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Environmental Aspects of Fertilizer Application in Modern Agriculture in the Aral Sea Region

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Abstract
Education in The article examines the ecological aspects of fertilizer application in modern agriculture in the Aral Sea region. The main reasons for the pollution of the environment by fertilizers should be considered not the fertilizers themselves, but the imperfection of the organizational forms, as well as the technology of storage, application of fertilizers, violation of the agronomic technology of their application in the crop rotation and for individual crops. Quantitative assessments of the consequences of harmful substances entering the soil on the day of scientific analysis should be based on a strictly established "dose-effect" relationship.

Keywords: Ecosystems, Fertilizers, Irrigated Lands, Soils, Spectral Analysis

Introduction

Due to the constant increase in the anthropogenic pressure on the biosphere and the intensification of the impact on the soil caused by the implementation of agricultural works and the activities of industrial enterprises, the question of assessing the ecological state of this extremely important and complex natural object is becoming increasingly urgent. An important object of environmental regulation is the ecological state of the surrounding natural environment, which is understood as a complex of properties that determine its ability to ensure the stable functioning of ecological systems, the natural environment and the preservation of the physical and geographical basis of the territory.

Most environmental problems cannot be solved without considering soil as an indispensable and irreplaceable component of the biosphere at all its structural levels. A necessary condition for ensuring a high level of economic development and a favourable medical and demographic situation in an administrative region is maintaining the balance between the use of natural resources and the state of the environment within the limits of environmental norms.

Review of Related Literature

The literature on soil science and ecological sustainability highlights the multifaceted role of soils in maintaining ecosystem stability and supporting agricultural productivity. Foundational works such as Kovda (1985) on the biogeochemistry of soil cover and Volvolsky & Nikitin (1990) on soil functions in the biosphere emphasize the central role of soils in regulating biogeochemical cycles and sustaining biodiversity. Karpachevsky (2005) further advanced the field through ecological soil science, underscoring the interconnection between soil health and environmental resilience.

Several studies address the challenges of soil degradation and salinization in Central Asia. Shirokova & Chernishev (1999) developed express methods for determining soil and water salinity in Uzbekistan, while Tolepova (2005) examined salt accumulation in the lower reaches of the Amu Darya. More recent work by Tolepova & Djumanazarova (2022) outlined principles for regulating the water-salt regime of irrigated soils in Karakalpakstan, highlighting practical approaches to drainage and soil management. These studies align with Chembarisov & Khodjamuratova (2008), who analysed collector-drainage waters in Karakalpakstan, pointing to the hydrological dimensions of soil salinity.

Ecological monitoring and assessment frameworks have also been developed to evaluate soil quality. Glazunov & Gendugov (2013) provided an ecological assessment of soils and lands, while Motuzov & Bezuglov (2007) emphasized soil ecological monitoring as a tool for sustainable management. Nabieva (2016) contributed insights into changes in soil properties and microbiological activity under pasture plants, linking soil health to vegetation dynamics.

Taken together, these studies reveal dual trajectory theoretical explorations of soil functions in the biosphere and applied research addressing salinization, water-salt regimes, and ecological monitoring in Uzbekistan and the Aral Sea basin. This convergence underscores the importance of integrating soil ecology, salinity management, and ecological monitoring to ensure sustainable land use and biodiversity conservation in vulnerable regions.

Objectives

Soil as a monitoring object, being a complex multiphase and multi-component system, has a number of specific natural functions and features. First, it is rich in fertility, the preservation, maintenance and multiplication of which is a priority task of man. Secondly, the soil, due to its peculiarities of structure and composition, performs a protective function, retaining pollutants and preventing them from entering adjacent environments and plant, animal, and human organisms. The other side of this is that by binding the pollutants, the soil itself can become their storage and a source of long-term pollution of groundwater and living organisms' tissues. The diversity of soil cover functions ensures the high significance of soil state indicators for assessing the state of the environment as a whole, based on their integrity, relatively low dynamism, and significant in formativeness .

It is known that increasing land productivity depends mainly on the land's reclamation state, which is expressed in the depth of groundwater occurrence, their mineralization level, soil salinity level, and crop yields.

The main reasons for the pollution of the environment by fertilizers should be considered not the fertilizers themselves, but the imperfection of organizational forms, as well as storage technologies, the application of fertilizers, the violation of the agronomic technology of their application in rotation and for individual crops (including non-proportionate or unbalanced), the imperfection of the fertilizers themselves, their chemical, physical and mechanical properties.

The irrigated area of Karakalpakstan is 504.8 thousand hectares; the Karakalpak Hydrogeological and Land Reclamation Expedition (Fig. 1) constantly monitor almost the entire area.

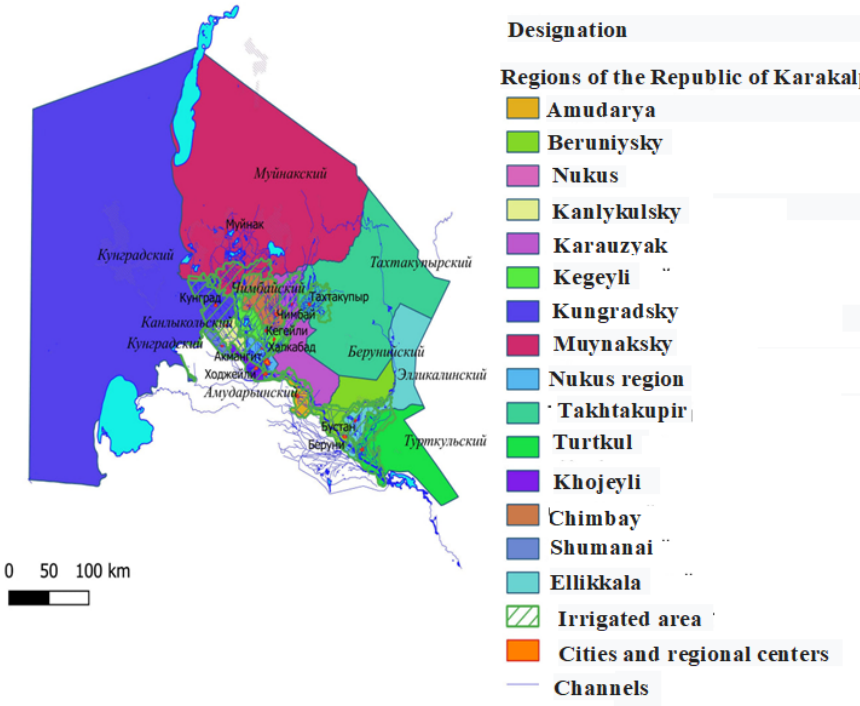
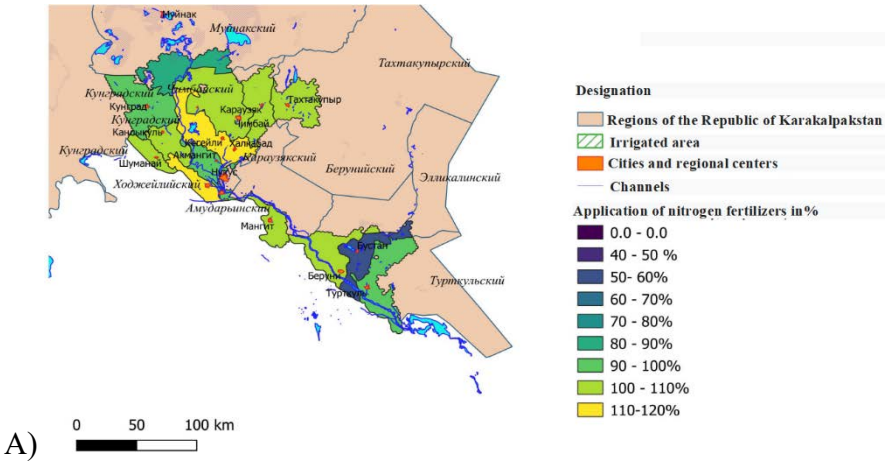


Figure 1. Map - diagram of the irrigated area of land in the Republic of Karakalpakstan

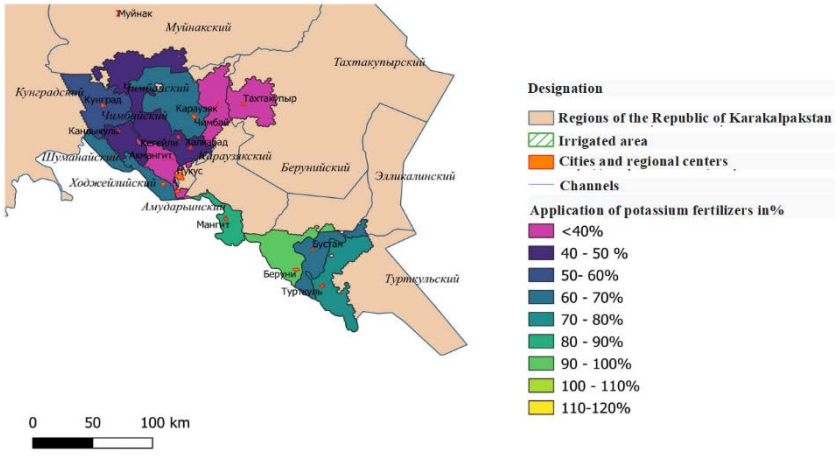
Most mineral fertilizers are characterized by physiological acidity, therefore their use in excess leads to the development of soil acidification processes. In addition, this leads to a decrease in the sum of absorbed bases, an intensification of mineralization processes, a violation of the ratio of mobile forms of macro-and microelements in the soil and the elemental composition of plants. Thus, the application of high doses of nitrogen fertilizers leads to a disruption in the exchange and supply of sulphur to plants, which negatively affects the quality of the harvest. As a result of soil acidity, phosphates are fixed in the soil, which deteriorates the phosphorus nutrition of plants; in addition, aluminium ions are released, which are toxic to soil biota and plants.

The classification of mineral fertilizers can be represented by three main chemical elements: nitrogen, potassium, and phosphorus. These three elements are leading in the nutrition of plants and have a significant impact on their growth and development. Nitrogen, phosphorus, and potassium are considered the foundation for the harmonious development of the plant world. Their absence or lack leads to weak growth and further

death of plants. The positive aspects of using mineral fertilizers are that they are quite cheap, and with minimal costs, they can significantly increase crop yields (Fig. 2).



A)



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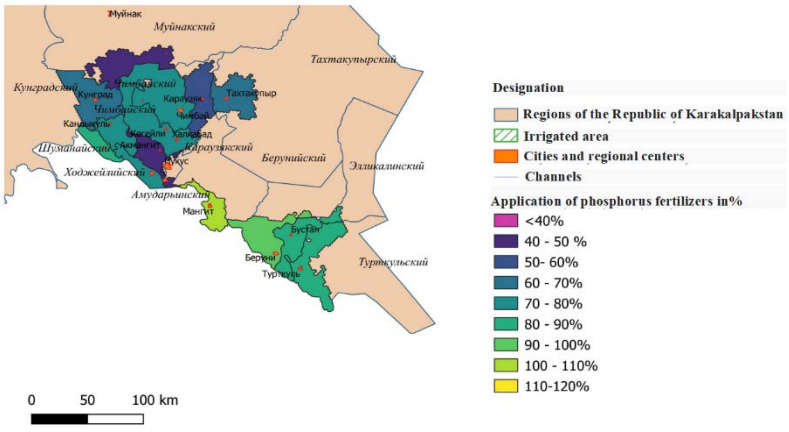


C)

Figure 2. Map - scheme for applying mineral fertilizers to irrigated lands of the Republic of Karakalpakstan (A - nitrogen, B - potassium, C - phosphorus fertilizers)

The unfavourable effects of fertilizers on the natural environment, the particular components of agrotsenoses can be very different (contamination of soils, surface and groundwater, soil compaction; disruption of nutrient cycle and balance, deterioration of agrochemical properties and soil fertility; deterioration of phytosanitary condition of crops and development of diseases of plants, reduction of productivity of agricultural crops and quality of the resulting products, etc.).

The deterioration of the reclamation state of irrigated lands is caused by an increase in groundwater levels and mineralization, irrational use of land and water resources, poor technical condition of the drainage network, and inefficient operation of irrigation systems. At the same time, soil salinization occurs in higher watershed areas. Overall, relatively low loam and clays develop desert-sandy soils. With increased drying, the solonchaks undergo semi-automorphic stages of residual solonchaks, followed by surface desalination.

The principles of environmental risk management include the normalization of harmful impacts and their reduction to a safe level, as well as the resolution of regional tasks for regulating and preventing the technological load and assessing the effectiveness of economic and administrative measures taken. Leading risk management mechanisms include determining the permissible content of pollutants in soil and other natural environments.

The ecosystem approach is based on the hypothesis that only the state of ecosystems can be normal if they maintain their integrity and the closed nature of the substance cycle. The approach operates on the principle of a weak link, when the maximum load should be recognized as such that there is no significant violation of the most vulnerable component of the ecosystem. As indicators of ecosystem stability, it is proposed to use: soil humus balance, indicators of preservation of the vertical and horizontal structure of the phytocenosis, indicators of soil productivity and fertility (closed biogeochemical cycles of the main elements of biogens, completeness of trophic chains, presence/removal of dominant species from the community structure, assimilation capacity, that is, the amount of pollutant that the system can perceive without disruption of its functioning).

Methodology

The research was conducted in the arid zone of the Republic of Karakalpakstan, occupied by irrigated soils, in the farms of the Shumanay, Kanlikul, Chimbay, and Taxtakupyr districts located in the central part of the South Aral Sea region. The climate of the Aral Sea region is sharply continental with dry and hot summers. To determine the degree of salinity, soil samples were taken from each site in the upper 0-20 cm layer by the envelope method. The content of chemical elements in soils in various regions of the Republic of Karakalpakstan was studied by spectral analysis in the laboratory of the Karakalpak Branch of the Academy of Sciences of the Republic of Uzbekistan.

Analysis

Excessive application of nitrogen fertilizers can lead to the accumulation of nitrates in the soil and agricultural products. Numerous toxic elements (Ni, Cu, Pb, Cr, Zn, fluorine toxic compounds) are found in the soil with phosphorus fertilizers (Fig. 3). Natural phosphates contain radioactive elements such as uranium, radium, and strontium. Increased phosphorus content in natural waters due to transport losses (34%), surface runoff and leaching from soils (21%), "discharge" of phosphorus from the agricultural cycle (almost

complete absence of organic matter utilization in the communal sector and reduction to 50% of organic matter utilization in animal husbandry, 45% of all receipts) leads to the eutrophiesis of water objects: water flowering, deterioration of conditions for direct water consumption.

Due to the increasing scale of soil contamination and, consequently, contamination of plant and animal products with heavy metals (cadmium, lead, mercury, copper, zinc, etc.), research on studying the conditions of their entry into the edible parts of plants and determining the actual extent of accumulation of these elements is of great importance. Cultivated plants are a source of a significant number of biophilic elements, as well as elements that are hygienically hazardous for humans and animals. In this regard, information is needed on the extent of accumulation of chemical elements, especially heavy metals, in products depending on growing conditions, plant species, and varieties.

As facts accumulate about the negative and positive effects of chemical elements on plants, animals and humans, the question of the need for more thoughtful selection of nutrients with the desired direction of their influence on the biological and nutritional value of plant products becomes increasingly urgent. Since plants are at the beginning of the biogeochemical food chain, controlling the content of chemical elements in plant products, the possibility of their regulation, and studying the dependence of human, animal, and plant health on biogeochemical environmental conditions are the most important tasks of ecological agro chemistry today and in the future.

Quantitative assessments of the consequences of the entry of harmful substances into the soil on the day of scientific analysis should be based on a strictly established "dose-effect" relationship. However, in modern toxicology and environmental protection activities, as a rule, an alternative nature of assessing such dependence is accepted, which presupposes the presence or absence of a toxic effect at a given level of exposure.

Findings and Discussion

The methodology for analyzing the risk of soil pollution is an integral part of environmental management, as it is ultimately intended for decision-makers and serves as a tool that allows for quantitative assessments of the probability of risk, providing a scientific basis for decision-making (Fig. 3). When assessing the safe level of chemical substances entering the soil, it is based on the idea that it is not permissible to exceed the limit of the ecological adaptation of the soil and the adaptation of the most sensitive population groups of organisms under the isolation, complex and combined action of harmful substances.

In this case, elements that perform important functions in photosynthetic organisms and soil-vegetative associations are of particular importance. Spectral analysis of the presence of various microelements in the soil showed that only 29 chemical elements were found in the studied areas. It should also be noted that in all four districts of Karakalpakstan, the maximum amount falls on the content of Si, which ranges from 35.7 to 44.5%.

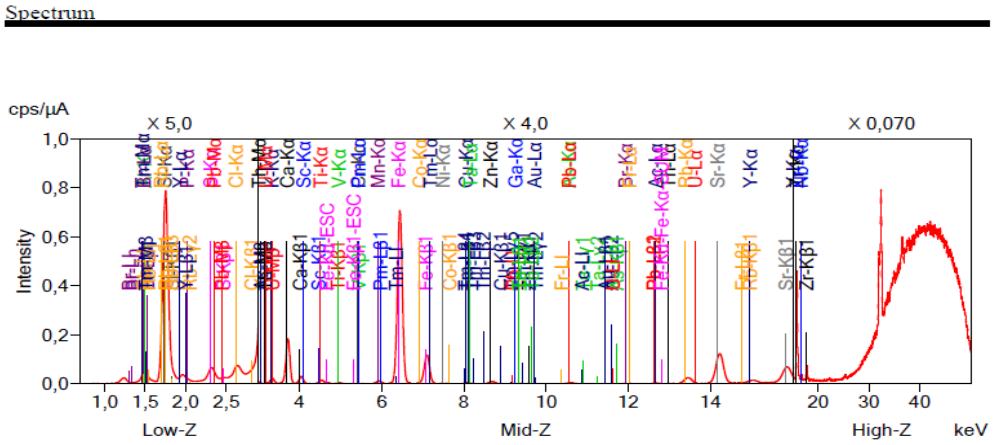
Si is one of the least studied microelements in plants and the soil-plant system. The high prevalence of silicon (200-350 g/kg in clayey and 450-480 g/kg in sandy soils) provides this element with a significant role in the processes of soil formation and soil fertility formation.

Table 1. Analysis results for the presence of various chemical elements in the soils of the studied areas of the Republic of Karakalpakstan (2023)

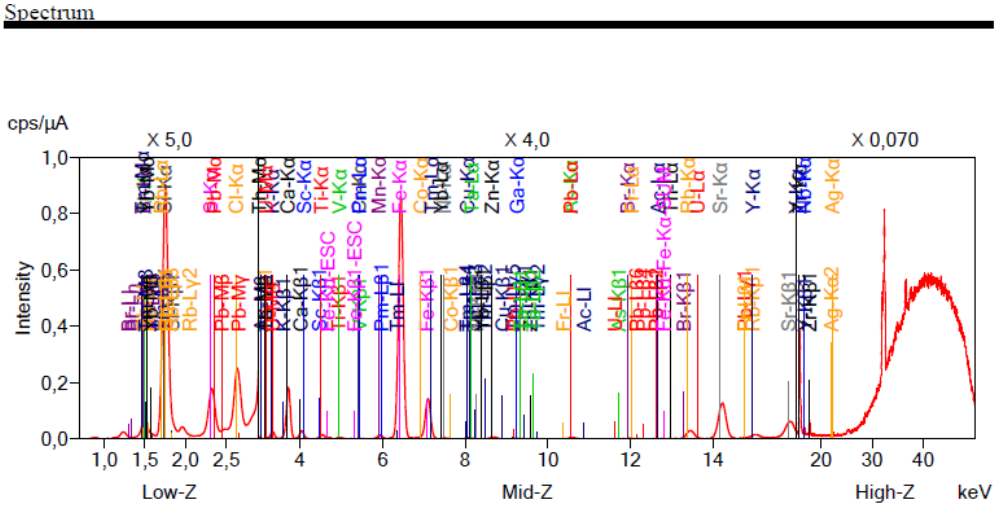
	Studied territories			
	Shumanay district (%)	**Kanlikul district (%)**	**Chimbay district (%)**	**Takhtakupyr district (%)**
Al	9,35	8,91	10,2	7,03
Si	42,6	37,4	35,7	44,5
P	0,0203	0,416	-	0,0185
S	0,366	1,87	1,50	0,220
Ti	1,29	1,21	1,19	1,31
V	0,136	0,148	0,161	0,166
Cr	0,0414	0,0380	0,0493	0,0443
Mn	0,277	0,330	0,343	0,244
Fe	11,2	12,4	14,8	9,26
Ni	0,0226	0,0259	0,0270	0,0171
Zn	0,0208	0,0475	0,0329	0,0179
As	0,0045	0,0084	0,0095	0,0055
Zr	0,0688	0,0525	0,0437	0,100
Nb	0,0056	0,0046	0,0047	0,0057
Ag	-	-	0,0035	-
Ir	-	-	-	0,0044
Ru	-	0,0017	-	-
Pb	0,0029	0,0028	-	-
Cl	0,209	0,354	0,972	0,166
K	4,52	4,65	4,93	5,12
Ca	27,7	29,6	27,7	29,2
Sc	1,40	1,53	1,50	1,58
Ga	0,0050	0,0046	0,0053	0,0042
Br	0,0011	0,0059	0,0029	0,0011
Rb	0,0333	0,0389	0,0477	0,0422
Sr	0,145	0,224	0,183	0,137

Y	0,0109	0,0112	0,0104	0,0105
Tm	0,103	0,131	0,132	0,0941
Th	0,470	0,454	0,466	0,653

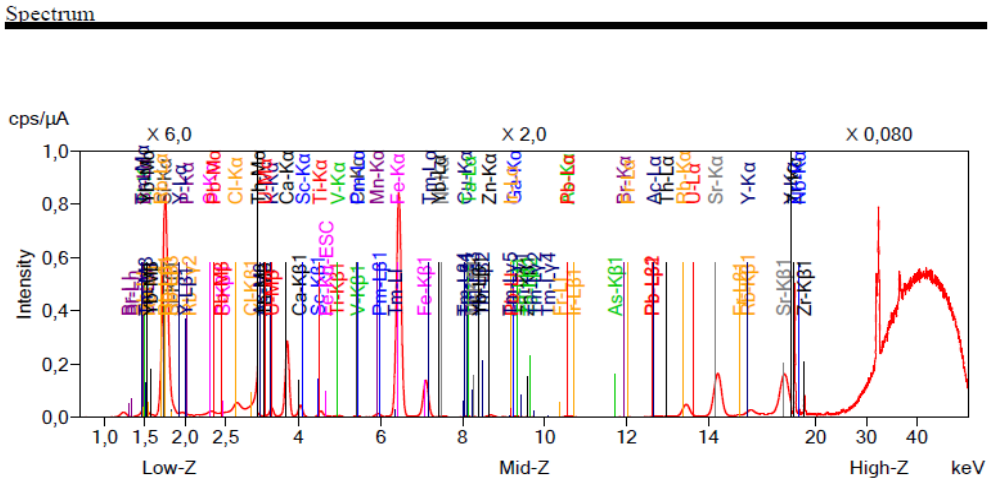
Like the human body, calcium plays a very important role for plants, as it directly participates in their development, ensuring balanced nutrition and growth. In particular, the substance is involved in metabolic processes, carbohydrate and protein component exchange. It is also impossible to achieve the correct structure of the cell walls without it. Calcium deficiency leads to a decrease in the absorption of starch and proteins, which are important for young leaves and growing shoots. According to our results, the Ca content in all studied areas ranges from 27.7 to 29.6% (Table 1).



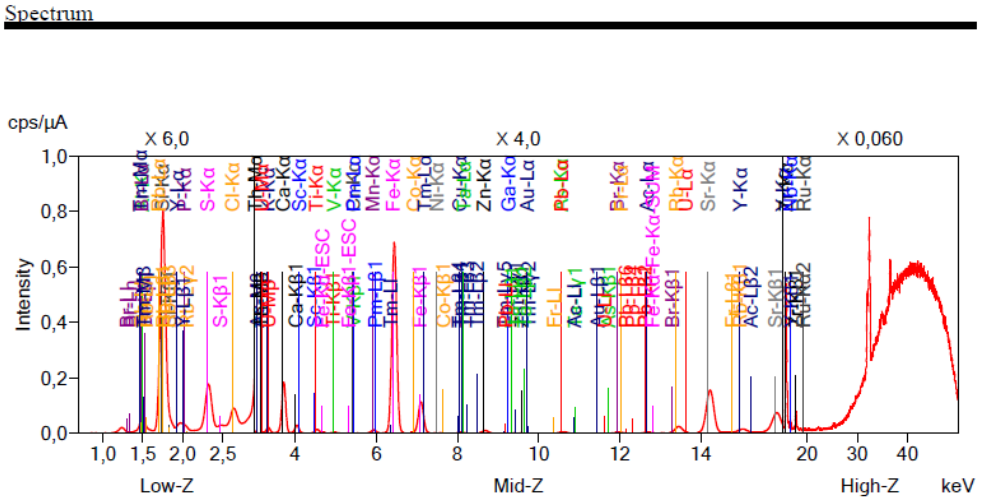
Shumanay district of the Republic of Karakalpakstan



Chimbay district of the Republic of Karakalpakstan



Takhtakupyr district of the Republic of Karakalpakstan



Kanlikul district of the Republic of Karakalpakstan

Figure 3. The results of the spectral analysis of the content of chemical elements in soils in various regions of the Republic of Karakalpakstan

Conclusion

Therefore, when assessing the ecological state of soils, it is important to distinguish between different types of soil degradation: physical, chemical, microbiological, as well as complex types of degradation. Ecological monitoring serves as a good tool for monitoring the state of soils and monitoring their degradation. The practice of using quantitative indicators of soil condition is becoming widespread. Therefore, the most important factor in the environmental safety of fertilizer application is the scientifically sound planning of fertilizer application.

The calculation of optimal doses, taking into account specific soil-climatic and economic conditions, plays a central role in planning. At the same time, the highest efficiency of fertilizer application is achieved where all necessary recommendations are followed, fertilizers are applied in accordance with the biological requirements of plants, taking into account the nutrient content of the soil.

The reclamation state of irrigated lands depends on many natural factors, and in most cases on human intervention, large-scale research is necessary. This requires a careful approach to their analysis and evaluation, as well as the adoption of appropriate preventive solutions when conducting soil protection and other agro technical measures.

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