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AGRO-ENVIRONMENTAL AND ECOTOXICOLOGICAL ASSESSMENT OF AGRICULTURAL SOILS OF AGROSPHERE

***Abstract.** Soils are the main component of terrestrial ecosystems that have been formed over geological time as a result of biotic and abiotic factors. Today, the issue of soil protection is particularly relevant in connection with the growth of the global population and uneven food security. Therefore, maintaining and improving soil fertility, providing the soil with agrochemical indicators within normal limits (pH, humus, nitrogen, phosphorus, potassium), preventing their depletion, erosion, salinization, waterlogging and pollution by toxic substances are key to achieving higher yields, increasing the number and purity the environment Therefore, the main challenge today is the rational use of land and potential resources in agricultural production, which requires appropriate scientific support.*

Implementation of measures to prevent soil pollution by heavy metals, pesticides, industrial emissions, strengthening the responsibility of land users and owners for the rational use and protection of land; increasing the productivity of agricultural land by optimizing the sown areas and the structure of crop rotation to increase the productivity of agricultural land, implementing state control over measures to protect and restore soil fertility – all this is a necessary condition for monitoring the condition of the soil.

***The purpose of the work** is to conduct a comparative characterization of the ecotoxicological and agroecological state of the soils of the agrosphere (on the example of the soils of the village of Sytkivtsi of the Raigorod Territorial Community of the Haysyn District of the Vinnytsia Region).*

***Research methodology.** Laboratory analyzes were carried out in a certified and accredited laboratory – the Scientific and Measuring Agrochemical Laboratory of the Educational and Scientific Institute of Agrotechnology and Environmental Sciences of the Vinnytsia National Agrarian University. Observations, records and measurements were carried out according to generally accepted methods: determination of the content of mobile forms of heavy metals (Pb, Cd, Zn, Cu) – after extraction with an acetate-ammonium buffer solution pH 4.8 by the method of atomic absorption spectrophotometry in accordance with SSU 4770.*

The research was conducted on the territory of the village of Sytkivtsi, Raigorod territorial community, Haysyn district, Vinnytsia region. Samples for analysis were taken at three points in the village Sitkivtsi, in order to find out the potential pollution on the territory of the territorial community and to compare the values with the values of a potentially clean homestead: homestead – area of 0.18 ha (organic fertilization – humus, siderates) open joint-stock company Sitkovetsky Sugar Plant (production and sale of products discontinued 17 years ago) and solid waste landfill (sanctioned).

***Scientific novelty.** The conducted research made it possible to determine the agro-ecological indicators of soils and the levels of accumulation of heavy metals (Pb, Cd, Zn and Cu) at various points of soil sampling in the agrosphere for their further use for agricultural purposes.*

***Conclusions.** It was investigated, the lowest agro-ecological indicators were found in the 3rd sample, which was selected within the authorized landfill: soil acidity – 5.8, average availability of soil with humus, nitrogen, mobile phosphorus and exchangeable potassium. It was established that in the studied samples the content of heavy metals was found to be the highest in the sample from the landfill compared to samples 1 and 2: lead – 5.17 mg/kg, cadmium – 0.38 mg/kg, zinc – 21.15 mg/kg and copper – 2.74 mg/kg, which did not exceed the maximum permissible norms. The hazard ratio was highest in sample 3 (sanctioned landfill), but did not exceed 1.*

***Key words:** soil, heavy metals, hazard ratio, agroecological indicators, agroecological condition, pollution, environment.*

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АГРОЕКОЛОГІЧНА ТА ЕКОТОКСИКОЛОГІЧНА ОЦІНКА ҐРУНТІВ СІЛЬСЬКОГОСПОДАРСЬКОГО ПРИЗНАЧЕННЯ АГРОСФЕРИ

Анотація. *Ґрунти є основним компонентом наземних екосистем, які формувалися протягом геологічного часу в результаті біотичних та абіотичних факторів. Сьогодні питання охорони ґрунтів є особливо актуальним у зв'язку із зростанням населення планети та нерівномірною продовольчою безпекою. Тому підтримка та покращення родючості ґрунтів, забезпеченість ґрунту агрохімічними показниками в межах норми (pH, гумус, азот, фосфор, калій), запобігання їх виснаженню, ерозії, засоленню, заболоченню та забрудненню токсичними речовинами є ключовими для досягнення вищих врожаїв, збільшення чисельності та чистоти довкілля. Тому головним викликом сьогодення є раціональне використання землі та потенційних ресурсів у сільськогосподарському виробництві, що потребує відповідного наукового супроводу.*

Здійснення заходів щодо запобігання забрудненню ґрунтів важкими металами, пестицидами, промисловими викидами, посилення відповідальності землекористувачів та власників за раціональне використання та охорону земель; підвищення продуктивності сільськогосподарських земель шляхом оптимізації посівних площ та структури сівозмін для підвищення продуктивності сільськогосподарських земель, здійснення державного контролю за проведенням заходів з охорони та відтворення родючості ґрунтів – це все є необхідною умовою для проведення моніторингу стану ґрунтів.

Мета роботи *– провести порівняльну характеристику екотоксикологічного та агроекологічного стану ґрунтів агросфери (на прикладі ґрунтів села Ситківці Райгородської територіальної громади Гайсинського району Вінницької області).*

Методологія дослідження. *Лабораторні аналізи проводили у сертифікованій і акредитованій лабораторії – Науково-вимірювальна агрохімічна лабораторія навчально-наукового інституту агротехнологій та природокористування Вінницького національного аграрного університету. Спостереження, обліки та вимірювання проводили за загальноприйнятими методиками: – визначення вмісту рухомих форм важких металів (Pb, Cd, Zn, Cu) – після вилучення ацетатно-амонійним буферним розчином pH 4,8 методом атомно-абсорбційної спектрофотометрії відповідно до ДСТУ 4770.*

Дослідження проводились на території села Ситківці, Райгородської територіальної громади, Гайсинського району, Вінницької області. Проби для аналізу відбирали в трьох точках с. Ситківці, щоб з'ясувати потенційне забруднення на території територіальної громади та порівняти значення із значеннями потенційно чистої присадибної ділянки: присадибна ділянка – площа 0,18 га (органічне внесення добрив – перегній, сидерати) відкрите акціонерне товариство Ситковецький цукровий завод (виробництво та реалізація продукції припинена 17 років тому) і сміттєзвалище твердих побутових відходів (санкціоноване).

Наукова новизна. *Проведені дослідження дозволили визначити агроекологічні показники ґрунтів та рівні накопичення важких металів (Pb, Cd, Zn та Cu) у різних точках відбору проб ґрунтів агросфери для подальшого їх використання в сільськогосподарських цілях.*

Висновки. *Досліджено, найнижчі агроекологічні показники виявлені в 3-ому зразку, що відібраний в межах санкціонованого сміттєзвалища: кислотність ґрунту – 5,8, середня забезпеченість ґрунту гумусом, азотом, рухомим фосфором та обмінним калієм.*

Встановлено, що у досліджених зразках вміст важких металів виявлено найвищим в зразку із сміттєзвалища, порівняно із 1 та 2 зразком: свинцю – 5,17 мг/кг, кадмію – 0,38 мг/кг, цинку – 21,15 мг/кг і міді – 2,74 мг/кг, що не перевищували гранично допустимих норм. Коефіцієнт небезпеки був найвищим у 3-му зразку (санкціоноване сміттєзвалище), але не перевищував 1.

Ключові слова: *ґрунт, важкі метали, коефіцієнт небезпеки, агроекологічні показники, агроекологічний стан, забруднення, навколишнє середовище.*

Formulation of the problem. The agricultural sector of Ukraine is one of the largest in the country's economy. A quarter of the world's reference soils – chernozems – are located in Ukraine, and

Ukraine is the third leader in the export (as of 2020) of grain and leguminous crops in the world – 50 million tons per year (according to the State Customs Service of Ukraine). It is no exaggeration to say that Ukraine can feed the world, but due to the full-scale russian invasion of Ukraine, value creation, price instability and cross-border supply of agricultural products have been disrupted. More than 100.000 units of machinery and equipment for soil cultivation (approximately 3.5 billion dollars) were destroyed, as well as granaries with a total capacity of 9.5 million tons. In general, about 20% of land in Ukraine is unsuitable for use due to mining, hostilities, and occupation (data from the Ministry of Agriculture) [5].

Agriculture of Ukraine is a source of income for 12 million people living in rural areas, almost 20% of the peasants who were engaged in growing agricultural products stopped working or reduced production due to the war. Although the consequences are visible mainly in the eastern regions of Ukraine along the front line, they are felt throughout the country [7].

Exports in Ukraine gained momentum every year and 2022 could become a record year for the independence of the country, but due to the blockade of Ukrainian ports, the amount of exported goods for 2023 is 30 billion dollars, which is 30% less than for 2021 [3]. At the same time, exports to countries geographically close to Ukraine increased: Hungary, Romania, Moldova, Slovakia and Bulgaria. Food is transported by land from the western regions of Transcarpathia, as well as Odesa [8].

The development of a multi-system economy and market relations led to the emergence of various types of private, small enterprises in the agricultural sector. There are the following types of small businesses in Ukraine:

– auxiliary private family farms – private property, owners and employees are family members;

– farm-peasant farms – collective ownership, family production associations of peasants for conducting agricultural production based on personal labor for the purpose of obtaining income [1].

Analysis of sources and recent research. Land resources are the main means of production and a factor of socio-economic development, ecological sustainability of the agrosphere [8; 9]. The state of the soil cover is one of the main indicators of the ecological state of the territory, as it receives direct effects from internal factors caused by the use of soils in agricultural production [7] and external effects caused by man-made activities [10; 11]. Significant external influences on the soil of the agrosphere are carried out by industrial facilities, transport highways and urbanized areas [12]. Considering the urban systems of agrarian regions, it should be noted that from a socio-economic point of view, they are poles of growth of adjacent rural areas, and from an ecological point of view, they are a certain source of constant supply of additional energy, in the form of waste, and substances with emissions into the atmospheric air and discharges into water bodies objects [14]. Such influences cause changes in the quality of the soil cover. Various approaches and methods are used to assess the agroecological condition of soils under certain conditions [6]. The concept of basic indicators characterizing the stability and ecological condition of the soil cover [13] and allowing to clearly distinguish the territories that are suitable for growing ecologically safe products should be taken into account in order to evaluate the soils of the agricultural sphere.

Today, agrarians use land resources mainly for the purpose of making money, and to a greater extent this is achieved by intensifying the application of fertilizers in order to obtain larger yields, but the question arises of the quality of this product, whether it will have a negative effect on the living organism, or provide benefit. Today, Ukraine is sufficiently supplied with food from domestic producers, so it is worth improving qualitative characteristics, not quantitative ones [6]. Use organic fertilizers, siderates (legumes, perennial grasses for crop rotation) as soil fertilizer, reduce the load of heavy machinery on the land, rationally apply mineral fertilizers, plant forest strips to retain moisture and reduce erosion processes, observe crop rotation for less soil depletion [9].

The purpose of the work is to conduct a comparative characterization of the ecotoxicological and agroecological condition of the soils of the agrosphere (on the example of the soils of the village of Sytkivtsi of the Raigorod Territorial Community of the Haysyn District of the Vinnytsia Region).

Presenting main material. We conducted research on the basis of agroecological indicators from three selected samples, and analyzed the actual value of the indicators (Table 1).

Table 1

Agroecological parameters of the soils of the village of Sitkivtsi, Raigorodskaya LC

Determination of agrochemical indicators	Units of measurement	SSU on the test method	Soil availability	Actual value
Sample 1 (homestead)				
Acidity – pH (saline)		SSU ISO 10390-2007	neutral	6.9
Humus	%	SSU 4362:2004	high	5.9
Hydrolyzed nitrogen (according to Kornfield)	mg/kg	SSU 7863-2015	high	249
Mobile phosphorus, P_2O_5 (according to Chirikov)	mg/kg	SSU 4115-2002	average	174
Exchangeable potassium, K_2O (according to Chirikov)	mg/kg	SSU 4115-2002	high	153
Sample 2 (Sytkovets sugar plant)				
Acidity – pH (saline)		SSU ISO 10390-2007	neutral	6.0
Humus	%	SSU 4362:2004	average	4.3
Hydrolyzed nitrogen (according to Kornfield)	mg/kg	SSU 7863-2015	average	174
Mobile phosphorus, P_2O_5 (according to Chirikov)	mg/kg	SSU 4115-2002	average	168
Exchangeable potassium, K_2O (according to Chirikov)	mg/kg	SSU 4115-2002	average	123
Sample 3 (Solid waste landfill)				
Acidity – pH (saline)		SSU ISO 10390-2007	sour	5.8
Humus	%	SSU 4362:2004	average	4.1
Hydrolyzed nitrogen (according to Kornfield)	mg/kg	SSU 7863-2015	average	151
Mobile phosphorus, P_2O_5 (according to Chirikov)	mg/kg	SSU 4115-2002	average	167
Exchangeable potassium, K_2O (according to Chirikov)	mg/kg	SSU 4115-2002	average	120

Based on agroecological indicators, it can be concluded that:

– in sample 1, which was selected on the homestead, the acidity indicator is neutral, the humus content is 5.9% (high), which is a high indicator of soil fertility, hydrolyzed nitrogen is 249 mg/kg, which is a high indicator, mobile phosphorus is 174 mg/kg, exchangeable potassium – 153 mg/kg;

– sample 2, selected on the territory of the Sitkovets sugar plant, the actual value of acidity is neutral, humus is 4.3%, the average content of hydrolyzed nitrogen, mobile phosphorus is 168 mg/kg, and the average value of exchangeable potassium is 123 mg/kg;

– sample 3, selected at the authorized landfill and agro-ecological indicators of this territory reach: acidity – 5.8, average content of humus, hydrolyzed nitrogen – 151 mg/kg, average supply of soil with mobile phosphorus and potassium exchange.

Based on the above indicators, it can be analyzed that the sample from the homestead has the most favorable indicators for growing agricultural crops compared to the samples from the sugar factory and the landfill. After all, in the 2nd and 3rd samples, we observe the average indicators of humus, nitrogen, phosphorus and potassium, which are important for root nutrition of plants.

Our research allowed us to determine the concentration of heavy metals lead, cadmium, zinc and copper in the soil (Table 2).

It was found that the content of lead in sample 3 was higher than the content of the same heavy metal in samples 1 and 2 by 1.65 and 1.14 times, respectively. The cadmium content in sample 3 was higher compared to samples 1 and 2 by 4.22 and 1.58 times, respectively. In sample 3, we observe an excess of zinc content compared to sample 1 by 1.85 times and sample 2 by 1.21 times. The copper content is the highest in sample 3 relative to the first by 3.65 and the second by 2.06 times, respectively. In sample 1, the lead concentration was 1.92 times lower than the maximum allowable norms, and in

Table 2

Ecotoxicological assessment of the condition of soils in the village of Sitkivtsi, Raigorodskaya LC

Heavy metals	Units of measurement	Actual content	MPC	HR
Sample 1 (homestead)				
Pb	mg/kg	3.12	6.0	0.52
Cd	mg/kg	0.09	0.7	0.12
Zn	mg/kg	11.42	23.0	0.49
Cu	mg/kg	0.75	3.0	0.25
Sample 2 (Sytkovets sugar plant)				
Pb	mg/kg	4.53	6.0	0.75
Cd	mg/kg	0.24	0.7	0.34
Zn	mg/kg	17.47	23.0	0.75
Cu	mg/kg	1.33	3.0	0.44
Sample 3 (Solid waste landfill)				
Pb	mg/kg	5.17	6.0	0.85
Cd	mg/kg	0.38	0.7	0.54
Zn	mg/kg	21.15	23.0	0.91
Cu	mg/kg	2.74	3.0	0.91

samples 2 and 3 – by 1.32 and 1.16 times. Sample 1 for cadmium was 7.77 times lower than the MPC. At the same time, samples 2 and 3 were 2.91 and 1.84 times lower than the MPC. Sample 1 and 2 did not exceed the standards and was lower in zinc by 2.01 and 1.31 times, and sample 3 by 1.08 times. Sample 1 did not exceed the permissible concentration of copper by 4.0 times, sample 2 by –2.25, and sample 3 – by 1.09 times, respectively.

According to our research, we calculated the indicators of the hazard ratio (Fig. 1), which is calculated according to formula 1. If this indicator exceeds 1, it means that these soils are not favorable for growing agricultural crops, but if its indicator has a value close to 1, it also indicates that the condition for using these soils for agricultural purposes may be the selection of specific agricultural plants.

$$HR = \frac{C}{MPC} \geq 1 \qquad (1)$$

where C – is the concentration of the pollutant, mg/kg; MPC – is the maximum allowable concentration of a pollutant, mg/kg.

The highest hazard ratio for lead is observed in sample 3 compared to sample 1 – 1.63 times and sample 2 – 1.13 times. Cadmium in sample 3 was in a higher concentration, compared to samples 1 and 2 by 4.5 and 1.58 times, respectively. The concentration of zinc in sample 3 is higher than the concentration in samples 1 and 2 by 1.85 times and 1.21 times, respectively. And the concentration of copper in the 1st sample is 3.64 times lower, and in the 2nd – 2.06 times lower, relative to the 3rd sample.

The hazard ratio of lead in sample 1 was 4.33, 1.06, and 2.08 times higher than that of Cd, Zn, and Cu, respectively. In the 2nd sample, the HR of lead and zinc is equivalent and is 0.75, but it is higher than the hazard ratio of cadmium by 2.2 times and copper by 1.7 times, respectively. And in sample 3,

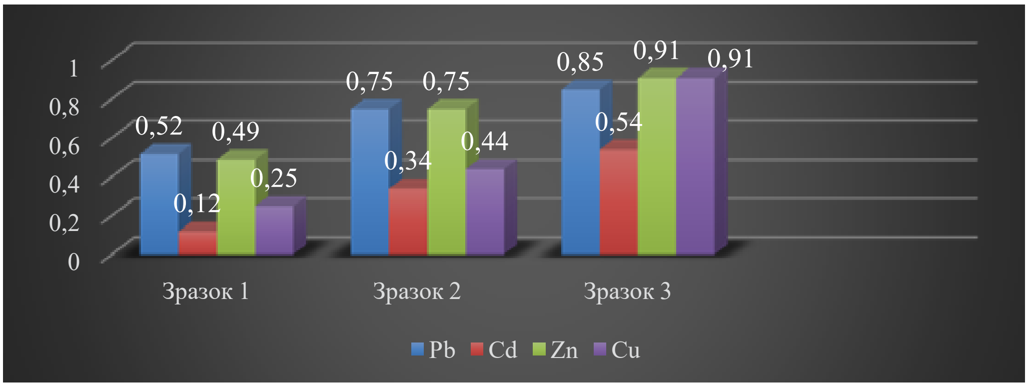

Fig. 1. The coefficient of danger of heavy metals in the soils of the village of Sitkivtsi, Raigorodskaya LC

the index of zinc and copper is 1.07 times higher than lead and 1.68 times higher than cadmium.

Considering that the hazard ratio of lead, cadmium, copper and zinc do not exceed the value of 1, these soils can be used for growing agricultural products without possible harm to health.

Conclusions. Compared to other samples, the soils of the homestead sample have relatively high levels of humus, hydrolyzed nitrogen, mobile phosphorus and exchangeable potassium with a neutral pH, the lowest agroecological indicators were found in the 3rd sample, which was selected within the solid waste landfill: soil acidity – 5.8, average availability of soil with humus, nitrogen, mobile phosphorus and exchangeable potassium.

In the examined samples, the content of heavy metals was found to be the highest in the sample from the solid waste landfill, compared to samples 1 and 2: lead – 5.17 mg/kg, cadmium – 0.38 mg/kg, zinc – 21.15 mg/kg, and copper – 2.74 mg/kg. All indicators are within the maximum permissible limits. The lowest indicators of the content of heavy metals in the soil were observed in the 1st sample (homestead plot) and were: lead – 3.12 mg/kg, cadmium – 0.09 mg/kg, zinc – 21.15 mg/kg, copper – 2.74 mg/kg. The hazard ratio was the highest in the 3rd sample (solid waste landfill), but did not exceed 1, which means that such soils are suitable for growing specific agricultural plants: thalaban *(Thlaspi caerulescens)*, which accumulates cadmium and zinc, Indian mustard *(Brassica juncea)*, ragweed *(Ambrosia artemisiifolia)*, hemp *(Apocynum cannabinum)*, pea or poplar, which store lead in their biomass.

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