, BDL: Below Detection Limit, ND: Not detected

which the majority of the results largely exceeded these limits. As showen in *Table 1*, Uluozlu et al.[24] (6.09 mg/kg w.w.), Shaheen et al.[32] (0.23 mg/kg w.w.), Abduljaleel et al.[27] (0.15 mg/kg w.w.), Kamaly and Sharkawy [25] (5.87; 9.63; 13.01; 14; 10.93; 10.01 mg/kg w.w.), El Bayomi et al.[26] (0.06; 0.09 mg/kg w.w.) reported Cd concentrations in chicken meat exceeding the threshold limit set by EU [74] (0.05 mg/kg w.w.). In liver of poultry the concentration of Cd recorded by Uluozlu et al.[24] (2.24 mg/kg w.w.) largely exceed the threshold limit set by EU [74] (0.5 mg kg^{1} w.w.) but the value they obtained in Kidney (0.25 mg/kg w.w.) is less the threshold limit (1 mg/kg w.w.) (*Table 4*). For Cd in meat of cattle; the values reported by Kasozi et al.[40] (0.4 mg/kg w.w.), Nkansah and Ansah [43] (0.079 mg/kg w.w.), Sathyamoorthy et al.[10] (6.6; 5.1 mg/kg w.w.), Adjei et al.[35] (0.1 mg/kg w.w.), Shaheen et al.[32] (0.57 mg/kg w.w.) all exceeded the limits set by EU [74] and FSANZ [75] (0.05 mg/kg w.w.). In the meat of sheep; Darwish et al.[42] (0.06 mg/kg w.w.), Raeeszadeh et al.[39] (0.23 mg kg^{1} w.w.), Abd-Elghany et al.[36] (0.30 mg/kg w.w.) recorded the highest concentrations which exceeded the limits set by EU [74] and FSANZ [75] (0.05 mg/kg w.w.). There are no threshold limits for Cd in eggs and milk. For the concentrations of Pb in meat of poultry *(Table 1);* in all studies concentations were higher than the permissible limits (0.1 mg/kg w.w.) set by EU [74]; FSANZ [75] and by JECFA [76] except those registered by Yilmaz and Gecgel [33] and Kamaly and Sharkawy [25]. In the liver of poultry the values recorded by Kamaly and Sharkawy [25] in differents brands of poultry (2.57; 3.15; 2.56; 2.58; 3.30; 5.55) largely exceeded the permissibl limit set by EU [74] (0.1 mg/kg w.w.). In the meat of cattle the majority of the concentrations of Pb greatly exceeded the permissible limit *(Table 5)*, e.g. Kasozi et al.[40] (5.4 mg/kg w.w.), Chowdhury et al.[41] (4.62 mg kg^{1} w.w.), Nkansah and Ansah [43] (1.15 mg/kg w.w.), Sathyamoorthy et al.[10] (4.6; 2.4 mg/kg w.w.), Shaheen et al.[32] (0.48 mg/kg w.w.) *(Table 2)*. In the meat of sheep the concentrations recorded by Darwish et al.[42] (0.25 mg/kg w.w.),

Table 5. Permissible limits in meat, poultry, eggs and milk

Trace Elements	Type of Food	Permissible Limits (mg/kg wet weight)	References
Cd	Meat of bovine animals, sheep and poultry	0.05	EU [74]
	Liver of poultry	0.5	EU [74]
	Kidney of poultry	1	EU [74]
	Meat of cattle and sheep	0.05	FSANZ [75]
Pb	Meat of bovine animals, sheep and poultry	0.10	EU [74]
	Meat of cattle, sheep and poultry	0.10	FSANZ [75]
	Meat of cattle, sheep and poultry	0.10	JECFA [76]
	Poultry offal	0.1	EU [74]
	Milk	0.02	EU [74]
		0.02	JECFA [76]

As: Arsenic, Cd: Cadmium, Pb: Lead, EU: Commission Regulation, FSANZ:Food Standards Australia New Zealand.JECFA: Joint FAO/WHO Expert Committee on Food Additives

Raeeszadeh et al.[39] (11.79 mg/kg w.w.), Abd-Elghany et al.[36] (0.48 mg/kg w.w.), Shaheen et al.[32] (1.15 mg/kg w.w.) far exceeded the permissible limits set by EU [74]; FSANZ [75] and by JECFA [76] (0.1 mg/kg w.w.). In the cow, goat and ewe milk the majority of the results *(Table 4)* exceed the permissible limit set by EU [74] and JECFA [76] (0.02 mg/kg w.w.). Capcarova et al.[68] (3.8 mg/kg w.w.), Ali et al.[62] (0.26 mg/kg w.w.), Shaheen et al.[32] (0.27 mg/kg w.w.), Ismail et al.[63] (0.03 mg/kg w.w.), Elatrash et al.[61] (3.43 mg kg[1] w.w.), Castro-González et al.[58] and Castro-González et al.[69] (0.03 mg/kg w.w.), Enb et al.[73] (0.06 mg kg[1] w.w.), Malhat et al.[67] (1.85; 3.5; 2.9; 4.4; 3.05 mg/kg w.w.), Monteverde et al.[60] (0.03 mg/kg w.w.) in cow milk. Yabrir et al.[66] (1.18; 0.07 mg/kg w.w.) in ewe and goat milk, respectively. Balli et al.[65] (0.42; 0.38; 0.33 mg/kg w.w.), Homayonibezi et al.[71] (0.14 mg/kg w.w.) recorded a values which largely exceed the permissible limit *(Table 5)*. No permissible limits are set for Pb in eggs.

Conclusion and Recommendation

In this review we have thoroughly analyzed and discussed the data of different studies on the contamination of certain foodstuffs of animal origin by three toxic trace elements (As, Cd and Pb), and the results have clearly identified the the presence of contamination in these foodstuffs by these trace elements. In the case of arsenic, the ofe highest concentrations have been recorded in cattle meat (5.6, 3.7 mg/kg w.w.). For Cd the highest concentrations were recorded in the meat of chicken and the meat of cattle (6.09 and 6.6, mg/kg w.w., respectively). The highest concentration of Pb was recorded in the meat of sheep (11.7 mg/kg w.w.). Surprisingly the majority of the concentrations of the three trace elements studied found in all these food matrices largely exceed the international regulatory thresholds which points to a potential hazard risk for the health of the consumer. To alleviate this potential international public health problem related to trace element poisoning via food, it will be very important for researchers in this field to make further assessments of this subject and to identify, if possible, the source of contamination for these foodstuffs by these contaminants by carrying out studies on water and food intended for the animals, and also to carry out regular monitoring and controls in order to prevent the risks to populations consuming these local foods.

Declarations

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