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TOXIC AND ECOLOGICAL ASSESSMENT OF AGRICULTURAL PRODUCTS OF AGROCENOZES OF THE RIGHT BANK FOREST STEPPE DEPENDING ON THE INTENSITY OF AGRICULTURAL CHEMISTRY

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Abstract

The article presents studies on the toxic-ecological assessment of agricultural products of agrocenoses of the Right-Bank Forest-steppe, depending on the intensity of chemicalization of agriculture. The aim of the research was to conduct a toxic-ecological assessment of agricultural products of agrocenoses and substantiate the principles of regulation of the toxic-ecological safety of the main products of agrocenoses at different levels of chemicalization of agriculture in the conditions of the Right-Bank Forest-Steppe.

The studies were carried out during 2019-2020. With grain and seeds that are grown in the conditions of intensive and resource-saving agriculture of the Right-Bank Forest-Steppe using laboratory tests in certified laboratories that have a certificate for conducting relevant research (Scientific and Measuring Agrochemical Laboratory of Vinnytsia National Agrarian University and the laboratory of the testing center of the Vinnytsia branch of the state institution soils of Ukraine).

According to the results of the studies, it was found that under conditions of intensive chemicalization of agriculture, more zinc accumulates in winter wheat grain; in the seeds of winter rape - lead and copper in the wet grain of corn - all lead, but less cadmium, copper and zinc. In the dried grain of corn, lead accumulates less, copper in sunflower seeds − cadmium.

The research results showed that a low accumulation rate of lead and cadmium in the conditions of resource-saving chemicalization of agriculture was found in the grain of spring barley − 40.0 and 0.3, respectively; copper − in winter wheat grain − 4.1; zinc − in grain of spring barley − 3.6

The lowest coefficient of lead accumulation under conditions of intensive chemicalization of agriculture was found in sunflower seeds − 22.5; cadmium, copper and zinc − in corn grain − 1.0, 9.5 and 10.6, respectively.

The article presents data on heavy metal contamination of winter wheat grain grown in intensive agriculture. The decrease of heavy metals content during grinding of winter wheat grain into different fractions of flour is studied: high quality, first grade, second grade and bran. It has been found that grinding winter wheat grain to different fractions can significantly reduce Pb content in high quality flour by 71,8%, first grade by 51,5%, second by 47,6%, but increase their content in bran by 61, 6%, compared to the Pb content of the grain; the content of Cd in high-quality flour decreases by 75,0%, the first grade by 50.0%, the second by 25,0%, but increases in bran by 60.0%, compared to the content of Cd in the grain; Cu content in high-quality flour is 72,0% lower, first-class – 52,0%, second - 47.4%, but higher in bran by 50,7%, compared to Cu content in grain; Zn content in high quality flour decreased by 95,9%, first grade by 54.6%, second by 51,7%, but at the same time increased in bran by 68,2%, compared to Zn content in winter wheat.

Keywords: agrocenosis; agricultural products; chemicalization; agriculture; heavy metals; corn; accumulation coefficient; winter wheat; spring barley.

Traditionally, it was believed that the main violators of the natural balance are industry and transport, and the possible harmful impact of agricultural production on the environment has been underestimated for a long time. In modern conditions of agricultural development, its negative impact on nature in many cases becomes much more serious than the impact of other branches of social production [1]. It is precisely with the development of agriculture that an increase in the deficit of water resources on the planet is associated, a decrease in the species diversity of flora and fauna, salinization, waterlogging and depletion of soils, the accumulation of especially persistent and dangerous pollutants in soils, waters and cultivated plants [2].

Grain farming is a priority branch of the agricultural sector with a high level of competitiveness in the domestic and world markets. Among the basic agricultural products that guarantee the country's food security, grain holds a special place. This is due to its extremely important importance directly for the manufacture of high-calorie food products, and especially bread. In most countries of the world, there is no alternative to bread as the staple food of the population. During storage, grain practically does not lose its qualities, therefore, it is suitable for creating state reserves for the production of food and feed [3, 4].

Environmental safety of grain products should be a priority at all stages of the food chain. The basis for the provision of which is the control of the residual amount of pesticides, radionuclides, toxic elements and mycotoxins in grain and products of its processing.

Aspects of assessing environmental risks and developing ways to improve the environmental safety of grain products are covered in the works of P. V. Pisarenko, 2003; A. F. Smagliya et al., 2006; S. S. Antonets et al., 2010; A. B. Bondareva et al., 2014; A.P. Tkachuka et al., 2018 and others, who note that the consequences of the intensification of agriculture in the twentieth century, the rapid development of the urban socio-sociosphere, the consequences of the Chernobyl disaster will determine the technogenic and environmental hazards for a long time. Therefore, in conditions of low farming culture, including one-sided and scientifically unjustified application of mineral fertilizers, plant protection products, plant growth stimulants when growing crops, it is likely that the dynamic balance in the soil-plant system will be disturbed and, as a consequence, the ecological state will deteriorate. microbiocenosis of soils, the accumulation of pollutants in the food phosphere, the products of agrocenoses, including the grain of food crops, threaten the biosphere.

The study of the above aspects is important for overcoming environmental risks in the agricultural sector, improving the food problem and does not lose its relevance.

Each branch of agriculture has a different impact on the environment. Thus, intensive technologies for growing cereals is a system of agrotechnical measures that allow you to maximize the genetic potential of varieties of agricultural plants through the use of modern achievements in breeding, agriculture, chemicalization and mechanization of production processes. These technologies contribute to the accumulation of heavy metals, nitrates, pesticides in agricultural products.

Now there are significant deviations from compliance with the main components of intensive technologies, in particular, there is a tendency to an increase in the use of pesticides and mineral fertilizers, which is a consequence of a limited set of crops in crop rotations and a deterioration in their rotation [5, 6, 7]. But the chemicalization of agriculture is accompanied by processes of pollution of the natural environment dangerous for the life of living organisms, including humans.

The main environmental problems of agriculture in Ukraine are: a high level of plowing of agricultural land and ineffective use of the high biopotentials of fertile lands; unjustified use of plant protection products, fertilizers, which, on the one hand, increases the yield of agricultural crops, and on the other hand, worsens the natural properties of soils; a significant level of contamination of agricultural land in the region with radionuclides due to the Chernobyl disaster [8, 9].

Serious problems for the environment arise in connection with the violation of technologies for the use of mineral fertilizers in agriculture. Introduced to fields, they are only partially absorbed by plants. A significant amount of nitrogen and phosphorus enters ground and groundwater, and from them migrates to rivers and lakes [10, 11].

Mineral fertilizers are one of the most effective means of increasing soil fertility, productivity and improving the quality of crop production. With their help, the processes of plant nutrition are controlled, the quality of the crop changes and the effect on fertility, physicochemical and biological properties of the soil is carried out [12, 13].

Recently, the application of mineral fertilizers for the main agricultural crops - winter wheat, rapeseed, sunflower and corn for grain − has sharply increased. This significantly increases the yield, but the environmental safety of such products may deteriorate.

The negative consequences of the use of mineral fertilizers are associated with the fact that, along with the main biogenic elements, they often contain various impurities in the form of salts of heavy metals, organic compounds, radioactive isotopes, which can lead to negative effects on the environment, crop production, fauna, health people working with fertilizers and the general population [14]. Raw materials for the production of mineral fertilizers - phosphorites, apatites, crude potassium salts - usually contain a significant amount of impurities - up to 5% or more. Arsenic, cadmium, lead, fluorine, strontium may be present with toxic elements, which should be considered as potential sources of environmental pollution and should be strictly taken into account when applying mineral fertilizers to the soil.

Despite a number of negative consequences of the use of mineral fertilizers, the results of scientific research indicate that, thanks to the use of fertilizers, it is possible to obtain an average of 45-50% increase in the yield of the main crops, which is much higher than the share of the increase in the yield from the variety, seeds, plant protection products or processing soil. Depending on the soil, climatic and other conditions, the increase in yield from the introduction of mineral fertilizers varies within significant limits. Thus, in the Polesye zone it is 100%, in the forest-steppe zone - 50%, in the humid steppe -− 30%, in the dry steppe −15% and in the irrigated steppe − 40% [15, 16, 17].

However, the results obtained considered certain aspects of the use of mineral fertilizers and their impact on the environment. They lack a systematic approach and there is no single concept for the environmentally safe use of mineral fertilizers, which requires new research and generalizations.

The most common types of mineral fertilizers used in the cultivation of crops with nitrogen fertilizers are ammonium nitrate, carbamide and ammonium sulfate, and of the complex ones − nitroammofosk. When growing grain crops, nitrogen fertilizers are most often used, and industrial crops - a combination of nitrogen fertilizers with nitroammophos.

To date, producers are increasing the rates of mineral fertilization when growing winter wheat, as the main food and profitable crop, up to 200 kg/ha or more of mineral nitrogen. When using ammonium nitrate, its physical application rate will be 592 kg/ha, urea − 431 kg/ha, ammonium sulfate − 962 kg/ha and nitroammofoska − 1227 kg/ha (table). However, nitroammofoska is included in the composition of the studied mineral fertilizers. The most radioactive mineral fertilizer (according to Cs-137) when applied per hectare will be nitroammofosk. Therefore, to reduce soil intoxication with sulfur and Cs-137, it is necessary to limit the use of ammonium sulfate and nitroammophoska or limit the rates of their introduction [4].

The aim of the research was to conduct a toxic-ecological assessment of agricultural products of agrocenoses and substantiate the principles of regulation of the toxic-ecological safety of the main products of agrocenoses at different levels of chemicalization of agriculture in the conditions of the Right-Bank Forest-Steppe.

The studies were carried out during 2019−2020. With grain and seeds, which are grown in conditions of intensive and resource-saving farming of the forest-steppe of the right bank.

We used intensive and resource-merciful chemicalization of agriculture, differed in the volumes of application of mineral fertilizers and pesticides when growing crops in the studied farms.

Laboratory analyzes of grain and seeds were carried out in certified laboratories with a certificate for carrying out the relevant research (Scientific and measuring agrochemical laboratory of the Vinnytsia National Agrarian University and the laboratory of the testing center of the Vinnytsia branch of the state institution «Institute of Soil Protection of Ukraine»).

Observations, counts and measurements were carried out according to generally accepted methods.

The technologies for growing field crops in experimental farms differed in the intensity of chemicalization, in particular, in the rates of application of mineral fertilizers and pesticides, as well as their development rate, and were common with other technological operations.

When growing winter wheat and spring barley, the technology provided for soil cultivation in the form of two-time disking, pre-sowing cultivation, sowing, mineral fertilization, rolling, fertilizing, pesticide application, and harvesting.

When growing corn, the technology provided for soil cultivation in the form of plowing, early spring harrowing, applying mineral fertilizers, pre-sowing cultivation, sowing, two-time inter-row loosening, top dressing (according to the scheme), the introduction of pesticides (according to the scheme), threshing.

And the differences in the technology of growing winter wheat using resource-saving technologies consisted in different rates of N90P35K35 fertilizers and three-time use of pesticides: Vitavax − seed dresser, Granstar − herbicide, application in spring, Alto − fungicide.

According to intensive technologies for growing winter wheat, N175P35K35 and seven-fold applications of pesticides were introduced: Vitavax - seed dressing, Decis - insecticide applied in spring, Granstar − fungicide, Tilt − fungicide introduced in May, Decis − insecticide introduced in June, Alto −fungicide, application in early and late June.

Technologies for growing spring barley for resource-saving technologies also consisted in different rates of fertilizers: N35P15K15 and three-time use of pesticides: Vitavax − seed dressing agent, Granstar − herbicide, application in spring, Alto − fungicide.

According to intensive technologies for growing spring barley, N90P35K35 and four-time application of pesticides were introduced: Vitavax − seed dressing, Granstar − fungicide, Alto − fungicide, Tilt − fungicide.When growing corn using resource-saving technologies, N100P40K40 was added, no chemical treatments were used.

According to intensive technologies of corn cultivation, $N_{200}P_{45}K_{45}$ and three-time application of pesticides were introduced: Titus − herbicide in the phase of 3-4 leaves, Karate − insecticide in the phase of 5-6 leaves, Alto − fungicide in the phase of 5-6 leaves.

The grain and seeds of field crops have many useful properties that determine their versatile use in the national economy. Therefore, for a comprehensive assessment of crop production, a set of indicators is used, the values of which are not the same in quality, even very specific and also determined by the technological characteristics of individual batches of grain or seeds of a particular crop. However, there are universal indicators by which information is obtained about food, feed and technological characteristics of the quality of grain or seeds before and during storage.

Information about the toxic and ecological characteristics of grain and seed products does not lose its relevance. Among all the variety of heavy metals, lead, cadmium, copper, zinc, etc. account for the largest volumes of their supply with chemical agents.

According to the results of laboratory studies, it was found that the actual content of lead in the grain of winter wheat grown under the conditions of resource-saving chemicalization of agriculture was 1.2 times higher than the MPC (Table 1). And in the seeds of peas in full ripeness − 1.7 times more MPC, in seeds of buckwheat, spring barley and soybeans, on the contrary, − in 2.1; 1.2 and 1.1 times less than the MPC.

The actual content of cadmium in the grain of winter wheat and spring barley grown under the conditions of resource-saving chemicalization of agriculture for the period of harvesting was 5.0 times less than the MPC, in buckwheat seeds − 1.7 times less than the MPC, in soybean seeds − 1.4 times more MPC in pea seeds is 1.1 times less than MPC.

Table 1

The content of heavy metals in the grain of agrocenoses, mg/kg

Culture name	Heavy metals							
	Pb*		Cd**		Cu***		Zn****	
	RUKHZ	IUKHZ	RUKHZ	IUKHZ	RUKHZ	IUKHZ	RUKHZ	IUKHZ
Winter wheat	0,60	1,03	0,02	0,04	3,35	17,44	27,50	26,50
Spring barley	0,40	1,05	0,02	0,25	4,34	13,65	24,80	23,70

* maximum permissible concentration for Pb − 0.5 mg/kg; ** maximum permissible concentration for Cd - 0.1 mg/kg; *** maximum permissible concentration for Cu − 10.0 mg/kg
**** maximum permissible concentration for Zn − 50.0 mg/kg RUHZ − resource-saving level of chemicalization of agriculture; IUKHZ − an intensive level of chemicalization of agriculture.

The actual copper content in buckwheat seeds grown under the conditions of resource-saving chemicalization of agriculture for the period of harvesting was 3.0 times less than the MPC, in winter wheat grain − 2.9 times less than MPC, in spring barley grain and pea seeds − 2.3 times less MPC, in soybean seeds − 1.3 times less than MPC.

The actual content of zinc in grain of spring barley, pea seeds grown under the conditions of resource-saving chemicalization of agriculture for the period of harvesting was 2.0 times less than the MPC, in buckwheat seeds − 1.9 times less than MPC, in winter wheat grain and soybean seeds - in 1.8 times less than the MPC.

It was found that the actual content of lead in the seeds of winter rape, wet corn grain (moisture content of 16.8%) during the harvesting period grown under conditions of intensive chemicalization of agriculture was 2.5 times higher than the MPC in dried corn grain (moisture content 12.1 %) − 2.3 times less than MPC, in spring barley grain − 2.1 times more than MPC, in winter wheat grain − 1.2 times more than MPC, in sunflower seeds − 1.1 times less than MPC.

The actual content of cadmium in sunflower seeds grown under conditions of intensive chemicalization of agriculture for the period of harvesting was 3.5 times higher than the MPC, in spring barley grain − 2.5 times more than the MPC, winter rape seeds - 1.3 times more than the MPC, in wet corn grain − 5.0 times less than MPC in winter wheat grain and in dried corn grain − 2.5 times less than MPC.

The actual content of copper in the seeds of winter rapeseed grown under conditions of intensive chemicalization of agriculture for the period of harvesting was 1.9 times higher than the MPC, in the grain of winter wheat − 1.7 times more than the MPC, in the grain of spring barley − 1.4 times more than the MPC., in wet corn grain − 10.5 times less MPC, in dried corn grain - 10 times less MPC, sunflower seeds met the maximum permissible concentration.

The actual content of zinc in the wet grain of corn grown under conditions of intensive chemicalization of agriculture for the period of harvesting was 2.8 times less than the MPC, in the dried corn grain − 2.2 times less than the MPC, in the grain of spring barley −2.1 times less than the MPC, in seeds of winter rape and in seeds of sunflower − 2.0 times less than MPC.

Comparison of the content of lead, cadmium, copper and zinc in winter wheat grain grown under conditions of intensive chemicalization and growing conditions for resource-saving chemicalization revealed a high content of the studied heavy metals, respectively, in 1.7; 2.0; 5.2; 3.5 times in grain with intensive chemicalization.

Comparison of the content of lead, cadmium, copper and zinc in spring barley grain grown in conditions of intensive chemicalization and growing conditions for resource-saving chemicalization revealed a high content of the investigated heavy metals, respectively in 2.6; 12.5; 3.1; 5.2 times in grain with intensive chemicalization.

It has been established that under conditions of intensive chemicalization of agriculture, more zinc accumulates in winter wheat grain; in the seeds of winter rape − lead and copper in the wet grain of corn − all lead, but less cadmium, copper and zinc. In the dried grain of corn, lead accumulates less, copper in sunflower seeds − cadmium.

The greatest accumulation of zinc in winter wheat and cadmium in sunflower seeds is due to the physiological processes of plants to absorb more zinc and cadmium. The greatest accumulation of winter lead and cadmium in rapeseed is due to the high rates of mineral fertilization for this crop.

Artificial drying of corn grain to a moisture content of 11.1% helped to remove 5.7% of excess moisture from its grain. The loss of moisture in corn grain can affect the change in the content of heavy metals in two ways: they can be removed with moisture during evaporation or increase their content with a decrease in the amount of moisture in the grain due to a decrease in the mass of an individual caryopsis. The results of laboratory analyze found that the lead content in dried corn grain was 5.7 times less than in wet grain. At the same time, the content of cadmium, copper and zinc in wet corn grain was 2.0; 1.05 and 1.3 times higher than dried.

The main indicator of the intensity of accumulation of heavy metals in grain and seeds is the coefficient of accumulation, which is determined by the ratio of the content of heavy metals in grain and seeds to the content of mobile forms of heavy metals in the soil on which field crops were grown. The lower the accumulation coefficient, the less heavy metals migrate from the soil to the plant.

The lowest coefficient of accumulation of lead and cadmium in the conditions of resource-saving chemicalization of agriculture was found in the grain of spring barley − 40.0 and 0.3, respectively; copper−in winter wheat grain − 4.1; zinc − in the grain of spring barley − 3.6 (Fig. 1).

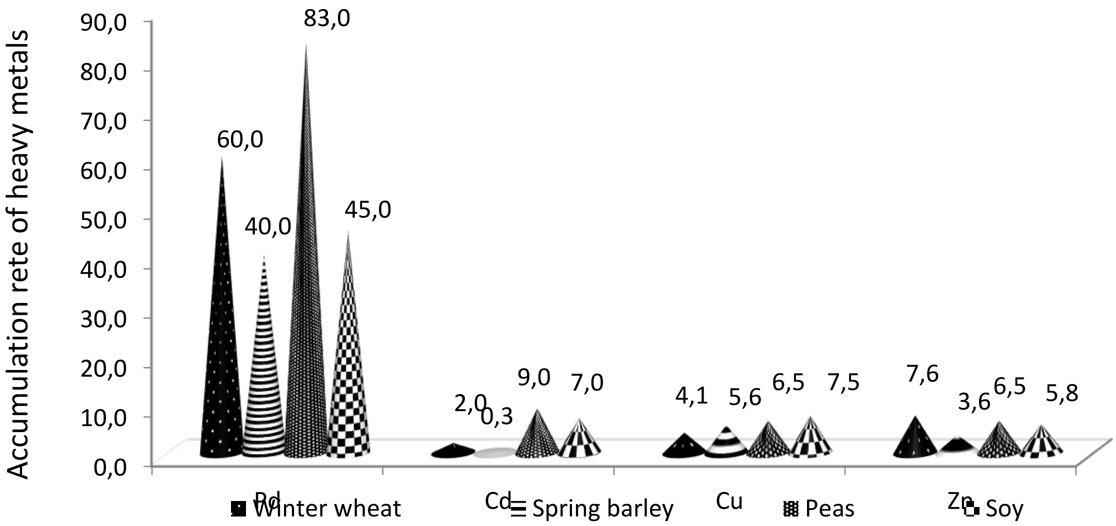

Figure: 1. Coefficient of accumulation of heavy metals in grain and seeds of field crops in conditions of resource-saving chemicalization of agriculture

The lowest coefficient of lead accumulation under conditions of intensive chemicalization of agriculture was found in sunflower seeds − 22.5; cadmium, copper and zinc − in corn grain − 1.0, 9.5 and 10.6, respectively (Fig. 2).

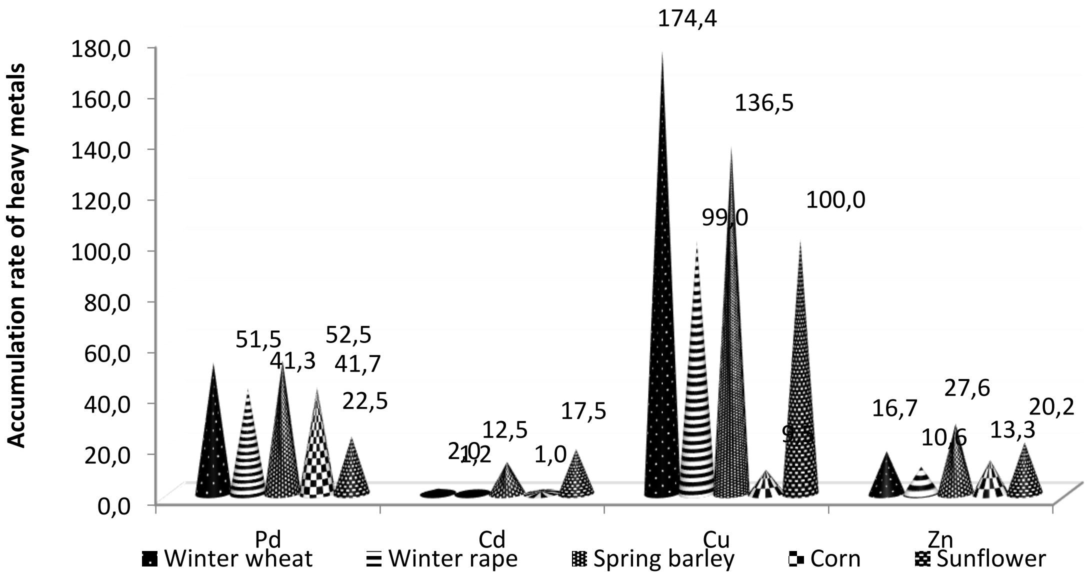

Figure: 2. Coefficient of accumulation of heavy metals in grain and seeds of field crops in conditions of intensive chemicalization of agriculture

The hazard coefficient of heavy metals is obtained by dividing the content of heavy metals in grain and seeds of field crops by the maximum permissible concentration of heavy metals in grain and seeds.

The lowest lead hazard factor under conditions of resource-saving chemicalization of agriculture was found in the grain of spring barley − 0.8; cadmium − in the grain of winter wheat and spring barley − 0.2, copper − in the grain of winter wheat − 0.3; zinc − in grain of spring barley, seeds of peas and soybeans − 0.5 (Table 2).

Table 2

The hazard coefficient of heavy metals in the main product (grain) of agrocenosis

Culture name	Heavy metals							
	Pb		Cd		Cu		Zn	
	RUKHZ*	IUKHZ**	RUKHZ	IUKHZ	RUKHZ	IUKHZ	RUKHZ	IUKHZ
Winter wheat	1,2	2,1	0,2	0,4	0,3	1,7	0,6	0,5
Spring barley	0,8	2,1	0,2	2,5	0,4	1,4	0,5	0,5

RUHZ* − resource-saving level of chemicalization of agriculture; IUKHZ** − an intensive level of chemicalization of agriculture.

The lowest lead hazard coefficient under conditions of intensive chemicalization of agriculture was found in sunflower seeds − 0.9; cadmium - in winter wheat grain − 0.2; copper and zinc − in corn grain − 0.1 and 0.4, respectively.

The hazard coefficient of lead in grain of spring barley grown under conditions of intensive chemicalization was 2.6 times higher, cadmium − 12.5 times, copper - 3.5 times more than for resource-saving chemicalization. In winter wheat grain, accordingly, the hazard coefficient of lead was 1.2 times higher, cadmium − 2 times, copper − 5.6 times higher than for resource-saving chemicalization.

To reduce the content of heavy metals in winter wheat grain, which was grown under conditions of intensive farming and slightly exceeded the MPC for lead and copper, we studied the change in the content of these heavy metals when grinding grain into various flour fractions: premium, first grade, second grade, and bran.

With a lead content in winter wheat grain of 1.03 mg/kg, which is 2.1 MPC, the lead content in bran was 2.68 mg / kg, which is 5.4 MPC and more by 61.6% than its content in the grain. In flour of the second grade, the content of lead in comparison with grain is less by 47.6%, the first grade − by 51.5%, the highest grade − by 71.8%. Consequently, with a lead content in winter wheat grain of 2.1 MPC, for food needs, you can use flour of the highest grade without restrictions or, with certain restrictions, flour of the first grade (Table 3).

With the copper content in winter wheat grain of 17.44 mg/kg, which is 1.7 times higher than the MPC, the copper content in bran was 35.34 mg/kg, which is 3.5 times higher than the MPC and 50.7% more than the grain. In the flour of the second grade, the content of copper in comparison with grain is less by 47.4%, the first grade − by 52.0%, the highest grade − by 72.0%. Therefore, when the content of copper in winter wheat grain is 1.7 MPC, flour of the second, first and highest grade can be used without restrictions for food needs.

Table 3

The content of heavy metals in the grain of winter wheat and products of its processing, grown at an intensive level of chemicalization of agriculture, mg/kg

Product name	Actual content of heavy metals			
	Pb*	Cd**	Cu***	Zn****
Winter wheat grain	1,03	0,04	17,44	26,50
Bran	2,68	0,10	35,34	83,20
Flour of the second grade	0,54	0,03	9,18	12,80
First grade flour	0,50	0,02	8,38	12,05
Flour of the highest grade	0,29	0,01	4,89	1,09

* maximum permissible concentration for Pb − 0.5 mg/kg; ** maximum permissible concentration for Cd − 0.1 mg/kg; *** maximum permissible concentration for Cu − 10.0 mg/kg
**** maximum permissible concentration for Zn − 50.0 mg/kg

On the basis of the studies carried out, there is a tendency towards a decrease in the content of heavy metals in winter wheat flour in the sequence: 2nd grade-1st grade-the highest grade, but an increase in the content of heavy metals in the bran. Possible reasons for a significant increase in the content of heavy metals in bran is their more concentration on the periphery of the seed, in particular in the shell. And since the bran is mainly represented by the shells of the caryopsis, it is in them that the content of heavy metals significantly increases. The low content of heavy metals in the premium flour as compared to the second grade flour is due to the screening of large flour fractions, and with them heavy metal dust in the low quality flour fraction.

Analyzing the qualitative data of grain products in terms of toxic and environmental indicators of agriculture grown using resource-saving chemicalization, we found that the actual content of lead, cadmium, copper and zinc does not exceed the maximum permissible concentrations. And with intensive chemicalization of agriculture, there is an increase in the content of heavy metals, in particular, in whole grain and bran, compared with their content in the first and second grade.

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