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ASSESSMENT OF HEAVY METAL CONTAMINATION OF THE AGRICULTURAL FIELDS IN THE KAMYSTY DISTRICT USING THE ICP-OES METHOD

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This article focuses on assessing the content of heavy metals (HM) in the soils of agricultural lands in the Kamysty district of the Kostanay region, Republic of Kazakhstan. The relevance of this study stems from the fact that heavy metal contamination of arable land poses a long-term environmental threat due to their accumulation in the soil. The primary objective of the agrochemical survey was to obtain reliable data on the content of priority pollutants – Cd, Pb, As, Cr, Zn and Ni – in the soils of the agricultural lands adjacent to the Altynsarin village. The study focused primarily on the dark chestnut soils of the district, characteristic of the steppe zone of Northern Kazakhstan. Potential sources of heavy metal (HM) input included both anthropogenic factors – the systematic application of fertilizers, which is one of the main sources of HM accumulation in the arable horizon – and natural-technogenic factors: wind-borne transport of mine dust and weathering products from tailings ponds (in particular, the Krasnooktyabrsky Mine) over distances of up to 20–70 km. Background soil samples were collected in the area near the Altynsarin village. The results obtained can serve as a basis for developing measures to reduce environmental risks and ensure the safety of agricultural products in the region.

***Keywords:** heavy metals, ICP-OES, soil contamination, Kostanay region, Kamysty district, agrochemical survey.*

ҚАМЫСТЫ АУДАНЫНЫҢ АУЫЛ ШАРУАШЫЛЫҒЫ АЛҚАПТАРЫНДАҒЫ АУЫР МЕТАЛДАРМЕН ЛАСТАНУЫН ICP-OES ӘДІСІ АРҚЫЛЫ БАҒАЛАУ

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Бұл мақала Қазақстан Республикасы Қостанай облысы Қамысты ауданының ауыл шаруашылығы жерлерінің топырағындағы ауыр металдардың (АМ) мөлшерін бағалауға арналған. Бұл зерттеудің өзектілігі егістік жерлердің ауыр металдармен ластануы олардың топырақта жиналуына байланысты ұзақ мерзімді экологиялық қауіп төндіретіндігіне негізделген. Агрохимиялық зерттеудің негізгі мақсаты – Алтынсарин ауылына іргелес орналасқан ауыл шаруашылығы жерлерінің топы-

рағындағы басым ластаушы заттардың (Cd, Pb, As, Cr, Zn және Ni) мөлшері туралы сенімді мәліметтер алу болды. Зерттеу негізінен Солтүстік Қазақстанның далалық аймағына тән осы ауданның күңгірт қара қоңыр топырақтарына бағытталған. Ауыр металдардың (АМ) түсуінің ықтимал көздеріне антропогендік факторлар (жыртылатын қабатта АМ жиналуының негізгі көздерінің бірі болып табылатын тыңайтқыштарды жүйелі түрде қолдану) және табиғи-техногендік факторлар (кен шаңы мен қалдық қоймаларынан, атап айтқанда Краснооктябрь кенішінен 20-70 км қашықтыққа желмен тасымалданатын үгінді өнімдері) жатады. Фондық топырақ үлгілері Алтынсарин ауылының маңындағы аумақтан жиналды. Алынған нәтижелер экологиялық тәуекелдерді азайту және өңірдегі ауыл шаруашылығы өнімдерінің қауіпсіздігін қамтамасыз ету жөніндегі шараларды әзірлеу үшін негіз бола алады.

Түйінді сөздер: *ауыр металдар, ICP-OES, топырақтың ластануы, Қостанай облысы, Қамысты ауданы, агрохимиялық зерттеу.*

ОЦЕНКА ЗАГРЯЗНЕНИЯ ТЯЖЕЛЫМИ МЕТАЛЛАМИ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПОЛЕЙ В КАМИСТИНСКОМ РАЙОНЕ С ПОМОЩЬЮ МЕТОДА ICP-OES

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Статья посвящена оценке содержания тяжёлых металлов (ТМ) в почвах сельскохозяйственных угодий Камыстинского района Костанайской области Республики Казахстан. Актуальность исследования обусловлена тем, что загрязнение пахотных земель тяжёлыми металлами представляет долгосрочную экологическую угрозу вследствие их накопления в почве. Основной целью агрохимического обследования являлось получение достоверной информации о содержании приоритетных загрязняющих веществ – Cd, Pb, As, Cr, Zn и Ni – в почвах угодий, прилегающих к селу Алтынсарино. Объектом исследования послужили преимущественно тёмно-каштановые почвы района, характерные для степной зоны Северного Казахстана. В качестве потенциальных источников поступления ТМ рассмотрены как антропогенные факторы: систематическое применение удобрений, являющихся одним из основным источником накопления ТМ в пахотном горизонте, так и природно-техногенные: ветровой перенос рудничной пыли и продуктов выветривания хвостохранилищ (в частности, Краснооктябрьского рудника) на расстояния до 20–70 км. Фоновые образцы почвы отбирались на территории вблизи села Алтынсарино. Полученные результаты могут служить основой для разработки мероприятий по снижению экологических рисков и обеспечению безопасности сельскохозяйственной продукции региона.

Ключевые слова: *тяжёлые металлы, ICP-OES, загрязнение почв, Костанайская область, Камыстинский район, агрохимическое обследование.*

Introduction

One of the major challenges facing modern agriculture is the impact of heavy metals on agricultural land. Heavy metals enter the environment from both natural sources and human activities. Natural sources include, among other things, the weathering of metal-bearing rocks by rainwater, as well as atmospheric deposition. Anthropogenic sources include industrial waste, transportation, the unregulated use of fertilizers containing heavy metals, and general urbanization processes. Unlike organic pollutants, heavy metals do not undergo biodegradation, and if they are not absorbed by plants or leached from the soil, they can accumulate and persist in it for a long time [1, c.2, 2, c.1810, 3, c.4, 4, c.3].

A significant portion of heavy metals released into the environment enters the lower troposphere via industrial emissions, migrates through the air, and settles in the surface soil layers. Any type of industrial soil contamination with heavy metals is assessed by the increase in metal concentration compared to its original natural background level, to which plant and animal organisms have long been adapted [4, c.3, 5, c.2, 6, c.3].

Soil contamination on agricultural lands, especially on cropland, poses a significant environmental problem, as it is a factor in the long-term accumulation and sustained migration of pollutants through food chains, with humans as the ultimate consumers. Heavy metals can accumulate in the soil and negatively affect all living organisms, including humans [4, c.4, 7, c.368]. The U.S. Environmental Protection Agency (USEPA) considers heavy metals such as Cd, Cr, As, Hg, Pb, Cu, Zn, and Ni to be priority pollutants [8, c.423]. Among these, Cd, Pb, As, Hg, and Cr are highly toxic and harmful to plant health even at relatively low contamination levels [4, c.4, 6, c.3, 7, c.369, 9, c.4].

Some elements are classified as essential mineral nutrients for plant growth and productivity. These include Cu, Zn, Fe, Mn, Mo, Ni, Mg, Ca, and B. At relatively low concentrations, these elements contribute to the normal functioning of plant cells, including the maintenance of ion homeostasis, pigment biosynthesis, photosynthesis, respiration, enzyme activity, gene expression regulation, sugar metabolism, nitrogen fixation, and others [4, c.4, 10, c.6, 11, c.3].

In the Kostanay region, the area of land under agricultural use totals 11.073 million hectares [12, c.190]. Of the agricultural land in the Kostanay region, 6.346 million hectares are arable land, and approximately 4.376 million hectares are used as pasture. The Kostanay region is one of the main agricultural regions of the Republic of Kazakhstan; the total sown area in the Kostanay region accounts for 22.7% of all sown areas in the Republic of Kazakhstan [13, c.270, 14, c.15]. In the agricultural sector of the Kostanay region, more than 54 million centners of grains and legumes and more than 4.8 million centners of oilseeds are harvested annually. The main agricultural soils of the Kostanay region are represented by ordinary and southern chernozems (Calcic Chernozems, IUSS WRB, 2022) and chestnut soils [15, c.102] (Gypsic Kastanozems, IUSS WRB, 2022). In many areas, the soils are subject to salinization [16, c.50]. Grain farming (wheat, barley, oilseeds, forage crops) predominates in the Kostanay region, so the fertilizer regime is typical of the northern steppe regions of Kazakhstan.

Chemical fertilizers, especially inorganic ones, are the most important factor in the intensification of crop production. Consequently, mineral fertilizers, including nitrogen (N), phosphorus (P), potassium (K), and complex (mixed) fertilizers, are regularly applied to agricultural land to provide plants with the necessary macronutrients. Nitrogen fertilizers are applied in the spring to increase the yield of grain crops. They are used most often due to nitrogen deficiency in chernozems after many years of cultivation; these include: ammonium nitrate (NH_4NO_3), urea ($CO(NH_2)_2$), and UAN (urea-ammonium nitrate mixture).

It has been shown that cadmium (Cd) concentrations in soil steadily increase as a result of phosphorus fertilizer application [17, c.496, 18, c.147, 19, c.7, 20, c.4, 21, c.6, 22, c.5]. Data from long-term field experiments confirm that Cd accumulation in the arable horizon directly correlates with the history of phosphorus fertilizer application and application rates [21, c.7, 22, c.6].

Wind transport must also be highlighted as one of the primary modes of heavy metal dispersion. Wind-borne dust transport is one of the key mechanisms for the long-range transport of heavy metals [23, c.4, 24, c.5]. The wind rose characteristic of Kazakhstan's steppe zone, with a predominance of northern, northwestern, and western directions, facilitates the transport of mine dust and weathering products from tailings ponds over distances ranging from 20 to 70 km.

Atmospheric transport comprises three main components: ore dust from blasting operations and transportation; dust from the surfaces of tailings ponds and overburden dumps; and emissions into the atmosphere during beneficiation processes. Fine particulate matter ($PM_{2.5}$–PM_{10}) with high concentrations of Cd, Cr, Cu, and Ni can be transported over significant distances and deposited in the soil cover of agricultural lands [23, c.6, 24, c.8].

The main objective of the agrochemical survey was to obtain reliable and objective information on the content of heavy metals in the soils of agricultural lands adjacent to the Altynsarin village.

Considering its spatial proximity (Figure 1), the Krasnooktyabrsky Mine may be regarded as a potential source of heavy metals (HMs).

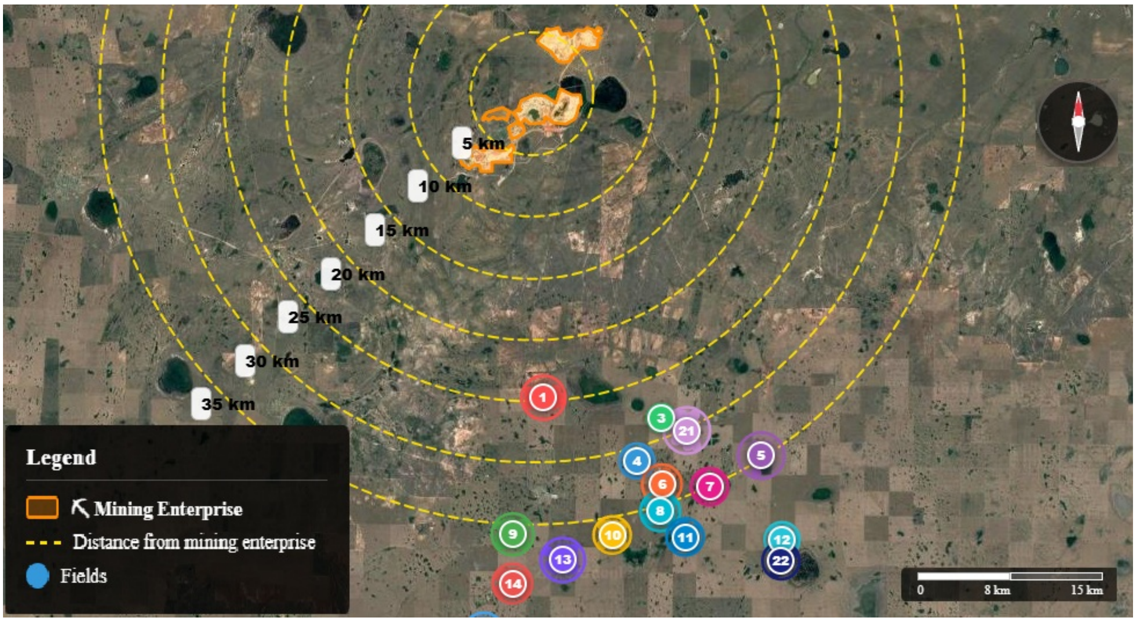

Figure 1 – The Krasnooktyabrsky Mine, showing the distances to the sampling points

Tasks: To determine the concentrations of mobile forms of heavy metals in the soils of the surveyed agricultural lands; to assess the average concentrations of heavy metals for each study site; to conduct a comparative analysis of heavy metal concentrations across different areas of the surveyed area; to evaluate the degree of soil contamination by heavy metals based on a comparison of the obtained data with the applicable regulatory standards.

The subject of the study is the soils of the Kamysty district. Most of the territory is covered by dark chestnut normal, dark chestnut, carbonate, and in some places residual carbonate soils, as well as dark chestnut solonetz and complexes of dark chestnut soils with solonetz; in the northwestern part, there are phosphatic chernozems. In the extreme southern part, medium-chestnut-colored saline soils and complexes of medium-chestnut-colored saline soils with solonets dominate. In the northern and southeastern parts, isolated solonetz patches are found [16, c.64]. For the background area, soil samples were collected from the area near the Altynsarin village.

Materials and Methods. The analysis included 340 soil samples collected from 22 fields. The fields are located near the Altynsarin and Filipovka villages in the Kamysty district of the Kostanay region.

Sampling and sample preparation were performed in accordance with **GOST 28168-89** this standard applies to the sampling of arable lands, hayfields, pastures, and forest nurseries and establishes methods for their sampling during agrochemical surveys.

The determination of mobile forms of macro- and microelements (As, Zn, Cd, Pb, Ni, Cr) was performed using inductively coupled plasma optical emission spectrometry (ICP-OES) with a Thermo Fisher Scientific iCAP Pro spectrometer. The determination of trace elements was performed in accordance with **GOST ISO 22036-2014** Determination of trace elements in soil extracts using inductively coupled plasma atomic emission spectrometry (ICP-AES).

Extraction of mobile metal forms from samples was performed in accordance with **PND F 16.1:2:2.2:2. 3.78-2013** method for measuring the mass fraction of mobile forms of metals: copper, zinc, lead, cadmium, manganese, nickel, cobalt, and chromium in samples of soil, earth, bottom sediments, and wastewater sludge using flame atomic absorption spectrometry

To extract mobile forms of heavy metals in soil, an acetate-ammonium buffer solution with a concentration of 1 N (CH_3COONH_4) with a pH range of 4.8–7.0, which ensured stable extraction conditions and prevented the precipitation of metals as hydroxide forms. The resulting extracts were filtered and subsequently analyzed in a multi-component mode, which allowed for the determination of macro- and microelement concentrations in soil samples with high accuracy and productivity.

To determine maximum permissible concentrations (MPCs), Hygienic Standards **GN 2.1.7.2041-06** (Maximum Permissible Concentrations (MPCs) of Chemical Substances in Soil) were applied.

Results and Discussion. An analysis of soils in the Kamysty district revealed that the heavy metal content in the samples studied was within acceptable limits and did not exceed maximum permissible concentrations (Table 1). Given the large sample size, consisting of 340 samples from 22 fields (an average of 15 samples per field), the three most informative indicators were used for further statistical and comparative analysis.

Table 1 – Heavy metal content in soil, mg/kg of soil

Sample Name	Indicators	As 189 nm	Zn 206 nm	Cd 214 nm	Pb 220 nm	Ni 231 nm	Cr 267 nm
		MPC					
		2	23	0,5	6	4	6
Field 1	average	0,189744	1,028063	0,046599	0,159	1,114649	0,807613
	max	0,237411	1,612354	0,051923	0,207247	1,52741	1,098281
	min	0,144324	0,66156	0,038017	0,118822	0,738978	0,504722
Field 2	average	0,180227	0,935436	0,050427	0,304399	1,823104	0,940256
	max	0,24012	1,279738	0,056278	0,367013	2,36937	1,154386
	min	0,140818	0,636156	0,045248	0,225838	1,525296	0,716272
Field 3	average	0,152069	1,13862	0,044324	0,194258	1,232814	0,979549
	max	0,18025	1,410503	0,052759	0,225667	1,444393	1,164276
	min	0,130432	0,750999	0,039894	0,161173	0,884524	0,672718
Field 4	average	0,166746	0,906633	0,047829	0,193467	1,19741	0,966167
	max	0,221256	1,612392	0,057135	0,221405	1,43135	1,165682
	min	0,119135	0,554054	0,039831	0,153218	0,837401	0,585486
Field 5	average	0,161205	0,731207	0,048541	0,177058	0,942448	0,76693
	max	0,18058	1,132364	0,053264	0,197481	1,147485	0,976064
	min	0,12742	0,496815	0,044938	0,138368	0,858897	0,676731
Field 6	average	0,16003	1,74502	0,058517	0,191528	1,089372	0,872869
	max	0,215574	2,259654	0,066161	0,203141	1,156937	1,06572
	min	0,09453	1,343901	0,051473	0,15711	0,990222	0,747852

Table 1 continued

Field 7	average	0,20888	0,803067	0,059484	0,264336	1,278716	0,758074
	max	0,253936	1,339555	0,064948	0,346101	1,474154	0,98622
	min	0,168536	0,4528	0,048283	0,143061	0,980934	0,622319
Field 8	average	0,169988	1,064944	0,055281	0,278346	1,491602	1,092347
	max	0,228201	1,403575	0,064117	0,318757	1,889209	1,47062
	min	0,125365	0,614526	0,048487	0,22237	1,131272	0,689532
Field 9	average	0,195031	0,705796	0,041267	0,189608	3,159906	0,320578
	max	0,225756	1,342308	0,050443	0,348299	3,715437	0,978859
	min	0,151408	0,449606	0,024064	0,132656	2,943959	0,1493
Field 10	average	0,158353	0,77603	0,046051	0,189432	0,956861	0,703933
	max	0,221355	1,320927	0,050871	0,321138	1,546157	1,176829
	min	0,102977	0,404875	0,031653	0,112854	0,776701	0,526937
Field 11	average	0,170087	0,642103	0,040719	0,168095	0,886901	0,717414
	max	0,200877	0,800064	0,049465	0,220644	1,43903	1,222555
	min	0,141501	0,513636	0,024074	0,101939	0,637301	0,509494
Field 12	average	0,163786	1,54157	0,056287	0,234326	1,01526	0,809183
	max	0,205567	1,896614	0,063369	0,431534	1,183461	0,960693
	min	0,120423	1,200209	0,04024	0,120656	0,762037	0,535321
Field 13	average	0,207983	1,004911	0,057937	0,250149	1,044282	0,793808
	max	0,250459	1,94619	0,082866	0,559447	1,301304	1,047201
	min	0,156476	0,438523	0,049408	0,164241	0,872512	0,643481
Field 14	average	0,244748	0,653236	0,043829	0,221597	3,549133	0,68447
	max	0,310444	1,252597	0,05728	0,312332	4,003149	1,094456
	min	0,168386	0,444709	0,026594	0,092985	3,02407	0,214749
Field 15	average	0,281411	0,628904	0,04283	0,209061	3,234539	0,368332
	max	0,322401	0,792642	0,055006	0,291989	3,470209	0,615323
	min	0,224372	0,479101	0,024033	0,159777	3,107331	0,2286
Field 16	average	0,235337	0,881695	0,03931	0,204007	3,316736	0,403149
	max	0,284859	1,229383	0,046195	0,26163	3,566244	0,70134
	min	0,178747	0,491351	0,033068	0,147831	3,055202	0,102278
Field 17	average	0,206003	0,594784	0,05513	0,270725	1,248157	0,834966
	max	0,234173	0,933666	0,060708	0,473489	2,003274	1,10217
	min	0,178307	0,385385	0,048618	0,199867	0,993121	0,607034
Field 18	average	0,191262	0,697132	0,053185	0,233444	1,253217	0,912793
	max	0,220517	1,433047	0,060831	0,282289	1,837596	1,469979
	min	0,150209	0,3313	0,046914	0,20775	0,690442	0,323346
Field 19	average	0,149473	0,883269	0,048027	0,224577	1,403117	1,014703
	max	0,186358	1,790246	0,055661	0,379001	1,97187	1,491856
	min	0,107761	0,586812	0,034158	0,150275	0,99836	0,644212
Field 20	average	0,135782	0,997903	0,043366	0,20987	1,299811	0,875907
	max	0,196443	1,258263	0,054548	0,305384	2,069499	1,217584
	min	0,085013	0,704897	0,016066	0,162851	0,934627	0,581062
Field 21	average	0,206643	0,866818	0,051018	0,248742	1,099277	0,827345
	max	0,243002	1,859512	0,05825	0,331778	1,506365	1,245074
	min	0,16484	0,365577	0,043597	0,169346	0,657407	0,515383
Field 22	average	0,199545	0,892916	0,060381	0,296695	1,675802	1,130884
	max	0,234303	1,258019	0,065421	0,34476	2,063379	1,899174
	min	0,16221	0,732243	0,057101	0,190452	1,35638	0,809693

An analysis of the experimental data presented in Table 3 indicates that the mobile forms of heavy metals (HM) in the topsoil of the studied agricultural lands do not, in most cases, exceed the maximum permissible concentrations (MPCs) as regulated by current sanitary and hygienic standards. The slight exceedance of regulatory limits observed in individual fields is localized and, in all likelihood, is due to the influence of local geochemical factors or localized anthropogenic impacts not associated with systematic contamination.

For a more detailed and clear interpretation of the results, the average HM concentrations across 22 fields were systematized and presented in Chart -1.

A comparative analysis of the average TM concentrations across the study fields generally shows that the values are similar for most elements, indicating a relatively uniform geochemical background within the study area.

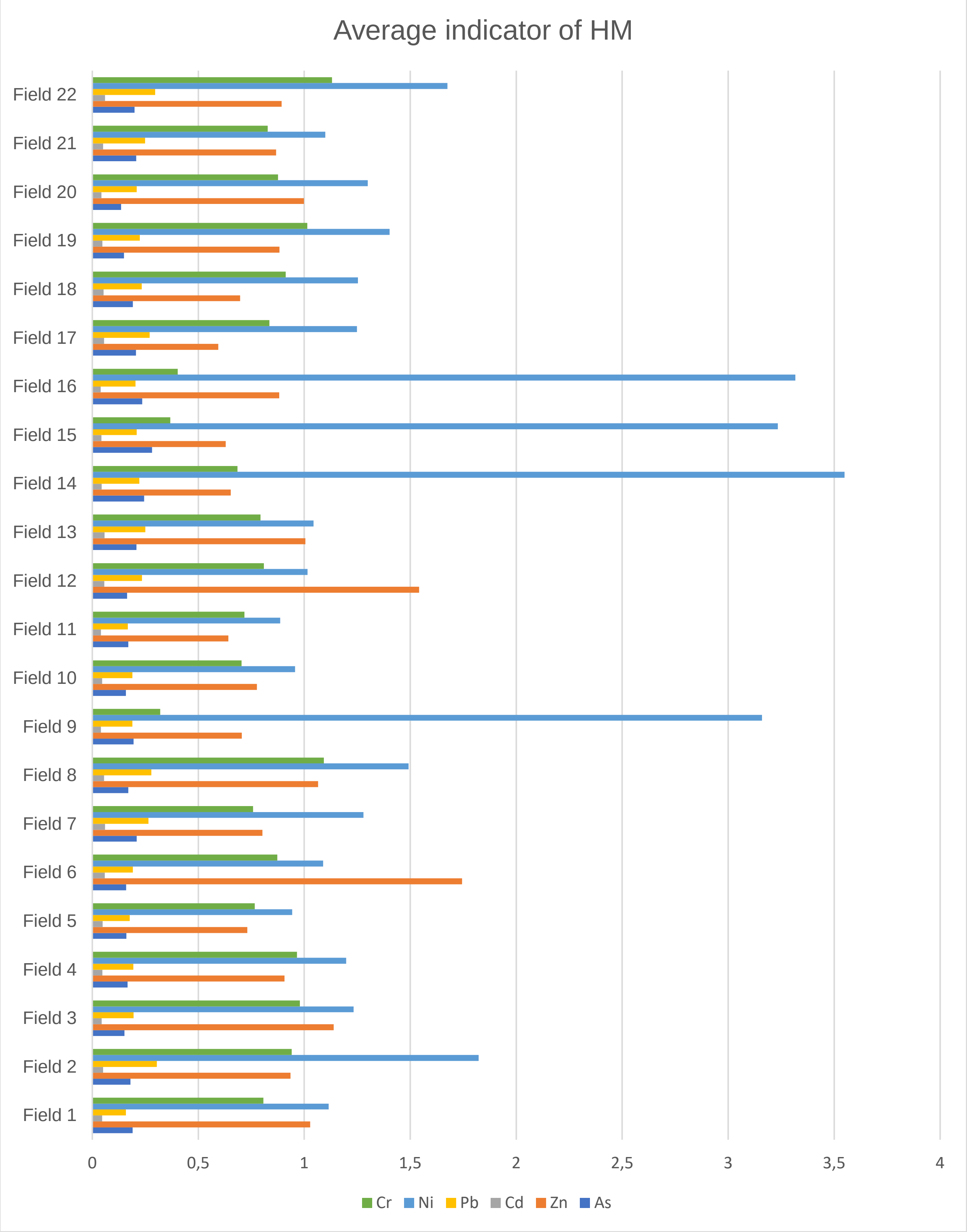

Chart – 1

The exception is nickel (Ni): according to Chart – 2, in fields Nos. 9, 14, 15, and 16, its average content in the mobile form is twice that of the other fields. It is characteristic that the anomaly covers precisely a group of adjacent fields, which rules out a random nature of the deviation and points to a localized anthropogenic or agrogenic source.

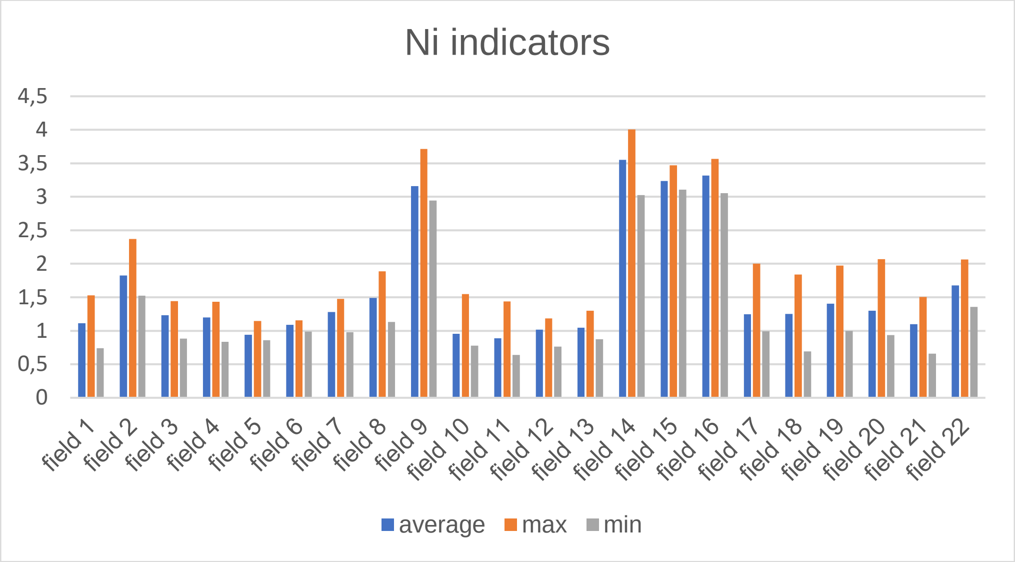

Chart – 2

A more detailed examination of the nickel results presented in Chart – 2 allows us to go beyond an analysis of average values and conduct a comprehensive assessment of the entire range of recorded values-from the minimum to the maximum values for each field. This approach makes it possible to more objectively assess the extent of the geochemical anomaly and its potential environmental significance.

It is noteworthy that in fields No. 9, 14, 15, and 16, not only the average but also the minimum recorded values of nickel content in mobile form exceed the corresponding minimum values of the other surveyed fields by 2-3 times. This circumstance is of fundamental importance from an analytical standpoint: if we were dealing only with point sources of emissions or local inclusions, the elevated concentrations would be reflected exclusively in the maximum values, whereas the upward shift of the entire range-including the minimum threshold-indicates a systematic and uniform accumulation of nickel across the entire area of the specified fields. This significantly strengthens the argument in favor of an anthropogenic, rather than natural, origin of the anomaly.

The results for Field No. 14 deserve special attention, where the maximum recorded nickel content reached 4.003 mg/kg, which corresponds to the lower threshold for exceeding the maximum permissible concentration of this element in soil. In fact, this field is very close to the regulatory threshold beyond which soil contamination with nickel is officially classified as a problem and requires the implementation of agroecological measures. A similar trend is observed in Field No. 9, where the maximum value was 3.7 mg/kg, which also indicates a significant approach to the MPC threshold and creates a zone of heightened environmental risk.

The combination of identified patterns – a sustained upward shift across the entire range of values, spatial clustering of anomalies within four fields, and the approach of maximum values toward regulatory limits-indicates that the process of nickel accumulation in these areas is progressive in nature. If current agrochemical practices continue without adjustments to the doses and types of fertilizers applied, there is a real likelihood that MPCs will be exceeded in the medium term, which will require restrictions on the use of these lands for food production.

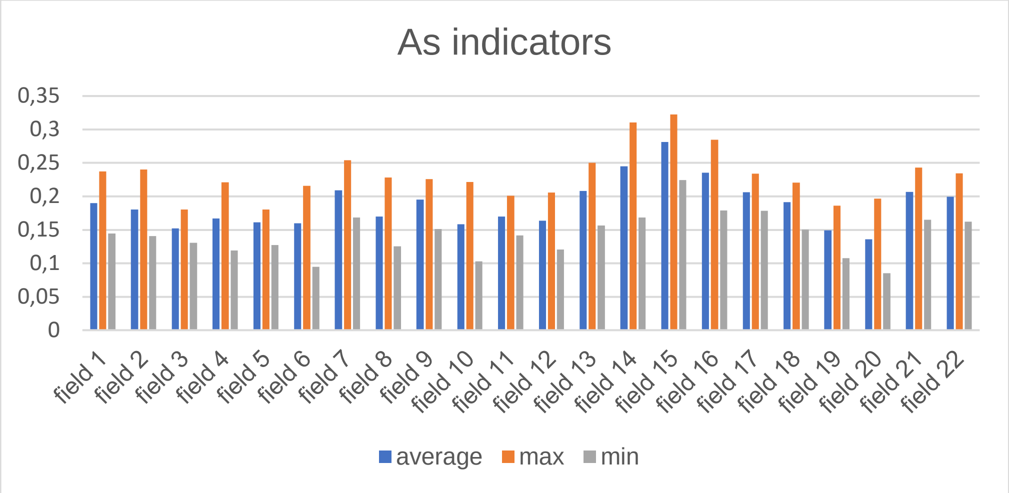

Chart – 3

An analysis of the data in Figure 3, which shows the distribution of mobile forms of arsenic (As) in the soils of the studied fields, indicates a consistently low concentration of this element throughout the entire surveyed area. The maximum recorded arsenic concentration was 0.32 mg/kg, which is 6.25 times lower than the established maximum permissible concentration (MPC) for this element in soil, which is 2.0 mg/kg. Such a significant gap between the actual values and the regulatory threshold precludes any grounds for classifying the soils of the study area as contaminated with respect to this indicator.

It is noteworthy that not only the average but also the maximum arsenic concentrations across all 22 surveyed fields show no tendency to approach the regulatory limit. The absence of fields with abnormally high concentrations, as well as the uniformly low distribution of values, indicate that sources of anthropogenic arsenic input into the soil cover of this territory are either absent or their contribution is negligible against the background of the natural geochemical background.

Based on the data obtained, it can be concluded that arsenic is present in the soils of the studied fields in trace amounts, without having a negative impact on the state of the soil ecosystem. The recorded concentrations do not pose a threat to soil biota, do not create a risk of the element accumulating in plant products above permissible limits, and do not pose a potential health hazard to the population consuming products grown on these lands. Thus, based on arsenic content, the soils in the Altynsarin village area are characterized as environmentally safe and compliant with all applicable sanitary and hygiene standards.

An analysis of Figure 4, which shows the distribution of mobile forms of zinc (Zn) in the soils of the study fields, indicates an extremely low concentration of this element throughout the entire surveyed area. The maximum concentration of mobile zinc was recorded in Field No. 6 and amounted to 2.3 mg/kg, which is more than 10 times lower than the established MPC standard for the mobile form of this element in soil, equal to 23 mg/kg. Such a significant gap between the actual indicators and the regulatory threshold clearly indicates the absence of zinc contamination in the soil cover of the study area.

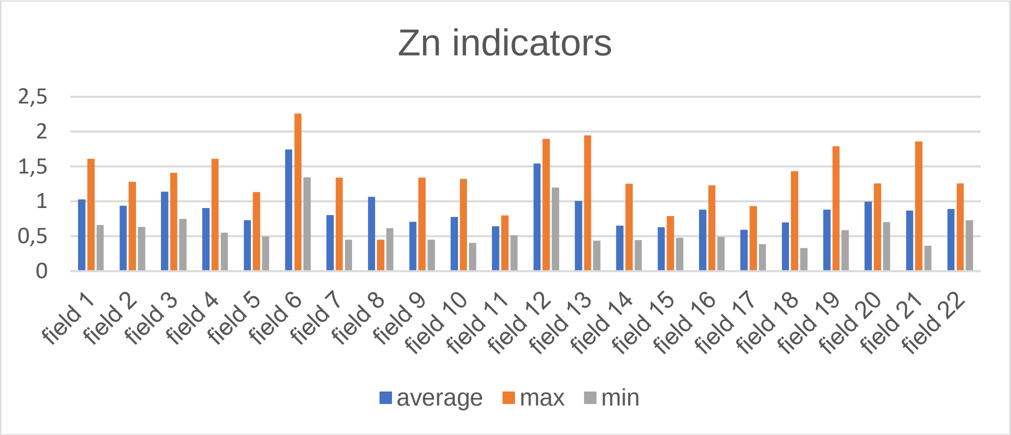

Chart – 4

Based on the data obtained, the soils of the studied fields are characterized as environmentally safe in terms of the content of mobile forms of zinc. The recorded concentrations do not pose a threat to soil biota, do not create conditions for excessive zinc accumulation in plant products, and do not carry a risk of negative impact on the ecosystem as a whole. This element, therefore, is not a limiting factor for the ecological condition of soils in the study area.

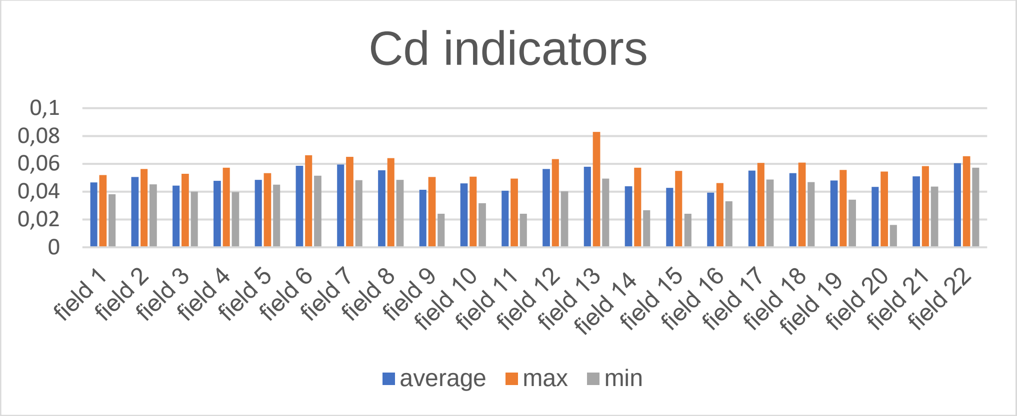

Chart – 5

The results of the study on the content of mobile forms of cadmium (Cd) in the soils of the surveyed fields, presented in Figure 5, indicate extremely low concentrations of this element throughout the entire surveyed area. The maximum value of mobile cadmium was recorded in Field No. 13 and amounted to 0.082 mg/kg, which is more than six times lower than the established MPC standard for mobile forms of this element (0.5 mg/kg). Such a significant gap between the actual values and the regulatory threshold unequivocally rules out the possibility of classifying the soils of the surveyed area as cadmium-contaminated.

A detailed examination of the data in Figure 5 for plot No. 13 reveals a fundamentally important analytical pattern: the average and minimum cadmium concentrations at this site are virtually identical. From a geochemical perspective, this fact has significant diagnostic value. The coincidence of the minimum and average values indicates that the vast majority of the samples collected are characterized by similar cadmium concentration values, which form a stable low-background level across the entire field area.

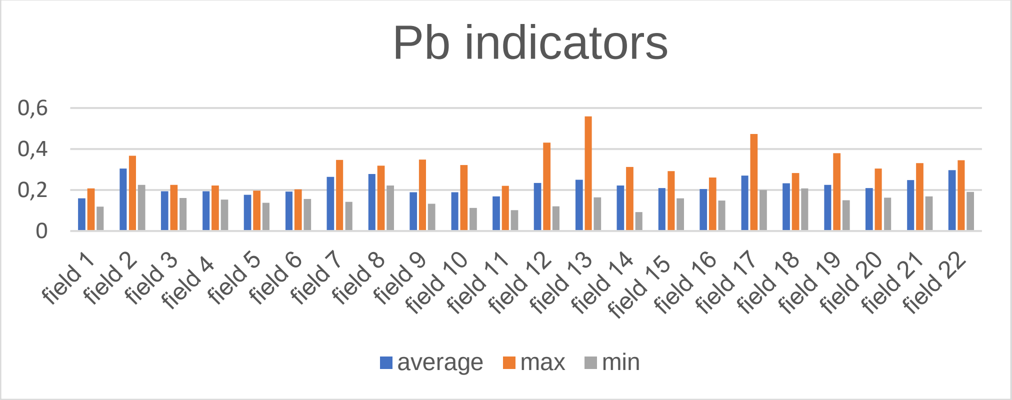

Chart – 6

An analysis of Figure 6, which shows the distribution of mobile forms of lead (Pb) in the soils of the studied fields, indicates a consistently low concentration of this element throughout the entire surveyed area. The maximum recorded concentration of mobile lead was 0.55 mg/kg, which is more than 10 times lower than the established MPC standard for this element, which is 6.0 mg/kg. Such a significant margin below the regulatory threshold clearly indicates the absence of lead contamination in the soil cover of the surveyed area.

A detailed examination of the range of values for Field No. 13, where the highest reading was recorded, reveals a fundamentally important pattern. The average and minimum lead concentrations in this area are at least two times lower than the recorded maximum, indicating that the value of 0.55 mg/kg represents an isolated local anomaly that does not reflect the overall geochemical characteristics of the field. The vast majority of samples collected in this area show significantly lower lead concentrations, forming a stable low-background level comparable to the values of the other surveyed fields.

Thus, the maximum value for Field No. 13 cannot be considered a representative indicator of the geochemical condition of this site as a whole.

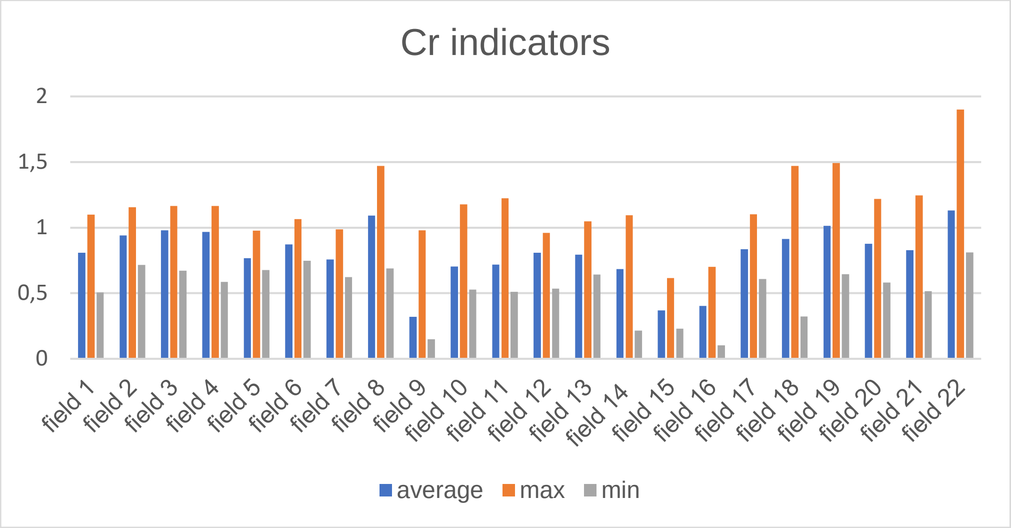

Chart – 7

Data on the content of mobile forms of chromium in the studied soils show generally low concentrations, although there are several areas with relatively elevated levels. The highest value was recorded in Field No. 22 at 1.9 mg/kg, which is more than three times lower than the maximum permissible concentration (MPC) for mobile chromium (6.0 mg/kg).

In fields No. 8, 18, and 19, concentrations ranging from 1.46 to 1.5 mg/kg were detected, exceeding the average background level of the other fields but remaining within regulatory limits. The similarity of absolute values at these three sites may indicate the presence of a common source of chromium, the nature of which requires further investigation. The most likely factors under consideration are the use of phosphorus-containing fertilizers and the lithological characteristics of the soil-forming rocks.

Based on the aggregate data obtained, all fields under study meet regulatory requirements for mobile chromium content and are characterized as environmentally safe.

Conclusion. The results of the study showed that the concentration of mobile forms of heavy metals in the soils of the surveyed fields does not exceed the established maximum permissible concentrations. This allows the soils in the area around the Altynsarin village to be classified as clean with regard to the elements studied. It was established that the average values of most heavy metals across the fields are similar, indicating a relatively homogeneous soil cover. At the same time, fields No. 9, 14, 15, and 16 showed higher nickel concentrations compared to the average values for the other plots, which may be related to specific agrochemical practices. The maximum concentrations of arsenic, zinc, cadmium, lead, and chromium remainned significantly below regulatory limits. The data obtained indicate the absence of hazardous soil contamination by mobile forms of heavy metals and can serve as a basis for further environmental monitoring of agricultural lands.

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ВЛИЯНИЕ УРОВНЯ НЕЙТРАЛЬНО-ДЕТЕРГЕНТНОЙ КЛЕТЧАТКИ В РАЦИОНАХ СУХОСТОЙНЫХ КОРОВ НА ФИЗИОЛОГИЧЕСКОЕ СОСТОЯНИЕ И ПРОФИЛАКТИКУ МЕТАБОЛИЧЕСКИХ НАРУШЕНИЙ

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В статье представлены результаты изучения влияния нейтрально-детергентной клетчатки в рационах сухостойных коров на физиологическое состояние и профилактику метаболических нарушений в транзитный период, т.е. за 3 недели до и 3 после отёла. Исследования проведены на коровах голштинской породы в условиях промышленного молочного хозяйства Северного региона Казахстана (ТОО «Олжа-Садчиковское», Костанайская обл.). Анализ кормов выполнялся методом детергентного анализа по системе Van Soest с использованием анализатора ANKOM в соответствии с требованиями AOAC, ISO и ГОСТ. Были разработаны рационы для раннего и позднего сухостоя с контролируемым уровнем НДК и сбалансированным энергопротеиновым обеспечением. Оценивали структуру рационов, потребление питательных веществ, косвенные показатели рубцового метаболизма, минеральный баланс и некоторые зоотехнические параметры. Установлено, что избыточное содержание структурной клетчатки в традиционных рационах снижает концентрацию обменной энергии, нарушает кальций-фосфорное соотношение, повышает катионно-анионную разность (DCAD) и увеличивает риск метаболических расстройств. Оптимизация уровня НДК способствовала стабилизации микрофлоры рубца, улучшению поедаемости кормов, снижению кормового стресса и повышению физиологической адаптации коров к отёлу и началу лактации.

Ключевые слова: *оптимизация рационов, потребление структурных углеводов, фракции пищевой клетчатки, рубцовый метаболизм, энергопротеиновый баланс, кальций-фосфорное соотношение, кормовой стресс.*

СУАЛУ КЕЗЕҢДЕГІ СИЫРЛАРДЫҢ АЗЫҚ РАЦИОНДАРЫНДАҒЫ БЕЙТАРАП-ЖУҒЫШ ЖАСҰНЫҚ ДЕҢГЕЙІНІҢ ФИЗИОЛОГИЯЛЫҚ КҮЙГЕ ЖӘНЕ МЕТАБОЛИТТІК БҰЗЫЛЫСТАРДЫҢ АЛДЫН АЛУҒА ӘСЕРІ

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