MILK CONTAMINATION WITH HEAVY METALS AS A RESULT OF ENVIRONMENTAL POLLUTION

M. Matei[1*], I.M. Pop (coord)[1], D. Simeanu[1], A. Albu[1], D. Lăpușneanu[1], R. Miron[1]

[1]*Faculty of Food and Animal Sciences, Iasi University of Life Sciences, Romania*

Abstract

Milk and dairy products are consumed by more than six billion people worldwide. The safety and quality issues regarding milk are constantly monitored, especially because milk can be exogenously or endogenously contaminated with many substances or polluting compounds during its production.

In order to highlight the importance of studying the impact of pollutants on animal production, the aim of this review was to focus on the literature and on the systematic analysis of over 40 researches consulted in various international profile databases regarding metal contamination of milk as a result of environmental pollution.

The overall assessment of the subject showed that heavy metal pollution is one of the modern forms of pollution that can affect the entire ecosystem. The results of the study showed that the assessment of heavy metal contamination of milk as a result of environmental pollution requires the integration of the entire production cycle and the assessment of the potential transfer of metallic pollutants during it, each component of the environment prone to be polluted having its contribution on animal production and finally on the human body.

Key words: *environment, pollution, heavy metals, milk*

INTRODUCTION

Characterized as an almost perfect and complete natural food, milk is one of the most popular products that enters the daily diet of all categories of consumers, from babies, children, old or sick (Kampire et al. 2011), milk consumption being recommended over time by many specialists (USDA, 2015). Moreover, as a result of changes in consumption patterns, milk has become an essential source of animal protein for lacto-vegetarian consumers, more and more numerous in recent years (Abou Donia et al. 2010).

Due to its balanced nutritional properties and the many recognized benefits in the prevention of various chronic diseases (Pereira, 2014), milk is often associated with a healthy diet and a better quality of diet (Maguire et al. 2013; Thorning et al. 2016).

However, during its production, milk may be contaminated exogenously or endogenously with many substances or polluting compounds from the environment. If exogenous contamination is the result of an inadequate technological process, but one that can be easily prevented and controlled, endogenous contamination is difficult to prevent due to its specificity.

Endogenous contamination can be either an accidental contamination of the animal body as a result of ingestion of various contaminants, improper administration of veterinary medicinal products or food contamination, but, most often, this is a consequence of contamination with various polluting compounds that come from the environment into animal feed and into the animal body and that can pose a real danger for safety of milk and for consumer safety.

Depending on the impacted element, environmental pollution can take different forms and depending on the emission sources, in the environment, there can be many types of pollutants. Global pollution monitoring has shown that heavy metal pollution has become one of the most important types of contamination of animal production chains (Miclean et al. 2019), as

*Corresponding author: matei.madalina55@yahoo.com
The manuscript was received: 07.10.2022
Accepted for publication: 02.11.2022

pollutants, heavy metals are particularly interesting in terms of special features in relation to the environment, being persistent, with bioaccumulative potential and high toxicity for living organisms (Garcia et al. 2019; Shafiq et al. 2019; EEA, 2021).

Heavy metal contamination of milk poses a threat to human health, because they are resistant to decomposition and degradation and has a high storage capacity along the food chain (Nkwunonwo et al. 2020). Milk and dairy products are consumed worldwide by over six billion people (Garcia et al. 2019; Verduci et al. 2019) and their safety and quality issues are constantly monitored around the world. However, the data show a tendency to monitor milk contamination, especially in terms of exogenous contaminants or accidental endogenous contaminants, being less focused on the study of milk contamination due to environmental pollution.

In order to highlight the importance of studying the impact of environmental pollutants on animal production and food safety, the aim of this review was to focus on the systematic analysis of several researches in the literature regarding heavy metal contamination of milk as a result of environmental pollution, including different topics, from causes and sources of pollution, the characteristics of heavy metals in relation to the possibility of transfer to the food chain or the identification of the proportions of heavy metals pollutants from milk.

MATERIAL AND METHOD

This paper is a systematic review of over 40 scientific papers, consulted in various international databases, regarding the study of the impact of environmental pollutants on animal production and food safety.

In order to clarify the environmental behavior of heavy metal pollutants, the study focused on grouping specialized data through systematic analysis associated with an own interpretation and discussion, to highlight the interrelationships between the environment and animal production.

The review includes current specialist data relevant to the study of environmental pollutants and their feasibility along the food chains and may be an important benchmark for future similar research.

RESULTS AND DISCUSSIONS

The study of the contamination of milk with heavy metals, as a consequence of environmental pollution was focused on the analysis and interpretation of data found in the literature on sources and causes of pollution, characteristics of heavy metals in relation to the possibility of their transfer between different trophic levels, an overview of the potential negative impact of heavy metals on animal production and on the human body by highlighting the proportions of residual heavy metals found in milk in various studies analyzed.

The general assessment of the subject highlighted that heavy metal pollution is one of the modern forms of pollution that can affect the entire ecosystem. Regardless of concentration, exposure to heavy metal pollution is chronic, so most of the reviewed research included the transfer of heavy metals from the environment to the animal body to quantify their effects on animal production and on the human body (Miclean et al. 2019).

In the literature, the study of heavy metals has been approached from different perspectives, authors such as Ramirez (2013) outlining the natural presence of heavy metals in the environment, but also positive roles for the biological processes in which they are involved, while authors such as Varol et al. (2020) studied anthropogenic heavy metals, reflecting research on the toxic potential of heavy metals for the environment even at very low concentrations.

Regarding the study of the main sources of environmental pollution with heavy metals, presented in figure 1, it was found that the presence of heavy metals in the environment has generally anthropogenic causes such as industrial activities, agriculture, emissions from various types of transport or waste from urban activities, Bi et al. (2009) generally reporting heavier heavy metal pollution in industrial areas or near urban settlements.

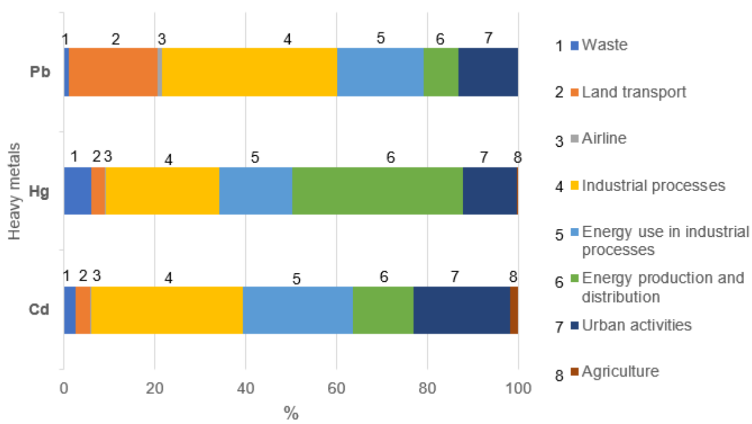

Fig. 1 Sources of heavy metal pollution (Pb, Hg, Cd) on sectors of activity (EEA, 2021)

Depending on the dose and duration of exposure, the vast majority of heavy metals can be considered contaminants for biota (Khan et al. 2014). In order to clarify the biological behavior of pollutants and to establish the relationship between the contamination of biota with heavy metals, the concentration rate and the rate of their elimination from the substrates in which they accumulated, Ali et al. (2019) highlighted the properties of heavy metals in terms of storage capacity, high persistence and the possibility of transfer between different trophic levels.

In order to determine the risks of exposure to heavy metal pollution and the influence of these compounds on the environment, various authors (Tahir et al. 2017; Miclean et al. 2019) evaluated the contamination with heavy metals by studying their traceability and the potential transfer of heavy metals accumulated from the environment in the soil and in vegetal production used as animal feed to the animal body and animal production (table 1), through the concentrations found in the research, highlighting the high possibility of accumulation and transfer of heavy metals in all elements of the environment.

Table 1 Heavy metal transfer factors in the food chain (Miclean et al. 2019)

	HEAVY METALS				Equation
	Pb	Cd	Cu	Zn	
TF[1] soil – feed	0.002–0.01	0.035–0.187	0.039–0.122	0.068–0.208	TF soil – feed = C_f^3/C_s^2
TF feed – milk	0.015–0.075	0.006–0.067	0.022–0.071	0.075–0.247	TF feed – milk = C_m^4/C_f

[1]**TF** = transfer factors; [2]$\mathbf{C_s}$=metal content in the soil (mg kg^{-1}); [3]$\mathbf{C_f}$ = metal content in the feed (mg kg^{-1}); [4]$\mathbf{C_m}$ = metal content in the milk (mg kg^{-1}).

In the same context, the ecotoxicity of heavy metals and the contamination with heavy metals of environmental substrates has been studied by many other specialists (Aprile et al. 2019; Shafiq et al. 2019; Malkowski et al. 2020;) who followed in their study a previous similar research conducted by Tahir et al. (2017), on the monitoring, by quarterly analysis for one year, of the distribution of residual heavy metals found in soil, feed, milk and blood collected from cows in a cattle breeding station, through which it reported and removed highlights the existence of significant proportions of heavy metals in natural substrates, due to a high degree of pollution, the average values being summarized in table 2.

Table 2 Heavy metal transfer factors in the food chain

Item	soil	water	feed	milk	blood	References
	mg kg-1	*mg L-1*	*mg kg-1*	*mg L-1*	*mg L-1*	
Pb	12.4–479	2.70–11.7	0.15–2.24	0.01–0.048	n/s[1]	*Miclean et al. 2019*
	3.116–8.403	n/s[1]	2.236–5.398	0.3–0.8	1.382–2.98	*Tahir et al. 2017*
Cd	0.75–8.36	0.34–2.8	0.10–1.44	0.003–0.01	n/s	*Miclean et al. 2019*
	1.9–6.8	n/s[1]	1.1–4.1	0.04–0.3	1.0–1.5	*Tahir et al. 2017*
Cu	38.3–211	24.8–85.2	3.43–10.8	0.095–0.44	n/s[1]	*Miclean et al. 2019*
Zn	117–590	673–1570	13.4–53.9	2.38–4.38	n/s[1]	
Co	2.85–9.17	n/s[1]	1.65–5	0.23–0.521	1.34–1.61	*Tahir et al. 2017*
Ni	1.6–64	n/s[1]	0.82–40	0.35–2.8	0.93–10.25	
Cr	0.019–0.11	n/s[1]	0.013–0.071	0.014–0.04	0.02–0.132	

[1]n/s = unspecified

In order to study the influence of heavy metal pollution on milk production, this review analyzed various current scientific papers, published in the last 5 years, to reflect the permanent presence of these pollutants in environmental substrates. As part of a production chain, the study of heavy metal milk contamination required the study of cycle contamination soil-feed-animal production-human body, Mantovani et al. (2010) mentioning that until animal production, the entire production cycle is prone to heavy metal contamination. There are many risk factors, both natural and environmental, as well as indirectly formed as a result of various activities on the soil, animal husbandry activities or those related to obtaining animal production.

Analyzed research on heavy metal contamination of milk as a result of environmental pollution (Bousbia et al. 2019; Safaei et al. 2020) has indicated that the level of contamination is not always constant and depends on the routes of exposure, the state and conditions of the environment or the nutrition and feeding of the animals.

In order to assess the content of heavy metals in milk, the proportions of the various residues identified in the specialized research analyzed were shown in Table 3.

By conducting this systematic review of heavy metal concentrations in milk, it was found that the highest levels of heavy metal contamination of milk were reported in samples collected from areas with strong industrial activity or near cities.

Regarding cadmium pollution, in the last five years, the highest levels of residues have been identified in Pakistan by Tahir et al. (2017), in milk samples collected from farms located in the vicinity of areas with heavy traffic; the proportions identified by Tahir et al. (2017) were between 0.04–0.3 mg/L, higher than those obtained in a similar study, by Miclean et al. (2019), respectively 0.003–0.01 mg/L.

The highest residual levels of copper in cow's milk were recorded in research conducted by Capcarova et al. (2019), in Slovakia (2.12 mg/L), in milk samples collected from cows that grazed near areas with intense agricultural activity. The values obtained in 2019 by Capcarova et al. (2019) however, are lower than the values obtained in a previous study in India, 36 mg/L, for milk samples from cows raised near one of the largest barite deposits in the world (Raghu, 2015).

Residual nickel concentrations in milk, identified in the analyzed studies, ranged between 0.01–10.1 mg/L, the maximum being recorded in Bangladesh, in the research conducted by Shaheen et al. (2016).

Similar to copper, the highest levels of lead were identified in research by Capcarova et al. (2019), being between 0.27–3.8 mg/L, however lower than those identified by Raghu (2015) in milk samples collected in the vicinity of an Indian urban center (60 mg/L) or than those identified by Aslam et al. (2011), in milk samples collected from animals that consumed water from sewage sources in a Pakistan city (23.24 mg/L).

Similar research has been conducted to identify milk contamination with arsenic (Ahmed et al. 2016), cobalt, chromium (Tahir et al. 2017) or zinc (Miclean et al. 2019).

Table 3 Heavy metals levels in milk

Item	Region and characteristic of the area	HM[1] levels (mg/L)	Method	*References*	Item	Region and characteristic of the area	HM levels (mg/L)	Method	*References*
As	Bangladesh	0.097 – 1.1	ICP – MS[2]	*Ahmed et al. 2016*	**Ni**	Bangladesh Industrial disposal areas	0.07 – 0.08	EDXRF	*Jolly et al. 2017*
Cd	Romania	0.003 – 0.01	GC[3]	*Miclean et al. 2019*		Pakistan Farm located near to the cities	0.01 – 0.08	AAS	*Ismail et al. 2017*
	Pakistan, near traffic road	0.04 – 0.3	-	*Tahir et al. 2017*		Slovakia Agricultural sector	0.84	AAS	*Capcarova et al. 2019*
Co	Pakistan, near traffic road	0.23 – 0.521	-	*Tahir et al. 2017*		India Copper mining area	0.62	ICP – MS	*Giri et al. 2019*
Cr	Pakistan, near traffic road	0.014 – 0.04	-	*Tahir et al. 2017*		Mexico Near waste area	0.01	ICP – OES	*Castro–Gonzalez et al. 2018*
Cu	Turkey	0.09 – 0.26	ICP – OES[4]	*Bakircioglu et al. 2019*		Pakistan, near traffic road	0.35 – 2.8	-	*Tahir et al. 2017*
	Pakistan Farm located near to the cities	0.04 – 0.09	AAS[5]	*Ismail et al. 2017*	**Pb**	Bangladesh Dairy farms	0.001 – 0.20	AAS	*Muhib et al. 2017*
	Bangladesh Industrial disposal areas	0.05 – 0.06	EDXRF[6]	*Jolly et al. 2017*		Pakistan Farm located near to the cities	0.014 – 0.033	AAS	*Ismail et al. 2017*
	Sudan Grazing areas	0.1 – 0.2	AAS	*Elsaim et al. 2018*		Pakistan, near traffic road	0.04 – 0.8	-	*Tahir et al. 2017*
	Canada	0.03 – 0.1	ICP – MS	*Zwierzchowski et al. 2019*		Bangladesh Industrial disposal areas	0.001 – 0.04	EDXRF	*Jolly et al. 2017*
	Slovakia Agricultural sector	2.12	AAS	*Capcarova et al. 2019*		Ethiopia Near metal leaching	0.15 – 0.29		*Akele et al. 2017*
	Mexico Near waste area	0.01	ICP – OES	*Castro–Gonzalez et al. 2018*		Slovakia Agricultural sector	0.27 – 3.8	AAS	*Capcarova et al. 2019*
	Pakistan	0.14	AAS	*Ahmad et al. 2017*		India Near to metallurgical complex	0.02 – 0.58	AAS	*Chirinos–Peinado et al. 2020*
	Algeria Poluted area	0.24	AAS	*Bousbia et al. 2019*		Iran Industrial regions	0.014	VM	*Shahbazi et al. 2016*
	Iran Industrial regions	0.427	VM[7]	*Shahbazi et al. 2016*		India Copper mining area	0.13	ICP – MS	*Giri et al. 2019*
	Ethiopia Near metal leaching	1.12	AAS	*Akele et al. 2017*		Kazakhstan	0.021 – 0.027	AAS	*Sarsembayeva et al. 2020*
	Romania	0.095 – 0.44	GC	*Miclean et al. 2019*		Iran	0.007	ICP – OES	*Safaei et al. 2020*
Ni	Bangladesh	0.062 – 10.1	ICP – MS	*Shaheen et al. 2016*		Romania	0.01 – 0.048	GC	*Miclean et al. 2019*
	Pakistan, near traffic road	0.35 – 2.85	-	*Tahir et al. 2017*	**Zn**	Romania	2.38 – 4.38	GC	*Miclean et al. 2019*

[1]**HM** = Heavy Metal; [2]**ICP – MS** = Inductively Coupled Plasma Mass Spectrometry; [3]**GC** = Gas Chromatography; [4]**ICP–OES**= Inductively Coupled Plasma–Optical Emission Spectrometry; [5]**AAS** = Atomic Absorption Spectrophotometry; [6]**EDXRF** = Energy Dispersive X-Ray Fluorescence; [7]**VM** = Voltammetric Analysis.

CONCLUSIONS

Industrial progress in recent years has led to increased environmental damage and heavy metal pollution has followed the same upward path, becoming a major current issue.

In line with the original purpose, the study highlights the importance of actively monitoring the contamination of animal production and food production as a result of environmental pollution.

Our review has indicated that the assessment of heavy metal contamination of milk as a result of environmental pollution integrates the assessment of the entire production cycle and the potential transfer of metallic pollutants, each environment prone to be polluted having its contribution to the bioaccumulative effect of pollutants in animal production and finally in the human body.

REFERENCES

1. Abou Donia, M.A., Abou–Arab, A.A., Enb, A., El–Senaity, M.H., Abd–Rabou, N.S. (2010). Chemical Composition of Raw Milk and the Accumulation of Pesticide Residues in Milk Products, Global Veterinaria, vol. 4, nr. 1: p 6.
2. Ahmad, I., Zaman, A., Samad, N., Ayaz, M., Rukh, S., Akbar, A. (2017). Atomic absorption spectrophotometery detection of heavy metals in milk of camel, cattle, buffalo and goat from various areas of Khyber-Pakhtunkhwa (KPK), Pakistan, Journal of Analytical & Bioanalytical Techniques, vol. 8, nr. 3.
3. Ahmed, M.K., Shaheen, N., Islam, M.S., Habibulla–Al–Mamun, M., Islam, S., Islam, M.M., Kundu, G.K., Bhattacharjee, L. (2016). A comprehensive assessment of arsenic in commonly consumed foodstuffs to evaluate the potential health risk in Bangladesh, The Science of The Total Environment, vol. 544: p 125–133.
4. Akele, M., Abebe, D., Alemu, A., Assefa, A., Madhusudhan, A., de Oliveira, R. (2017). Analysis of trace metal concentrations in raw cow's milk from three dairy farms in North Gondar, Ethiopia: chemometric approach. Environmental Monitoring and Assessment, vol. 189, nr. 10: p 499.
5. Ali, H., Khan, E., Ilahi, I. (2019). Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation, Hindawi Journal of Chemistry, vol. 2019, nr. 4: p 1–14.
6. Aprile, A., De Bellis, L. (2020). Heavy Metals Accumulation, Toxicity, and Detoxification in Plants, International Journal of Molecular Sciences, vol. 21: p 4103.
7. Aprile, A., Sabella, E., Francia, E., Milc, J., Ronga, D., Pecchioni, N., Ferrari, E., Luvisi, A., Vergine, M., De Bellis, L. (2019). Combined Effect of Cadmium and Lead on Durum Wheat, International Journal of Molecular Sciences, vol. 20, nr. 23: p 5891.
8. Aslam, B., Ijaz, J., Hussain, F., Zia Ur, R. (2011). Uptake of heavy metal residues from sewerage sludge in the milk of goat and cattleduring summer season, Pakistan Veterinary Journal, vol. 31, nr. 1: p 75–77.
9. Bakircioglu, D., Topraksever, N., Yurtsever, S., Kizildere, M., Kurtulus, Y.B. (2018). Investigation of macro, micro and toxic element concentrations of milk and fermented milks products by using an inductively coupled plasma optical emission spectrometer, to improve food safety in Turkey, Microchemical Journal, vol. 136: p 133–138.
10. Bi, X., Feng, X., Yang, Y., Li, X., Shin, G.P.Y., Li, F., Qiu, G., Li, G., Liu, T., Fu, Z. (2009). Allocation and source attribution of lead and cadmium in maize (*Zea mays L.*) impacted by smelting emissions, Environmental Pollution, vol. 157: p 834–839.
11. Bousbia, A., Boudalia, S., Gueroui, Y., Ghebache, R., Amrouchi, M., Belase, B., Meguelati, S., Belkheir, B., Benidir, M., Chelaghmia, M.L. (2019). Heavy metals concentrations in raw cow milk produced in the different livestock farming types in Guelma province (Algeria): contamination and risk assessment of consumption, JAPS: Journal of Animal&Plant Sciences, vol. 29, nr. 2: p 386–395.
12. Capcarova, M., Binkowski, L.J., Stawarz, R., Schwarczova, L., Massanyi, P. (2019). Levels of essential and xenobiotic elements and their relationships in milk available on the Slovak market with the estimation of consumer exposure, Biological Trace Element Research, vol. 188, nr. 2: p 404–411.
13. Castro–Gonzalez, N.P., Calderon–Sanchez, F., (2018). Heavy metals in cow's milk and cheese produced in areas irrigated with waste water in Puebla, Mexico, Food Additives&Contaminants Part B. Surveillance, vol. 11, nr. 1: p 33–36.
14. Chirinos–Peinado, D.M., Castro–Bedriñana, J.I. (2020). Lead and cadmium blood levels and transfer to milk in cattle reared in a mining area, Heliyon, vol. 6, nr. 2: e03579.
15. Elsaim, M.H., Ali, Y. (2018). Evaluation of some heavy metals in fresh cow's milk from different regions of Sudan, American Journal of Applied and Industrial Chemistry, vol. 2: p 8–14.

16. European Environment Agency (EEA), (2021). Heavy metal emissions, May 2021.
17. Garcia, S.N., Osburn, B.I., Cullor, J.S. (2019). A one health perspective on dairy production and dairy food safety, One Health, vol. 7.
18. Giri, S., Singh, A.K. (2019). Human health risk assessment due to metals in cow's milk from Singhbhum copper and iron mining areas, India, Journal of Food Science and Technology, vol. 57, nr. 4: p 1415–1420.
19. Ismail, A., Riaz, M., Akhtar, S., Farooq, A., Shahzad, M.A., Mujtaba, A., (2017). Intake of heavy metals through milk and toxicity assessment, Pakistan Journal of Zoology, vol. 49, nr. 4: p 1413–1419.
20. Jolly, Y.N., Iqbal, S., Rahman, M.S., Kabir, J., Akter, S., Ahmad, I. (2017). Energy dispersive Xray fluorescence detection of heavy metals in Bangladesh cows' milk, Heliyon, vol. 3, nr. 9: e00403.
21. Kampire, E., Kiremire, B.T, Nyanzi, S.A., Kishimba, M. (2011). Organochlorine Pesticide in Fresh and Pasteurized Cow's Milk from Kampala Markets, Chemosphere, vol. 84, nr. 7: p 923–927.
22. Khan, N., Jeong, I.S., Hwang, I.M., Kim, S.S., Choi, S.H., Nho, E.Y., Choi, J.Y., Park, K.S., Kim, K.S. (2014). Analysis of minor and trace elements in milk and yogurts by inductively coupled plasma-mass spectrometry (ICP-MS), Food Chemistry, vol. 147: p 220–224.
23. Maguire, J.L., Lebovic, G., Kandasamy, S., Khovratovich, M., Mamdani, M., Birken, C.S., Parkin, P.C. (2013). The relationship between cow's milk and stores of vitamin D and iron in early childhood, Pediatrics, vol. 131, nr. 1: p e144–e151.
24. Malkowski, E., Sitko, K., Szopinski, M., Gieron, Z., Pogrzeba, M., Kalaji, H.M., Zieleznik–Rusinowska, P. (2020). Hormesis in Plants: The Role of Oxidative Stress, Auxins and Photosynthesis in Corn Treated with Cd or Pb, Intenational Journal of Molecular Sciences, vol. 21, nr. 6: p 2099.
25. Mantovani, A., Frazzoli, C. (2010). Risk assessment of toxic contaminants in animal feed, CAB Reviews Perspectives in Agriculture Veterinary Science Nutrition and Natural Resources, vol. 5: p 1–14.
26. Miclean, M., Cadar, O., Levei, E.A., Roman, R., Ozunu, A., Levei, L. (2019). Metal (Pb, Cu, Cd, and Zn) Transfer along Food Chain and Health Risk Assessment through Raw Milk Consumption from Free-Range Cows, International Journal of Environmental Research and Public Health, vol. 16, nr. 21: p 4064.
27. Muhib, M.I., Chowdhury, M.K., Easha, N.J., Rahman, M., Shammi, M., Fardous, Z., Bari, M.L., Uddin, M.K., Kurasaki, M., Alam, M.K. (2016). Investigation of heavy metal contents in cow milk samples from area of Dhaka, Bangladesh, International Journal of Food Contamination, vol. 3, nr. 1: p 1–10.
28. Nkwunonwo, U.C., Odika, P.O., Onyia, N.I. (2020). A review of the health implications of heavy metals in food chain in Nigeria, The Scientific World Journal, 6594109.
29. Pereira, P.C. (2014). Milk nutritional composition and its role in human health, Nutrition, vol. 30, nr. 6: p 619–627.
30. Raghu, V. (2015). Study of dung, urine, and milk of selected grazing animals as bioindicators in environmental geoscience—a case study from Mangampeta barite mining area, Kadapa District, Andhra Pradesh, India, Environmental Monitoring Assessment, vol. 187: p 4080.
31. Ramirez, R. (2013). The gastropod Osilinus atrataas a bioindicator of Cd, Cu, Pb and Zn contamination in the coastal waters of the Canary Islands, Chemistry and Ecology, vol. 29, nr. 3: p 208–220.
32. Safaei, P., Seilani, F., Eslami, F., Sajedi, S.R., Mohajer, A. (2020). Determination of essential nutrients and heavy metal content of raw cow's milk from East Azerbaijan province, Iran, International Journal of Environmental Analytical Chemistry, p. 1–11.
33. Sarsembayeva, N.B., Abdigaliyeva, T.B., Utepova, Z.A., Biltebay, A.N., Zhumagulova, S.Zh. (2020). Heavy metal levels in milk and fermented milk products produced in the Almaty region, Kazakhstan, Veterinary World, vol. 13, nr. 4: p 609–613.
34. Shafiq, S., Zeb, Q., Ali, A., Sajjad, Y., Nazir, R., Widemann, E., Liu, L. (2019). Lead, Cadmium and Zinc Phytotoxicity Alter DNA Methylation Levels to Confer Heavy Metal Tolerance in Wheat, International Journal of Molecular Sciences, vol. 20, nr. 19: p 4676.
35. Shahbazi, Y., Ahmadi, F., Fakhari, F. (2016). Voltammetric determination of Pb, Cd, Zn, Cu and Se in milk and dairy products collected from Iran: An emphasis on permissible limits and risk assessment of exposure to heavy metals, Food Chemistry, vol. 192: p 1060–1067.
36. Shaheen, N., Ahmed, M.K., Islam, M.S., Habibullah–Al–Mamun, M., Tukun, A.B., Islam, S., Rahim, A.T. (2016). Health risk assessment of trace elements via dietary intake of 'non-piscine protein source' foodstuffs (meat, milk and egg) in Bangladesh, Environmental Science and Pollution Research, vol. 23, nr. 8: p 7794–7806.

37. Tahir, M., Iqbal, M., Abbas, M., Tahir, M.A., Nazir, A., Iqbal, D.N., Kanwal, Q., Hassam, F., Younas, U. (2017). Comparative study of heavy metals distribution in soil, forage, blood and milk, Acta Ecologica Sinica, vol. 37, nr. 3: p 207–212.
38. Thorning, T.K., Raben, A., Tholstrup, T., Soedamah–Muthu, S.S., Givens, I., Astrup, A. (2016). Milk and dairy products: good or bad for human health? An assessment of the totality of scientific evidence, Food & Nutrition Research, vol. 60: p 32527.
39. US Department of Health and Human Services & US Department of Agriculture, (2015). Dietary Guidelines for Americans, ed. 8.
40. Varol, M., Sunbul, M.R. (2020). Macroelements and toxic trace elements in muscle and liver of fish species fromthe largest three reservoirs in Turkey and human risk assessment base on the worst-case scenarios, Environmental Research, vol 184: p 26.
41. Verduci, E., D'Elios, S., Cerrato, L., Comberiati, P., Calvani, M., Palazzo, S., Martelli, A., Landi, M., Trikamjee, T., Peroni, D.G. (2019). Cow's milk substitutes for children: nutritional aspects of milk from different mammalian species, special formula and plant-based beverages, Nutrients, vol. 11, nr. 8: p 1739.
42. Zwierzchowski, G., Ametaj, B.N. (2019). Mineral elements in the raw milk of several dairy farms in the province of Alberta, Foods, vol. 8, nr. 8: p 345.