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EFFECT OF HEAVY METALS ON SOIL FERTILITY AND CROP YIELDS

АУЫР МЕТАЛДАРДЫҢ ТОПЫРАҚ ҚҰНАРЛЫЛЫҒЫНА ЖӘНЕ ДАҚЫЛДАРДЫҢ ӨНІМДІЛІГІНЕ ӘСЕРІ

ВЛИЯНИЕ ТЯЖЕЛЫХ МЕТАЛЛОВ НА ПЛОДОРОДИЕ ПОЧВ И УРОЖАЙНОСТЬ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР

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Abstract. One of the important tasks of modern agroecology is the study of the patterns of circulation in the biosphere of chemical elements that are regulators of biological processes. *The goal* – is to determine the quantitative and qualitative effect of heavy metals in soil on crop yields and beneficial properties of products obtained. At the same time, it was found that soil contaminated with heavy metals not only worsens the quality of products and food, but also reduces cadastral value of land. *Methods* – economic and statistical in analysis and assessment of the current state, abstract and logical, used to identify industry and regional characteristics. *Results* – urgent problem of degradation of agricultural lands, their desertification in the Republic of Kazakhstan is considered. The conducted research shows that the content of lead and arsenic corresponds to the norm, and cadmium and mercury exceed the normative indicators and do not meet food safety requirements. *Conclusions* – heavy metals lead, cadmium, mercury, arsenic are toxic even in very low concentrations. Heavy metals enter agricultural lands from mineral fertilizers and plant protection products. It is generally accepted that their effect is negative if the yield is significantly reduced by 10% or more. It is necessary to carry out a detailed survey of the sphere of agricultural production on contaminated soils. It is practically impossible to reduce total concentration of heavy metals in unproductive arable land, but it is possible to significantly reduce their mobility and make them less accessible to plants, reduce accumulation of toxic substances in their biomass, improve the quality of land plots and, accordingly, their cadastral price.

Аңдатпа. Қазіргі агроэкологияның маңызды міндеттерінің бірі - биологиялық процестердің реттегіштері болып табылатын химиялық элементтердің биосферасындағы цикл заңдылықтарын зерттеу. *Мақсаты* – топырақтағы ауыр металдардың ауылшаруашылық дақылдарының өнімділігіне және алынған өнімдердің пайдалы қасиеттеріне сандық және сапалық әсерін анықтау. Сонымен қатар, ауыр металдармен ластанған топырақ өнім мен азық-түлік сапасын нашарлатып қана қоймай, жердің кадастрлық құнын төмендететіні анықталды. *Әдістері* – экономикалық-статистикалық қазіргі жағдайды талдау және бағалау кезінде, дерексіз-логикалық, салалық және аймақтық ерекшеліктерді анықтауда қолданылады. *Нәтижелері* – ауыл шаруашылығы алқаптарының тозуының, олардың Қазақстан Республикасында шөлейттенуінің өзекті мәселесі қаралуда. Жүргізілген зерттеу қорғасын мен мышьяктың мөлшері нормаға сәйкес келетіндігін, ал кадмий мен сынаптың нормативтерден асып түсетіндігін және тамақ қауіпсіздігі талаптарына сәйкес келмейтіндігін көрсетеді. *Қорытындылар* – ауыр металдар қорғасын, кадмий, сынап, мышьяк өте төмен концентрацияда да улы болып табылады. Ауыр металдар ауылшаруашылық жерлеріне минералды тыңайтқыштардан, өсімдіктерді қорғау құралдарынан түседі. Егер егін 10% немесе одан да көп сенімді түрде төмендесе, олардың әсері теріс деп саналады. Ластанған топырақтарда ауыл шаруашылығы өндірісі саласына егжей-тегжейлі зерттеу жүргізу қажет. Өнімсіз егістіктегі ауыр металдардың жалпы құрамын қысқарту іс жүзінде мүмкін емес, бірақ олардың қозғалғыштығын едәуір төмендетіп, өсімдіктерге қол жетімділігін төмендетуге, олардың биомассасында улы заттардың жиналуын азайтуға, жер учаскелерінің сапасын және сәйкесінше олардың кадастрлық бағасын арттыруға болады.

Аннотация. Одна из важных задач современной агроэкологии – изучение закономерностей круговорота в биосфере химических элементов, которые являются регуляторами биологических процессов. *Цель* – определение количественного и качественного влияния тяжелых металлов, находящихся в почве, на урожайность сельскохозяйственных культур и полезные свойства получаемых продуктов. Вместе с тем, выявлено, что грунт, загрязненный тяжелыми металлами, не только ухудшает качество продукции и продовольствия, но и уменьшает кадастровую стоимость земли. *Методы* – экономико-статистический при анализе и оценке современного состояния, абстрактно-логический, применяемый при выявлении отраслевых и региональных особенностей. *Результаты* – рассматривается остроактуальная проблема деградации сельскохозяйственных угодий, их опустынивание в Республике Казахстан. Проведенное исследование свидетельствует, что содержание синца и мышьяка соответствует норме, а кадмия и ртути превышает нормативные показатели и не соответствует требованиям пищевой безопасности. *Выводы* – тяжелые металлы свинец, кадмий, ртуть, мышьяк являются токсичными даже в очень низких концентрациях. В земли сельхозназначения тяжелые металлы попадают из минеральных удобрений, средств защиты растений. Принято считать их действие отрицательным, если урожай достоверно снижается на 10% и более. Необходимо проведение детального обследования сферы сельхозпроизводства на загрязненных почвах. Практически невозможно сократить валовое содержание тяжелых металлов в непродуктивной пашне, однако можно значительно снизить их подвижность и сделать менее доступными для растений, уменьшить накопление отравляющих веществ в их биомассе, повысить качество земельных участков и соответственно их кадастровую цену.

Key words: agricultural land, heavy metals, degradation, erosion, industrial production, industrial pollution, minerals, environment, cadastral value.

Түйінді сөздер: ауыл шаруашылығы мақсатындағы жерлер, ауыр металдар, тозу, эрозия, өнеркәсіптік өндіріс, техногендік ластану, пайдалы қазбалар, қоршаған орта, кадастрлық құн.

Ключевые слова: земли сельскохозяйственного назначения, тяжелые металлы, деградация, эрозия, промышленное производство, техногенное загрязнение, полезные ископаемые, окружающая среда, кадастровая стоимость.

Introduction. Land has value as the main basis for all processes of the life of society in the political, economic, social, industrial, environmental and other spheres, an objective assessment of which is one of the most important conditions for the normal functioning and development of a multidisciplinary economy.

Most of the territory of Kazakhstan horticultural is located in conditions highly vulnerable to anthropogenic desertification, when in combination with natural factors of

desertification the ecological situation is sharply deteriorating. Another cause of land degradation is urbanization and intensive degradation of desert habitats - unsystematic road network, regulation of river flows, illegal cutting of saxaul for firewood for sale.

As a result of urbanization and intensive agricultural development of the foothill strip more in the south and east of the country the natural vegetation cover is highly disturbed. Roads, pipelines, and power lines, which are being laid at an increasing rate, have a great impact on the fauna. The area of land occupied by mining enterprises is steadily growing.

Currently, there is a massive change in soil formation processes in the Republic. In the north of the country, arable land is subject to humus loss, in the south there is a process of desertification salinization. In western and southern Kazakhstan, there is contamination with heavy metals, radionuclides, as well as waste from industrial enterprises (oil products and components of Chemical Industries). In the central and eastern parts of the country, there is a man-made destruction of the land cover, with leads to a decrease in fertility and increase in chemical and radioactive pollution [1].

Irrational use of resources and poor management have led to a reduction in productive land, a decrease in fertility, a decrease in agricultural production and, consequently, environmental degradation.

Material and methods of research. The study is based on the principles of a systematic approach, the results of research by experts in the field of evaluation of the cadastral value of land, taking into account technogenic pollution.

Determination of the cadastral value of agricultural land is carried out in conjunction with the assessment of environmental and economic damage, depending on the degree of contamination of land requiring different types of reclamation.

The most productive lands are most often subject to intensive pollution. Among industrial factors of soil degradation, mining of minerals is very significant. The greatest damage is caused by open pit mining. It is associated with the alienation of significant land areas, which as a result of mining operations become unsuitable for agricultural use.

At the same time, the actual situation of agricultural land does not always meet the requirements of environmental safety of agricultural products.

Active development of the country's natural resources is carried out without taking into account the environmental consequences that lead to the pollution of land, as well as the soil cover. Vast areas of agricultural land are being destroyed and are losing their ability to restore their properties and reproduce their fertility. The most common heavy metals found in contaminated land are Pb, Cr, As, Zn, Cd, Cu and Hg. These metals are important because they reduce crop yields due to risks of bioaccumulation and biomagnification in the food chain.

Results and their discussion. The main factor of environmental change is man-made processes that are formed during the operation of mining facilities. The main mining processes that affect the environment are: withdrawal of mineral resources (fuel and energy resources, non-ferrous and ferrous metals, mining and chemical raw materials, hydromineral resources) and environmental resources (land, water, air, flora, fauna); chemical and thermal pollution of the biosphere; physical impact (acoustic, electromagnetic, radioactive). These impacts can be global (local - appearing in an area with a radius of 15 to 70-100 km) and regional - covering vast areas at a distance of up to 1000-1500 km. The character of receipt of pollutants in atmosphere, water objects, on soil is defined by: maximum single emission and discharge; annual emission, discharge of pollutants [2].

Such processes as soil salinization, reduction of humus, water and wind erosion, secondary salinization due to water discharge after irrigation are noted on more than 90% of arable soils of the republic. At present, the problems of irrational land use in livestock and pasture management are exacerbated by the large number of small agro-activities and livestock formations that do not have sufficient resources to fully manage the territories [3].

According to qualitative characteristics of lands in the Republic of Kazakhstan there are more than 90 million ha of eroded and erosion-greatest lands, of which 29.3 million ha are practically eroded. Wind erosion (deflated) in the republic amounted to 24.2 million ha or 11.3% of agricultural lands.

The strongest negative impact of wind erosion of soils is manifested in dry years, when there is an acute shortage of soil moisture. Erosion processes are particularly active in the vast massifs of Kyzylkum Sands, Moyunkum, Big and Small Badger, Saryishikotrau, in desert, semi-desert and steppe zones with a light mechanical composition and carbonate soils. The main areas of agricultural land subject to wind erosion in Almaty region-5 million hectares, Atyrau and Turke-

stan-3.1 million hectares, Kyzylorda-2.8 million per hectare, Zhambyl and Aktobe-2.0 million hectares. The largest share of eroded agricultural lands (more than 30% of their total area) is located in Almaty, Atyrau and Turkestan regions. In the composition of agricultural land, the lowest share of eroded lands (up to 5%) is in Akmola, Karaganda, Kostanay and North Kazakhstan regions (figure) [4].

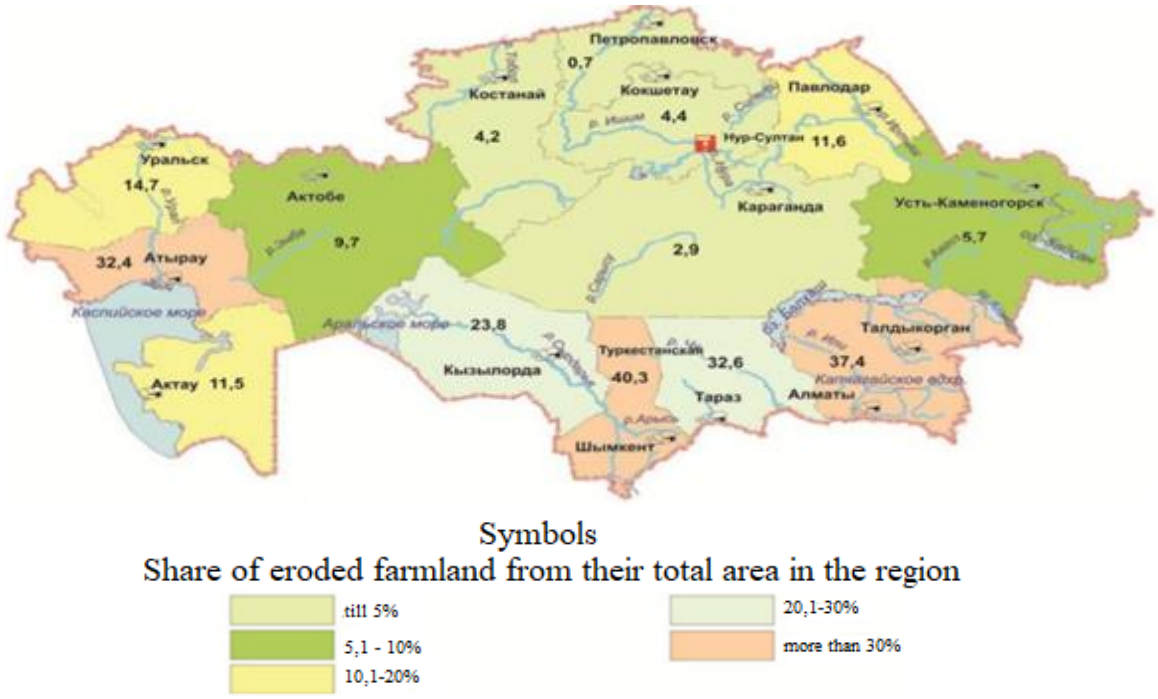

Figure - Erodated soil of the Republic of Kazakhstan

According to the land balance as of the end of 2021, the total area of disturbed lands in the Republic is 245.2 thousand hectares, of which 55.8 thousand hectares are worked off and subject to recultivation. The largest number of disturbed lands is located in Kostanay, Karaganda, Mangistau, Akmola, Pavlodar and East Kazakhstan regions. The Republic has accumulated more than 20 billion tons of industrial waste, of which every tenth ton is toxic. More than 300 types of minerals have been explored in Kazakhstan.

The Republic's resource-rich subsoil is being developed in all regions by open pit or open-pit mining methods. Kostanay region, due to historically established development associated with the predominance of mining of non-ferrous metallurgy, is one of the most disadvantaged regions in the Republic. In Kostanay region the contaminated lands are spread in the industrial zones of cities as well as in the areas of mining and processing of minerals.

Agricultural lands around industrial facilities of various types can contain toxic elements in quantities that exceed maximum permissible concentrations (MPCs) by tens or hundreds of times. The most "dirty" in this respect are the enterprises of mining and enrichment industry, non-ferrous metallurgy, chemical and petrochemical, machine and machine tool construction, electronic and electrical engineering, as well as heat and power industry (table 1) [5].

Table 1 - Degree of soil contamination by heavy metals around heavy metallurgy enterprises, mg/ kg

Distance	Pb	Zn	Cd
Near	1 500	3 400	50
Up to 5 km	850-4000	500-600	7-8
5-10 km	30-90	120-170	1-2
10-15 km	55-70	80-110	1-1,5

Throughout Kazakhstan, there is a trend of deterioration in land quality, resulting in lower factors, nutrients, vegetation species composition and, ultimately, overall fertility, which reduces the potential for agricultural production. This is mainly due to the lack of

activities to improve soil fertility and the absence of pasture irrigation. The use of neither mineral nor organic fertilizers does not allow for sufficient restoration of soil fertility [6].

Also, the number of abandoned, unprofitable open pit mines in the RK will reach 50 thousand units by the end of the current decade, with a total area of about 50 thousand sq. km.

Pollution of soils by heavy metals leads to the loss of nutrients, to the development of erosion, to the oppression of vegetation or to complete death [7].

At the same time, the cumulative accumulation of contaminants in the soil in the vicinity of open, in areas of cereal cultivation, leads to a decrease not only, its quality, fertility, bonitet, but also deteriorates the food safety of crops and products.

Under these conditions, improvement of assessment methods and selection of an effective way to increase the cadastral value of agricultural land in the Republic of Kazakhstan cannot be implemented without establishing the sources and causes of pollution, organization of measures to reduce emissions, localization or elimination of the source of pollution. Only under these conditions can high cost - effectiveness be achieved for reclamation and involvement of unused and abandoned lands in agricultural turnover [8,9].

The analysis of physico-chemical aspects of heavy metals and its accumulation in the tissues and the ear of wheat, rice and horticultural products is related to the biological system of crop production as a nonequilibrium system, which provides its stability, growth and development due to the outflow of entropy into the environment. All these processes are either energy-consuming (photosynthesis) or exothermic, which take place in the soil due to diffusion, phase transitions of the first kind, adsorption and transfer of mineral salts, including salts of heavy metals to vegetative organs and fruits.

At the same time, the contamination of agricultural land with heavy metals not only leads to deterioration of the quality of crop products, but also sharply reduces their cadastral value.

The table below shows the food safety requirements for grain, processed products and horticultural products (table 2).

Table 2 - Food safety of grain, processed products and horticultural products

Toxic elements, permissible levels, mg/kg, not more	Food grain, including wheat, rye, triticale, oats, barley, millet, buckwheat, rice, corn, sorghum	Fruit and vegetable products	Processed products
Lead	0,5	0,5-0,4	0,3
Arsenic	0,2	0,2-0,5	0,2
Cadmium	0,1	0,03-0,1	0,06
Mercury	0,03	0,02-0,05	0,02

Table 2 shows that the permissible levels of the presence of toxic elements as they move along the food chain: raw materials - finished product noticeably decreases. To establish the quantitative and qualitative changes in the biological potential of grain and heavy metals content, preparatory activities were carried out methodology of field studies in farms of Kostanay region. Grain sampling was carried out taking into account the factor of remoteness of the object of research from the source of environmental pollution. In these studies, the content of heavy metals - cadmium, lead, arsenic and mercury is determined to monitor the environmental safety of agricultural products.

In the course of the study data on the content of trace elements and heavy metals: lead, cadmium, mercury, arsenic and trace elements in the grain, chaff of wheat Omskaya-18, Lyubava-5 and Boevchanka were obtained. The figure shows that the content of lead in the studied samples is markedly lower than MPC = 0,85 mg/kg and ranges from 0,124 in the grain of Omskaya 18 to 0,166 in the wheat Boevchanka.

In the grain of wheat "Omskaya-18", chaff: cadmium - Cd from 0,208 mg/kg to 0,214 mg/kg and from 0,211 mg/kg to 0,315 mg/kg, and 0,379 mg/kg respectively, in wheat "Lyubava" - 0,196 mg/kg.

In the samples of wheat Omskaya-18, Lyubava-5, and Boevchanka more more 2-fold excess of MPC was detected. At the same time in the chaff of wheat Omskaya-18 revealed the content of mercury - 0,047 mg/kg, which is significantly higher than the MPC (0,03 mg/kg).

The content of mercury in the chaff of wheat "Omskaya-18", was - 0.047 mg/kg. The content of lead in the examined samples is noticeably lower than MPC = 0,85 mg/kg and

varies from 0,124 in the grain Omskaya 18 to 0,166 in the wheat Boevchanka. In wheat Boevchanka - 0,214 mg/kg with an allowable MAC of 0.10 mg/kg MPC 0.03 mg/kg.

According to the above-mentioned data, it becomes clear how anthropogenic human activity affects the quality of products such as grain. Many different internal and external parameters, such as quantity, quality, type assortment of grain, consumer demand and so on, influence the functioning of grain products complex [10].

Kazakhstan has the lowest grain yield compared to other countries. If we compare the yield in Kazakhstan for (14.6 c/ ha), during this time in Russia, it has increased from 26.5 to 34.3 c/ha. In Australia, whose climate is comparable to Kazakhstan, the yield is higher in 2020-2021. Australia has a record wheat harvest of 33.34 million tons. It should be noted that the yield is largely influenced not only by climatic conditions of growing crops, but also by varieties, as well as a set of character heat to improve soil fertility, one of which is the use of fertilizers.

It should be noted that income from exports of wheat and meslin has increased for 4 years. In 2021 the figure increased by 24.7%, the shipment increased by 10.3% to 5.8 million tons. Wheat, produced in special natural and climatic conditions on the territory of Kazakhstan, has excellent baking characteristics because of its high, more than 20%, content of gluten. About 80% of the wheat produced belongs to the highest classes, so Kazakhstan is one of the top 10 wheat exporters in the world. Average prices in recent years are 800-850 US dollars per ton [11].

The increase in the growth rate of land use efficiency in terms of physical indicators is not so significant, but nevertheless amounts to 84%. In the total share of crop production for the last year there is an active growth of yield (up to 16.7%) of sugar beet, potatoes and vegetables in the open field (from 0.8 to 3.9%). It is these crops that ensured the growth of land use efficiency in natural equivalent [12].

When land is contaminated with heavy metals, not only soil fertility is damaged, but also economic entities, loss of income during the period of land plot restoration or loss of income in case of land plot withdrawal from turnover.

Conclusions

1. Deterioration of fertility is largely due to non-compliance with the scientifically sound system of farming, which involves a number of agromeasures. It is worth recognizing that today not all agricultural producers pay proper attention to the protection of the fertile layer of land. The indicator of proper work of the enterprise is a stable yield.

2. According to the results of chemical tests, it is clear that the content of lead and arsenic in the samples (Wheat Omskaya - 18, Polova Omskaya - 18, Wheat Lyubava -5. Combat wheat) meet the food safety requirements. At the same time, the content of cadmium and mercury in the samples exceeded the MPC and did not comply with the Uniform Sanitary and Epidemiological Requirements.

3. The emoval of industrial and domestic waste to landfills leads not only to pollution, but also to irrational use of land, creates a real threat of significant pollution of the atmosphere, surface and ground water, increased transportation costs and irretrievable loss of valuable materials and substances.

4. According to these research results, it is possible to assess the damage caused to the yield of agricultural products of the Republic of Kazakhstan.

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