ЭКОЛОГИЯ ПОЧВ

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CHANGES IN THE ECOLOGICAL AND BIOLOGICAL PROPERTIES OF LIGHT-CHESTNUT SOILS IN THE SOUTH-EAST OF KAZAKHSTAN UNDER HEAVY METAL POLLUTION

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Abstract: The article gives an ecological assessment of the influence of heavy metals on the biological properties of light-chestnut soils in the southeast of Kazakhstan. Heavy metals significantly affect the abundance, species composition, and vital activity of soil biota. They inhibit not only the processes of mineralization and synthesis of various substances in soils, but also the biological activity of soils. The results of the study expand the information base on the specifics of soil biological activity indicators; provide an opportunity to optimize research when planning environmental monitoring of contaminated soils, as well as expand the possibilities for interpretation obtained during monitoring. The paper presents data on the study of the effect of heavy metals on the biological activity of soils. A review of literature data on the content of heavy metals in the environment is given, and the negative impact of some of them on the biological properties of light-chestnut soil is described. The species of soil invertebrates were identified, as well as soil enzymes that should be used as bioindicators for monitoring the contamination of light-chestnut soils with heavy metals. Heavy metals such as Pb, Cd, Cu, Zu, to their special chemical and biological properties, tend to bio-accumulation. It has been established that some soil invertebrates show potential resistance to soil contamination with heavy metals. Soil fauna is a good indicator group for assessing the degree of disturbance of light-chestnut soils. The results obtained will expand knowledge about changes in the biological activity of light-chestnut soils under the influence of HM pollution in the ecosystems of southeastern Kazakhstan.

Key words: soil, heavy metals, pollution, indication, agroecological assessment, mesofauna, enzymatic activity of soils, humus

INTRODUCTION

As a result of human economic activity, the environment is polluted by chemical means of intensifying industry and agricultural production. Human impact on the biosphere in the modern world is global. Every year 6-7 million hectares of soil become unsuitable for agriculture[1]. At present, according to the data of the Ministry of Natural Resources of the Russian Federation, the distribution area of technogenic emissions around industrial complexes covers an area of 18 million hectares.

As a result of the changes that occur in the soil under the influence of the activity of soil animals (improvement of soil aeration, water permeability, creation of agronomically valuable soil structure, uniform mixing of organic and mineral particles, nitrogen enrichment, etc.), the overall fertility of the soil increases. This position is confirmed by many researchers who conducted special experiments mainly on earthworms.

Under the conditions of global environmental pollution by a wide range of ecotoxicants, along with others, the problem of deterioration of the biological properties of soils becomes acute. With an It is known that the study of the elemental composition of soils cannot provide the necessary information about the impact of adverse factors associated with human economic activity on soils and vegetation growing on them. Only the use of soil animals, as well as indicators of their activity, can provide the necessary operational data on the impact of a complex of adverse factors, which include toxic elements contained in the soil [4].

Soil fertility is affected not only by the course of decomposition and changes in organic residues in the soil under the influence of soil animals, but also by changes in the mineral part. Here it is necessary, first of all, to note the changes in the salt and petrographic composition that occur in the soil due to the mixing of different horizons by animals, which many researchers point out in their works. Further, the secretions of many animals (for example, single ground bees and ants) change the reaction of the soil towards a decrease in acidity (often the pH shifts by one). Finally, we must stop at the change in the petrographic composition. Snails are known to enrich the soil with calcium carbonate in the form of aragonite shells. Earthworms contribute to the secondary formation of biogenic calcite in the soil [5]

Earthworms not only bury stones, as was brilliantly described by Darwin, but are able to wear out, i.e. destroy them; Recent experiments have shown that as a result of passing through the intestines of worms for more than two years, basalt flour, taken in a mixture with straw as a substrate for the culture of worms, has changed greatly. In the "soil" formed by worms from basalt flour and rotting straw, which consisted of excrement, the percentage of individual compounds changed in comparison with the initial minerals (basalt flour). Significantly increased the content of CaO and only a few – one and a half oxides, decreased the percentage of SiO_2, Na_2O, K_2O and MgO. This means that the destruction clearly affects the basalt [6, 7].

The mechanical composition of the soil also changes when passing through the intestines of worms and other invertebrates, in particular, the content of clay colloidal particles increases.

All these aspects of the activity of soil animals should attract the close attention of soil scientists, since they are important for soil fertility.

No less attention should be paid to the study of the negative impact of soil animals, in order to develop methods for eliminating their harmful activities.

Among the soil-dwelling animals there are a huge number of harmful species that feed on living plants, dangerous pests, the activity of which reduces the yield of cultivated plants, and in some cases makes it even impossible to cultivate them.

In the studies of M.V. Dabakhova [8], methods of biological assessment of the ecological state of park soils in Nizhny Novgorod (catalase, invertase, nitrification activity, CO_2 emission intensity, cellulolytic activity) were tested in the framework of soil-ecological monitoring. It is established that the most interesting of the studied indicators that characterize the state of soils under the influence of HM are such as the activity of the enzyme catalase and the nitrifying ability of soils.

When studying the change in the content of chemical elements in plants under the influence of various amounts of heavy metals in the soil, Grigoryan K. V. [9] found that the latter, along with the toxic effect on the plant itself, manifested in a decrease in the supply of elements necessary for the plant, sharply reduce the intensity of redox processes in the soil.

Soil is an indicator of natural processes, and its condition is the result of long-term exposure to various sources of pollution. Emissions into the atmosphere from industrial enterprises, heat power facilities, and transport lead to soil contamination, deterioration of their physical and chemical condition and, as a result, to a decrease in fertility. Under the conditions of modern man-made loads characterized by the intensification of the migration of pollutants, urban soils are in the most vulnerable position. Emissions of air pollutants from stationary sources (excluding vehicle emissions) on average per inhabitant of the region exceed sanitary and hygienic standards (23.3 kg).

Limited land resources make it an urgent task to return all types of disturbed and degraded soils, including oil-contaminated ones, to agricultural production. Soil contamination with petroleum products occurs everywhere in large and small cities, around gas stations, the number of which increases every year, along roads, wherever there is oil-related human activity. Oil and refined products, even in small quantities, can cause significant damage to the environment.

The soil slowly accumulate contaminants, while carrying out a protective function in relation to other natural formations. But, playing a barrier role, they are gradually exposed to pollution themselves, and at some stage it can reach such levels that the soil cover becomes unsuitable for agricultural use. On such soils, in order to obtain environmentally friendly crop production, techniques are needed that limit the mobility of pollutants and lead to a decrease in the toxic effect on plants. In the conditions of the forest-steppe Middle Volga region, the problem of creating a complex of methodological developments for the study of the ecological state of urban and suburban biogeocenoses, the development of evaluation criteria for the degree of degradation of vegetation cover and soils and methods of their rehabilitation is relevant.

One of the methods of preserving and increasing soil fertility is the introduction of organic and mineral fertilizers in conjunction with the observance of crop rotations, tillage systems, the use of new adapted varieties, and land reclamation measures. When using fertilizers, there is a risk of heavy metals entering the soil, which are the most toxic elements for living organisms. Therefore, it is important to know the conditions of their existence in the soil in relation to the use of agrochemicals.

Bioindicator types of soil biological activity under anthropogenic load on the soil, in particular with prolonged use of fertilizers, can respond to very weak effects due to dose accumulation. The use of living organisms as biological indicators for environmental change makes it necessary to develop a number of criteria on the basis of which indicator species can be selected. In this regard, we conducted research on the study and selection of soil bioindicators for agrocenoses of the south-east of the republic at different levels of mineral fertilizers application.

MATERIALS AND METHODS

The objects of research are light-chestnut soil, mesofauna of soils, soil enzymes.

The research was conducted in 2019-2020.

Field experiments were laid in the irrigated light -chestnut soil in a crop rotation deployed in space and time with alternation: 1 – rape; 2 – barley.

The area of the experimental plot is 54 м^2 (3,6x15), the repetition of the experiment is 3 times. Objects of research - rape, barley.

In soil samples, determination according to generally accepted methods-humidity-by weight method, total humus - by I.V. Tyurin; specific gravity-by pycnometric method; volume mass using Kaczynski drill; total porosity – by calculation method, for determining biological indicators: soil mesofauna-by Gilyarov manual disassembly method and determination of soil enzyme activity-by Hoffmann and Pallauf methods.

RESULTS AND DISCUSSION

The biological activity of the soil is a sensitive indicator of the occurrence of a stress situation in the soil and it changes earlier than other soil characteristics. It is an indicator of the impact of heavy metals on soil organisms. The toxic effect of heavy metals is manifested in the inhibition and blocking of certain metabolic processes of soil organisms, as well as changes in the abundance of soil fauna and its composition.

We calculated the amount of HM that entered the soil with fertilizers for 14 years in light -chestnut soils, which was 0.3 -39.1 g for cadmium, 3.1 – 231.2 g for lead, 1.4 – 189.2 g for zinc, and 32.5-77.2 g for copper per 1 hectare. At the same time, the largest amount of TM enters the soil with phosphorus fertilizers.

In light -chestnut soils, an increase in the content of heavy metals is observed with an increase in the doses of phosphorus fertilizers applied. At the same time, the content of TM, along with the norms of fertilizers, is also influenced by culture. Thus, under barley crops, the content of HM is higher and there is a direct dependence on the norms of fertilizers. Under rapeseed crops there is a decrease in HM, and on more fertilized variants their number is significantly reduced (Table 1).

Table 1 - The effect of fertilizers on the content of heavy metals in light -chestnut soils, mg/kg of soil

Experience Options	Cd		Pb		Cu		Zn	
	rape	barley	rape	barley	rape	barley	rapes	barley
Control without fertilizer	0,32	0,45	3,55	3,84	0,65	0,41	2,51	2,76
P_{150}	0,33	0,38	4,42	5,98	0,74	0,58	3,42	3,48
P_{150} + $N_{60}P_{60}$	0,38	0,44	6,89	6,07	0,77	0,78	3,89	5,35

This is due, apparently, to the biological feature of the plant, the root secretions of which have an acidic reaction of the medium. On the fertilized variants, a higher yield and a powerful root system are formed, which, apparently, reduces the negative impact of HM despite the high level of fertilizer use – 210 kg of d. v. phosphorus per 1 ha.

The application of the bioindication method to determine the effect of heavy metals on soil biocenoses in our studies involved the determination of such characteristics as enzyme activity, soil mesofauna.

Our studies took into account the activity of soil enzymes in the variants where mineral fertilizers were applied. It was found that there is a decrease in the activity of enzymes when applying triple doses of fertilizers compared to the control (Table 2).

Table 2 - Activity of light-chestnut soil enzymes in the application of various doses of mineral fertilizers

Experience Options	Invertase, mg of glucose per 1 g of soil for 4 hours	Urease, mg NH_3 per 1 g of soil for 24 h	Dehydrogenase, mg TTF per 1 g of soil for 24 h	Catalase, ml $KMnO_4$ / 1 g soil	Phosphatase, mg P_2O_5 per 1 g of soil
$N_0P_0K_0H_0$	9,4	1,38	1,31	8,7	1,9
$N_1P_1K_1$ H_1	10,0	1,46	1,25	8,2	3,7
$N_2P_2K_2$ H_2	12,1	1,62	1,30	7,8	3,8
$N_3P_3K_3$ H_3	7,6	0,87	1,21	8,1	4,5

Dehydrogenase and catalase react poorly to changes in the content of HM in the soil. Invertase and urease enzymes react more, where their lowest enzyme activity is observed in the variant with high doses of fertilizers – 7.6 and 0.87 mg, respectively. Phosphatase in the variants with the introduction of triple doses of fertilizers does not experience suppression of activity, which can probably be explained by its increase with an increase in the content of mobile phosphorus in the soil.

As shown by the results of the conducted analyses to determine the enzymatic activity of light-chestnut soils, it is largely determined by the level of concentration of biophilic elements and the content of mobile forms of heavy metals in the soil (Table 3).

Table 3 - Enzyme activity in light-chestnut soils

Experience Options	Invertase, mg of glucose per 1 g of soil for 4 hours	Urease, mg NH_3 of soil/ day	Dehydrogenase, mg TTF per 1 g of soil for 24 h	Catalase, ml $KMnO_4$ / 1 g soil	Phosphatase, mg P_2O_5 per 1 g of soil
P_0	10,2	0,41	0,43	4,45	3,6
P_{150}	11,4	0,46	0,43	4,33	4,1
P_{150}+ $N_{60}P_{60}$	10,3	0,47	0,47	4,65	4,3

In these soils, the enzyme that reacts to changes in soil properties is invertase. This can also be explained by the peculiarities of the soil itself – the predominance of regenerative soil processes.

Soil mesofauna is an important indicator of the state of the environment, which is due to their ability to interact with many components of theire cosystems and the soil for them acts as a habitat in general.

In the study of soil mesofauna, the methods of layer-by-layer sampling of soil samples with a size of 50×50 cm in the field were used, which are generally accepted in soil-zoological studies. Excavations were carried out three times a season to study seasonal fluctuations in population. The number of soil invertebrates was determined by the direct accounting method – the number of objects taken into account per unit of soil surface area (ex/m2).

Analysis of mesofauna data on the studied variants of the experiment, collection showed that common species are insect larvae from the family- *Curculionidae, Scarabaeidae, Tenebrionida and Formicidae,* since these species have plasticity (the ability to live in a variety of biotopes). The dominant species are the larvae of insects- *Curculionidae, Scarabaeidae.*

The main part of the mesofauna was concentrated in the upper layers of the soil (0-10; 10-20 cm), then up to 40 cm there were single specimens. This distribution of invertebrates is related to the physical properties and its mechanical composition. The size of the particles is also to a large extent determine the soil porosity and its water and air permeability. The supply of oxygen and moisture to the soil depends on the porosity. It is on the conditions of humidification and aeration, as well as on the temperature, that the depth to which soil invertebrates go depends. The depth at which the mesofauna is kept also depends on the mechanical and aggregate composition of the soil. Since large particles at a depth of 0-20 cm do not stick together so tightly and have less resistance to soil animals laying passages.

More species have been recorded on fertilizer variants. There are more numerous species from the family *Tenebrionida, Scarabaeidae*. Therefore, the application of optimal doses of organic and mineral fertilizers does not significantly affect the complex of soil mesofauna. However, it has a positive effect on the condition of plants, which leads to an increase in the overall productivity of the agrocenosis and some changes in microclimatic conditions. As a result of fertilization, the biomass of plants increases by 2 times. All this leads to changes in micro conditions on the soil surface and in its upper layers.

It is established that the quantitative and qualitative composition of the mesofauna of soils is associated with a certain type of soil.

In our mesofauna studies, we focused on the study of the main agrochemical indicators that affect the soil mesofauna, and at the same time formed under its influence. The results of our research have established that light-chestnut soils have favorable physical properties.

In our experience it was found that resettlement of mesofauna in the study plots indicates the timing of application of organic and mineral fertilizers, which helps to improve vital activity of soil invertebrates, which in turn depend on optimization of many of the main agrophysical and agrochemical soil properties (density, specific gravity, soil moisture, soil pH, a sufficient amount of root and crop residues, the maximum allowable rate of heavy metals and radionuclides), (Table 4).

Table 4 - Effect of fertilizers on the mesofauna of light-chestnut soils

Experience Options	Soil invertebrates	
	number of groups	total number of ex / m^2
$N_0P_0K_0H_0$	23	92.0
$N_1P_1K_1$ H_1	32	128.0
$N_2P_2K_2$ H_2	36	144.0
$N_3P_3K_3$ H_3	14	56.0
$N_2P_2K_2H_0$	18	72.0
$N_1P_3K_3H_3$	13	52.0

From the table data, it can be seen that the total number of mesofauna in the variant with manure ($N_2P_2K_2$ H_2) was - 144 ex/m2, while in the control variant (without fertilization) their number was – 92.0 ex/m^2.

In our view, the higher the number on the variant with manure, due to its direct and indirect impact: direct impact of expression of an additional supply of manure mesofauna of the family *Curculionidae* indirect – nutrients manure are an additional source of nutrition and organic matter that improve soil structure its water-physical properties and increase the buffer capacity.

Anthropogenic stressors occur at such a rate that biological systems do not have time to adapt to them [11], however, their biological characteristics change under the influence of all factors [12, 13]. One of the most toxic substances that enter the biosphere in the results of human production activities can be attributed to heavy metals. In small amounts, they are found in every organism, but a significant increase in their concentration can lead to the death of animals.

Heavy metals accumulate in the soil and litter, plants and animals, and enter the human body, causing poisoning and diseases [14]. The role of animals in the biogenic migration of substances in terrestrial ecosystems is poorly understood. The activity of animals in biogeocenoses can be considered as a factor regulating this biogenic cycle [15].

The block of soil-litter invertebrates is characterized by an early reaction to the pollution of their habitat by heavy metals. It is known that representatives of mesofauna act as their active accumulators

[16]. Of particular interest is the migration of trace elements along the trophic chains of these animals and other elements, both to determine their resistance to toxicants and to identify loads on the ecosystem as a whole [17]. So, insects-representatives of the mesofauna, the concentration of heavy metals in food is one of the main factors that determines their content in the animal's body. The absorption of toxic trace elements in them in most cases occurs through the intestines. Subsequently, their redistribution is observed in all parts of the body. Studies on accumulation of heavy metals in soil and litter vertebrates was carried out in close proximity to the motorway.

The content of heavy metals in invertebrates was carried out using the method of atomic absorption spectrophotometry on the AAS-30 spectrophotometer according to the standard method [18].

It is known that macro-and microelements enter the body of animals and bioaccumulate in them during nutrition. Therefore, the features of the accumulation of heavy metals in invertebrates are of great interest not only at the taxonomic but also at the trophic level.

The structural and functional composition of representatives of the soil mesofauna is diverse and includes representatives of zoophages, phytophages and saprophages. Representatives of each trophic group have a specific way of feeding.

Invertebrates living in the upper soil horizon-litter, are closely related on the one hand with plants, which, like animals, accumulate heavy metals and are the object of nutrition of representatives of phytophages. On the other hand, they are associated with the litter, which performs barrier functions on the path of toxicants entering the soil, being not only the habitat of the studied group of animals, but also the object of destructive influence of representatives of saprophages. During the research, we registered representatives of the *Curculionidae, Scarabaeidae, Tenebrionida and Formicidae*, in which the content of heavy metals was determined.

Representatives of each functional group accumulate heavy metals in different amounts. Naturally, the highest content in representatives of all functional groups of trace elements of biogenic origin, such as Cu, Zn, Pb, Cd. It was revealed that such highly toxic elements as Cd, Pb accumulate in invertebrates in much smaller amounts.

Copper. There were no significant differences in the accumulation of copper by representatives of all trophic groups. Each of the three trophic groups of soil invertebrates accounts for 32.9-36.1 % of this element from its content in the studied groups of soil invertebrates.

Zinc. If the share in the accumulation of zinc in representatives of zoophages and saprophages is 34.4–35.1 %, then phytophages in comparison with them accumulate it 1.14-1.16 times less.

One of the toxic elements that has the most negative impact on the life of representatives of the mesofauna is lead. This element is accumulated in the largest amount by representatives of zoophages-1.14 times more than phytophages and, in turn, 1.19 times more than saprophages.

Cadmium in the greatest quantity is accumulated by the representatives of saprophages and 54.5 % of the total content in the soil mesofauna, while the least of Topalov of 6.9 %. Comparative analysis of heavy metals content from representatives of various functional groups of invertebrates shows that cadmium, in comparison with all micronutrients accumulates animals in the smallest quantity (1.1 to 9.1 mg/kg dry mass) (Table 5).

Table 5 - Accumulation of heavy metals by soil invertebrates representatives of different functional groups on the motorway (mg/kg dry weight)

Functional groups	Cu	Zn	Pb	Cd
Phytophages	592,3	2816,6	138,3	7,5
Zoophages	633,5	2033	175,8	2,5
Saprophages	661,7	2123,1	91,5	10,2

In connection with the above, the importance of these groups of invertebrates in the migration of heavy metals through food chains, including vertebrates, is difficult to overestimate. In the future, it is necessary to continue monitoring the migration of heavy metals in biogeocenoses, including trophic networks. And also to identify the main factors that determine the processes of bioaccumulation and biomagnification.

The obtained data can be used for bioindication and monitoring studies of environmental pollution both in the region and abroad.

CONCLUSIONS

It was found that against the background with the introduction of rotted manure, as evidenced by the receipt of small amounts of HM with manure into the soil. Mineral fertilizers applied separately do not significantly affect the change in the content of HM in the soil. The introduction of mineral fertilizers contributed to the change in the content of heavy metals

It was found that the enzymatic activity of light-chestnut soils is largely determined by the level of concentration of biophilic elements and the content of mobile forms of heavy metals in the soil.

Analysis of mesofauna data on the studied variants of the experiment, collection showed that common species are insect larvae from the family- *Curculionidae, Scarabaeidae, Tenebrionida, Formicidae,* since these species have plasticity (the ability to live in a variety of biotopes). The dominant species are the larvae of insects- *Curculionidae, Scarabaeidae.*

It is established that the quantitative and qualitative composition of the mesofauna of soils is associated with a certain type of soil. It was found that such highly toxic elements as Cd, Pb accumulate in invertebrates in much smaller amounts.

It was found that there were no significant differences in the accumulation of copper by representatives of all trophic groups. It has been established that one of the toxic elements that has the most negative impact on the life of representatives of mesofauna is lead. This element is accumulated in the largest amount by representatives of zoophages-1.14 times more than phytophages and, in turn, 1.19 times more than saprophages.

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ҚАЗАҚСТАННЫҢ ОҢТҮСТІК-ШЫҒЫСЫНДАҒЫ АҚШЫЛ-ҚЫЗҒЫЛТ ТОПЫРАҚТАРЫНЫҢ АУЫР МЕТАЛДАРМЕН ЛАСТАНҒАН ЖАҒДАЙДАҒЫ ЭКОЛОГИЯЛЫҚ-БИОЛОГИЯЛЫҚ ҚАСИЕТТЕРІНІҢ ӨЗГЕРУІ"

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Мақалада Қазақстанның оңтүстік-шығысындағы ашық-қызғылт топырақтарының биологиялық қасиеттеріне ауыр металдардың әсерін экологиялық бағалау берілген. Ауыр металдар топырақ биотасының санына, түр құрамына және өмірлік белсенділігіне айтарлықтай әсер етеді. Олар топырақтағы әртүрлі заттардың минералдануы мен синтездену процестерін ғана емес, сонымен қатар топырақтың биологиялық белсенділігін де тежейді. Жұмыста ауыр металдардың топырақтың биологиялық белсенділігіне әсерін зерттеу туралы мәліметтер келтірілген. Қоршаған ортадағы ауыр металдардың мазмұны туралы әдебиеттерге шолу жасалды, олардың кейбіреулері ашық-қоңыр топырағының биологиялық қасиеттеріне теріс әсерін сипаттайды. Топырақтағы омыртқасыз жануарлардың түрлері, сондай-ақ ашық-қоңыр топырақтардың ауыр металдармен ластануын бақылау үшін биоиндикатор ретінде пайдалану қажет топырақ ферменттері анықталды. Арнайы химиялық және биологиялық қасиеттеріне байланысты Pb, Cd, Cu, Zu сияқты ауыр металдар биоаккумуляцияға бейім. Кейбір топырақ омыртқасыздары топырақтың ауыр металдармен ластануына ықтимал қарсылық көрсететіні анықталды. Топырақ фаунасы – ашық-қоңыр топырақтарының бұзылу дәрежесін бағалау үшін жақсы көрсеткіш тобы. Алынған нәтижелер Қазақстанның оңтүстік-шығыс экожүйелеріндегі ауыр металлдармен ластануының әсерінен ашық-қызғылт топырақтың биологиялық белсенділігінің өзгеруі туралы білімдерін кеңейтеді.

Түйінді сөздер: топырақ, ауыр металдар, ластану, көрсеткіш, агроэкологиялық бағалау, мезофауна, топырақтың ферментативті белсенділігі, гумус

РЕЗЮМЕ

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ЭКОЛОГИЧЕСКАЯ ОЦЕНКА ВЛИЯНИЯ ТЯЖЕЛЫХ МЕТАЛЛОВ НА БИОЛОГИЧЕСКИЕ СВОЙСТВА СВЕТЛО-КАШТАНОВЫХ ПОЧВ ЮГО-ВОСТОКА КАЗАХСТАНА

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В статье дана экологическая оценка влияния тяжелых металлов на биологические свойства светло-каштановых почв юго-востока Казахстана. Тяжелые металлы существенно влияют на численность, видовой состав и жизнедеятельность почвенной биоты. Они подавляют не только процессы минерализации и синтеза различных веществ в почвах, но и биологическую активность почв. В работе представлены данные по изучению влияния тяжелых металлов на биологическую активность почв. Приведен обзор данных литературы по содержанию тяжелых металлов в окружающей среде, описывается негативное воздействие некоторых из них на биологические свойства светло-каштановой почвы. Выявлены виды почвенных беспозвоночных животных, а также почвенные ферменты, которые необходимо использовать в качестве биоиндикаторов для мониторинга загрязнения светло-каштановых почв тяжелыми металлами. Тяжёлые металлы, такие как Pb, Cd, Cu, Zu, благодаря специальным химическим и биологическим свойствам, имеют тенденцию к биоаккумуляции. Установлено, что некоторые почвенные беспозвоночные проявляют потенциальную устойчивость к загрязнению почвы тяжёлыми металлами. Почвенная фауна являются хорошей индикаторной группой для оценки степени нарушения светло-каштановых почв. Полученные результаты расширят знания об изменении биологической активности светло-каштановых почв под влиянием загрязнения ТМ в экосистемах юго-востока Казахстана.

Ключевые слова: почва, тяжелые металлы, загрязнение, индикация, агроэкологическая оценка, мезофауна, ферментативная активность почв, гумус.