CURRENT CHALLENGES REGARDING THE INTERRELATION BETWEEN ENVIRONMENTAL POLLUTION, ANIMAL PRODUCTION AND CONTAMINATION ISSUES IN ANIMAL SOURCE FOODS

Mădălina MATEI, Silvia Ioana PETRESCU, Dragoș LĂPUȘNEANU, Cristina RADU-RUSU, Daniel SIMEANU, Ioan Mircea POP

Faculty of Food and Animal Sciences, Iași University of Life Sciences "Ion Ionescu de la Brad", Iași, Romania

REVIEW

Abstract

Obtaining good quality animal productions, in a polluted environment, represents only one of the various challenges of the relationship between environment and animal production. The purpose of this study was focused on the relationship between environmental pollution and animal production, especially on evaluation the contamination problems on the agro-food chain in order to ensure the safety of animal source foods. In order to clarify the biological behavior of pollutants and their transfer particularities, and also, to develop appropriate strategies for environmental protection, this paper highlights some of the most important aspects of the literature regarding the types and proportions of organic pollutants founded in vegetal production used as animal feed and also in the animal source foods obtained. The incidence of organic pollutants founded in feed and animal products analyzed in various research shows that animal feed and animal production may be liable to continuous contamination, the levels identified highlighting how pollutants can affect the safety of feed and food.

Keywords: pollutants, incidence, feed, food.
#Corresponding author: madalina.matei@uaiasi.ro

INTRODUCTION

Industrial and technological advances have led to release of high amounts of pollutants from various productive sectors, making pollution a topical issue for a modern society. Environmental destabilization is often a result of human activities, which generate a multitude of substances with ecotoxicological relevance for natural ecosystem.

The expansion of the world population and the increase in living standards have led in recent years to the increase in high-quality food demands. By transforming agricultural crops into feed and using animals for obtaining different production, the agriculture and animal husbandry sector has become the main supplier of food products with high nutritional value for society (Baumgard et al., 2017).

Ranking the contaminants according to their persistence in the environment, highlights one of the most harmful groups of pollutants with special ecotoxicological relevance for the ecosystem: persistent organic pollutants (POPs). Low degradability in the environment and long-distance transfer potential allow this category of pollutants to easily accumulate in the natural substrate, water, air or soil being important vectors for contamination of plants and animal body (Loganathan et al., 2011).

The particularities of transfer of pollutants in environmental components have created a strong connection between environmental pollution, animal production and humans (Ali et al., 2019; Zubairi et al., 2021).

Animal production as a result of intensive growth and diversification of productions has made animals themselves an important problem in the interrelationship with environmental pollution. Although it depends on the relationship with environment, contrary, raising animals can represent a source of pollution, animals being harmful to environment because of waste and gaseous emissions, but also because of residues from the current care treatments (Dumitraș, 2008).

The purpose of this study was focused on review of several researches on the relationship between environmental pollution and animal production, especially evaluating contamination problems on the agro-food chain in order to ensure the safety of animal products.

This comparative study was carried out to clarify the biological behavior of pollutants in environment, the particularities of transfer along food chain, as well as to develop suitable strategies for protecting the environment and reducing exposure to pollution.

Therefore, this paper highlights some of the most relevant aspects of the literature regarding the types and proportions of organic pollutants, as representative modern pollutants, found in vegetal production used as animal feed and also in animal food sources obtained, in order to outline their incidence.

MATERIAL AND METHOD

This paper includes a bibliographic study of the most relevant aspects of the literature on the types and proportions of organic pollutants found in vegetal production used as animal feed and in animal production obtained, along with the identification of the main sources of pollution, factors which favors their accumulation in plant and animal body, their mobility characteristics and also their toxicity in relation to the contaminated substrate.

The analytical methods used to identify the presence of POPs generally include lipid extraction step, partitioning and purification of samples and separating of polluting residues according to variable detection limits.

Separation, quantification and confirmation of presence of pollutants in feed and food samples is usually done by analytical, and high selectivity methods, based on principles of chromatographic separation, such as: high performance liquid chromatography coupled with mass spectrometry–LC-MS (Sun et al., 2020; Bommuraj et al., 2020); high performance liquid chromatography with UV detection (Rezaei et al., 2014); gas chromatography (Piskorska–Pliszczynska et al., 2017); gas chromatography coupled with mass spectrometry–GC–MS (Welsh et al., 2019); gel permeation chromatography (Chen et al., 2017).

The study include specialized data from the last two decades and can be an important basis for future research in this topic.

RESULTS AND DISCUSSIONS

The destabilization of environment is most often a result of human activities, conscious or not, but which generates a multitude of components that interact with the elements of ecosystem, from soil, water, air, plants, animals and up to human body.

Being symbionts of nature, in relation to pollution, the components of ecosystem can not be ranked by importance. However, over time, focus has been particularly on awareness of negative effects of pollution on vegetal production–as feed, on animal husbandry–in terms of productions, but also on humans–as consumers of animal productions, all these being areas where pollutants can outline a sufficiently complex path (Zubairi et al., 2021).

In environment, non-degradable pollutants are dynamic and their behavior is differentiated. For this reason, because of their particularities, they become a real threat to all trophic levels. The influence of pollutants is in generally quantified in terms of proportions, time spent in the body, by physiological mechanisms developed by organism, but also by characteristics of host tissue (Ali et al., 2019).

In relation to their properties, organic pollutants have high mobility in the environment, their particularities being highlighted in numerous papers (Ali et al., 2019; Jaspers et al., 2014), which describe them as an important environmental contaminants.

The pollution cycle begins with soil and plants. In next step, the accumulation of pollutants in different parts of plants provided as feed leads to the bioaccumulation of pollutants in animal body and then their transfer to production (Kim et al., 2013).

Being the interface between soil and atmosphere, after Teil et al. (2004); Yang and Zhu (2007), in plants, pollutants can reach by air deposition or root absorption. According to Creaser et al. (2007), distribution sources mentioned above are related to many variables such as wind speed and direction, temperature (influences the way substances are present in the atmosphere), plant permeability, as well as the physico-chemical properties of pollutants.

Through feed intake, the animal body may be exposed to accumulation of polluting or contaminating compounds, especially those with a preference for fatty tissues. Data from the literature, provided by EFSA (2005) and Tao et al. (2009), showed in this topic, that lipids can serve as "storage deposits" in the body, for pollutants with high lipophilicity; the main route of entry into animal body is consumption of feed in whose composition can be found.

In case of animal productions, the particularities of pollutants transfer from animal body in productions were studied by Thomas et al. (1999), highlighting the importance of physiological condition of animals as an influencing factor in this cycle.

According to Manciulea & Dumitrescu (2016), exposures to organic pollutants are generally chronic, so assessing their incidence and their influence requires grouping them into categories, in relation to the toxicity applied on different substrates, according to figure 1.

Based on the mobility characteristics, Rodriguez–Hernandez et al. (2015) noted that organic pollutants can be easily transferred to the chain: soil–vegetal production–animal production. Particularly, Pop et al. (2006) had pointed out that the transfer of substances from feed into animal body and animal production is well reflected in case of cows and milk.

As a result of variables in production process, from animal husbandry to finished product, Rychen et al. (2008) described milk and dairy products as among foods with a high risk of exposure to POPs contamination. In milk, accumulation of persistent organic compounds is the consequence of their main properties: chemical persistence and lipophilicity, being frequently stored in body tissues rich in lipids and subsequently transmitted to milk production (Avancini et al., 2013).

Monitoring of pollutants and contaminants in food substrates has shown that persistent organic substances have been little studied as factors of milk contamination. The increase of incidence in dairy analyzed samples has made the monitoring and identification of organic pollutants in cow's milk more frequent. Thus, aspects of contamination with persistent organic pollutants in milk and dairy products have been mentioned in various studies on organochlorine pesticides such as DDT, HCH, Aldrin, Dieldrin, Clordan or Heptachlor (Nida`m et al., 2009; Tsiplakou et al., 2010).

The presence of POPS as modern pollutants has long been a topic of interest, especially because their identification from different substrates requires complex, selective and accurate methods and techniques of analysis (CEC, 2011).

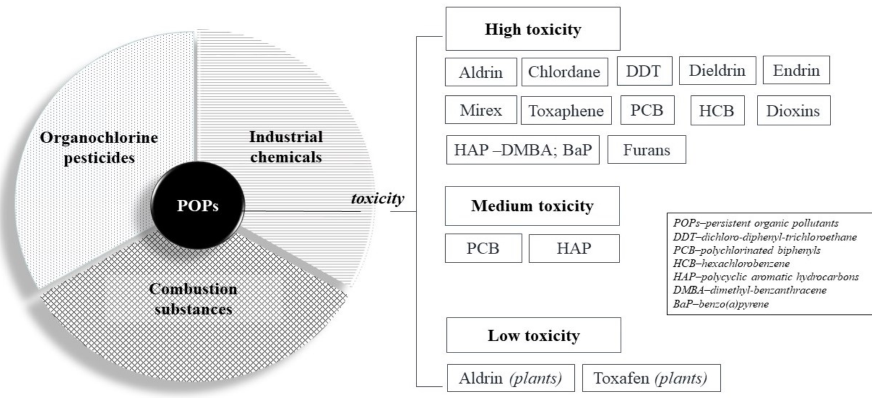

Figure 1 **Classification of organic pollutants according toxicity**

The change in emissions of organic pollutants has led to the development of many global legislative frameworks to reduce the consequences of pollution, eliminate existing pollutants or prevent possible contamination. Therefore, toxic potential of organic pollutants has been intensively monitored over time, and the most harmful of these have become part of legislation in this regard. According to environmentalists, at least 12 such organic substances with toxic properties and negative influences on living organisms became, in 2001, part of the Stockholm Convention on Persistent Organic Pollutants. According to the European Chemicals Agency (2021), currently, the list of banned or restricted organic pollutants reaching about 28 hazardous chemicals.

The proportions of organic pollutants in feed, the particularities of transfer in animal body and animal production, and also their relevance for milk contamination were studied by Tremolada et al. (2014); Piskorska–Pliszczynska et al. (2017) which outlined, by analyzing their proportions, the transfer potential of pollutants into cow's milk, the results obtained by them being similar with the results obtained in a previous study, developed by Lake et al. (2013), which found that any detection of organic pollutants in animal body or in animal production indicates the presence of contaminants in administered feed.

Both in environment, in plants and animal body, is difficult to understand the behavior of pollutants because their characteristics are related to multiple factors.

On organic pollutants, environmental factors do not have a high capacity for action because they cannot withstand the permanent accumulation that takes place in the environment. However, as Daly & Wania (2005); Manciulea & Dumitrescu (2016) point out, temperature, vapor pressure and sunlight can still be important for the pollutants cycle in nature: low temperatures–facilitate the passage of POPs from vapors into particles suspended in the atmosphere, causing slower migration from one area to another; high temperatures–facilitate the atmospheric expansion of pollutants; sunlight–increase the persistence of organic pollutants.

The literature includes numerous research on POPs pollution, most of sources including human activities such as industrial processes and agricultural practices, transport or inadequate waste management. If for plants, the main source of contamination with organic pollutants is their absorption from the soil, for animal body, the main path of contamination is the consumption of contaminated feed (EFSA, 2005), while in animal production the presence of pollutants is a consequence of their metabolic transfer from the body (Aytenfsu et al., 2016).

Table 1

Proportions of POPs identified in feed and milk in different regions

POPS[1]		REGION	QUANTITY $ng\ g^{-1}$	METHODS	REFERENCES
VP - Feed	OCP[2] (γ – HCH[3]; DDE[4], Endosulfan sulfate)	India	1.90–2.95	GC[13]	Bedi et al., 2018
	∑PCB*[7]	France	52.20–79.86	GC-HRMS[13]	Costera et al., 2006
	PCDD[8] (TCDD[9], OCDD[10]); PCDF[8] (TCDF[9], OCDF[10])	France, Spain	60–1490	GC-HRMS[13]	Costera et al., 2006 Schuhmacher et al., 2004
	PCDD[8] (TCDD[9], OCDD[10]); PCDF[8] (TCDF[9], OCDF[10]); DL–PCBs[11]	Poland	20–100	GC[13]	Piskorska–Pliszczynska et al., 2017
	DL–PCB** [11]	Iran	Ns.	GC – ECD[13]	Ahmadkhaniha et al., 2017
AP - Milk	OCP[2] (α, β, γ – HCH[3]; HCB[6], DDE[4], DDT[5], Endosulfan sulfate; α, β – endosulfan, Dieldrin)	France, Iran, Romania, Pakistan	0.46–41.46	GC-HRMS[13] HPLC[14]	Costera et al., 2006; Jahed Khaniki, 2007; Rusu et al., 2016; Sajid, 2015
	α, β, γ – HCH[3]	Romania	Ns.	GC – MS[13]	Rusu et al., 2016
	HCB[6], DDT[5], DDE[4]	USA	Ns.	LC – MS[14]	Zubairi et al., 2021
	∑PCB*[7]	Iran, USA	18.92–172.4	GC – ECD[13]; QuEChERS – GTMS ***	Ahmadkhaniha et al., 2017 Chen et al., 2017
	PCDD / PCDFs[8]	Italy, Poland, Iran	1.77–5.84	GC-HRMS[13] HPLC – UV [14]	Desiato et al., 2014; Rezaei et al., 2014
	DL – PCBs[11]	Iran, Italy, Poland	0.13–5.18	GC – ECD[13]; GC-HRMS[13]	Ahmadkhaniha et al., 2017; Piskorska–Pliszczynska et al., 2017
	ΣPAH[12]	China, New Zealand, Europe	8.18–9.38	HPLC[14]	Sun et al., 2020
		Iran	1.42	HPLC–MS / FID[14]	Shariatifar et al., 2019

[1]POPs=persistent organic pollutants; [2]OCP=organo–chlorine pesticides; [3]HCH=hexachlorocyclohexane; [4]DDE=dichloro–difenil–dicloroetano; [5]DDT=dichloro–difenil–tricloroetano; [6]HCB=hexachlorobenzene; [7]PCB=polychlorinated biphenyls; [8]PCDD/F=dibenzo-p-dioxins and dibenzofurans polychlorinated; [9]TCDD/F=dibenzo-p-dioxins and dibenzofurans tetra chlorinated; [10]OCDD/F=dibenzo-p-dioxins and dibenzofurans octa chlorinated; [11]DL–PCB=dioxin-like PCBs; [12]PAHs=polycyclic aromatic hydrocarbons;[13]GC=gas chromatography (HR/MS=high resolution/mass spectrometry; ECD=electron capture detector); [14]HP/LC=high performance liquid chromatography (MS/FID=mass spectrometry/flame ionization detector); VP=vegetal production; AP=animal production; Ns.=unspecified; *∑PCB (77,81,126,169,105,114,118,123,156,157,167,189,28,52,101,138,153,18); **∑DL–PCB (77, 81, 126, 169, 105, 114, 123, 156, 157, 167, 189);*** purified by gel permeation chromatography and quantified by chromatography gas–triple mass spectrometry quadruple.

In relation to their particularities, the incidence of organic pollutants has been the subject of some studies developed in different regions of the world, different proportions of pollutants being identified, on their traceability system, from vegetal production used as feed, to animal body and its production, by different detection methods (Table 1). Bedi et al. (2018)

studied the exposure of ruminants to POPs in relation to feed, by determining, in particular, the incidence of organochlorine pesticides (OCPs) in feed supplied to cattle and presence of their residues in milk. Following the study, the authors highlighted the presence of OCPs, identifying proportions between 1.90–2.95 ng/g in all feed samples.

PCDD/PCDF and PCB proportions were determined for some feed samples collected near industrial pollution sources in Spain by Schuhmacher et al. (2004). In France, Costera et al. (2006), determined the presence of pollutants in animal feed and also the possibility of transferring their residues in milk. The data reported by the both studies after the experimental period showed an average proportions of PCDD/PCDF in the analyzed feeds of 60–1490 ng/g, values higher than those reported by Piskorska–Pliszczynska et al. (2017) in a similar study in Poland, which showed proportions of dioxins and furans in cows feed of 20–100 ng/g.

Data about POPs contamination of milk and dairy products have been mentioned in various studies on OCPs of type α, β, γ–HCH; HCB, DDE, DDT, α, β–endosulfan, Dieldrin (Costera et al., 2006; Jahed Khaniki, 2007; Rusu et al., 2016), PCB (Ahmadkhaniha et al., 2017; Chen et al., 2017), PCDD/PCDFs and DL–PCBs (Ahmadkhaniha et al., 2017; Desiato et al., 2014; Jirdeji et al., 2015; Piskorska–Pliszczynska et al., 2017; Rezaei et al., 2014) or PAH (Shariatifar et al., 2019; Sun et al., 2020).

Recent studies developed by Welsh et al. (2019) for the assessment of OCPs incidence in milk showed residues of several pesticides in about 70 % of the samples taken. Also, to quantify the degree of OCPs contamination in milk, Vasconcelos–Rego et al. (2019) have carried out a review of several works over the last two decades, high proportions of polluting residues from contaminated feed being identified in milk in different parts of the world.

In Romania, Rusu et al. (2016) determined the OCPs incidence (HCH, DDT) in milk collected in vicinity of an urban area from NE of the country, by analyzing samples from individual farms or producers. Results obtained during the experimental period indicated that in all samples important residual contents of γ–HCH (lindane) were identified, while DDT compounds were not detected in any samples.

In their study, Chen et al. (2017) determined 19 types of polychlorinated biphenyls (PCBs) from eight milk samples, variable proportions of PCBs being detected in all milk samples analyzed. Based on identified proportions, three of the most common types of PCBs were highlighted.: PCB–101 (23.6 pg/mL milk); PCB–118 (25.2 pg / mL milk); PCB–138 (25.3 pg/mL milk).

CONCLUSIONS

The incidence of organic pollutants found in the environment shows that animal feed and animal source foods can be prone to continuous contamination, the proportions identified highlighting how pollutants can affect the safety of feed and food.

Pollution must include consistent efforts at all levels, by identifying safe alternatives to reduce the impact on environment and identifying appropriate methods to reduce toxicity and environmental damage.

REFERENCES

Ahmadkhaniha, R., Nodehi, R.N., Rastkari, N. & Aghamirloo, H.M., 2017. Polychlorinated biphenyls (PCBs) residues in commercial pasteurized cows' milk in Tehran, Iran. J. Environ. Health Sci. Eng. 15(1), 15.

Ali, H., Khan, E. & Ilahi, I., 2019. Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity and Bioaccumulation. Hindawi J. Chem. 4, 1–14.

Avancini, R.M., Silva, I.S., Rosa, A.C., Sarcinelli, P.D. & de Mesquita, S.A, 2013. Organochlorine Compounds in Bovine Milk from the State of Mato Grosso do Sul-Brazil. Chemosphere 90 (9), 2408.

Aytenfsu, S., Mamo, G. & Kebede, B., 2016. Review on Chemical Residues in Milk and Their Public Health Concern in Ethiopia. J. Nutr. Food Sci. 6(4), 524.

Baumgard, L.H., Collier, R.J. & Bauman D.E., 2017. A 100-Year Review: Regulation of nutrient partitioning to support lactation. JDS, 100, 10353–10366.

Bedi, J.S., Gill, J.P.S., Kaur, P. & Aulakh, R.S., 2018. Pesticide residues in milk and their relationship with pesticide contamination of feedstuffs supplied to dairy cattle in Punjab (India). J. Anim. Feed Sci. 27, 18–25.

Bommuraj, V., Chen, Y., Gal, O., Ben Ari, J., Kertsnus-Banchik, E., Barel, S. & Shimshoni, J.A., 2020. Human pharmaceutical and pesticide residues in Israeli dairy milk in association with dietary risk assessment. Food Addit. Contam. 14, 1–11.

Chen, X., Lin, Y., Dang, K. & Puschner, B., 2017. Quantification of Polychlorinated Biphenyls and Polybrominated Diphenyl Ethers in Commercial Cows' Milk from California by Gas Chromatography–Triple Quadruple Mass Spectrometry. PLoS ONE 12(1), 1–8.

Commission Regulation (EU) 836/2011 amending Regulation (EC) 333/2007 laying down the methods of sampling and analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuff. Official Journal of the European Union L 215/9.

Costera, A., Feidt, C., Marchand, P., Le Bizec, B., & Rychen, G., 2006. PCDD/F and PCB transfer to milk in goats exposed to a long-term intake of contaminated hay. Chemosphere 64(4), 650-657.
Creaser, C.S., Wood, M.D., Alcock, R., Copplestone, D. & Crook, P.J., 2007. UK Soil and Herbage Pollutant Survey Report no. 8, Environmental Concentrations of Polychlorinated Biphenyls (PCBs). Environment Agency, UK.
Daly, G.L. & Wania, F., 2005. Organic contaminants in mountains. Environ. Sci. Technol. 39(2), 385-398.
Desiato, R., Bertolini, S., Baioni, E., Crescio, M.I., Scortichini, G., Ubaldi, A., Sparagna, B., Cuttica, G. & Ru, G., 2014. Data on milk dioxin contamination linked with the location of fodder croplands allow to hypothesize the origin of the pollution source in an Italian valley. Sci. Total Environ. 499, 248–256.
Dumitraș, A., 2008. Efectele poluării asupra degradării mediului înconjurător. ProEnviron. 2, 110-113.
European Chemical Agency (ECHA), 2021. List of substances subject to pops regulation.
European Food Safety Authority (EFSA), 2005. Opinion of the scientific panel on contaminants in the food chain on a request from the commission related to the presence of non-dioxin-like polychlorinated biphenyls (PCB) in feed and food. The EFSA Journal 284, 1-137.
Jahed Khaniki, Gh.R., 2008. Chemical Contaminants in Milk and Public Health Concerns: A Review. Int. J. Dairy Sci. 2, 104–115.
Jaspers, V., Megson, D. & O'Sullivan, G., 2014. POPs in the Terrestrial Environmental. Environ. Forensics 291-356.
Jirdeji, Z.S., Qajarbeygi, P., Hosseini, H. & Babaei, A.H.H., 2015. The survey of polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and dioxin-like polychlorinated biphenyls levels in pasteurized cow's milk collected in Qazvin. J. Food Saf. Hyg. 1(1), 8–12.
Kim, M., Cho, B.H., Lim, C.M., Kim, D.G., Yune, S.Y., Shin, J.Y., Bong, Y.H., Kang, J., Kim, M.A. & Son, S.W., 2013. Chemical residues and contaminants in foods of animal origin in Korea during the past decade. J. Agric. Food Chem. 61(10), 2293–2298.
Lake, I.R., Foxall, C.D., Fernandes, A., Lewis, M., Rose, M., White, O. & Dowding, A., 2013. Seasonal variations in the levels of PCDD/Fs, PCBs and PBDEs in cows' milk. Chemosphere 90(1), 72-79.
Loganathan, B.G. & Kwan–Sing Lam, P., 2011. Global Contamination Trends of Persistent Organic Chemicals. CRC Press 1, Boca Raton, Fla, USA.
Manciulea, I. & Dumitrescu, L., 2016. Poluanți organici persistenți–Introducere. Transilvania University of Brașov, "Learning Toxicology through Open Educational Resources (TOX-OER).
Nida'm, S., Rafat, A. & Hussein, E., 2009. Organochlorine Pesticide Residues in Dairy Products in Jordan. Chemosphere 77(5), 673.
Piskorska–Pliszczynska, J., Maszewski, S., Mikolajczyk, S., Pajurek, M., Strucinski, P. & Olszowy, M., 2017. Elimination of dioxins in milk by dairy cows after the long–term intake of contaminated sugar beet pellets. Food Addit. Contam. 34(5), 842-852.
Pop, I.M., Halga, P. & Avarvarei, T., 2006. Nutriția și alimentația animalelor. Editura TipoMoldova, Iași.
Rezaei, M., Akbari Dastjerdi, H., Jafari, H., Farahi, A., Shahabi, A., Javdani, H., Teimoory, H., Yahyaei, M. & Malekirad, A.A., 2014. Assessment of dairy products consumed on the Arakmarket as determined by heavy metal residues. Health 6(5), 323-327.
Rodríguez–Hernández, A., Camacho, M., Boada, L.D., Ruiz–Suarez, N., Almeida–González, M., Henríquez–Hernández, L.A., Zumbado, M. & Luzardo, O.P., 2015. Daily intake of anthropogenic pollutants through yogurt consumption in the Spanish population. J. Appl. Anim. Res. 43, 373-383.
Rusu, L., Harja, M., Suteu, D., Dabija, A. & Favier, L., 2016. Pesticide Residues Contamination of Milk and Dairy Products. A case study: Bacău District Area, Romania. J. Environ. Prot. Ecol. 17(3), 1229-1241.
Rychen, G., Jurjanz, S., Toussaint, H. & Feidt, C., 2008. Dairy ruminant exposure to persistent organic pollutants and excretion to milk. The Animal Consortium 2(2), 312-323.
Sajid, M.W., 2015. Pesticides residues and aflatoxins in milk and their dissipation during processing. National Institute of Food Science and Technology–Faculty of Food, Nutrition and Home Sciences, University of Agriculture, Faisalabad.
Schuhmacher, M., Nadal, M. & Domingo, J.L., 2004. Levels of PCDD/Fs, PCBs, and PCNs in soils and vegetation in an area with chemical and petrochemical industries. Environ. Sci. Technol. 38(7), 1960–1969.
Shariatifar, N., Dadgar, M., Fakhri, Y., Shahsavari, S., Moazzen, M., Ahmadloo, M., Kiani, A., Aeenehvand, S., Nazmara, S. & Khanegah, A.M., 2019. Levels of polycyclic aromatic hydrocarbons in milk and milk powder samples and their likely risk assessment in Iranian population. J. Food Compos. Anal. 85, 1–46.
Sun, Y., Yan, K., Wu, S. & Gong, G., 2020. Occurrence, spatial distribution and impact factors of 16 polycyclic aromatic hydrocarbons in milks from nine countries. Food Control 113, 1–10.
Tao, S., Liu, W.X., Li, X.Q., Zhou, D.X., Li, X. & Yang, Y.F., 2009. Organochlorine pesticide residuals in chickens and eggs at a poultry farm in Beijing, China. Environ. Pollut. 157(2), 497–502.
Teil, M.J., Blanchard, M. & Chevreuil, M., 2004. Atmospheric deposition of organochlorines (PCBs and pesticides) in northern France. Chemosphere 55(4), 501–514.
Thomas, G.O., Sweetman, A.J. & Jones, K.C., 1999. Metabolism and body–burden of PCBs in lactating dairy cows. Chemosphere 39(9), 1533-1544.
Tremolada, P., Guazzoni, N., Parolini, M., Rossaro, B., Bignazzi, M.M. & Binelli, A., 2014. Predicting PCB concentrations in cow milk: validation of a fugacity model in high-mountain pasture conditions. Sci. Total Environ. 487, 471–480.
Tsiplakou, E., Anagnostopoulos, C.J., Liapis, K., Haroutounian, S.A. & Zervas, G., 2010. Pesticides Residues in Milks and Feedstuff of Farm Animals Drawn from Greece. Chemosphere 80(5), 504.
Vasconcelos–Rego, I.C.V., dos Santos, G.N.V., dos Santos, G.Ni.V., Ribeiro, J.S., Lopes, R.B., dos Santos, S.B., de Sousa, A., Mendes, R.A., Taketomi, A.T.F., Vasconcelos, A.A. & Taube, P.S., 2019. Organochlorine pesticides residues in commercial milk: a systematic review. Acta Agronomica 68(2), 25-33.
Welsh, J.A., Braun, H., Brown, N., Um, C., Ehret, K., Figueroa, J. & Barr, D.B., 2019. Production–related contaminants (pesticides, antibiotics and hormones) in organic and conventionally

produced milk samples sold in the USA. Public Health Nutr. 22(16), 2972-2980.
Yang, Z. & Zhu, L., 2007. Performance of the partition-limited model on predicting ryegrass uptake of polycyclic aromatic hydrocarbons. Chemosphere 67(2), 402–409.
Zubairi, N.A., Takaijudin, H. & Yusof, K.W., 2021. A Review on the Mechanism Removal of Pesticides and Heavy Metals from Agricultural Runoff in Treatment Train. Int. J. Environ. Ecol. Eng. 15(2), 75–86.