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AGROECOLOGICAL ESTIMATION OF SOIL COVER OF MEDIUM URBROECOSYSTEMS (ON THE EXAMPLE OF KHMELNITSKY, UKRAINE)

AGROEKOLOGICZNA OCENA GRUNTÓW MIEJSKICH EKOSYSTEMÓW (NA PRZYKŁADZIE CHMIELNICKIEGO, UKRAINA)

АГРОЭКОЛОГИЧЕСКАЯ ОЦЕНКА ПОЧВЕННОГО ПОКРОВА СРЕДНИХ УРБОЭКОСИСТЕМ (НА ПРИМЕРЕ Г. ХМЕЛЬНИЦКИЙ, УКРАИНА)

Abstract

The article assesses the soil condition of the urboecosystem in the medium

population city, based on the example of Khmelnytskyi (Ukraine) by agrochemical parameters (acidity, humidity, humus content, nutrients, calcium, magnesium, sulfur), by the content of lead and by the degree of salinity. It has been determined that for medium urboecosystems, soils with weak-alkaline and alkaline reactions, low water supply, low concentration of mineral and water-soluble nitrogen and relatively high humus content are characteristic. Urbosoils are full with phosphorus, potassium and calcium, to a lesser extent, with magnesium. Soil salinity, as well as the presence of lead, are characteristic of areas near motorways, but remain within acceptable limits.

Keywords: *urban soils, urboecosystem, agrochemical indicators, lead.*

Streszczenie

W artykule jest oceniony stan gruntów w średnim wg liczby mieszkańców miejskim ekosystemie na przykładzie miasta Chmielnicki (Ukraina) na podstawie wskaźników agrochemicznych (kwasowość, wilgotność, zawartość próchnicy, elementy odżywcze, wapń, magnez, siarka), a także na podstawie zawartości ołowiu oraz stopnia zasolenia. Wyznaczono, ze dla średnich miejskich ekosystemów charakterystyczne są gleby o reakcji słabo zasadowej lub zasadowej, niskim zabezpieczeniu wody, słabą koncentracją mineralnego i wodorozpuszczalnego azotu oraz względnie wysokiej zawartości próchnicy. Grunty miejskie mieszczą wielką ilość fosforu, potasu oraz wapnia, w mniejszym stopniu – magnez. Zasolenie gruntów jak i występowanie ołowiu jest charakterystyczne dla terenów położonych przy drogach, nie przekracza to jednak dopuszczalnych ilości.

Słowa kluczowe*: grunty miejskie, miejskie ekosystemy, wskaźniki agrochemiczne, ołów.*

Аннотация

Статья содержит результаты исследования городских почв в средних по численности населения урбоекосистемах на примере г. Хмельницький (Украина) по агрохимическим показателям (кислотность, влажность, содержания гумуса, элементов питания, кальция, магния, серы), по содержанию свинца и степени засоленности. Определено, что для средних урбоэкосистем характерны почвы со слабощелочной и щелочной реакцией, низким содержанием влаги, невысокими концентрациями минерального и водорастворимого азота и сравнительно высоким содержанием гумуса. Урбоземы достаточно обеспечены фосфором, калием и кальцием, в меньшей степени – магнием. Засоленность почв, как и наличие свинца, характерны для участков возле автотранспортных магистралей, однако находятся в пределах допустимого.

Ключевые слова: *городские почвы, урбоэкосистема, химический состав почв, свинец.*

Statement of the problem in general outlook and its connection with important scientific and practical tasks. The increase in anthropogenic load in urboecosystems, where most of the population of Ukraine mainly concentrates, is accompanied by anthropogenic pollution of the environment. The greatest transformation undergo urban soils, due to their high absorption capacity. The difference of urban soils from natural soils is the redistribution, the change of agrochemical and toxicological indicators.

Soil pollution in cities is mainly due to emissions from motor vehicles and industrial

enterprises, as well as the result of people's progressive construction activities. In its turn, the types of pollution and its scale in conditions of different urboecosystem sizes significantly differ, which causes the formation of urbosoils with different physical, chemical, toxicological and other properties. Therefore, the study of the ecological state and the characteristics of urban soils in urban ecosystems with different population numbers is an important task, since in the future this information enables people to analyze and take effective management decisions for the relevant city services in order to prevent soil contamination.

Analysis of latest research where the solution of the problem was initiated. Studies of transformation processes of natural soils in urban conditions were conducted by both domestic and foreign scientists. Environmental problems of urban lands on the example of large cities were investigated by Ya.V.Genyk (1994), O.V.Didoshak (2000), V.P.Kucheriavyi (2001), O.V. Medvedieva (2004), N.L. Rychak (2006), I.M. Voloshyn (2013) and others.

The city of Khmelnytskyi is an administrative center of the Khmelnytskyi oblast, occupying the area of 86 square km, and the population of the city is about 270 thousand people. This is an industrial, commercial and cultural center of Podillya and the southern part of Ukrainian Volyn, located on the banks of the South Buh River, which flows into the Black Sea.

According to socio-economic indicators, the city is typical among the regional centers of western and central Ukraine. The largest share in the industrial production of the city is occupied by chemical and petrochemical, machine building and food industries, as well as construction. In general, the man-made factors of the urban ecosystem of the city of Khmelnytskyi are formed as the result of the impact on the environment of transport, industrial enterprises and utilities.

Natural soils of the city of Khmelnytskyi were formed mainly on carbonate forest deposits, the most common are forest-steppe cinder soils, which combine clear-gray forest soils, gray forest soils and dark gray cinder soils. The expansion of the city leads to a steady reduction of the areas of land with natural soils due to their transformation into urbosoils. More than half of the territory of Khmelnytskyi is occupied by anthropogenic deposits (bulk, including soils of bulk constructions, artificial road coverings, ditches from mineral processing, a planar cultural layer, deposits of artificial reservoirs).

Aims of the paper. The purpose of the study is to assess the state of the urban soils of the city of Khmelnytskyi according to agrochemical parameters (acidity, humidity, content of humus, nutrients, calcium, magnesium, sulfur, as well as chemical elements that characterize the salinity of soils) and to the content of lead. To do this, 9 test areas were selected on which the soil samples were collected. The test areas were laid down on the territory of the city in such a way that they included various types of anthropogenic influences, characteristic of the medium scale urban ecosystems (Fig. 1):

1) the impact of industrial enterprises (industrial zones):

- test area 1 – plant for the production of thermoplastic machines;
- test area 2 – the factory for the production of packaging polymer products (polyethylene forms, bottles, stretch films, etc.);

2) the impact of recreational activities (recreational zones):

- test area 3 – park of culture and rest named after Mykhaylo Chekman is a park with the landscape architecture of local significance, located on the right bank of the urban reservoir on the South Buh river. The area of the park is 140 hectares. There are more than 30 species of trees and shrubs growing on its territory, a network of natural and artificial canals is organized, a summer theater, a dance floor, pavilions, attractions, sports and children's playgrounds, a zoo, places for rest;
- test area 4 – arboretum “Podillya” is a park with the landscape architecture of local significance. The area of the dendrological park is 30.5 hectares, 174 species of

ornamental forms of wood plants grow on its territory brought from the botanical gardens of Moldova and Ukraine;

3) the influence of water protection zones of water objects of the city (flood territories):

- test area 5 – the floodplain of the Ploska river, which falls into the South Buh River within the city area;
- test area 6 – water protection zone of the lake in the Ozerna neighborhood. The lake is located on one of the unnamed inflows of the South Buh;

4) the impact of motor transport (transportation highways):

- test area 7 – Lvivske shosse street is one of the main highways of the South-Western part of the city;
- test area 8 – Podilska street is located in the central part of the city. The name of the street is underlined by the fact that Khmelnytskyi is located on the territory of Podillya - the historical and natural-geographical region of Ukraine;
- test area 9 – Chornovola street is one of the main highways of the South-Eastern part of the city.

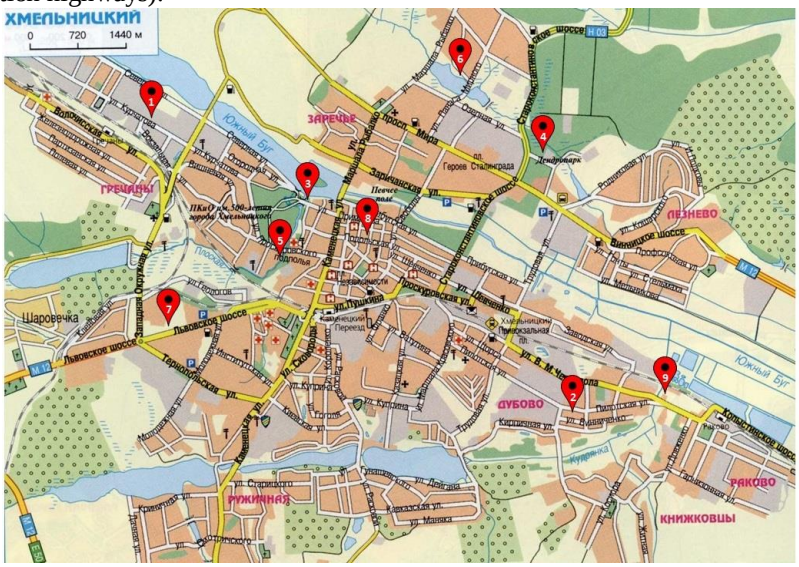


Fig. 1. Places of test areas for the selection of prototype samples on the city map of Khmelnytskyi

Source: Developed by authors.

Sampling and determination of agrochemical indices of soils were conducted in accordance with the normative and technical documents of Ukraine (DSTU) and ISO.

Exposition of main material of research with complete substantiation of obtained scientific results. Soil response is an important indicator that has a great influence on the growth and development of plants, as well as microbiological, chemical and biological soil processes. The soil reaction depends to a large extent on the absorption by plants of nutrients of soil and fertilizers, the mineralization of organic matter, the efficiency of fertilizer application, yield and its quality. Also, acidity of soils greatly affects the availability of nutrients for plants. Excessively high (more than 9.0 units) and excessively low (less than 4.0 units) pH soil values are toxic to the root system of plants.

For natural soils of Khmelnytskyi, the numbers of the pH value in the range from 4.0 units (clear-gray cinder soils) to 6.3 units (typical black soils) are characteristic. However, under the influence of such morbid factors as industry and transport, according to the results of the study (Table 1), there is an alkalinization of soils.

According to the data obtained, the value of the acidity of the root-bearing layer in the

urban soils of the city of Khmelnytskyi varies widely, however, soils with a light-alkaline and alkaline reaction predominate. The highest pH values are typical for the industrial zone and near the transport highways.

Table 1. Indicators of the pH of urban soils in Khmelnytskyi

№ test area		title	pH H_2O, units	pH KCI, units	Gradation the soil
Industrial zone	1	factory for the manufacture of thermoplastics machines	8,25	7,53	alkaline
	2	a factory for the production of polymer products packaging	8,16	7,78	alkaline
Recreation zone	3	Park of culture and rest named after Mykhaylo Chekman	7,94	7,35	slightly alkaline
	4	«Podillya» arboretum	5,43	3,83	sour
Flood territories	5	flood plain of the Ploska River	8,11	7,56	alkaline
	6	water protection zone of the lake	8,08	7,58	alkaline
Transportation highways	7	Lvivske shosse street	8,11	7,60	alkaline
	8	Podilska street	7,52	7,85	slightly alkaline
	9	Chornovola street	8,05	7,92	alkaline

Source: Developed by authors.

The closest to the natural parameters is the pH value of the soil of the "Podillya" arboretum, indicating the smallest changes in this edaphotop under the influence of urbogenesis, including due to the typical forest-steppe vegetation, which is widespread in its territory.

Moisture content is an important factor in soil fertility, which largely determines the intensity of biological processes, plant growth and development. At the same time, both the shortage and the excess of soil moisture can negatively affect. There are significant variations in moisture content in the city of Khmelnytskyi, depending on the season (Fig. 2). At the end of winter, the soil is well-humidified and has satisfactory and good indicators of the total and active moisture reserve (Table 2, Fig. 3). The greatest moisture content of the soil is characteristic for recreational and water protection zones, whose surface is covered with vegetation, which, in our opinion, is determined by the phytomelioration (snow-protection) effect of developed park and flood phytocoenoses. At the end of the vegetation season, soil moisture drops sharply in 2.6-9.0 times (on average 3.3-4.0 times) in all areas. The same trend is observed in terms of moisture reserve. Most of the moisture remains in the soils of parks and water protection zones. Attention is drawn to the fact that in the areas most used by the city's population, the differences in moisture content in winter and at the end of the growth season are the largest, indicating a greater loss of moisture in these areas. In our opinion, this is due to an increase in soil density, which causes deterioration of water and physical properties, and according to the data [10], it contributes to a decrease in moisture up to 14 % of the initial value in the warm months of the year. Most moisture is preserved in the "Podillya" arboretum, the territory of which has a thick vegetation (trees, shrubs, grass cover), which reduces solar insolation. Thus, in the summer, urbosoils lose a significant amount of moisture, while an effective factor in preventing these losses is green planting. This necessitates the preservation of green plantations as the most important elements of the urboecosystem.

The main feature of the soil is the presence

in it of a specific group of organic substances - humus compounds, which are formed during the decomposition and humification of organic residues. The content of humus in urban soils varies depending on its amount in the original natural soil, as well as on the use of mineral and organic fertilizers, the introduction of organic rubbish, etc. As a rule, the content of organic substances in urbosoils is higher than in the background soils. In all the old urban soils, especially in the soils of parks, squares, gardens, the content of humus reaches values from 8 % to 12 %, and on average from 4 % to 6 %. Sometimes the "old-soiled" lands acquire the character of blacksoil-like ones [10].

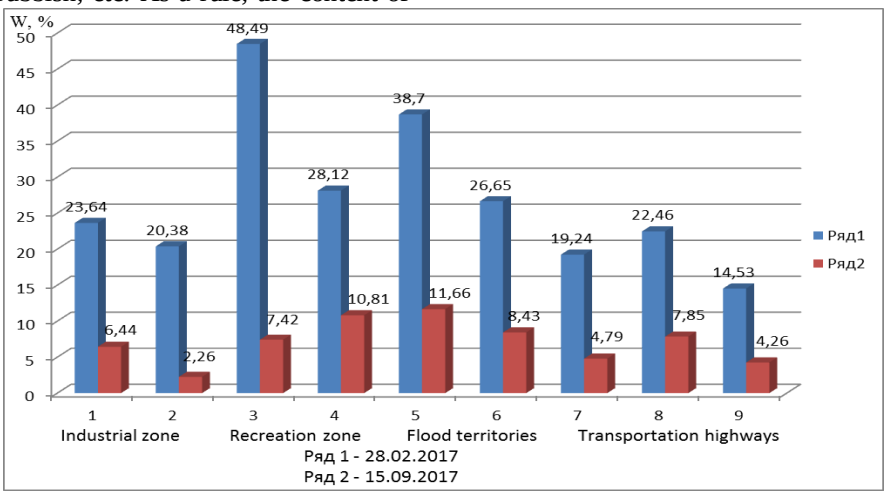


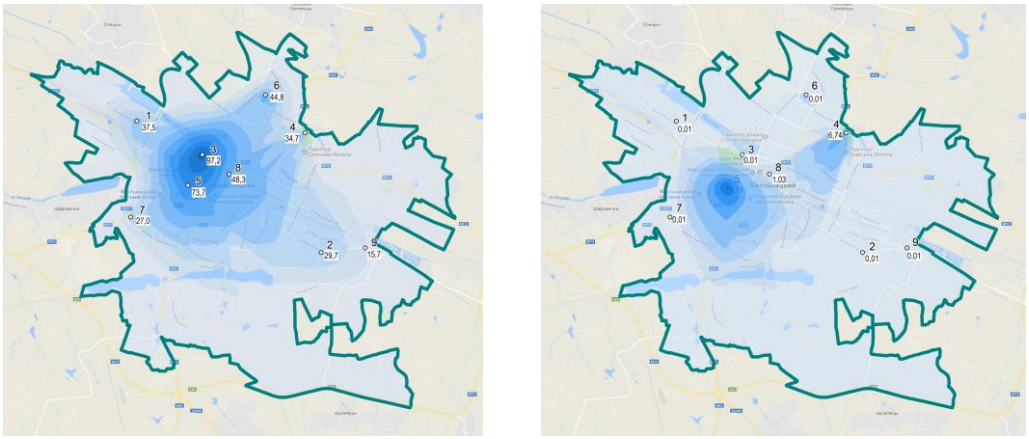
Fig. 2. Humidity of the soil of the city of Khmelnytskyi

Source: Developed by authors.

Table 2. Total moisture content in soils of Khmelnytskyi city, mm

№ test area		Title	by 28.02.2017	by 20.09.2017
Industrial zone	1	factory for the manufacture of thermoplastics machines	56,7	17,80
	2	a factory for the production of polymer products packaging	48,9	5,42
Recreation zone	3	Park of culture and rest named after Mykhaylo Chekman	116,4	15,45
	4	«Podillya» arboretum	53,9	25,94
Flood territories	5	flood plain of the Ploska River	92,9	27,99
	6	water protection zone of the lake	64,0	18,84
Transportation highways	7	Lvivske shosse street	46,2	11,49
	8	Podilska street	67,5	20,23
	9	Chornovola street	34,9	10,22

Source: Developed by authors.



28.02.2017 20.09.2017

Fig. 3. Active moisture reserve in the soils of the city of Khmelnytskyi, mm
Source: Developed by authors.

As a rule, the content of organic substances in urbosoils is higher than in the background soils. In all the old urban soils, especially in the soils of parks, squares, gardens, the content of humus reaches values from 8 % to 12 %, and on average from 4 % to 6 %. Sometimes the "old-soiled" lands acquire the character of blacksoil-like ones [10].

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Our data on the content of humus in the soils of Khmelnytskyi (Fig. 4) correspond to the general trend. In general, the average index of humus content in urbosoils of the city of Khmelnytskyi is 4 % and is higher than in the natural soils of this territory (2-3 %). The highest values are forecasted for recreational and flood areas, which is stipulated by measures to improve plant growth in these areas of the city. Also, the formation of humus is facilitated by the constant natural transformation of plant remains and the least impact on industrial enterprises and transport. The smallest values corresponding to the natural background indicators are recorded on test areas located in the industrial zone. The content of humus closely correlates with the value of the active moisture content in the soil (the correlation coefficient is equal to 0.91), because the process of humus accumulation is much slower under low humidity conditions.

Important for soil ecosystem functions is the content of nutrients (nitrogen, phosphorus, potassium). The content of total nitrogen in different soils ranges from 0.03 % to 0.50 % [11]. Alkaline hydrolyzed nitrogen characterizes the degree of soil cultivation, as well as the degree of nitrogen supply, since its content is closely correlated with the content of nitrogen removed, humus content, total nitrogen and nitrification capacity. Due to lack of nitrogen, inhibition of plant growth, necrosis, dryness is observed.

When determining the content of mobile forms of nitrogen (mineral and alkaline hydrolyzed), their insufficient content in the soils of the city was detected (Table 3), except recreational and flood areas.

The content of alkali hydrolyzed nitrogen is closely correlated with the content of humus in the corresponding areas (the correlation coefficient is equal to 0.94). This indicates that the content of mineral fertilizer residues in the city is minimal, and the main source of nitrogen is organic compounds of the soil. Low intensity of nitrogen accumulation can be

explained by slow microbiological processes, including due to low moisture supply of urbosoils. Phosphorus in soil is found in two forms - mineral and organic. Organic phosphorus can participate in various chemical reactions, and it becomes available to plants after mineralization of organic matter. The content of total phosphorus in soils ranges from 0.05 % to 0.15 % P_2O_5, most of the phosphorus of the soil is in hard-to-reach forms that becomes available to plants due to the influences of root isolates and microorganisms [11].

Potassium is the third most nutritious element for plants after nitrogen and phosphorus. It is absorbed, mainly in the ionic form and in the form of the K + ion, and plays a significant role in maintaining the electroneutrality, both in the soil solution and in the plants. It neutralizes the negative charges of anions of nitrates, phosphates, and the like. The need for plants in potassium is high, which often exceeds the potential of soils [12].

The content of total potassium in soils is 0.5-2.9 % K_2O. In the soil it is in various forms: water soluble, exchangeable, fixed, potassium of microorganisms and potassium of minerals. Water-soluble and directly exchangeable potassium is well absorbed by plants and is considered as mobile forms of potassium. Some researchers note high levels of content of urbosoils and weakly ground soils with phosphorus and potassium, where their content can be as high as 100-200 mg/100 g of soil and 40 mg/100 g of soil [10]. The content of mobile forms of phosphorus and potassium in Khmelnytskyi city urbosoils (Table 4) is smaller than these data, but in general, the determined concentrations of these elements correspond to the medium and high levels of soil contents.

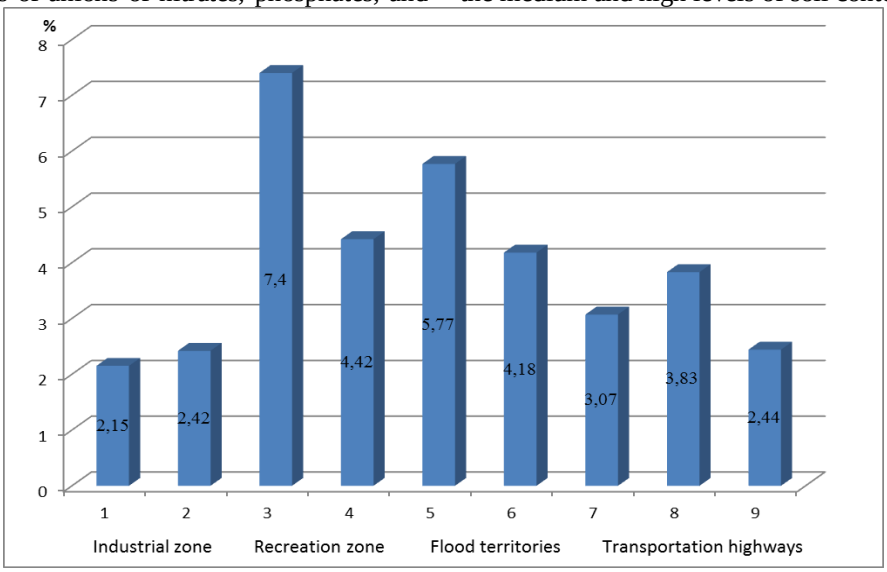

Fig. 4. The content of humus in urbosoils of Khmelnytskyi

Source: Developed by authors.

Table 3. Content of mobile nitrogen forms

№ test area	Title		Nitrogen (mineral), mg/100 g	Gradation of soil	Nitrogen (alkaline hydrolyzed), mg/100 g	Gradation of soil
Industrial zone	1	factory for the manufacture of thermoplastics machines	0,13	very low	7,8	very low

Continuation of Table 3

	2	a factory for the production of polymer products packaging	0,70	very low	9,4	very low
Recreation zone	3	Park of culture and rest named after Mykhaylo Chekman	0,81	very low	22,7	increased
	4	«Podillya» arboretum	1,53	low	16,5	medium
Flood territories	5	flood plain of the Ploska River	0,38	very low	16,0	medium
	6	water protection zone of the lake	1,66	medium	14,0	low
Transportation highways	7	Lvivske shosse street	0,58	very low	11,2	low
	8	Podilska street	0,77	very low	11,5	low
	9	Chornovola street	0,44	very low	6,2	very low

Source: Developed by authors.

Table 4. Content of mobile forms of phosphorus and potassium in urbosoils of Khmelnytskyi

№ test area		Title	P_2O_5, mg/100 g	Gradation of soil, at P_2O_5	K_2O, mg/100 g	Gradation of soil, at K_2O
Industrial zone	1	factory for the manufacture of thermoplastics machines	10,9	encreased	11,7	encreased
	2	a factory for the production of polymer products packaging	6,0	medium	20,6	very high
Recreation zone	3	Park of culture and rest named after Mykhaylo Chekman	20,1	very high	13,0	high
	4	«Podillya» arboretum	15,9	high	19,5	very high
Flood territories	5	flood plain of the Ploska River	7,1	medium	29,3	very high
	6	water protection zone of the lake	34,4	very high	65,1	very high
Transportation highways	7	Lvivske shosse street	41,6	very high	32,3	very high
	8	Podilska street	19, 5	high	19,2	very high
	9	Chornovola street	17,9	high	28,5	very high

Source: Developed by authors.

Thus, the soil cover of the city of Khmelnytskyi is well filled with both phosphorus and potassium.

The upper layers of the soil usually contain 0.7-9.28 % CaO and 0.5-2.3 % MgO. A significant amount of calcium and magnesium in the process of plant nutrition can be exchanged for other cations, for example, hydrogen [11].

The content of exchangeable calcium and exchangeable (mobile) magnesium in urbosoils of Khmelnytsky (Table 5) differs significantly in different parts of the urboecosystem.

Except for two areas (industrial and near the highway) the city urbosoils have encreased and high concentrations of calcium. The availability of magnesium is lower and is characterized as medium. In this case, areas with low calcium content also have low concentrations of exchangeable (mobile) magnesium.

Sulfur is one of the main elements of plant nutrition necessary for normal growth and formation of their high productivity. Therefore, sulfur is considered "the fourth macroelement", given its physiological significance, like nitrogen, and the removal from the soil, which is close to phosphorus in size. The physiological effects of sulfur and nitrogen are synergistic, since they play an important role in the synthesis of protein, which helps to increase the yield and improve its quality. The sulfur content in soils is 0.05-0.25 %. In soils, sulfur may be in the form of elementar sulfur, hydrogen sulfide, sulfides, sulfates, sulfites, thiosulfates, and the like. Up to 90 % of sulfur in the soil is contained in organic form, which becomes available in the course of mineralization by microorganisms to sulfate ion SO_4^{2-}, which can migrate beyond the zone of assimilation by root systems.

The determined sulfur content (Table 6) indicates its rather small concentration in the urbosoils of Khmelnytskyi, which is much smaller than the background value.

Table 5. The content of exchangeable calcium and exchangeable (mobile) magnesium

№ test area		Title	Ca, mg/100 г	Gradation of soil, at Ca	Mg, mg/100 г	Gradation of soil, at Mg
Industrial zone	1	factory for the manufacture of thermoplastics machines	245	encreased	15	medium
	2	a factory for the production of polymer products packaging	100	low	7	low
Recreation zone	3	Park of culture and rest named after Mykhaylo Chekman	414	very high	16	medium
	4	«Podillya» arboretum	225	encreased	22	medium
Flood territories	5	flood plain of the Ploska River	355	high	21	medium
	6	water protection zone of the lake	248	encreased	17	medium
Transportation highways	7	Lvivske shosse street	165	medium	14	medium
	8	Podilska street	277	encreased	27	encreased
	9	Chornovola street	81	low	7	low

Source: developed by authors.

Table 6. Content of sulfur, sodium and chlorine in soils of Khmelnytskyi

№ test area		Title	S, mg/kg	Na^+, mg/100 g	Cl^-, mg/100 g	Qualitative reaction to lead content*
Industrial zone	1	factory for the manufacture of thermoplastics machines	<4,0	1,80	2,5	-
	2	a factory for the production of polymer products packaging	<4,0	0,68	<0,01	-
Recreation zone	3	Park of culture and rest named after Mykhaylo Chekman	<4,0	0,85	2,5	-
	4	«Podillya» arboretum	12,8	4,10	1,25	-
Flood territories	5	flood plain of the Ploska River	7,5	1,05	<0,01	-
	6	water protection zone of the lake	<4,0	3,20	<0,01	-
Transportation highways	7	Lvivske shosse street	<4,0	1,60	<0,01	+
	8	Podilska street	10,5	2,80	<0,01	+
	9	Chornovola street	<4,0	0,95	1,25	+

Note: The qualitative reaction to lead content was conducted relative to the maximum permissible concentration.

Source: developed by authors.

Sodium refers to elements that are conventionally required for plants. In the chemical and physiological sense, sodium is close to potassium. The main deposits of sodium in the soil are represented by various silicate soluble minerals. Sodium content in urbosoils is 50-70 mg/kg [10].

Chlorine is required for plants in small quantities. Along with alkaline and alkaline earth ions, chlorine has a positive effect on fluidity of tissues and protoplasm of cells. This element activates the enzymes that carry out photosynthesis reactions. Today, in the urban ecosystems, technogenic introduction of sodium and chlorinated compounds to the soil is observed with the use of salt and sand mixtures in the fight against ice-cold, which may negatively affect the condition of the urban flora. The determined salinity indices (the content of sodium cations and chloride ions) in urbosoils of Khmelnytskyi (Table 6) are low compared to the concentrations characteristic of large urboecosystems.

The most widespread heavy metal in the soils of urboecosystems is lead, the availability of which is attributed to the activity of motor vehicles. According to a qualitative assessment, lead traces were detected in areas near traffic highways, but its content did not exceed the maximum permissible concentration, therefore no quantitative determination was made.

Conclusions. As a result of the agroecological assessment of soils in the medium-sized urban ecosystems, for example, the city of Khmelnytskyi, the agrochemical parameters and lead content were determined which differ significantly within the city depending on the degree of anthropogenic loading. According to the obtained data, the soils with a weakly alkaline and alkaline reaction (pH = 5.43-8.25 units) prevail in the structure of the soil cover. The section of the recreational zone with forest vegetation is approximate to the natural value of acidity. Soil humidity varies depending on the season,

depending on the presence of vegetation and the degree of soil compaction. The content of humus in urbosoils is 2.2-7.4 %, with the largest values characteristic for the recreational and flood areas of the city, the smallest – for areas of the industrial zone.

For soils of Khmelnytskyi, very low and low concentrations of mineral (0.13-0.77 mg/100 g) and alkali hydrolyzed (6.2-14.0 mg/100 g) nitrogen are characteristic, except for the recreational and flood areas where nitrogen provision is characterized as medium and encreased. Low intensity of nitrogen accumulation is associated with low soil moisture content.

Khmelnytskyi's soils are well filled with both phosphorus and potassium. Most areas are characterized by high calcium content. The availability of magnesium is lower and is characterized as medium.

All local edaphotops of the city of Khmelnytskyi have relatively low salinity (the content of sodium cations and chlorine ions), which indicates the lack of salinization of urban soils in the medium size of teritory and population cities, including near highways. Also, in these areas, the presence of lead in quantities that do not exceed the maximum permissible concentration is determined. In general, the state of the urban soils of Khmelnytskyi is satisfactory in comparison with the metropolises and does not pose a threat to the functioning of the urban ecosystem. Along with this, in order to optimize their condition, it is necessary to remove uncontrolled consolidations and increase the number of green plantations.

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