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BIODIAGNOSTICS OF URBAN SOILS OF MELITOPOL URBOSYSTEM ON THE BASIC OF THE ANALYSIS OF THE ECOMORPHIC MESOFAUNA STRUCTURE

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The article deals with the results of biodiagnostics of urban soils of Melitopol urbosystem on the basis of the analysis of the ecomorphic mesofauna structure. It was established that increasing the level of pollution of edaphotops by heavy metals in one case causes the depression of the vitality of certain groups of saprophages (representatives of the Isopoda class, the Enidae, Helicidae families), in the other – the activation of their vitality (representatives of the Diplopoda and Chilopoda classes, the Lumbricida family and the Aranei row). The peculiarities of ecomorphic structure and patterns of spatial-temporal dynamics of the distribution groups of terrestrial mollusks should be used for biodiagnostics of the ecological state of edaphotops.

Functional zones, mollusk fauna, soil mesofauna, ecological condition, vitality

Under the influence of anthropogenic loading in urbosystems, edaphotops degradation is observed. Effective indicators of their state are mesofauna groups that specifically react to changes in environmental parameters [8, 10, 11, 12, 14, 15].

Biodiagnosis on the basis of analysis of the ecomorphic structure of invertebrates allows to evaluate the quality of the soil environment. Environmentally hazardous factors cause a change in the conditions for the existence of mesopedobionts. Depending on the intensity of anthropogenic loading, three types of dynamics of invertebrate animal groups that are adapted to existence in a critical state are distinguished. Thus, the spatial distribution of the soil mesofauna acts as an important biodiagnostic feature [3, 5, 9]. In order to increase the effectiveness of biodiagnostics, it is important to use available monitoring tools for the functioning of mesopedobionts complexes in the transformed soil. The objective

of the work is to analyze the ecomorphic mesofauna structure and to evaluate the state of the edaphotops of the Melitopol urbosystem.

Materials and methods of research

The experimental part of the work was carried out during 2012–2018 in the city of Melitopol, Zaporizhzhia region. The research program provided a biodiagnostic assessment of the ecological state of the edaphotops, based on the analysis of the ecomorphic structure of the soil mesofauna (Table 1).

Table 1 – Location of functional zones of the city of Melitopol

№	Coordinates	Names of objects for functional purpose
1	46°50'48.4"N, 35°23'28.5"E	Industrial zone
2	46°50'21.4"N, 35°21'59.1"E	Recreational area (city park)
3	46°50'59.0"N, 35°20'40.3"E	Industrial zone
4	46°51'51.5"N, 35°23'26.5"E	Housing (multistory buildings)
5	46°49'05.6"N, 35°18'06.6"E	Industrial zone
6	46°49'48.4"N, 35°21'31.4"E	Orchards
7	46°50'30.9"N, 35°22'33.0"E	Housing (multistory buildings)
8	46°52'02.7"N, 35°19'24.5"E	Housing (individual buildings)
9	46°51'08.8"N, 35°22'31.3"E	Individual buildings, highway
10	46°49'26.1"N, 35°21'01.5"E	Transport area
11	46°49'38.5"N, 35°19'21.6"E	Transport and industrial zone
12	46°49'00.0"N, 35°22'51.1"E	Transport area
13	46°49'05.3"N, 35°22'37.4"E	Housing and motorway area
14	46°52'15.3"N, 35°25'00.9"E	Recreation zone (parks, squares)
15	46°53'09.2"N, 35°20'36.7"E	Housing (multistory buildings)

The basis of the method of biodiagnostics of the quality of edaphotops is the comparison of the vitality index of soil invertebrates of the studied functional zones with the control site. Calculations were performed according to the formula (1):

$$\Delta G_b = (G_{bk}-G_{bi}) / G_{bk}100\% \quad (1)$$

The ecological status of urban edaphotops was evaluated according to the criteria given in Table 2.

Table 2 – Criteria for assessing the quality of urban edaphotops (according to Batdiyev, 2007)

Decrease in vitality index	Criteria for assessing the ecological state of edaphotops				
	favorable	strained	critical	crisis	disastrous
G_i %	less than 11	11-25	26-50	51-80	more than 80

The mesopedobionts were used as bioindicators for the degree of pollution of edaphotops. They are the representatives of the Diplopoda classes (*Megaphyllum rossicum* (Timotheew, 1897), *Rossiulus kessleri* (Lohmander, 1927), Chilopoda (*Geophilus proximus* (C.L. Koch, 1847), *Lithobius curtipes* (C.L. Koch, 1847), Aranei, Isopoda, families of Trachelipodidae (*Trachelipus rathkii* (Brandt, 1833), Armadillidiidae (*Armadillidium vulgare* (Latreille, 1804), Lumbricidae, Enidae (*Chondrula tridens* (O.F. Muller, 1774), *Brephulopsis cylindrica* (Menke, 1828), Limacidae (*Limax sp.*), Hygromiidae (*Xeropicta derbentina* (Krynicki, 1836), *Xeropicta krynickii* (Krynicki, 1833), *Monacha fruticola* (Krynicki, 1833), *Xerolenta obvia* (Menke, 1828), Helicidae (*Helix albescens* (Rossmässler, 1839), *Eobania vermiculata* (O.F. Muller, 1774), Bradybaenidae (*Fruticicola fruticum* (O.F. Muller, 1774).

Ground mollusks were determined according to N.V. Gural-Sverlova and R. I. Gural [2], earthworms – according to T.S. Vsevolodova-Perel [1], centipedes – according to N.T. Zaleskaya and A. Shileiko [4], predatory centipedes – according to P. A. Stoev [12], N. G. Chorniy, S. I. Golovach [7], and woodlice – according to M. Shmoltser [11]. Spiders were determined to the level of family [6].

Results and discussion

Dendroflora of functional zone № 14 was represented by *Robinia pseudoacacia* L., *Gleditsia triacanthos* L., *Acer negundo* L., *Cotinus coggygria* Scop., *Ulmus carpinifolia* Gled., *Celtis occidentalis* L., *Pinus sylvestris* L. The decrease in the vitality rate of invertebrates in this recreational zone of $\bar{G}_b$ relative to G_{max} (60 ex/m^2) was 9.5 %. Thus, the ecological state of the soil can be characterized as favorable. As a result of the study of soil

invertebrates, the following groups of pedobionts – representatives of Lumbricidae, Aranei, Trachelipodidae, Limacidae, Helicidae, Diplopoda and Isopoda families were identified. In all investigated areas phytophages were dominant among trophic groups (68.3%).

Saprophages accounted for 30.4 % of the total mesopedobionts. The smallest group is represented by zoophages (1.3%). The complex of saprophages is quite wide, and contains the cenomorphic forms of prathants, stepants and sylvants. Their hygromorphs range from ultrahygrophylls to xerophylls. Earthworms are represented by endogeic prathants *Aporrectodea trapezoides* and the sylvants *Octolasion lacteum*. The range of hygromorph oligochaetes is within the boundaries from hygrophylls to mesophylls. In addition to earthworms, the trophic group of saprophages includes woodlice. Among them there were epigeic prathants – *Trachelipus rathkii* and *Armadillidium vulgare*. Moreover, the misanthropic representatives of the Trachelipodidae family are characteristic of anthropogenic undisturbed landscapes, while polytopic mesophylls (*Armadillidium vulgare*) are often found in urbanized habitats. The two-legged centipedes are represented by *Megaphyllum rossicum*, but the number of saprophages is low. This may be due to the fact that calciphylls are less adapted to weakly acidic environment. The gastropods is a large and diverse group of phytophages of this functional zone, and are represented by two cenomorphs – prathants (*Limax sp., Eobania vermiculata*) and stepants (*Chondrula tridens, Brephulopsis cylindrica, Xeropicta derbentina*). Representatives of the Lycosidae family form a complex of zoophages of this functional zone – 1.3 %.

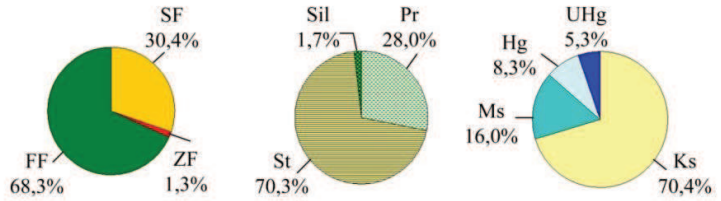

Figure 1 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the recreational zone (№ 14)

Thus, the predominance in the mesofauna of this zone of molluscs, woodlice and earthworms indicates a relatively good condition of the soil (Fig. 1).

The ecological state of the edaphotops of the zone number 8 is assessed as strained. Decrease in vitality index of invertebrates was 23.8 % (G_b = 45.7 ex./m^2 relative to G_{max} = 60 ex./m^2). As a result of the study of mesopedobionts, the representatives of the Lumbricidae, Aranei, Trachelipodidae, Limacidae, Helicidae and Diplopoda families were identified. In all investigated areas, the dominant group among trophomorphs were phytophagous (71 %). Saprophages accounted for 28.1 % of the total number of mesopedobionts. A group of zoophages is not big (0.9 %). The complex of saprophages is represented by such cenomorphic forms as prathants, stepants and polludants. The range of their hygromorphs varies from ultrahygrophylls to xerophylls. Earthworms are the dominant group in the saprophage complex of this functional zone and are represented by endogeic stepants *Aporrectodea rosea* and endogeic prathants *Ataborethoda trapezoides*. In the spectrum of hygromorphs ultra-, hygro- and hygrophylls are dominant. Earthworms, along with the misanthropic woodlice *Trachelipus rathkii* and centipedes *Rossiulus kessleri* form a complex of calciphylls. Phytophages are numerous and diverse groups of mesopedobionts, and are represented by two cenomorphs – prathants (*Limax sp.*) and stepants (*Xeropicta derbentina, Helix albescens*). The range of hygromorphs of gastropods is fairly wide and is in the range from hygrophylls to xerophylls. The complex of zoophages is poorly represented (less than 1 %). Thus, the predominance of molluscs and earthworms in the mesofauna indicates the presence of soil pollutants in this functional zone (Fig. 2).

The ecological status of the soils of industrial zone number 3 is characterized as disastrous. The decrease in the vitality of invertebrates was 96.5 % (G_b = 2.1 ex./m^2 relative to G_{max} = 60 ex./m^2). As a result of the study of mesopedobionts, representatives of the Lumbricidae, Thomisidae, Helicidae families were identified. In all examined sites, the dominant group among trophomorphs were phytophages (64.3 %). The number of saprophages accounted for 14.3 % of the total number of mesopedobionts; the group of zoophages increased significantly

(21.4 %) compared to control. Saprophagas of the production site are represented by endogeic stepants *Aporrectodea rosea*. Phytophages are the largest group. However, in the area of the industrial zone, they are represented by one cenomorph – xerophytic stepants (*Xeropicta derbentina)*. Earthworms together with *Xeropicta derbentina* mollusks form a complex of calciphylls.

The proportion of zoophages increases significantly, the representatives of the Thomisidae family predominate among them. They are characterized by high tolerance to the pollutants of different etiologies (Fig. 3).

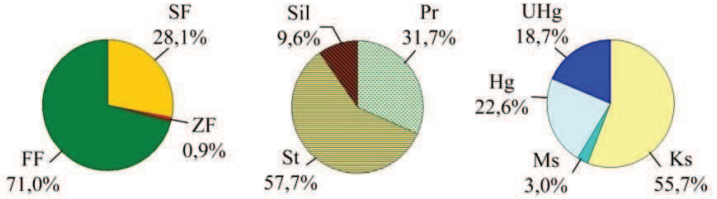

Figure 2 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the residential development zone (№ 8)

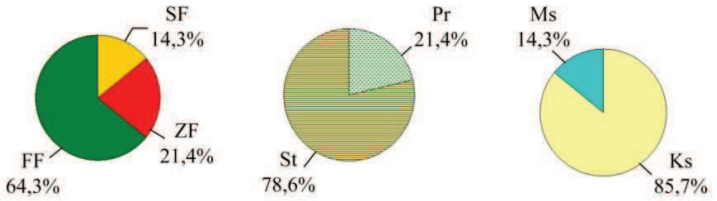

Figure 3 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the industrial zone (№ 3)

The decrease in the vitality index of mesopedobionts in zone number 10 (international highway), G_b relative to G_{max} = 60 ex./m^2, was 45.7 %. The ecological state of the soil can be characterized as critical. The following groups of pedobionts were identified: representatives of the Lumbricidae, Limacidae, Helicidae, Thomisidae and the Diplopoda families. Dominant among trophic groups are phytophages (90 %). Saprophages accounted for 9 % of the total mesopedobionts. The smallest group

is represented by zoophages (1 %). The complex of saprophages consists of such cenomorphic forms: prathants, stepants and polludants. The range of their hygromorphs is within the boundaries from ultrahygrophylls to xerophylls. Earthworms are represented by endogeic stepants *Aporrectodea rosea*. In addition to earthworms, the trophic group of saprophagous calciphylls includes the two-legged centipedes *Rossiulus kessleri*. The numerous and diverse group of phytophagous mollusks were two cenomorphs – prathants (*Limax sp.*) and stepants (*Xeropicta derbentina, Helix albescens*). The range of hygromorphs of mollusks is within the boundaries from hygrophylls to xerophylls.

Representatives of the Arachnida class form a small-scale complex of zoophages of this functional zone – 1 %. Thus, all the investigated groups of soil invertebrates, except woodlice, were marked in the mesofauna of zone № 10 (Fig. 4).

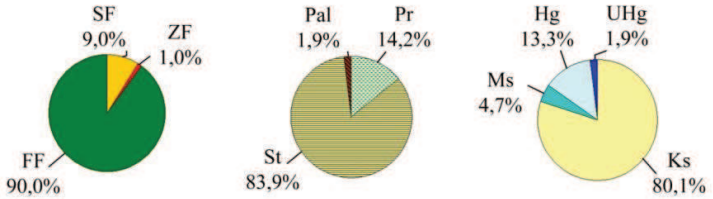

Figure 4 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the motorway zone (№ 10)

The ecological state of soils of zone number 13 is characterized as a crisis. The decrease in the vitality index of mesopedobionts was 58.2% (G_b = 25.1 ex./m^2 relative to G_{max} = 60 ex./m^2). As a result of the study of soil invertebrates, representatives of the Lumbricidae, Limacidae, Helicidae, Chilopoda, Arachnida families were found. The dominant group among trophomorphs was phytophagous (91.8 %), and among the cenomorphs – stepants (93.7 %). The complex of saprophages was 3.8 %, and zoophages – 4.4 %. In addition to the characteristic of most investigated functional zones of spiders – representatives of zoophages, the predatory endogeic dugouts were found in this area. Phytophages are represented by two cenomorphs –

xerophytic stepants (*Xeropicta derbentina*) and hygrophilic prathants (*Limax sp.*). Earthworms together with mollusks form a complex of calciphylls (Fig. 5).

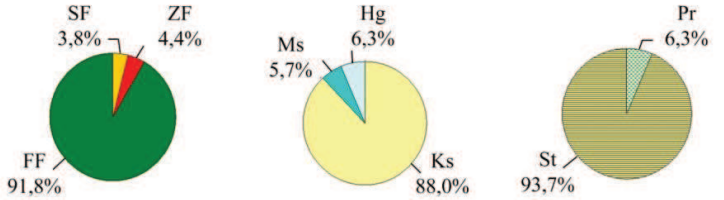

Figure 5 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the residential area (№ 13)

Dendroflora of industrial zone № 5 is represented by *Robinia pseudoacacia* L., *Acer negundo* L., *Celtis occidentalis* L., *Catalpa bignonioides* L., *Populus nigra* L., *Populus alba* L. The decrease of the vitality index of invertebrates in this functional zone $\bar{G}_b$ relative to G_{max} = 60 ex./m^2 was 94 %. Thus, the ecological state of the soil can be characterized as disastrous. As a result of the study of soil invertebrates, the following groups of pedobionts were identified – representatives of the Diplopoda and Chilopoda classes, the Lumbricidae family, the Aranei series. The dominant among the trophic groups of mesopedobionts of the zone of industrial objects were the saprophages (75 %). Zoophages accounted for 25 % of the total number of soil invertebrates, while phytophages were absent at all. An increase in the number of predators is characteristic of the anthropogenically transformed territories of the city ecosystem.

The complex of saprophagous calciphylls is represented by two cenomorphic forms – stepants and sylvants. Their range of hygromorphs was within the boundaries from hygrophylls to xerophylls. Among the earthworms, alkalophilic lumbricides were dominant – endogeic stepants *Aporrectodea rosea*. This is due to the ability of these species to accumulate moving forms of heavy metals. In addition to earthworms, *Rossiulus kessleri* was found among saprophages (21.4 %). Predatory centipedes are represented by stepants mesophilus – *Geophilus proximus*.

Together with the representatives of the Aranei family, they form a complex of zoophages of this zone. Thus, in zone number 5 homogenization of groups of mesopedobionts was observed, which testifies to the presence of high level of soil contamination (Fig. 6).

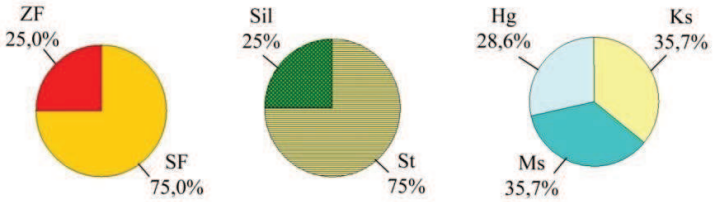

Figure 6 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the industrial zone (№ 5)

The ecological state of the soils of industrial zone number 1 is characterized as disastrous. The decrease in the vitality index of invertebrates was 86.5 % (G_b = 8.1 ex./m^2 relative to G_{max} = 60 ex./m^2). Among the soil invertebrates, representatives of the Lumbricidae, Helicidae and Aranei families were identified. The dominant group among trophomorphs was phytophagous (90.2 %). The number of trophomorphs of saprophages and zoophages was approximately the same (by 4.9 %). Representatives of the Lumbricidae family of the production facility area are represented by endogeic stepants *Aporrectodea rosea*. Representatives of the Aranei series form a complex of zoophages of this functional zone – 4.9 %.

The most numerous group of phytophages in the zone of the production facility were the representatives of the Helicidae family, represented by one cenomorph – xerophylic stepants (*Xerolenta obvia, Xeropicta derbentina*). In the industrial zone № 1 homogenization of the cenomorph composition of the mesopedobionts (stepants) is noted, which indicates a high level of soil contamination of the area (Fig. 7).

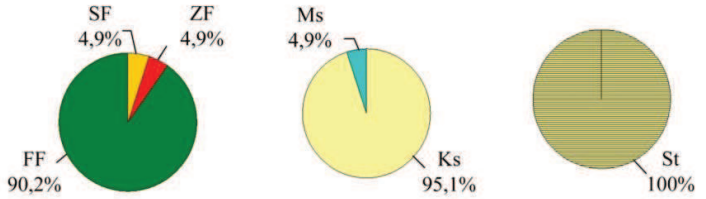

Figure 7 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the industrial zone (№ 1)

The ecological state of soils of zone number 12 is characterized as a crisis. The decrease in the vitality index of invertebrates was 66.3 % (G_b = 20.2 ex./m^2 relative to G_{max} = 60 ex./m^2). The proportion of saprophages decreased significantly. As a result of the study of soil invertebrates, representatives of the Lumbricidae, Helicidae, Limacidae, Geophilidae families and the Aranei series were identified. In all examined sites, the dominant group among trophomorphs were phytophages (92.9 %). Saprophages (3.1 %) are represented by endogeic stepants *Aporrectodea rosea*. Hygromorphs of earthworms contain hygrophylls and mesophylls. Reduction in the number of lumbricides may be due to the high content of the heavy metal (Pb, Cd, Zn and Cu) in the soil of this functional zone. The group of zoophages is represented by predatory centipedes (1.6 %) and several species of the Aranei class (2.4 %). The most numerous group were phytophages, whose spectrum of hygromorphs ranged from hygrophylls to xerophylls. In the open, dry areas of the zone stepants dominated – *Helix albescens, Xeropicta derbentina, Brephulopsis cylindrica* and *Chondrula tridens*. The latter was presented to a lesser extent. The complex of mollusks-calciphylls was supplemented by *Eobania vermiculata* and epigeic prathants *Limax ecarinatus*.

Thus, in the mesofauna of zone number 12, all investigated groups of soil invertebrates are present, except woodlice (Fig. 8).

Dendroflora of Transport Area № 11 was represented by *R. pseudoacacia, A. negundo, P. nigra, P. alba*. The decrease in the vitality index of invertebrates in this zone, G_b relative to G_{max} = 60 ex./m^2, was 78.3 %. Thus, the ecological state of the soil can be characterized as a crisis.

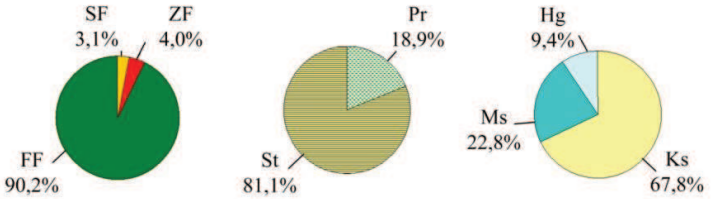

Figure 8 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the motorway zone (№ 12)

The following groups of pedobionts were found: representatives of the Diplopoda and Chilopoda classes, the Lumbricidae, Helicidae families and the row of Aranei. The dominant among trophic groups of mesopedobionts of the zone of production facilities were phytophages (84 %). Zoophages accounted for 6.1 %, and saprophages – 9.9 % of the total number of soil invertebrates. The complex of saprophagous calciphylls is represented by one cenomorphic form – stepants. However, the range of their hygromorphs is much broader – from hygrophylls to xerophylls. Saprophages are represented by the stepant *Dendrobaena nassonovi*, which is well adapted in alkaline medium and has the ability to accumulate moving forms of heavy metals. In addition to earthworms, the group of saprophages is represented by two-legged centipedes – xerophilic stepant *Rossiulus kessleri*. In the group of zoophages predatory centipedes *Geophilus proximus* and representatives of the Aranei series dominated. Among their hygromorphs meso- and xerophylls predominated. The group of phytophages, was the most numerous. It was characterized by a tendency for homogenization. It was represented by one cenomorph – *Xeropicta derbentina*, xerophilic stepant.

Thus, in zone number 11 there was a clearly expressed domination of one cenomorph (stepant), which confirms the degradation of the soil of this functional zone (Fig. 9).

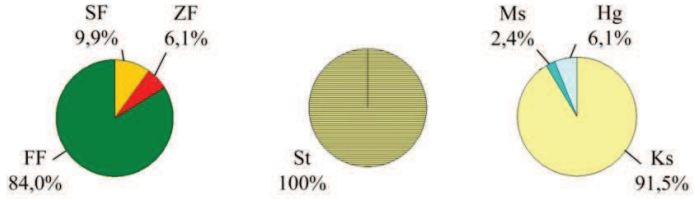

Figure 9 – The trophic, ceno- and hygromorphic spectrum of the animal population of the motorway zone (№ 11)

The basis of the dendroflora of the functional zone № 15 is *A. negundo, Fraxinus excelsior, P. nigra, P. alba*. Decrease of the vitality index of invertebrates in this functional zone, G_b relative to G_{max} = 60 ex./m^2, was 40.2 %. Thus, the ecological state of the soil can be characterized as critical. In this functional zone, all groups of invertebrates were present: representatives of the Diplopoda and Chilopoda classes, the Helicidae, Limacidae, Bradybaenidae, Lumbricidae families, the rows of Aranei, Isopoda. Dominant trophic groups of mesopedobionts of the residential development area were saprophagous (48.3 %) and phytophagous (46 %). Zoophages accounted for 5.7 % of the total number of soil invertebrates. The complex of saprophages is represented by worms, centipedes and woodlice. Cenomorphic forms are stepants, prathants and polludants. The range of their hygromorphs was within the boundaries from ultra-hygrophylls to mesophylls. Among lumbricides, epigeic, endogeic and norni forms were detected. The *Dendrobaena nassonovi* stepant has a high ability to accumulate cadmium and lead, which confirms the excess of background data of the moving forms of heavy metals. The saprophages, in addition to earthworms, were represented by *Rossiulus kessleri* and *Megaphyllum rossicum*. However, the number of two-legged centipedes was insignificant. The trophic group of saprophages also includes polytop mesophilus *Armadillidium vulgare*, which is common in urbanized habitats. The zooophagous complex was represented by stepant mesophilus – *Geophilus proximus* (3.4 %) and representatives of the Aranei series (2.3 %). Numerous groups were phytophages, whose spectrum of hygromorphs ranged from hygrophylls to mesophylls.

The complex of mollusks of this functional zone was represented by the epigeic prathant *Limax sp.*, as well as representatives of the Helicidae families.

Thus, in the residential area, a variety of the mesomorphic composition of the mesopedobionts is noted, which indicates the satisfactory condition of the soil in the territory (Fig. 10).

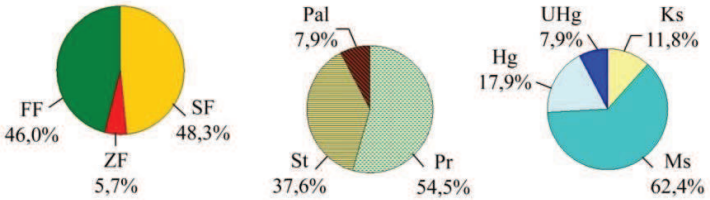

Figure 10 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the residential area (№ 15)

The decrease in the vitality index of mesopedobionts in zone № 7, G_b relative to G_{max} = 60 ex./m^2, was 50 %. Thus, the ecological state of the soil can be characterized as critical. Among the mesopedobionts, representatives of the Diplopoda, Helicidae, Limacidae, Bradybaenidae, Thomisidae, Lumbricidae, Aranei, Isopoda families were identified. The dominant trophic group of soil invertebrates of this functional zone was saprophages (63.6 %), with the share of phytophages accounting for 35.8 %. The least number of groups were zoophages (less than 1%). Saprophages are represented by worms, centipedes and woodlice, among which two of the cenomorphic forms – stepants and prathants, dominated. The range of their hygromorphs ranged from mesophylls to xerophylls.

In addition to earthworms (25.2 %), a complex of saprophagous calciphylls contained a two-legged centipedes *Rossiulus kessleri* (15.9 %) and woodlice *Armadillidium vulgare* (22.5 %), which belong to the polytope mesophilic group. A representative of the Thomisidae family (0.6 %) was noted among zoophages. Quite a large group were phytophages represented by the epigeic prathant *Limax ecarinatus*, the mesophilic stepant *Chondrula tridens*, and widely distributed in the area snail *Monacha fruticicola*. Despite the fact that in zone number 7 there

were all groups of mesopedobionts, their cenomorphic composition was characterized by a high level of homogenization, which may indicate degradation of the soil (Fig. 11).

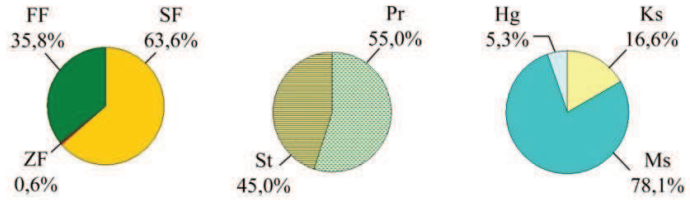

Figure 11 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the residential area (№ 7)

The ecological state of soils № 9 is characterized as disastrous. The decrease in the vitality of invertebrates was 93 % (G_b = 4.2 ex./m^2 relative to G_{max} = 60 ex./m^2). As a result of the study of mesopedobionts, representatives of the Diplopoda, Chilopoda, Lumbricidae, Helicidae, Aranei families were identified.

In all examined areas, the dominant group among trophomorphs were phytophages (71.4 %). The number of zoophages was 19.1 %, and the saprophages – 9.5 %. The group of zoophages in comparison with control has increased significantly, which indicates a strong anthropogenic transformation of the biotope of this zone. The saprophages of the zone are represented by earthworms of the Lumbricidae family and xerophilic stepant *Rossiulus kessleri*.

Herbivores mesopedobionts is the most numerous group of this territory. They are represented by two cenomorphs – xerophilic stepant *Xerolenta obvia* and mesophilic prathant *Brephulopsis cylindrica*. Lumbricides, together with mollusks and centipedes-saprophages, form a complex of calciphylls. The group of zoophages of this functional zone, besides the endogeic dugout, is composed of representatives of the Aranei series.

Thus, it should be noted that in zone number 9, 4 of the 5 groups of mesopedobionts, which are studied, are marked, but they are characterized by small numbers and are mainly

represented by two cenomorphs – stepants and prathants. This once again confirms the disastrous ecological state of the soils of this zone (Fig. 12).

Figure 12 – Spectrum of trophic, ceno- and hygromorphs of the animal population of the residential area (№ 9)

Flora of functional zone № 2 contains a large variety of trees and shrubs, and is represented by *R. pseudoacacia, Ailanthus altissima* (Mill.) Swingle*, A. negundo, Salix babulonica* L.*, Platanus orientalis* L., several species of *Syringa* L.*, Quercus* L.*, Jasminum* L.*, Tilia cordata* Mill.*, Caragana arborescens* Lam.*, Juniperus virginiana* L.*, Juniperus Sabina* L.*, Platycladus orientalis* (L.) Franco*, P. sylvestris, Picea pungens* Engelm. Also in the dendroflora of the city there are *Catalpa bignonioides* Walt., *Elaeagnus angustifolia* L., *Morus nigra* L., *Populus bolleana* Lauche, *P. alba* L.

Decrease of vitality index of invertebrates in this zone is noted, G_b relative to G_{max} = 60 ex./m^2, was 24.7 %. Thus, the ecological state of the soil can be characterized as stressful. As a result of the study of soil invertebrates, representatives of the Lumbricidae, Limacidae, Helicidae, Bradybaenidae, Aranei, Isopoda, and Diplopoda families were identified. In all investigated areas, the dominant among trophic groups were saprophages (55.3) and phytophagous (41.9 %). The smallest group is represented by zoophages (2.8 %). The complex of saprophages is quite broad, and includes the cenomorphic forms of prathants, stepants, sylvants and polludants. The range of their hygromorphs is within the boundaries from ultra-hygrophylls to xerophylls. Among the saprophagous lumbricides the endogeic prathants *Aporrectodea trapezoides*, norni stepants *Dendrobaena nassonovi* and endogeic sylvants *Octolasion lacteum* were found. The range of their hygromorphs was within the boundaries from ultrahygrophylls to mesophylls. In addition to earthworms, the

trophic group of saprophages consists of the woodlice *Trachelipus rathkii* and the two-legged centipedes *Rossiulus kessleri*. In addition, *Armadillidium vulgare* is widespread in this area. A group of zoophages is small, but it includes several species of the Aranei series. Along with saprophages, phytophages is a numerous and diverse group among mesopedobionts of zone 2. They are represented by epigeic prathant (*Limax ecarinatus*), stepant (*Helix albescens*) and shrub snail *Fruticicola fruticum*. The range of hygromorphs of gastropods was within the limits of the hygrophylls and the mesophylls. Thus, in the mesofauna of the recreational zone, all five groups of invertebrates, characterized by a considerable diversity of the cenomorphic composition, were found. This is the evidence of a good state of soils in this functional zone (Fig. 13).

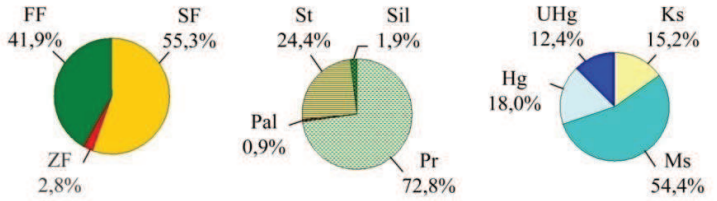

Figure 13 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the recreational zone (№ 2)

The ecological condition of soils of the functional zone number 6 is assessed as a stressful one. The decrease in the vitality index of invertebrates was 24,3 % (G_b = 45,4 ex./m^2 relative to G_{max} = 60 ex./m^2). As a result of the study of mesopedobionts, representatives of the Lumbricidae, Bradybaenidae, Limacidae, Helicidae, Aranei, Isopoda families, Diplopoda and Chilopoda classes were identified. In all examined sites, the dominant group among trophomorphs were phytophages (62.4 %). Saprophages accounted for 33.9 % of the total mesopedobionts. The group of zoophages is the smallest (3.7 %). The complex of saprophages is represented by the following cenomorphs: prathants, stepants and sylvants. The range of their hygromorphs varies from hygrophylls to xerophylls. However, most of them are mesophylls.

Earthworms are the dominant group in the saprophage complex and are represented by the endogeic stepant *Aporrectodea rosea*, endogeic sylvant *Octolasion lacteum* and endogeic prathant *Aporrectodea trapezoides*. In the spectrum of their hygromorphs mesophylls dominate. This may be due to periodic irrigation of the investigated object. The group of saprophages is complemented by the polytope mesophilus *Armadillidium vulgare* and the two-legged centipedes *Megaphyllum rossicum*. Woodlice and chickpeas form a complex of calciphylls, which group is small in the weakly acidic medium (10.4 %).

Phytophages is a numerous and diverse group among the invertebrates of this area, and are represented by several species of gastropods from the Bradybaenidae, Limacidae, Helicidae families. Their range of hygromorphs varies from hygrophylls to mesophylls. The complex of zooophagous animals is represented by several species of spiders and a predatory centipedes Lithobius curtipes. The latter is epigeic prathant and prefers well-moisturized edaphotops.

Thus, all five groups of soil invertebrates have been identified in the mesofauna zone № 6. Despite the fact that according to the indicator of vitality, the ecological status of soils is evaluated as tense, it may indicate the relative well-being of the soil (Fig. 14).

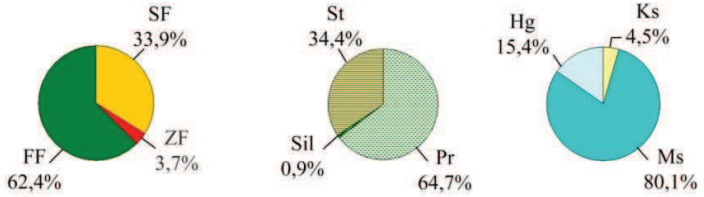

Figure 14 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the recreational zone (№ 6)

The decrease in the vitality index of mesopedobionts in zone № 4 (G_b relative to G_{max} = 60 ex./m^2) was 22.5 %. Thus, the ecological state of the soil can be characterized as stressful. Representatives of the Lumbricidae, Limacidae, Helicidae, Enidae, Aranei, Isopoda, and Diplopoda families were found. In

all examined areas, the dominant among trophic groups were saprophages (59.4 %). Phytophages accounted for 39% of the total number of mesopedobionts. The smallest group is represented by zoophages (1.6 %). The complex of saprophages consists of such cenomorphic forms: prathants, stepants and polludants, which are characterized by a wide spectrum of hygromorphs – from ultrahygrophylls to xerophylls.

Earthworms are represented by endogeic prathants *Aporrectodea trapezoides* and endogeic stepants *Aporrectodea rosea*. In addition to earthworms, the trophic group of saprophagous calciphylls includes the two-legged centipedes *Rossiulus kessleri* and woodlice *Armadillidium vulgare*. A small group of zoophages includes several species of the Aranei series. Varieties of phytophages were mollusks, represented by two cenomorphs – prathants (*Limax ecarinatus*) and stepants (*Xerolenta derbentina, Chondrula tridens*). The range of hygromorphs of mollusks in this zone was within the limits from hygrophylls to xerophylls.

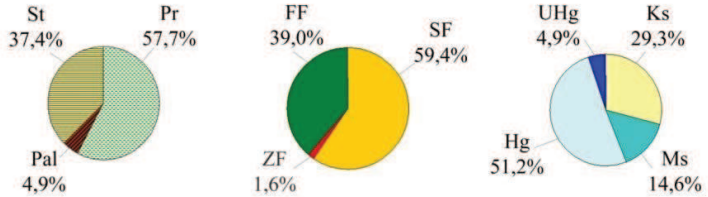

Figure 15 – The spectrum of the trophic, ceno- and hygromorphs of the animal population of the residential area (№ 4)

Table 3 – Bioindicative estimates of the soil cover of the city of Melitopol

Coordinates	Total indicator of soil contamination, Z_c	Category of soil contamination	Indicator of vitality of mesopedobionts	Ecological condition of the territory
1	**2**	**3**	**4**	**5**
46°50'48.4"N, 35°23'28.5"E	122,90±3,28	dangerous	0,15±0,04	disastrous

Table 3 (cont'd)

1	2	3	4	5
46°51'08.8"N, 35°22'31.3"E	6,29±0,38	dangerous	0,50±0,07	disastrous
46°50'59.0"N, 35°20'40.3"E	101,95±3,32	dangerous	0,04±0,01	disastrous
46°51'51.5"N, 35°23'26.5"E	17,07±0,33	permissible	0,52±0,07	strained
46°49'05.6"N, 35°18'06.6"E	107,81±2,65	dangerous	0,06±0,01	disastrous
46°49'48.4"N, 35°21'31.4"E	12,75±0,22	permissible	0,50±0,07	strained
46°50'21.4"N, 35°21'59.1"E	10,14±0,20	permissible	0,33±0,05	strained
46°50'30.9"N, 35°22'33.0"E	8,48±0,23	permissible	0,51±0,06	critical
46°52'02.7"N, 35°19'24.5"E	45,69±0,84	permissible	0,06±0,01	strained
46°49'26.1"N, 35°21'01.5"E	16,92±0,30	permissible	0,45±0,06	critical
46°49'38.5"N, 35°19'21.6"E	31,46±0,68	moderately dangerous	0,18±0,03	crisis
46°49'00.0"N, 35°22'51.1"E	70,28±1,07	dangerous	0,28±0,04	crisis
46°49'05.3"N, 35°22'37.4"E	32,07±0,86	moderately dangerous	0,35±0,06	crisis
46°53'09.2"N, 35°20'36.7"E	3,68±0,08	permissible	0,60±0,09	critical
46°52'15.3"N, 35°25'00.9"E	11,97±0,56	permissible	0,40±0,05	favorable

Thus, it should be noted that in zone number 4 all the studied groups of mesopedobionts are represented by three cenomorphs – stepants, polludants, prathants. Moreover, the latter were significantly overwhelming. This is confirmed by the strained ecological state of the soils of this zone (Fig. 15).

Conclusions

1. The presence of the heavy metals in the soil of contaminated functional zones of urbosystem causes decrease of activity, reduction of quantity and biodiversity and transformation of the ecomorphic structure of the populations of soil invertebrates. It was established that increasing the level of pollution of edaphotops by heavy metals in one case causes the depression of the vitality of certain groups of saprophages

(representatives of the Isopoda class, the Enidae, Helicidae families), in the other – the activation of their vitality (representatives of the Diplopoda and Chilopoda classes, the Lumbricida family and the Aranei row).

2. The peculiarities of ecomorphic structure and patterns of spatial-temporal dynamics of the distribution of terrestrial malacafeon groups should be used for bio-diagnostics of the ecological state of edaphotops.

3. According to the bio-diagnostic assessment and ecomorphic analysis of groups of pedobionts, functional areas with disastrous (26.7 %), strained (26.7 %), critical (20 %), crisis (20 %) and favorable (6.6 %) ecological conditions of the territory were established.

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БІОДІАГНОСТИКА МІСЬКИХ ҐРУНТІВ УРБОСИСТЕМИ МЕЛІТОПОЛЯ НА ОСНОВІ АНАЛІЗУ ЕКОМОРФІЧНОЇ СТРУКТУРИ МЕЗОФАУНИ

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У статті представлені результати біодіагностичної оцінки стану міських ґрунтів на основі аналізу екоморфічної структури мезопедобіонтів.

Використання ґрунтових безхребетних дозволяє швидко оцінити якість ґрунтового середовища. Екологічно небезпечні чинники середовища обумовлюють зміну умов існування мезопедобіонтів. У залежності від інтенсивності антропогенного навантаження, виділяють три типи динаміки угруповань безхребетних тварин, які адаптуються до існування в критичному стані. Таким чином, просторовий розподіл ґрунтової мезофауни виступає важливою біодіагностичною ознакою. Для підвищення ефективності біодіагностики важливо застосовувати доступні засоби

відстеження за функціонуванням комплексів мезопедобіонтів у трансформованому ґрунті. Експериментальна частина роботи виконувалася в місті Мелітополі Запорізької області. Програмою досліджень була передбачена біодіагностична оцінка екологічного стану едафотопів Мелітополя, на основі аналізу екоморфічної структури ґрунтової мезофауни. За результатами було встановлено, що наявність у ґрунтах забруднених функціональних зон урбосистеми важких металів зумовлює зниження активності, зменьшення кількості, скорочення біорізноманіття та трансформацію екоморфічної структури популяцій ґрунтових безхребетних тварин. Визначено, що збільшення рівня забруднення едафотопів важкими металами в одному випадку викликає депресію життєвості окремих груп сапрофагів (представників класу *Isopoda*, родин *Enidae, Helicidae*), в іншому – активізацію їх життєвості (представники класів *Diplopoda* та *Chilopoda*, родини *Lumbricida* та ряду *Aranei*). Виявлено, що особливості екоморфічної структури та закономірності просторово-часової динаміки розповсюдження угруповань наземної малакофауни доцільно використовувати для біодіагностики екологічного стану едафотопів. За даними біодіагностичної оцінки та екоморфічного аналізу груп педобіонтів встановлені функціональні зони з катастрофічним (26,7 %), напруженим (26,7 %), критичним (20 %), кризовим (20 %) та сприятливим (6,6 %) екологічним станом території.

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ADDITION TO ANALYSIS OF MORPHOLOGICAL PARAMETERS OF MINES ON TWO INVASIVE LEAF-MINING LEPIDOPTERA SPECIES (*PARECTOPA ROBINIELLA* CLEMENS, 1863 AND *PHYLLONORYCTER ROBINIELLA* CLEMENS, 1859) ON BLACK LOCUST

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