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STUDY OF THE DEGREE OF HEAVY AND TOXIC METAL POLLUTION OF SOILS AND FORAGES OF PEASANT FARMS IN THE ALMATY REGION

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ABSTRACT

The present article provides the interim results of the grant project "Veterinary and sanitary control and monitoring assessment of migration of heavy metals in the food chain "water-soil-feed-products"" to the study of heavy metal pollution of soil and plant-based forages on the territory of Almaty region of. The levels of Hg, Cd, Pb, andAs have been defined in the arable layer of soils in the basic farms. The compounds of toxic elements in forages used in the diets of milking cows have been monitored.Main types of soil, feed (hay, silage, haylage, concentrates) served as research materials. The toxic elements in all objects of the research have been analyzed using a novAA350 atomic absorption spectrometer and a TaLab voltammetrican alyser. The laboratory researches have been carried out in the Kazakh-Japanese Innovation Center under the aegis of the Kazakh National Agrarian University.

Keywords: heavy metals, soil, food safety, forage, veterinary and sanitary control, the maximum permissible concentration.

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1. INTRODUCTION

Heavy metal pollution of soils, water and plants in large cities and their surroundings has become one of the most pressing environmental issues [1]. The concentration of population, industry and transport have generated some typical urban problems, related particularly to the quality of life and ecological state of the cities.

Heavy metals now rank second in terms of danger level, yielding to pesticides and significantly outpacing such widely known pollutants, as carbon dioxide and sulphur. In the long term, they may be more hazardous than waste from nuclear power plants and solid waste [2]. Heavy metalpollution is due to their extensive use in industrial production. Due to imperfect purification systems, heavy metals are being released into the environment, including soil, polluting and poisoning it. Heavy metals refer to particular pollutants, the observations of which are mandatory in all environments.

The soil is the main environment into which heavy metals are released, including from the atmosphere and the aquatic environment. It also serves as a source of secondary pollution of surface air and waters entering from it into the World Ocean. From the soil,heavy metals are assimilated by plants, which then fall into food [3-5].

Similarly, obtaining high yields of crops is impossible without the use of chemical fertilizers. Fertilizer systems ensure the potential productivity of crops and contribute to the reproduction of soil fertility [6]. However, depending on the physicochemical properties of soil, species and doses of mineral fertilizers used, the change in the level of fertility is not always unambiguous. In soils, there is often an accumulation of various heavy metals, the source of which being the fertilizers applied [7, 8]. A rather large amount of heavy metals is introduced with mineral fertilizers. Such accumulation leads to increased concentrations of heavy metals in soil and crop production, and ultimately in a human body. Therefore, when applying mineral fertilizers, it is necessary to know the degree of their influence on the accumulation of heavy metals in the soil.

Lead, mercury, cadmium and arsenic are considered to be major pollutants mainly because their technogenic accumulation in the environment is particularly rapid [9, 10]. These elements suppress the most significant metabolic processes; inhibit the growth and development of plants. In agricultural production, it leads to a decrease in productivity and quality of products.

At present, in the territory of the Almaty region of the Republic of Kazakhstan, a multifactorial complex has emerged that pollutes the surrounding natural environment. Heavy metals' accumulation in vegetative forage mass inevitably leads to an increase in their concentrations in cattle blood, organs, tissues and milk. Toxic elements tend to accumulate in animals' bodies and livestock products (milk, meat) with an increase in the concentration of several or even tens and hundreds of times compared to their content in soil, water and plants [11, 12]. However, scientific research on migration and accumulation of toxic elements in the organs and tissues in cattle does not reflect an integrated approach to learning thereof in the soil-forage-food products system [13, 14].

Special information about migration, accumulation and distribution of toxic elements in the food chain will help in predicting their contents in plant- and animal-based food raw materials, as well as rationing their supply to food chains in order to prevent pollution of productive animals' bodies, and to obtain livestock products that meet the hygienic GOST requirements, which defines the scientific and practical value of the work.

The aim of this work was to study the influence of various levels of mercury, cadmium, lead and arsenic (*Hg, Cd, Pb*, and *As*) in the soil and the components of the diet of cattle on bioaccumulation thereof in animal products in basic farms of the Almaty region. The aim was also to scientifically justify the possibility of obtaining ecologically safe livestock products in dairy cattle breeding.

2. MATERIALS AND METHODS

As the research objects, samples of soils and forages of the basic farms located in the Almaty region were used, namely: KazAgroStandart, LLP and Aydarbaev peasant farm. To determine the content of heavy metals in the soil, samples were taken from the upper humus horizon to the arable layer depth (0-30 cm).The soil samples were taken in spring, after the snow melting, as per GOST 28168-89 "Soils. Sampling". The mass of each sample was 400 g. The water samples were taken as per GOST 31862-2012 "Drinking water. Sampling". The forage samples were taken as per GOST 6497-2014 "Fodder. Sampling".

The samples were prepared by dry and acid mineralization. The work was performed on the novAA350 atomic absorption spectrometer (AnalytikJena, Germany), which was a new generation device for automated analysis by flame atomic absorption spectroscopy with deuterium correction of background radiation (deuterium lamp with a hollow cathode) suitable for rapid transition to the atomic emission spectroscopy without the use of hollow cathode lamps.

Laboratory studies to determine the content of salts of heavy metals and toxic elements in soil and forages were carried out in accordance with the following regulatory documents:

ST RK ISO 8288-2005 ‘Determination of the content of cobalt, nickel, copper, zinc, cadmium and lead. Flame atomic absorption spectrometric methods’;

M-MVI-80-2008 ‘Method for performing measurements of the mass fraction of elements in soil, ground and bottom sediment samples using atomic emission and atomic adsorption spectrometry’;

GOST 30692-2000 ‘Forage, mixed feed, raw mixed feed. Atomic absorption method for determination of copper, lead, zinc and cadmium content’;

MU 08-47/162 ‘Voltammetric method for measuring the mass concentration of mercury’; and

MU 31-09/04 ‘Method for performing measurements of the mass concentration of arsenic by the method of inversion voltammetry on TA-type analyzers’.

3. RESULTS AND DISCUSSION

3.1. Defining the degree of heavy and toxic metal pollution of soils

- When studying the soil samples, it has been revealed that the content of mercury, lead, cadmium and arsenic in soil cover on the studied parameters does not go beyond the permissible concentrations in the base farms of the Almaty region.
- The concentration of cadmium in the soil cover of the KazAgroStandard LLP averaged 0.0234 mg/kg, which did not exceed the maximum permissible concentration (MPC) of absolutely dry soil matter (Table 1).

Table 1 The content of toxic elements in the soil cover of basic farms, mg/kg (M±g)

Indicator	Sample name	*Cd*	*Pb*	*As*	*Hg*
	MPC mg/kg	1.0	32	2.0	2.1
KazAgroStandard LLP	K/1-1-1	0.0224	0.2814	0.1643	0.2128
	K/1-1-2	0.0244	0.2580	0.3258	0.9561
Aidarbayev peasant farm	A/1-1-1	0.0229	0.2501	0.2652	0.4124
	A/1-1-2	0.0235	0.2953	0.3419	0.3986
	A/1-1-3	0.0264	0.2888	0.5214	0.4875

- ✓ The cadmium concentration for the soil cover of the Aidarbayev peasant farm amounted to 0.0222, 0.0244 and 0.0264, respectively. The lead concentration in the KazAgroStandard LLP averaged 0.2697, and in the Aidarbayev peasant farm - 0.2780.
- ✓ The concentration of mercury in soil samples from the KazAgroStandard LLP was 0.2128 and 0.95161 mg/kg, which did not exceed the MPC, and in the soil from the Aidarbayev peasant farm, the mercury level averaged 0.4328 mg/kg.
- ✓ Thus, the content of cadmium, mercury, arsenic and lead in the soil samples from the KazAgroStandard LLP and Aidarbayev peasant farm located on the territory of the Almaty region did not exceed the MPC.

3.2. The study of the amount of heavy metal salts and toxic elements consumed by dairy cows in the stall-feeding period diets

A stable forage base is necessary for farms for the sustainable development of dairy farming. During the research, the chemical composition and nutrient value of feeds used in feeding of dairy cows in various soil and climatic zones of the Almaty region were studied, and the content of heavy metals such as lead, cadmium and of toxic elements such as mercury and arsenic, as well as their content in the cows' diet during stall-feeding period were determined (Table 2). The content of heavy metals (Pb, Cd, Hg, As) in the lactating cows' chain (water - soil - winter diet feed - milk of cows) has shown that the indicators exceeding MPC or other critical indicators of heavy metals were not characteristic of the region's soil cover and water. By their nutritional value and mineral composition, the average weighted diets slightly deviated from the standards and corresponded to the productivity level and the physiological status of milking cows. In winter, the same feeds were fed in a canned form, which could not but influence the degree of contamination of diets and, accordingly, products.

Table 2 The content of toxic elements in the fodder of basic farms, mg/kg (M±g)

No.	Fodder type	Indicator Name	MPC mg/kg	Result (mg/kg)
KazAgroStandard LLP				
1	Barley	Cd	0.3	0.00168
		Pb	3.2	0.0986
		As	0.5	0.0063
		Hg	0.05	0.0034
2	Silage	Cd	0.3	0.0217
		Pb	3.2	0.0768
		As	0.5	0.0036
		Hg	0.05	0.0008

3	Mixed feed	Cd	0.3	0.0096
		Pb	3.2	0.8459
		As	0.5	0.0072
		Hg	0.05	Not detected
4	Sunflower cake	Cd	0.3	0.059
		Pb	3.2	0.0498
		As	0.5	0.0088
		Hg	0.05	0.0014
5	Carbohydrate prebiotic food	Cd	0.3	0.0398
		Pb	3.2	0.9132
		As	0.5	0.0065
		Hg	0.05	Not detected
Aidarbayev peasant farm				
1	Corn	Cd	0.3	0.0147
		Pb	3.2	0.6471
		As	0.5	0.0009
		Hg	0.05	Not detected
2	Barley	Cd	0.3	0.0138
		Pb	3.2	0.7894
		As	0.5	0.0054
		Hg	0.05	Not detected
3	Silage	Cd	0.3	0.0228
		Pb	3.2	0.8465
		As	0.5	0.0062
		Hg	0.05	0.0007
4	Soy bean meal	Cd	0.3	0.02572
		Pb	3.2	0.8521
		As	0.5	0.0012
		Hg	0.05	0.0003
5	Distillery stillage	Cd	0.3	0.0339
		Pb	3.2	0.8467
		As	0.5	0.0011
		Hg	0.05	Not detected
6	Mixed feed (barley + corn)	Cd	0.3	0.0383
		Pb	3.2	0.6785
		As	0.5	0.0017
		Hg	0.05	Not detected
7	Mixed feed from cereals	Cd	0.3	0.0499
		Pb	3.2	0.7421
		As	0.5	0.0027
		Hg	0.05	0.0004
8	Finish mixed feed	Cd	0.3	0.0558
		Pb	3.2	0.9822
		As	0.5	0.0049
		Hg	0.05	Not detected

- ✓ The study of the mixed feed, silage, concentrates indicated the content of mercury from 0.0004 to 0.0065 mg/kg, cadmium - from 0.00168 to 0.059 mg/kg, lead - from 0.06475 to 0.0986 mg/kg, which did not go beyond the indicators for each type of feed.
- ✓ Heavy metals (Hg, Cd, Pb) and arsenic (As) are contained in diurnal diets of lactating cows in various quantitative combinations. The cows from the KazAgroStandard LLP received the greatest amount of As and Hg with daily diet. Their quantities were the following: 0.0065 and 0.0011 mg/kg. The cows from the Aidarbayev peasant farm received the greatest amount of Cd and Pb with the daily diet. Their quantities werethe following: 0.0319 and 0.7981 mg/kg, respectively, in the feedof natural moisture. However, their quantity did not exceed the MPC.
- ✓ It has been found that in the winter stall period the migration rates of heavy metals and toxic elements depend both on the level of their content in feeds and on the type of element.

3.3. Studying the level of transition of heavy and toxic metals from soil to the basal forages of basic farms in the Almaty region

- ✓ The levels of transition of heavy and toxic metals from soil to basal forages of the Almaty region basic farms during the period from January to June were studied (intermediate studies).
- ✓ According to our studies, the natural climatic conditions of growth, the biological characteristics of the plant itself, and the technology of cultivation of forage crops influence the accumulation of toxic substances in plants of forage crops, and then - in forages. The studies have shown that the accumulation of heavy metals in forages depends to a large extent on the content of these metals in the soil (0-30 cm plowing layer) and their eventual availability for plants.
- ✓ Thus, the lead content in corn was 0.0986 mg/kg, and the cadmium content was 0.00168 mg/kg. Heavy metals are more likely to accumulate in legumes, and to a lesser extent - in corn, since the root system of legumes has barrier properties in relation to these toxic elements. Probably, the organic acids (lactic and acetic) present in the silage increase the availability of heavy metal salts to absorption in the gastrointestinal tract.
- ✓ Analysis of the forage crops and forage prepared from them showed the accumulation of cadmium of 0.059 mg/kg in the sunflower cake. Low lead content has been observed in forage crops, which is explained by the low content of lead in the soil, and consequently in the vegetative mass of forage plants. As a rule, the content of other toxic elements was within the permissible levels in the forages. In the forages, the content of heavy metals such as mercury and arsenic was below 0.01 mg/kg, or was not detected. In terms of the content of these metals, all forages were safe.The interim studies show that metals are better assimilated by animals when they are fed with canned forages (haylage, silage) since this is probably facilitated by a high content of organic acids in these types of feed. The studies continue.

3. CONCLUSION

- Thus, these data indicate that getting environmentally safe raw milk is only possible with the regular monitoring of the farms' environment, which should not be polluted by toxic elements.
- When studying the soil and forage samples, it has been revealed that the content of mercury, lead, cadmium and arsenic in the soil cover on the studied parameters does not go beyond the permissible concentrations in the base farms.
- The comparative analysis of the actual content of toxic elements in the feed as well as their maximum permissible levels has shown that the basic farms of the Almaty region have every opportunity to receive environmentally safe livestock products.

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