Chapter

Influence of Heavy Metals on Quality of Raw Materials, Animal Products, and Human and Animal Health Status

Anna Bartkowiak

Abstract

Heavy metals constitute one of the threats to the natural environment and the health of living organisms. The sources of contamination of the environment with heavy metals are mainly industry, thermal and chemical processing of mineral resources, burning of coal, gases and liquid fuels, municipal economy (rubbish dumps, sewage), and agriculture consuming mineral fertilizers, plant protection agents, utilizing huge loads of pollution accompanying animal production. Accumulation of toxic elements in plant tissues leads to disturbances in plant reproduction and thus to lowering of their nutritional value. In humans and animals, in turn, it may cause poisoning and the occurrence of various disorders and diseases, including cancer. There are different ways to reduce the penetration of heavy metals into crops and deactivation in animal organisms—by using the tolerance of plants to heavy metals, cleaning the environment through phytoremediation, the use of antagonistic type interactions to reduce bioaccumulation in animal tissues, as well as the properties of compounds of organic and mineral origin. The aim of the chapter is to present the problems of environmental pollution and accumulation of heavy metals (mainly cadmium, mercury, and lead) in tissues of farm animals, their impact on human and animal health, as well as the possibility of inactivation of heavy metals in animal organisms.

Keywords: heavy metals, soil and plants, quality of raw materials, animal products, health status

1. Introduction

Problems concerning heavy metals are studied all over the world, including in Europe. This is because they constitute one of the threats to the natural environment and the health of living organisms, and thus pose a problem in the implementation of the concept of sustainable development [1, 2].

In the accepted classification of elements participating in life processes, heavy metals, such as mercury, lead, and cadmium, do not play any significant role in metabolism. They are considered to belong to the group of extreme toxicants with known embryotoxic, teratogenic, mutagenic, and carcinogenic effects. Even in trace amounts, they pose a real threat to living organisms. In the natural environment, there are also other heavy metals, such as arsenic, zinc, nickel, copper, which are also toxic and may cause poisoning and cancer. The effects of heavy metals entering the human body can be revealed even after many years [3].

In the past, the danger resulting from the presence of these metals in the environment concerned only certain groups of people employed in specialized branches of industry. Currently, as a result of development and civilization changes, toxic elements may appear in high concentrations far beyond the sources of contamination. This violates the biological balance of ecosystems, and their presence in the trophic chain creates exposure conditions for wide groups of the population [3].

The sources of contamination of the environment with heavy metals are the mining industry and mechanical, thermal, and chemical processing of mineral raw materials. Other important sources of emission of metallic elements are large-scale burning of coal, gases, and liquid fuels (motorization), municipal economy (waste dumps, sewage), and agriculture consuming mineral fertilizers, plant protection agents, utilizing huge loads of pollution accompanying animal production and processing industry. Monitoring studies of soils, drinking water, plants, as well as tissues of farm animals and products of animal origin (milk, eggs, honey) indicate considerable variability of heavy metal concentrations in this material, from trace to many times exceeding permissible values. In the case of animals, it depends on the animal species, life stage, husbandry system, and location of the breeding facility [3–8].

It has been repeatedly shown that mineral fertilizers have heavy metals in their composition, which lead to soil pollution. Fertilizers can be ranked in ascending order of heavy metal contamination—nitrogenous, potassic, calcareous, and phosphatic. The accumulation of these elements in the fertilizer material depends primarily on the technology used and the material from which they are produced (**Table 1**) [7, 9, 10].

Agriculture is the dominant land-use industry where large amounts of agrochemicals are applied. Unfortunately, metals and pesticides in the soil can reach aquatic ecosystems through leaching, soil erosion, and surface runoff [11]. The combination of heavy metals with pesticides is very dangerous because they can cause very serious health consequences for humans and animals. They contribute to neurodegenerative disorders, musculoskeletal diseases, and hormonal imbalances, are carcinogenic, cause genetic damage [12].

Source	Ace	Cd	Cu	Hg	Ni	Pb	Zn
Sewage sludges	2–26	2–1500	50–3300	0.1–55	16–5300	50–3000	700–49,000
Nitrogen fertilizers	2–120	0.05–8.5	1–15	0.3–3	7–38	2–1450	1–42
Phosphate fertilizers	2–1200	0.1–170	1–300	0.01–1.2	7–38	7–225	50–1450
Limestones	0.1–24.0	0.04–0.1	2–125	0.05	10–20	20–1250	10–450
Manure	3–25	0.3–0.8	2–60	0.09–0.2	7.8–30	6.6–15	15–250
Pesticides (%)	22–60	—	12–50	0.8–42	—	60	1.3–25

Source: own study based on [7].

Table 1.
Agricultural sources of heavy metals contamination in soils (ppm DW).

Therefore, the aim of the chapter is to present the problems of environmental pollution and accumulation of heavy metals (mainly cadmium, mercury, and lead) in tissues of farm animals, their impact on human and animal health, as well as the possibility of inactivation of heavy metals in animal organisms.

2. Heavy metal contamination of soils, plants, and drinking water

The excess of heavy metals in the soil inhibits the development of microorganisms and disrupts processes related to the transformation of organic matter. It also causes the accumulation of toxic elements in plant tissues, leading to disturbances in plant reproduction and thus lowering their nutritional value. [13–15] Excessive accumulation of the mentioned elements in the soil, however, is harmful to plants in particular [3, 7, 16, 17].

In soil, heavy metals can occur in different forms—dissolved in soil solution, exchangeable in organic and inorganic components, being structural components of soil grids, and as insoluble sediments with other soil components. The first two forms are the most available to plants. The concentration of elements in the soil depends on the pH of the soil—the higher (to slightly alkaline) the higher the immobilization of elements. The mobility of heavy metals in the soil varies. In acidic soils, Cd, Ni, and Zn are particularly mobile, Cr is moderately mobile and Cu and Pb are immobile. In neutral and alkaline soils, Cr is highly mobile, Cd and Zn are moderately mobile, and Ni is immobile. Other factors, such as cation exchange capacity, redox potential, organic matter content, type and amount of clay minerals, and oxide content of antagonistic elements Fe, Al, and Mn, also determine the increase of heavy metals in the soil and thus their availability to plants [18].

The natural cadmium content in soils is 0.2–1.05 mg kg^{-1} d.m. It is a highly mobile, active element, and easily assimilated by plants because of the available form of Cd^{2+} ion. The environmental hazard is related to the fact that Cd is one of the most toxic metals that show adverse effects on soil biological activity, plant metabolism, human health, and the animal kingdom. Excess cadmium in the plant manifests itself by twisting of leaves and the appearance of brown spots on the leaves [7].

Another toxic element is lead. Its natural content in soil is strongly related to the composition of the rock substrate. It is characterized by the lowest mobility among heavy metals. The highest Pb content in soil is found in highly industrialized areas. Lead can enter the body from two sources—the food chain and through inhalation of soil dust. It is a very dangerous metal with negative effects on humans, animals, and plants. Excess lead leads to reduced yields and dark green or red spots on leaves. Lead content in soil exceeding 500 mg kg^{-1} is a toxic value. A characteristic feature of this heavy metal is its accumulation in the human body, as it does not disintegrate in this environment. Getting into the human body a dose of about 20–50 g leads to death [7, 19–23].

In the case of copper, its excess causes tissue damage and elongation of root cells, alteration of membrane permeability and leakage of ions (e.g., K) and solutes from roots, peroxidation of chloroplast membrane lipids and inhibition of photosynthetic electron transport, immobilization of Cu in cell walls, in cell vacuoles and nondispersive Cu-protein complexes, as well as DNA damage and consequently inhibition of photosynthetic processes. Manganese, on the other hand, has a significant effect on some soil properties, particularly raising pH. Mn compounds are known for their rapid oxidation and reduction under varying soil conditions, thus oxidizing [7].

Nickel has become a major pollutant that is released during emissions from metal processing and increasing coal and oil burning, sludge application. Some phosphate fertilizers may also be an important source of Ni [3, 7].

In Poland, the permissible content of heavy metals (so-called risk-causing substances) on agricultural land is defined by the Regulation of the Minister of Environment of September 1, 2016, on the manner of conducting the assessment of land surface pollution (Annex No. 1 to the Regulation) [24]. According to the Ordinance, risk-causing substances that are particularly important for the protection of the earth surface and the permissible contents of these substances in the soil and the permissible contents of these substances in the soil [mg kg^{-1} dry mass of the earthy parts of the soil (<2 mm)] are defined (**Table 2**)—for depths 0–0.25 m ppt and more than 0.25 m ppt, with the division taking into account the soil groups and separated based on their use, the soil subgroups separated based on the soil properties (defined for the soil group II) and the soil and groundwater permeability.

Koncewicz-Baran and Gondek [25] investigated the content of general forms and bioavailable elements (Cd, Cr, Ni, Cu, Pb, Zn, and Mn) in agriculturally used soils showed that among the investigated soils, the natural content of Ni, Cu, and Pb was the highest. In other soils, increased content of Cd and Zn was determined.

Li et al. [26] pointed out the problem of soil contamination in China due to increased industrial development and urbanization. In Hunan Province, Central China, a study was conducted on the content of heavy metals in soil (Pb, Zn, Cu, Cd, As, Hg, Cr, and Ni). The results showed that the content of each heavy metal in the soil varied spatially. The highest accumulation was shown for Cd, followed by Pb, Zn, As, and Hg.

Plants can accumulate toxic metals from the soil over a very wide range. This depends on its temperature, reaction, water capacity, and potential. Under conditions of high immission, plants take up heavy metals from the air through the leaf blades. Strong accumulation of heavy metals in the root system and the aboveground parts of plants is a result of a poorly developed mechanism of chemical homeostasis in plants, which leads to non-selective absorption of elements and creates a high risk of including heavy metals in the food chain system. Changes in toxic metal concentrations in fodder plants may occur as a result of drying, ensiling, and granulation processes. In

Element	Permissible content
Arsenic (As)	10–50
Chromium (Cr)	150–500
Cadmium (Cd)	2–5
Cobalt (Co)	20–60
Copper (Cu)	100–300
Molybdenum (Mo)	10–50
Nickel (Ni)	100–300
Lead (Pb)	100–500
Mercury (Hg)	2–5

Source: own study based on [24].

Table 2.
Permissible content of selected elements causing the risk.

addition, heavy metals can be introduced into animal feed rations through enrichment with yeast, meat, bone, and fish meals and inorganic mineral additives, such as phosphate, dolomite, and chalk [3].

Karimi et al. [27] investigated the levels of toxic heavy metals (As, Cd, Hg, Pb) in agricultural products, such as legumes, wheat, and potatoes, in Markazi Province, Iran. Markazi Province is the most industrialized region in the country. Lead mines and other industrial activities are located there, which carries the presence of heavy metals in the soil. The results showed that among the samples analyzed, the carcinogenic risk index was within the acceptable level. However, in the case of wheat, it was found to be the most important source of toxic metal exposure due to its high consumption compared to the other crops, i.e., earthlings and legumes.

Studies conducted in Nigeria, where soils are contaminated with oil, showed that among the heavy metals tested (Pb, Cd, Cr, Mn, Fe, and Zn), for crops in the test samples, the elements Pb and Cr exceeded the limits set by WHO [28]. In Turkey of 12 districts of Sakarya city where cucurbit crops are grown, organochlorine pesticides have been applied to fields for more than 30 years. Studies of heavy metals (As, Cd, Cu, Cr, Ni, Pb, Zn) showed that the concentrations of Cu, Ni, and Cr were at 108.2 mg kg^{-1}, 219.9 mg kg^{-1}, and 173.1 mg kg^{-1}, respectively, and were the highest, i.e., 2–7 times higher than the limits given in the Turkish Soil Pollution Control Regulation [29].

Exposure of animals to heavy metals from drinking water is a very big problem. It is difficult to estimate, especially when animals use random intakes and when they are kept in an extensive (poultry) or grazing (sheep, cattle) way. Naveedullah et al. [11] conducted a study on the distribution of selected metals (Zn, Cu, Mn, Fe, Cr, Cd, and Pb) in soils in the Siling reservoir watershed in China, the various ecological and health risks associated with selected metals to the inhabitants. Protection of soil quality in the reservoir watershed is of great importance to preserve water quality, which is a source of drinking water. The study revealed seasonal variations of selected heavy metal content in soil samples. In addition, the multivariate analysis conducted showed significant anthropogenic, point, and non-point pollution of selected metals in the Siling reservoir watershed. Through the use of enrichment factor, geoaccumulation index and contamination factor, moderate to high contamination was found in soil samples during the summer and winter seasons. Low soil pH and high organic matter content increase the leaching of some elements from the soil into the aquifer formations and increase the toxic metal content in the water sources. According to the authors, the quality and quantity of fertilizers used were important causes leading to the accumulation of heavy metals in soils depending on land use.

3. Heavy metal content of animal tissues and raw materials of animal origin

Among animal products, cow's milk generally contains a number of trace elements in its composition, and its value as an environmental bioindicator is quite low. The mammary gland of cows forms a natural biological barrier that limits the passage of toxic elements from the mother's body to the food. However, milk may contain higher amounts of heavy metals, as a result of their breeding in industrial areas or secondary contamination in technological processes. The conducted studies on the content of heavy metals in animal tissues and raw materials of animal origin mostly confirm bioaccumulation of these elements in living organisms and products of animal origin.

For example, in Poland, on farms located in the direct vicinity of the Turów power plant, high concentrations of Pb, reaching even 1.865 mg kg^{-1},were detected in milk. Also, in milk collected directly from cows on smallholder farms in Lower Silesia, Pb content in 22.6% of samples exceeded the permissible level, Cd in 29.4%, and Hg in 50% of samples [30].

In pigs, the main source of possible contamination of pig tissues is feed, which due to the use of various additives may increase the concentration of heavy metals. The sources may be also dust and gas emissions from the industry caused by intensive air exchange in the livestock building. The average Pb content in the muscle tissue of fattening pigs is 0.05–0.58 mg kg^{-1} d.m. The concentration of Cd in muscles ranges from 0.02 to 0.04 mg kg^{-1} [30].

Sheep belong to good bioindicators of the environment because they are kept in extensive and pasture systems. Research shows that in industrial areas, cadmium accumulated in kidneys and udder. On the other hand, lead was found in the ribs, liver, and long bones. Zinc was most abundant in ribs and long bones, and Cu in kidneys, bones, and udder [30].

Conventional farms in central Greece were analyzed for the heavy metal content of copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb), nickel (Ni), and chromium (Cr) in muscle tissues, livers, kidneys, feces and staple mixtures for livestock, such as cows and sheep. The study showed that the transfer of heavy metals from feed to animal products varied below acceptable risk levels. In experiment 2, feed for animals kept under different feeding systems and seasons on different farms (sheep, dairy cows, and pigs) was studied. The analyses conducted showed relatively high concentrations of Cu in pig feces (155 ± 9.13) and Zn in sheep feces (144.56 ± 5.78) [31].

Excessive accumulation of heavy metals can occur in poultry, particularly from backyard rearing. Poultry is exposed to landfills (farm waste), animal feces, and contaminated roadside ditches. It may eat contaminated soil, plants, and geohelminths. The study by Kołacz et al. [30] shows that in hens kept in the Lower Silesia region exceedances of Pb in chicken muscles occurred in 20% of samples, and chicken eggs in I4.3% of samples. In the case of Cd, exceedances concerned I4.8% and 7.9%, whereas Hg exceedances concerned 45.5% and 64.5%, respectively. Relatively high accumulation of mercury occurred in hen eggs, with averages often exceeding the nationally permissible limit of 0.02 mg Hg kg^{-1}. Kołacz et al. [32] performed an assessment of the degree of bioaccumulation of heavy metals (Cd, Cu, Hg, Pb, and Zn) in the muscles and livers of free-range hens in the copper Belt region. The results showed that the organ accumulating the higher amounts of heavy metals was chicken liver, in which the permissible content of Pb and Cd was exceeded. In the muscles, however, the Pb content was exceeded.

Duck and goose eggs are a good indicator of environmental contamination with heavy metals in the rural environment. Studies performed in industrialized areas exposed to metal-bearing dust emissions and other sources have shown many times higher concentrations of As, Cd, and Hg, slightly less Pb and Cu compared to sites not exposed to industrial emissions [33].

Bees are a very good bioindicator of the heavy metal content of micronutrients and toxic metals in the environment. Roman [34] conducted a study in two regions—industrial and agroforestry, with the aim of indicating whether worker bees and drones accumulate toxic metals. Toxic elements (Ni, Cr, Pb, Cd, and Se) were found in all samples, with higher concentrations of Ni, Cr, Cd, and Pb detected in the organisms of worker bees, while higher concentrations of Se were found in the organisms of drones. The organism of worker bees is a filter that retains from 20.45 (Pb) to 36.36%

(Cd) of toxic metals from the honey raw material in the process of processing it into honey. In a study conducted in Wroclaw, Poland, concerning the content of heavy metals in multiflower honey and propolis, it was found that the highest concentration of elements was in propolis: Zn—48.1, Cu—6.95, Pb—5.74, As—0.66, and Cd 0.19 mg kg^{-1}. Statistically, a significantly lower concentration of zinc, copper, arsenic, and cadmium was in honey, except for lead, whose content was higher than permissible values in 85% of samples [35].

Horses due to their use in different environmental conditions belong to a group of animals potentially exposed to bioaccumulation of heavy metals, especially in industrialized and urbanized areas. Few studies show that horse muscles do not contain excess As, Cd, Hg, and Pb, while kidneys almost always accumulate large amounts of Cd, and liver Zn and Cd [30].

Szkoda et al. [36] also conducted studies on the content of lead, cadmium, and mercury in tissues of game animals from selected main industrial areas in Poland—roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), and wild boar (*Sus scrofa*). Studies are a useful source of information about the quality of ecosystems in which they live. The highest acceptable level of lead in meat was exceeded in 21% of analyzed samples. High cadmium concentration was determined in kidneys (above the maximum level of 1 mg kg^{-1} in 88% of samples). The highest concentration of toxic elements was found in roe deer and wild boar from Upper Silesia, which indicates high environmental contamination in comparison with other areas.

Heavy metal levels of wildlife biotopes from two different industrially exploited areas in Slovakia were studied in the Zemplín region of Slovakia. Various tissues (lungs, liver, kidneys, spleen, heart, and muscles) were sampled from animals, such as red deer, roe deer, mouflon, chamois, wild boar, European hare, among others. The content of elements exceeded the legal limits allowed for human consumption—mercury in 29%, cadmium—28%, and lead—23%. Chromium concentration did not exceed the limit in any sample. Of the wildlife living there, wild boar was the most heavily burdened species [37].

4. Effects of heavy metals on human and animal health

Heavy metals enter the human and animal body through the respiratory tract, sometimes even through the skin in the case of chemicals capable of crossing the skin barrier, and the digestive tract. Food is the main source of toxic elements. The deficiency of macro- and micro-nutrients in the body causes heavy metals to be absorbed in their place. When there is poor nutrition and a lack of essential nutrients in the body, the liver that performs detoxification cannot perform this important task [8, 38].

Copper is one of the elements with important functions in the human and animal body. It takes part in oxidation-reduction processes, regulates the metabolism, transport of iron. In the form of complexes with amino acids and albumin, it is transported to the liver, kidneys, intestines, and other tissues. Excess copper mainly causes decreased hemoglobin concentration, liver, and kidney damage [8, 14, 39].

Zinc accumulates in vertebrates in the liver, forming complexes with various proteins, and also in the kidneys and sex glands. Symptoms of zinc intoxication are—impaired immune response, reduction of HDL cholesterol fraction, decreased level of copper in the blood. On the other hand, acute zinc poisoning is manifested by vomiting, epigastric pain, fatigue, and sluggishness. Zinc chloride ($ZnCl_2$) is irritating to the skin, mucous membranes, and conjunctiva, causing burns in higher concentrations [8, 14, 39].

Cadmium is easily absorbed in living organisms. It enters the human body primarily through food, water, and inhalation as a result of tobacco smoking. Cadmium accumulates primarily in the kidneys and liver. Cadmium poisoning causes nausea, vomiting, salivation, abdominal pain, kidney damage, and circulatory failure. In addition, exposure to cadmium oxide fumes, exceeding the concentration of 0.5 mg Cd kg^{-3} causes, among others—emphysema, kidney function damage, changes in the skeletal system, pain in the limbs and spine [8, 14, 39].

Mercury poses a very high risk to living organisms. Mercury enters the body primarily from food via the digestive system and inhalation. Mercury compounds can interfere with most enzymatic reactions because they react with proteins containing sulfhydryl groups. The highest concentrations of mercury are found in the kidneys, but the brain is the most susceptible. Mercury vapor toxicly affects the lungs, eventually causing respiratory failure and death. In addition, chronic exposure to low concentrations of mercury vapor causes damage to the central nervous system with symptoms of weakness, memory impairment, mood swings, headache and limb pain, mucositis and gingivitis, and others [8, 14, 39].

Lead is also a highly toxic element. It enters the human body through the digestive system with water and food, and inhalation. It accumulates in the liver, heart, kidneys, as well as in the skin and muscles. Symptoms of lead poisoning of the human organism include disorders of the blood-forming system and the central nervous system. Lead is a mutagenic, carcinogenic, and embryotoxic element [8, 14, 39].

Kołacz et al. [40] conducted a study on the blood of cows from the copper industry region (LGOM) showed a significantly higher Cu content (1.67 mg l^{-1}) compared to the agricultural region (0.72 mg l^{-1}). In both regions, the content of Cd did not exceed 1.65 µg l^{-1}, Pb in the industrial region was 0.021 mg l^{-1}, and in the agricultural region 0.031 mg l^{-1}. On the other hand, the level of Hg in the blood of cows, in both regions was similar and was about 0.03 µg l^{-1}. It was found that the copper industry does not adversely affect the blood parameters of dairy cows. In the whole blood of dairy cows, a lead level of 0.1 mg l^{-1} is considered normal, 0.1–0.3 mg l^{-1} is considered elevated, and above 0.35 mg l^{-1} is considered toxic.

5. Ways to reduce heavy metal penetration into crops and inactivation in animals

Accumulation of heavy metals by crop plants varies genotypically. The transfer coefficient of elements from soil to plant is expressed as the ratio of the concentration in the plant to the total concentration in the soil. For example, low transfer coefficients for cadmium are found in maize, pea, oat, and wheat grains, while high Pb and Cd are found in wheat grains. Low coefficients are found for Zn transfer in spinach and lettuce leaves and roots of various plants. Therefore, it is better to grow crops with low metal uptake (some cereals, legumes, vegetables) on polluted soils, while leafy vegetables on unpolluted soils [41].

The mechanisms of plant tolerance to metal are important in plant breeding. It depends on the species, plant growth phase, tissue or organ, type of metal, time of action, and applied dose. In zinc tolerance, mainly processes related to its detoxification by organic acids and storage in vacuoles are involved. In tolerance to lead mainly processes in the cell walls are immobilized, while for cadmium mainly detoxification by phytochelatins or accumulation in the cell walls are involved. Due to the existing network of mechanisms in plants that protect against toxic effects of heavy metals, in the future, it may be a way to restore the biocenotic balance in ecosystems destroyed by industrial human activities [42].

Some plants have a natural ability to accumulate heavy metals, which is used in the process of environmental cleanup (so-called phytoremediation). Known species accumulate 1–2% of metals in tissues (so-called hyperaccumulators), for example, boll weed (Thlaspi sp.). However, due to the low biomass yields of these species, the practical usefulness of the plants is limited. Plants that are to be effective in the uptake of heavy metals should be characterized by the following features—fast growth, high biomass yield and easy harvesting, deep root system, and accumulation of large amounts of heavy metals in the aboveground parts. Several phytoremediation technologies can be distinguished—phytoextraction, i.e., removal of heavy metals by accumulation in the above-ground parts of plants, phytostabilization, i.e., immobilization of metals in soil and reduction of their availability in the environment, phytostimulation, i.e., support by plants of naturally occurring microbial degradation processes in the rhizosphere, phytodegradation, i.e., decomposition of organic substances by plants and related microorganisms and phytovolatilization, i.e., transformation of contaminants into a volatile state. The plants most commonly used for bioaccumulation belong to many families, of which the crucifers (Cruciferae), grasses (Poaceae), butterflies (Papilionacae), composite plants (Asteraceae), willow plants (Salicaceae), and clove plants (Caryophyllaceae) deserve special attention [17].

Barrero-Moreno et al. [43] conducted biofilter modeling using rice husk as filter material to remove heavy metals from water. The use of bioadsorption represents great potential because lignocellulosic materials can be obtained in large quantities, are inexpensive, and can selectively remove Cd (II), Cu (II), and Cr (VI) from aqueous solutions. Based on the results, rice husk was found to be a good alternative for making filters with the ability to remove Cd (II), Cu (II), and Cr (VI) with 83.21%, 67.11%, and 92.18% efficiency, respectively, for specific values of filter height, temperature, and pH.

In sustainable agricultural production, one of the ways to reduce environmental and human, and animal health risks is to use fertilizer from agricultural biogas plants. It can be used in liquid or solid form as fresh matter, granulate, or compost. The introduced organic matter can prevent the leaching of toxic elements on the one hand, and their uptake by plants on the other [41]. Studies on the content of selected heavy metals (Fe, Zn, Mn, Pb, Cd, Ni, and Cu) in soils fertilized with mineral fertilizers (NPK and CaNPK) and with digestate and granulate did not show exceeding of permissible standards. The content of elements was compared to unfertilized objects. It was found that the applied post-fermentation masses are safe for fertilizer use. Statistically lower contents of Zn, Cu, and Mn were found after fertilization with fresh digestate compared to control objects, while lower amounts of Cu, Fe, and Cd were found after the application of granules [44].

Compost from digestate is also a product used in fertilization. The content of selected heavy metals (Fe, Zn, Mn, Pb, Cd, Ni, and Cu) in soils fertilized with mineral fertilizers (NPK and CaNPK) and with compost was analyzed to demonstrate its environmental safety and, indirectly, animal and human health. The content of elements was compared to objects not fertilized with mineral fertilizers (object 0) and with compost (K—control). The study showed that the long-term application of nitrogen, phosphorus, or potassium fertilizers increased the content of available forms of heavy metals in the soil. On the other hand, application of compost from post-fermentation mass caused a statistically significant decrease in bioavailable forms of metals, especially in object CaNPK—Ni, Pb, and Fe and object 0—Zn and Ni. In the case of the NPK object, a significant reduction in the content of all the metals studied except Cu occurred [45].

Detoxification of contaminated natural environments is based on different solutions—the use of antagonistic type interactions in reducing bioaccumulation in animal tissues and the use of properties of compounds of organic and mineral origin.

Vitamins play a special role in reducing the bioaccumulation of heavy metals in the animal organism. They actively participate in body protection by increasing the absorption and cellular bioavailability of elements that are antagonists, maintaining the physiological concentration of ions of these elements, and participating in free radical reactions. Vitamin C in animal feed rations reduces cadmium retention and increases the effectiveness of elements antagonistic to this element, such as Fe, Cu, and Ca. Vitamin C can reduce cadmium concentration in the kidney and liver by 35–40%. Vitamin D, with Ca and Zn, and vitamin A with calcitriol and fluorine can also significantly reduce Cd concentration in tissues. On the other hand, vitamin E can counteract the activity of dehydrogenases, lowered by cadmium [46, 47]. Antagonists of cadmium are elements, such as Zn, Cu, Se, Fe, Mn, Mg, and Ca. In the case of lead, the antagonists are: Fe, Cu, Zn, Mg, Se, Ca, P, and K, while mercury may be selenium. Interactions involve competition in absorption for common transport sites and mutual displacement from metalloproteins, enzymes, DNA, RNA, and cell receptors [46].

Aluminosilicates (e.g., zeolites bentonites, kaolin), humic acids, or flavonoids play a special role in the process of heavy metals reduction in the animal organism. Aluminosilicates, due to their complex-forming, sorption, and ion-exchange properties, counteract the bioaccumulation of heavy metals in animal tissues. Studies using kaolin and zeolite as litter additives for broiler chickens showed a reduction of Hg by over 93%, Pb by almost 31%, and Cd by over 31% in birds' livers. The use of aluminosilicates in animal feed rations resulted in a reduction of Cu, Pb, Cd, Cr, and Ni content in animal tissues. The study with the application of a mixture of humic acids (brown coal and peat) and aluminosilicates (bentonite) showed more than twofold decreased Pb accumulation in animal livers. From the group of flavonoids, quercetin is an organic compound showing the ability to attach metal ions and form complex compounds. Flavonoids that are present in propolis can form chelate compounds with heavy metals, which contributes to the detoxifying effect of this bee product [46].

6. Conclusions

Industry, motorization, agriculture, and other sources are the cause of heavy metal contamination of the natural environment (soil, plants, water). Toxic metals easily pass into the organism, sometimes they excessively accumulate in tissues and organs, for example, in muscles, blood, liver, or animal hair, as well as in milk of cows, eggs of poultry, and honey, creating certain dangers for human health. There are various ways to reduce the accumulation of these elements in crop plants and deactivation in living organisms. For this purpose, the mechanisms of tolerance of plants to metal, plants having a natural ability to accumulate heavy metals in the process of cleaning the environment (phytoremediation), or the use of fertilizers which are a byproduct of agricultural biogas plants are used. For the deactivation of heavy metals in the body of humans and animals, antagonistic type interactions and the properties of compounds of organic and mineral origin are used.

Author details

Anna Bartkowiak
Institute of Technology and Life Sciences—National Research Institute, Falenty, Poland

*Address all correspondence to: a.bartkowiak@itp.edu.pl

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