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INTENSITY OF HEAVY METAL CONTAMINATION OF FODDER GRAIN OBTAINED IN THE CONDITIONS OF THE RIGHT BANK FOREST STEPPE

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In the conditions of technogenic load on the environment, one of the priority areas is the monitoring of heavy metals in the trophic chain: «soil → plant (feed) → animal → product → human». In order to prevent poisoning of agricultural animals with heavy metals, it is recommended to systematically monitor the presence of toxic metals in the feed ration. Of particular concern is the production of poultry meat at home, where it has free access to natural minerals, most of which contain heavy metals and other toxicants. Based on this, there is a need for constant monitoring of the contamination of the fodder base of poultry kept at home and the use of control measures to increase the safety of domestic products. The content of heavy metals in meat is one of the most important sanitary indicators of its safety in conditions of contamination of feed with heavy metals. to improve the sanitary safety of poultry products by the level of cadmium and lead. For the correct organization of poultry feeding, it is necessary to take into account, first of all, the nutritional value of feed and its quality. The basis of the ration of agricultural poultry is grain feed (55–80% of the ration), which is part of compound feed. In order to control feed safety, it is necessary to conduct monitoring at all stages of production: starting with the production of raw materials and components, their further processing, storage, transportation and before use. A soil sample taken in the conditions of the Right Bank Forest-Steppe of Ukraine was studied and analyzed, and an excess of the MPC in it and vegetative mass for cadmium by 1.28 and 1.5 times, respectively. barley, corn and sunflower meal. At the same time, exceedances of maximum permissible concentrations were investigated. In particular, in wheat grain, which, among the concentrated feeds of poultry kept at home, makes up 55% on average, an excess of cadmium and copper was found by 2.1 times and 2.0 times, respectively. An excess of the maximum permissible concentrations by 3.0 times was also observed in sunflower meal. The lowest level of heavy metals such as lead, cadmium, zinc and copper was observed in corn grain. *Key words:* soil, fodder grain, heavy metals, coefficient of danger.

Інтенсивність забруднення важкими металами фуражного зерна отриманого в умовах Лісостепу Правобережного. Врадій О.І.

В умовах техногенного навантаження на довкілля одним з пріоритетних напрямків є моніторинг важких металів у трофічному ланцюгу: «ґрунт → рослина (корм) →тварина →продукція →людина». З метою попередження отруєнь сільськогосподарських тварин важкими металами рекомендується систематично проводити контроль за наявністю токсичних металів у кормовому раціоні. Особливе занепокоєння викликає виробництво м'яса птиці в домашніх умовах, де вона має вільний доступ до природних мінералів, більшість з яких містить важкі метали та інші токсиканти. Виходячи з цього, виникає необхідність постійного моніторингу зараженості кормової бази птиці, що утримується в домашніх умовах, та застосування заходів контролю для підвищення безпеки вітчизняної продукції. Вміст важких металів у м'ясі є одним із найважливіших санітарних показників його безпеки в умовах забруднення кормів важкими металами та підвищення санітарної безпеки продукції птахівництва за вмістом кадмію та свинцю. Для правильної організації годівлі птиці необхідно враховувати, перш за все, поживність корму та його якість. Основу раціону сільськогосподарської птиці складають зернові корми (55–80% раціону), які входять до складу комбікормів. Для контролю безпечності кормів необхідно проводити моніторинг на всіх етапах виробництва: починаючи з виробництва сировини та компонентів, їх подальшої обробки, зберігання, транспортування і до використання. Досліджено та проаналізовано проби ґрунту, відібраних в умовах Правобережного Лісостепу України, виявлено перевищення ГДК у грунті та вегетативній масі по кадмію у 1,28 та 1,5 раз відповідно у зерні ячменю, кукурудзи та соняшникового шроту. При цьому досліджувалися перевищення гранично допустимих концентрацій. Зокрема, у зерні пшениці, яке являється концентрованим кормом птиці, що утримується в домашніх умовах і становить у середньому 55%, виявлено перевищення вмісту кадмію у 2,1 та міді у 2,0 рази відповідно. Перевищення гранично допустимих концентрацій у 3,0 рази виявлено також у соняшниковому шроті. Найменший вміст важких металів, таких як свинець, кадмій, цинк і мідь, спостерігався в зерні кукурудзи. *Ключові слова:* грунт, фуражне зерно, важкі метали, коефіцієнт небезпеки.

Formulation of the problem. The man-made activity of the population has led to the pollution of the natural environment with various toxicants, including heavy metals, which move along the trophic chains from the soil to the plants, significantly affecting the quality of the harvest. A particular problem is the growing intensity of pollution of agricultural soils due to the high level of chemicalization in the field of crop production. As a result, heavy metals are introduced into the soil every year, creating certain problems regarding the quality of crop production [2, 33].

Currently, a powerful source of heavy metal contamination of agricultural soils is mineral fertilizers and means of combating weeds and plant pests, which are used in agriculture. About 130 million tons of fertilizers are applied to the soil every year, including more than 70 million tons of nitrogen, 39 million tons of phosphorus, and 26 million tons of potassium fertilizers

[3, 32]. The use of organic fertilizers in crop production also pollutes the soil with heavy metals [4, 10] In particular, about 25 g of zinc, 4 g of copper and 0.3 g of cobalt enter the soil with one ton of litter manure. It is known that one kilogram of dry mass of organic fertilizers contains lead – 6.6–16 mg, zinc 15–250, copper – 2–60, cadmium – 0.3–0.8, manganese – 30–550, nickel – 7.8–30 milligrams [7, 8].

Having migration properties, heavy metals pollute all components of the biosphere, namely: soil, water, and air [9, 12]. In terms of toxicity, metals rank second after pesticides. They rank first in the volume of emissions into the natural environment. Such metals as lead, cadmium, mercury are extremely toxic to humans and animals even in very small concentrations. Some of these elements play an important role, increasing the biological activity of enzymes, hormones and vitamins. It should be noted that lead is characterized by low migration properties. Lead can accumulate in the soil in high concentrations. This element is classified as a particularly dangerous pollutant due to its toxicity and the intensity of its entry into the environment.

The connection of the author's work with important scientific and practical tasks. It is known that the average lead content in agricultural soils can reach up to 10 mg/kg. Lead in agricultural soils is unevenly distributed: up to 57–74% of this element remains in the 0–10 cm layer and from 3 to 8% – at a depth of 30–40 cm [14]. Cadmium is a highly toxic chemical element. Solubility and migration of cadmium in soils depends on their active acidity. In particular, it has the greatest mobility in acidic soils in the range of 4.5–5.5, while it is not mobile in alkaline soils. Cadmium intensively migrates from the soil through the root system into plants and their products [11, 16]. The concentration of cadmium in terms of dry matter in plants is $1*10^{-4}$%. The average content of cadmium in the dry matter for cereal grain ranges from 0.013 to 0.22 mg/kg, in legumes – 0.08–0.28, in herbs – 0.07–0.27 mg/kg [17].

Copper is classified as a moderately toxic element. It is widely used, in particular, in mechanical engineering, the chemical industry, and other branches of the national economy. In agriculture, a number of preparations containing copper compounds are used, for example, fungicides, anti-helminths, etc. Unlike other studied metals, copper is considered an element necessary for life, as it is a component of the active groups of many enzymes [15, 30]. Copper performs a number of functions in the body, namely: participates in hematopoiesis, promotes the transformation of iron into an organically bound form, which in turn enhances the synthesis of hemoglobin, participates in carbohydrate and mineral metabolism.

Analysis of recent research and publications. Among the heavy metals, cadmium and zinc are more available elements for plants compared to lead, chromium and mercury. Zinc is necessary for crop formation, but in high concentrations it acts as a toxicant, which negatively affects living organisms [29]. The soil is a sorption barrier of heavy metals, especially its humus layer. It was found that high-buffer carbonate horizons fix about 99% of heavy metals that fell in a layer of 10–20 cm. In weakly acidic soils, migration can occur to a depth of 40 cm. In low-buffer soils, the penetration of heavy metals is observed up to 60–80 cm. In general, it was established, that horizontal migration occurs 3–4 times more intensively than vertical migration [28].

The increased content of heavy metals in the soil contributes to their intensive migration into plants [18]. It is known that the concentration of heavy metals in a plant can be tens or even hundreds of times higher than their concentration in the soil. The main factors that affect the migration of heavy metals from the soil to plants include: the amount of organic matter, the mechanical composition of the soil, acidity and the content of phosphorous substances in it [27].

Acidic soils have a lower ability to retain metals than neutral ones [19], although the main sorption of heavy metals is observed in an alkaline environment. The influence of strong dissociations of substances formed during the interaction of the components of chemical production emissions with atmospheric moisture, causes a change in the pH of the soil solution, negatively affects the soil absorption complex, the buffering capacity of soils. Due to the insufficient amount of moisture, neutral reaction, oxidizing conditions, stability of humus, the mobility of metals is limited, which determines their accumulation in the upper root humus horizon of soils [26].

The use of such grain as fodder contributes to the accumulation of heavy metals in the body of animals, including birds, which is accompanied by contamination of the products produced from them [20]. The population's consumption of livestock products contaminated with heavy metals causes a number of disorders, accompanied by the occurrence of various diseases [25]. It has been proven that in the conditions of zinc smelters and in the areas of lead and zinc ore development and shale deposits, the transfer of heavy metals into livestock products with feed is 16 times higher, compared to a conditionally clean area [21].

A previously unsolved part of the overall problem. Feed raw materials play a leading role in the poultry food chain, and up to 95% of heavy metals enter the poultry body mainly through the trophic chain, in particular, with feed and water [24]. The most resistant to heavy metals among agricultural plants are winter rye, winter wheat, oats and barley. Rye adapts better to heavy metals, and barley the least [22].

In order to reduce the migration of heavy metals through food chains, a number of measures are being introduced to reduce their mobility in the soil and reduce their accumulation in agricultural products (Baggio et al., 2016). Maize has a pronounced resistance to heavy metals, which allows effective use of territories

contaminated by these substances without removing them from agricultural use. A positive relationship between the accumulation of heavy metals in corn grain and the amount of protein was revealed, with correlation coefficients for lead of 0.95, cadmium – 0.88, and zinc – 0.77 [1].

In order to control the entry of toxic metals in Ukraine, the Order of the Ministry of Agrarian Policy and Food No. 131 dated 19.03.2012 approved the "List of maximum permissible levels of undesirable substances in fodder and feed raw materials for animals", which regulates the content of feed and feed raw materials for animals heavy metals, mycotoxins, toxins of various origins. Summarizing the analysis of primary sources, it should be noted that in modern conditions of man-made load on the soils of agricultural lands, there is a need for constant monitoring of the migration of heavy metals in the soil-plant-human organism system in order to predict their movement in natural systems and the high level of risk from these toxicants.

Research results. The analysis of the intensity of pollution of agricultural land within the limits of local man-made load (Fig. 1) showed that the concentration of cadmium in the soil was 1.28 times higher compared to the MPC, while that of lead, zinc, and copper was 1.2 times lower, 4.6 and 9.5 times, respectively.

The highest content of heavy metals in arable land soils was Pb, compared to Cd, Zn, and Cu by 2.7, 3.8 and 1.0 times, respectively.

The results of studies on the intensity of heavy metal contamination of feed raw materials for poultry (Table 1) showed that the concentration of lead, cadmium, copper and zinc in corn grain was lower, compared to the MPC, by 7.1, 30.0, 44.0 respectively. 2.0 and 600.0 times, in wheat grain the concentration of lead, copper and zinc was lower than the MPC by 1.2, 4.2 and 1.9 times, respectively, while cadmium exceeded the MPC by 2.1 times. In oat and barley grains, the concentration of lead, cadmium, copper, and zinc was 16.7, 11.5, 19.2, and 66.0 times lower than the MPC, respectively. In sunflower meal, it was found that the content of lead, zinc, and copper was 1.25, 7.0, and 30.3 times lower, respectively, and cadmium was 3.0 times higher compared to the MPC.

Compared to the MPC, the highest intensity of contamination of feed raw materials of the poultry diet was observed in wheat grain. Thus, in wheat grain, lead, cadmium, zinc and copper were 5.7, 21.0, 239.4 and 22.6 times higher compared to similar raw materials of corn, oats – by 4.4, 12.3, 5.1 and 1.9 times, barley – 1.3, 8.0, 2.6 and 2.3 times, respectively (Fig. 2).

Compared to wheat, sunflower meal had 12.0 times lower zinc content, 3.6 times more copper, and 1.4 times more cadmium.

Analyzing the coefficient of danger of heavy metals in fodder grain (Table 2), it should be noted that this indicator was the highest for lead in wheat grain and sunflower meal. Specifically, compared to corn, oat, and

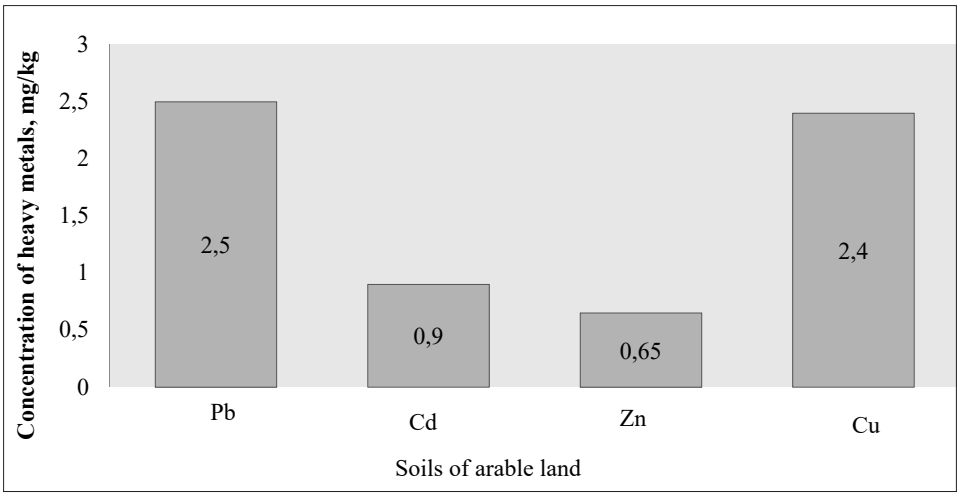

Fig. 1. Intensity of heavy metal contamination of arable land soils

Table 1

Concentration of heavy metals in fodder grain, mg/kg (x ± SE, n = 4)

Components of poultry diet	Pb	MPC	Cd	MPC	Cu	MPC	Zn	MPC
Corn	0.07 ± 0.04	5.0	0.01 ± 0.02	0.3	0.05 ± 0.03	30.0	1.13 ± 0.02	50.0
Wheat	0.41 ± 0.01	0.5	0.21 ± 0.03	0.1	11.97 ± 0.04	30.0	25.61 ± 0.03	50.0
Oat	0.09 ± 0.01	5.0	0.01 ± 0.02	0.3	2.34 ± 0.05	30.0	13.12 ± 0.01	50.0
Barley	0.33 ± 0.03	5.0	0.02 ± 0.02	0.3	4.53 ± 0.01	30.0	11.32 ± 0.03	50.0
Sunflower meal	0.42 ± 0.02	0.5	0.32 ± 0.03	0.1	0.99 ± 0.03	30.0	7.12 ± 0.02	50.0

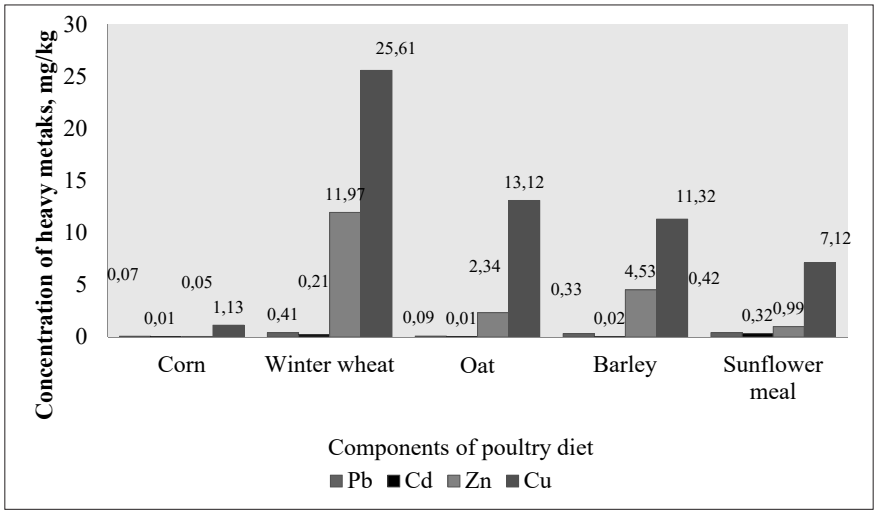

Fig. 2. Comparative characteristics of the intensity of fodder grain contamination, mg/kg

Table 2

The coefficient of danger of heavy metals in feed

Components of poultry diet	% in the diet	Pb	Cd	Zn	Cu
Corn	30	0.014	0.01	0.05	1.13
Wheat	55	0.8	0.21	11.97	25.60
Oat	5	0.018	0.017	2.34	13.12
Barley	5	0.06	0.026	4.53	11.30
Sunflower meal	5	0.8	0.3	0.99	7.12

barley grains, the hazard ratio of lead in wheat and sunflower meal was 5.7, 44.4, and 13.3 times higher, respectively. The highest hazard ratio of cadmium in fodder grain was found in sunflower meal, which was 0.3 mg/kg.

Compared to corn, wheat, oat, and barley grains, the hazard ratio of cadmium in sunflower meal was 30.0 times higher, 1.4, 17.6, and 11.5 times, respectively. The highest zinc hazard ratio was in wheat grain compared to corn grain, oat, barley, and sunflower meal at 239.4 times, 5.1, 2.6, and 12.1 times, respectively. The copper hazard ratio was 22.6 times highest in corn grain, 1.9 times in oats, 2.3 times in barley, and 3.6 times in sunflower meal compared to wheat grain.

That is, in the study areas of the Right Bank Forest Steppe, an excess of heavy metals in fodder grain was detected for cadmium in wheat grain and sunflower meal. At the same time, it should be noted that wheat and sunflower meal are characterized by a high content of lead, although without exceeding the maximum permissible limit.

Main conclusions. In the conditions of the Right-Bank Forest-Steppe of Ukraine, there is a 1.28- and 1.5-fold excess of the MPC in soil and vegetative mass for cadmium, respectively.

In the fodder grain of the diet of poultry in the conditions of the Right-Bank Forest-Steppe of Ukraine, an excess of the MPC was found in poultry grain for cadmium and copper by 2.1 times and 2.0 times, respectively, and in sunflower meal for cadmium by 3.0 times.

In the conditions of agricultural lands of gray forest soils with soil content of Pb – 2.5 mg/kg, Cd – 0.9 mg/kg, Zn – 0.65 mg/kg and Cu – 2.4 mg/kg in the produced fodder grain exceeding the MPC of these toxicants was not observed, except for Cd in poultry grain and sunflower meal. The highest content of Pb, Cd, Zn, and Cu was found in fodder grain of winter wheat.

The discussions in this paper. Man-made pollution of the environment with harmful substances, especially agricultural soils, to one degree or another can affect the safety of feed raw materials for poultry, the level of which depends on the efficiency of its use in poultry farming. It is known that in technogenically polluted territories, a certain part of heavy metals is translocated in plants and their products, in particular, grain, which occupies the main part of the diet of poultry.

Contamination of poultry feed with heavy metals on its free access to soil minerals creates a danger of obtaining high-quality poultry products.

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