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Impact of military activities on the biogenicity of southern chernozem

Abstract. Among a number of significant problems that have arisen as a result of military operations on the territory of Ukraine is the degradation of soils, which requires finding ways to accelerate the processes of their recovery after damage. The purpose of the study was to assess the biogenicity indicators of the state of southern chernozem and low-humus sands under military influence and the use of a recovery complex, which consisted of organic fertiliser Parostok and

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bacterial-metabolic preparation Ultrachist. The research methods included laboratory analysis of samples using microbiological seeding on media suitable for microorganisms of ecological-trophic, functional, and taxonomic groups, and statistical data processing to determine the reliability of discrepancies. The conducted studies indicated a significant negative impact on the density of populations of soil microorganisms of southern chernozem from rocket hits and low-humus sands from fires as a result of military operations. The number of representatives of the native microbiota in soils has tripled after the military impact. The biogenicity indicators of southern chernozem and low-humus sands decreased by 7.7 and 4.9 million CFU/g of dry soil (2.6 and 2.3 times), respectively, compared to the control. The restoration complex contributed to the growth of soil biogenicity in all variants of the experiment. In the damaged samples, the increase in indicators under the action of the recovery complex was higher than in the control samples. The use of the recovery complex in the background southern chernozem conditions increased the biogenicity of the soil by 4.2 times, and after a missile hit – by 6.1 times. In the slightly humus-rich sands of forest lands under the influence of the restoration complex, an increase in its biogenicity was observed by 1.9 times, while in the sample after pyrogenic exposure by 9.9 times. The proposed recovery complex based on organic matter and beneficial microorganisms can be considered as a stabilisation factor that will activate the microbiota of degraded soil for the restoration of soil ecosystems

Keywords: soil microorganisms; low-humus sands; impact of military operations; degradation of the microbiocoenosis; recovery complex

INTRODUCTION

Chernozem soils are unique in their morphological, physical, and chemical characteristics and perform versatile functions, in particular, productive, biospheric, ecological, and social. The military actions of recent years have affected all links of ecosystems on the territory of Ukraine. The negative consequences of military influence on the condition of soils are associated with mechanical damage to their natural structure, the ingress of chemicals, in particular heavy metals and petroleum products, which leads to long-term deterioration of soil quality and loss of its productive properties. First of all, the soil microbiota responds to changes in conditions, which is a key component of ecosystems and an indicator of soil condition. Studies of soil microorganisms are relevant, as they allow assessing the processes occurring in degraded soils, and the search for ways to increase microbiological activity will improve the condition of the soil and, as a result, restore soil ecosystems.

Studies of the soils of Ukraine after a full-scale invasion and intensification of military operations show that more than 5 million hectares of chernozems alone have undergone military degradation, as noted by S. Balyuk *et al.* (2023) and S. Balyuk *et al*. (2025). O. Dmitrenko *et al.* (2023) in their research showed that soil degradation due to the use of mortar weapons was confirmed by the presence of heavy metals after a year of observations. The damage caused by the war to the environment reaches tens of billions of USD (Hryhorczuk *et al.*, 2024). Soils that have been degraded as a result of destruction, fires, chemical and other types of pollution require active actions in finding ways to restore them.

The role of both aerobic and anaerobic microorganisms in bioremediation of heavy metal-contaminated soils is known, which is based on the ability of some representatives of the microbiota to absorb, deposit, or change the valence of heavy metals, which allows reducing their concentration in the soil to a safe level (Abo-Alkasem *et al.*, 2023; Galkin *et al.*, 2024). A. Danial & F. Dardi (2023) proved that there are known bacteria that have the ability to biosorb metals, which reduces their movement and toxicity in the soil. The study by A. Johnsen *et al.* (2021) pointed to the ability of destructive microorganisms to promote the restoration of diesel-contaminated soils even at low temperatures.

The soil microbiota is sensitive to various factors, so it is an indicator of changes that occur under their influence (Goulart *et al.*, 2025). Soil biogenicity is one of the most important indicators of the activity of microbiological processes of metabolism and energy in the trophic chains of the soil biocoenosis. Therefore, increasing the activity of the soil microbiota is an important area of research that has great prospects in solving the problem of restoring degraded soils, research aimed at restoring microbiological balance is particularly relevant, since it is microorganisms that are the initial link in restoring trophic connections in soil ecosystems.

Since the natural processes of reclamation of contaminated soils are long-term and often insufficiently effective, there is a need to use biological means that can accelerate these processes. The paper by V. Vakhnyak *et al.* (2025) emphasised that the restoration of degraded soils is a strategically important factor in ensuring the country's food security, especially in the face of increasing anthropogenic and military loads. The researchers proved that degradation processes negatively affect not only soil fertility, but also the stability of agroecosystems in general, so the introduction of effective biological methods of restoration is key to preserving the productive potential of chernozems. The paper noted the expediency of using organic and biological preparations that can activate microbiological processes, improve the structure of the soil and restore its ecological functions. It is known that the use of organic fertilisers in combination with microbial preparations has a positive effect on the activation of the soil microbiota and accelerates the restoration of biological balance in degraded ecosystems.

Therefore, the purpose of the study was to evaluate the effectiveness of combined application of organic fertiliser Parostok and biological preparation Ultrachist in restoring damaged and contaminated soils, in particular, by stimulating microbiological processes, increasing biogenicity, and improving the physical and chemical properties of chernozems. The objective of the study was to determine the extent to which these preparations can enhance the metabolic activity of soil microbiota, promote the detoxification of pollutants, and restore the natural productivity of soil, which is crucial for the rehabilitation of ecosystems affected by military operations.

MATERIALS AND METHODS

The study was conducted during 2023-2024, which allowed tracing the dynamics of recovery processes in soils after applying organic fertilisers and biologics. Organic fertiliser Parostok was used to restore and increase humus reserves, improve the phytosanitary condition of soils, and reduce the negative anthropogenic impact of chemical pollutants. It accumulated a large number of macro- and microelements, biologically active substances, and a balanced symbiotic consortium of effective microorganisms. In turn, the biologic Ultrachist is a bacterial and metabolic agent containing highly effective natural strains of microorganisms, which in a stable symbiosis with each other can decompose pesticides, toxic and explosive substances, and hydrocarbons of oil and petroleum products. It was designed for detoxification and remediation of environments contaminated with organic and chemical substances. In addition, the biological product acts not only as a direct destructor of pollutants, but also as an activator of biological destruction, since it can stimulate the native microbiota, which accelerates processes several times. The study took into consideration the impact on the environment, as outlined in the Universal Declaration on Bioethics and Human Rights (2005).

The research was conducted at the Ukrainian Laboratory for Quality and Safety of Agricultural Products at the National University of Life and Environmental Sciences of Ukraine. Soil sampling from locations that represented different types of environmental violations was carried out in the Mykolaiv region: southern chernozem from residential territory of Snihurivka Territorial Community and soil contaminated with pesticides as a result of a rocket hit in a warehouse with toxic chemicals; low-humus sands of the Halytsynove forest and forest lands after fires as a result of armed conflict. Organic fertiliser Parostok, supplemented with bacterial-metabolic biological product Ultrachist, was used as a restoring complex (RC). The model experiments were conducted in triplicate in 500 cm^3 vessels with 0.3 kg of soil and the calculation of preparations in accordance with the recommended application rate: organic fertiliser Parostok – 4 t/ha, Ultrachist – 10 cm^3 of working solution per

1 dm^3 of soil. Microbiological seeding was carried out after 7 days of composting at a temperature of 25°C and humidity of 55-70%. The study was conducted according to the following scheme: control 1 – residential areas near the zone affected by rocket strikes; pesticide contamination due to rocket strikes on a pesticide storage facility in a residential area; control 2 – forest land that did not undergo pyrogenic impact; forest land after fires caused by armed conflict. RC was added to each of the options.

The number of microorganisms of various taxonomic (bacteria, including actinobacteria, and microscopic fungi (micromycetes) and ecological and trophic groups (pedotrophic, ammonifying, amylolytic, oligotrophic, oligoazotrophic microorganisms, etc.) was determined by seeding soil cultures on appropriate nutrient media. For the total number of bacterial coenosis (pedotrophs) – soil agar was used, ammonifiers – meat-peptone agar, oligoazotrophs – Ashby medium, amylolytics – starch-ammonia agar, phosphatmobilisers – Menkina medium, oligotrophs – starvation agar, humatrophs – humate agar, actinobacteria – potato-glucose agar, micromycetes – Czapek medium. The composition of media was generally accepted in soil microbiology (Volkogon *et al.*, 2010). The number of microorganisms was expressed in colony-forming units (CFU) per 1 g of absolutely dry soil. The humidity of soil samples was determined by the thermostatic-weight method to recalculate the obtained number of colonies at a certain dilution of soil suspension. Mathematical statistics methods were used to calculate the confidence interval of the number of microorganisms.

Assessment of the course of processes occurring in the soil was determined using microbiological indicators of total biological activity (biogenicity = cultural nitrogen-fixing activity (NFA) + mineralising activity (MPA) + Ashby bacteria (Ashby) + humate-decomposing microorganisms (HA), mln CFU/g of dry soil), nitrogen pool mobilisation coefficient (KMAF = (MPA + NFA) / (Ashby + HA)) (Rieznik, 2021), mineralisation coefficients and indices and nitrogen immobilisation (K min = NFA / MPA), oligotrophy (K olig = HA / MPA), oligoazotrophy (K oligaze = Ashby / MPA).

RESULTS AND DISCUSSION

Soil damage as a result of military operations led to a decrease in the population density of the ecological-trophic and taxonomic groups of microorganisms under study. The native microbiota of southern chernozem decreased by 3.4 times due to a rocket hit on an agrochemical warehouse (Table 1). Pyrogenic effects on the low-humus sands of the Halytsynove forest also affected a decrease in the number of pedotrophs, three times compared to the control.

Table 1. Number of microorganisms of the main ecological, trophic, and taxonomic groups in soil samples

A)

Variant	Number of microorganisms by group, million CFU/g of dry soil				
	ammonifying	amylolytic	pedotrophic	phosphate mobilising	oligoazotrophic
Control 1 – background soil near the area affected by rocket impact	1.9±0.02	1.3±0.08	2.7±0.22	0.4±0.01	3.9±0.22
Control 1 + Recovery Complex (RC)	13.8±0.11	11.5±1.76	15.7±0.15	21.9±0.16	17.5±0.45
Contaminated with pesticides and explosives after a rocket hit	2.1±0.05	0.3±0.03	0.8±0.07	0.5±0.05	0.5±0.05
Contaminated with pesticides and explosives + RC	12.2±0.49	1.4±0.01	6.1±0.33	13.7±0.46	3.1±0.15
Control 2 – forest areas (background – in the absence of fire exposure)	0.2±0.01	2.0±0.09	0.9±0.06	0.2±0.02	2.1±0.06
Control 2 + RC	4.1±0.3	3.3±0.04	6.6±0.2	1.5±0.09	4.6±0.23
Forest lands after fires	0.6±0.02	0.1±0.01	0.3±0.03	0.4±0.03	0.2±0.02
Forest lands after fires + RC	12.6±0.07	6.9±1.62	9.7±0.26	8.0±0.43	8.8±0.21

Table 1, Continued

B)

Variant	Number of microorganisms by group				
	million CFU/g of dry soil		thousand CFU/g of dry soil		
	oligotrophic	humate-decomposing	cellulolytic	actinobacteria	micromycetes
Control 1 – background soil near the area affected by rocket impact	5.5 ± 0.52	4.7 ± 0.30	30.9 ± 3.69	359.4 ± 6.67	32.1 ± 0.58
Control 1 + Recovery Complex (RC)	10.9 ± 0.11	16.0 ± 0.53	34.9 ± 0.75	1.061.5 ± 5.29	80.7 ± 22.28
Contaminated with pesticides and explosives after a rocket hit	2.0 ± 0.19	3.5 ± 0.59	6.1 ± 0.11	38.4 ± 1.53	24.5 ± 1.0
Contaminated with pesticides and explosives + RC	13.5 ± 0.86	7.0 ± 0.30	15.6 ± 0.75	254.2 ± 13.7	13.8 ± 1.15
Control 2 – forest areas (background – in the absence of fire exposure)	4.4 ± 0.16	2.6 ± 0.06	13.6 ± 1.56	43.2 ± 1.53	90.6 ± 1.53
Control 2 + RC	4.6 ± 0.07	5.6 ± 0.40	27.7 ± 1.33	335.1 ± 2.65	135.0 ± 2.52
Forest lands after fires	2.9 ± 0.46	1.5 ± 0.06	3.1 ± 0.09	97.2 ± 5.57	119.6 ± 0.58
Forest lands after fires + RC	9.2 ± 0.39	10.1 ± 0.33	13.7 ± 1.32	269.6 ± 1.15	100.6 ± 5.51

Source: compiled by the authors

Studies of the effect of the proposed recovery complex on the number of microorganisms revealed significant changes in indicators that depended on the initial sample (Table 1). All groups of microorganisms that showed an increase in their number, especially in damaged soils, were sensitive to the introduction of the recovery complex. Thus, the number of microorganisms that absorb organic nitrogen in soil contaminated with pesticides and explosives under the action of RC increased by 5.8 times and by 21 times in samples of forest land after fires. The same trends of increase of 4.6 and 69 times, respectively, were observed in the number of microorganisms that assimilate mainly mineral forms of nitrogen, and in the pedotrophic microbiota, where the increase in their number was 7.6 and 32.3 times, respectively, when using the recovery complex. Exceptions were groups of ammonifying and phosphatmobilising microorganisms in the organic-depleted soil of forest lands under the influence of fires.

The reaction of microorganisms capable of converting soil phosphates was different with a negative military effect, while the addition of RC also contributed to a 27.4-fold increase in their numbers in relation to contaminated soil and a 20-fold increase in forest land after fires. Diazotrophs play an important role in the nitrogen cycle. Their introduction into agrocoenoses is one of the priorities of agricultural microbiology (Kozar, 2021). The sensitivity of nitrogen-fixing bacteria to contamination affected their number by a decrease of 7.8 times, while the addition of RC brought the indicators closer to the background soil (3.1 million CFU/g of dry soil). Forest fires reduced their number in low-humus sandy soil by 10.5 times, and RC provided an increase of 44 times compared to the control.

The missile hit, which caused contamination of southern chernozem with pesticides, affected a decrease in the number of oligotrophs and humate-decomposing microorganisms by 2.7 and 1.3 times, respectively (Table 1B). The recovery complex contributed to an increase in the number of microorganisms of these groups by 6.7 and 2.0 times, respectively, compared to contaminated soil. Fires of forest lands also negatively affected their number, while under the action of RC, there was an increase in indicators by 3.1 and 6.7 times, respectively, compared to damaged soil.

An important role in enriching soils with organic matter is played by microorganisms that have the ability to decompose cellulose. Highly active cellulolytic microorganisms that have a complex of useful properties, in particular protective action, are potential bioagents of drugs for use in environmentally friendly agricultural technologies. When using the reducing complex, the number of microorganisms that decompose cellulose increased in controls 1 and 2 by 1.1 and 2 times, while in damaged soils this increase was more significant and amounted to 2.6 and 4.4 times, respectively. In the soils of controls 1 and 2, when exposed to VC, there was also an increase in the number of micromycetes by 2.5 and 1.5 times, respectively, while in damaged samples it was observed to decrease.

Actinobacteria are an important component of the soil microbiota, have a wide range of beneficial properties and are widely used in biotechnology, as noted by I. Levchuk *et al.* (2022) and M. Loboda *et al.* (2024). Among this taxonomic group, there are representatives that are able to decompose resistant herbicides that are dangerous to the environment, and thus act as potential bioremediation agents (Rebai *et al.*, 2024). Under conditions of pollution, there was a significant decrease in their number by 9.4 times to the background soil, but the introduction of a recovery complex stimulated their partial recovery by 6.6 times to the contaminated soil.

No less important is the ecological role of actinobacteria in soil recovery after fires. S. Jiang *et al.* (2025) in their studies showed that in soils exposed to pyrogenic effects, actinobacteria can become dominant. In forest soils after fires caused by armed conflict, their numbers were higher than the background level, reaching 97,200. CFU/g of dry soil, which increased 2.8 times under the action of RC. The negative impact of the missile hit affected a decrease in the biogenicity of southern chernozem by 7.7 million CFU/g of dry soil and 2.6 times compared to control 1 (Fig. 1). Fires as a result of military operations at the location of the Halytsynove forest also significantly reduced the biogenicity of low-humus sands by 4.9 million CFU/g of dry soil, which was 2.3 times in relation to control 2.

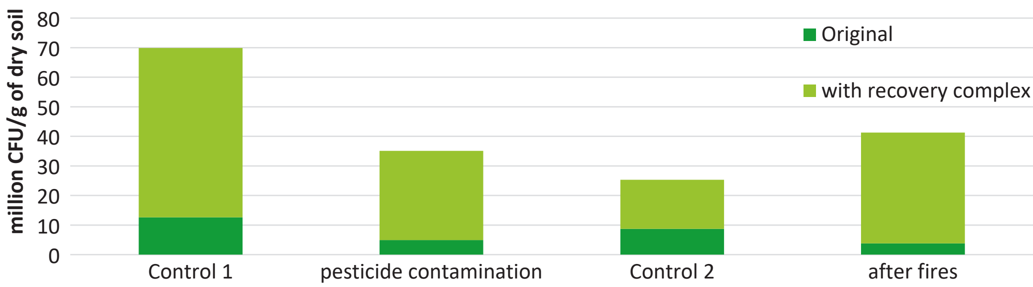

Figure 1. Soil biogenicity under military action
and the use of a recovery complex, million CFU/g of dry soil

Note: control 1 – southern chernozem near the zone of impact of a missile hit in a warehouse with agrochemicals; control 2 – low-humus sands of forest land with no impact from fires

Source: compiled by the authors

The restoration complex contributed to the growth of soil biogenicity in all variants of the experiment. In addition, the growth rate was higher in the damaged samples than in the control soil. Thus, RC in the conditions of background southern chernozem (control 1) provided an increase in soil biogenicity by 4.2 times, while after a missile hit – by 6.1 times. The same trends, but with a larger gap, were also observed in low-humus forest fands: 1.9 times in control 2 and 9.9 times in samples after fires as a result of armed exposure. One of the most important indicators of the biological component of soil is microbial biomass, which also responds sensitively to changes occurring in the pedosphere. The military impact affected the reduction of biomass of soil microorganisms, while the recovery complex reduced the negative impact of factors (Melnychuk *et al.*, 2025). Biogenicity is closely related to microbial biomass values, as evidenced by the Pearson correlation coefficient, which was in the range of 0.68 in control 2 with the addition of RC to 1 in samples of low-humus forest sands after fires as a result of armed exposure.

The calculation of indices allows assessing the intensity and course of processes occurring in soils under the influence of certain factors. The military impact caused a violation of the direction of microbiological processes of the studied soils, which affected a decrease in the indicators of most indices and coefficients. The coefficient of mineralisation and immobilisation in southern chernozem was at the level of 0.68, pollution caused its decrease by 4.9 times, which indicates the suppression of mineralisation processes (Table 2).

Table 2. Orientation of microbiological processes in soil samples

Variant	Indexes and coefficients					
	pedotrophicity	oligotrophicity	mineralisation and immobilisation	oligoazototrophicity	mobilisation of nitrogen reserves	microbial transformation of organic matter
Control 1 – background soil near the area affected by rocket impact	1.42	2.89	0.68	2.05	0.34	4.67
Control 1 + recovery complex (RC)	1.14	0.79	0.83	1.27	0.89	30.36
Contaminated with pesticides and explosives after a rocket hit	0.38	0.95	0.14	0.23	0.96	168.8
Contaminated with pesticides and explosives + RC	0.50	1.11	0.11	0.25	0.82	118.51
Control 2 – forest areas (background – in the absence of fire exposure)	4.5	22.0	10.0	10.5	0.34	0.22
Control 2 + RC	1.61	1.12	0.80	1.12	0.8	9.19
Forest lands after fires	0.50	4.83	0.17	0.33	0.23	4.2
Forest lands after fires + RC	0.77	0.73	0.55	0.7	1.08	35.6

Source: compiled by the authors

The introduction of the complex contributed to an increase in the coefficient of mineralisation and immobilisation by 3.2 times in conditions of low-humus sands damaged by fires as a result of military operations, which indicates the activation of the nitrogen cycle. Contamination with pesticides and explosives after a missile hit had a different effect on the coefficients of nitrogen reserves mobilisation and microbial transformation of organic matter, where the increase in indicators was 2.8 and 35.7 times, respectively. The use of the recovery complex has somewhat stabilised the situation, with low indicators increasing and decreasing at high indicators.

The soil microbiota is an important component of healthy ecosystems and can play an essential role in restoring degraded soils, contributing to increasing their biodiversity, functionality, and sustainability (Peddle *et al.*, 2025). T. Krell *et al.* (2023) proved that microorganisms are exposed to various influences in natural niches and are sensitive to changes in living conditions. O. Demydenko (2021), investigating the correlations of ecological and trophic groups of soil microorganisms with soil fertility, showed that the increase in biogenicity due to the increase in the number and activity of ammonifying, amylolytic, pedotrophic, oligotrophic microorganisms and a decrease in the activity of humate-decomposing groups of microorganisms ensures the reproduction of humus in the conditions of podzolized chernozem. The practical use of microorganisms, combining them into suitable complexes for their intended purpose, enhances their functional activity and provides greater stability and efficiency (Tytova *et al.*, 2023). Therefore, the study of the microbiota of degraded soils and the search for ways to regulate its activity is one of the priority areas in present-day conditions.

Thus, the conducted research showed that military exposure in the form of rocket hits, fires, and pollution with pesticides and explosives significantly reduces the number and activity of most ecological-trophic and taxonomic groups of soil microorganisms, disrupts the biogenicity and microbial biomass of soils, and also negatively affects the key indicators of mineralisation and immobilisation of organic matter. However, the use of the reducing complex contributed to a significant restoration of the abundance and functional activity of the microbiota in all groups, especially in degraded soils, increased nitrogen mobilisation coefficients, and stabilised mineralisation processes. The results show that the integrated use of biological and organic components is an effective approach for the rehabilitation of damaged soils, increasing their productivity and environmental sustainability, which is important for the restoration of affected agroecosystems and forest lands.

CONCLUSIONS

The conducted studies indicate a negative military impact on the microbiota of southern chernozem, which is sensitive to various environmental factors, which affected a significant decrease in the population density of the main ecological-trophic, taxonomic, and functional groups of soil microorganisms. The number of representatives of the native microbiota in soils after military exposure decreased by 3-3.4 times. Indicators of biogenicity of southern chernozem decreased by 7.7 million CFU/g of dry soil, or 2.6 times compared to the control. Fires as a result of military operations at the location of the Halytsynove forest also significantly reduced the biogenicity of low-humus sands by 4.9 million CFU/g of dry soil, which was 2.3 times in relation to the control. A decrease in the number of representatives of the microbiota of ecological-trophic, functional, and taxonomic groups indicates a violation of the biological activity of the soil and the nutrient cycle. The restoration complex contributed to the growth of soil biogenicity in all variants of the experiment. In the damaged samples, the increase in indicators under the action of the recovery complex was higher than in the control samples. The use of RC in the conditions of background southern chernozem provided an increase in soil biogenicity by 4.2 times, after a missile hit – by 6.1 times. In the low-humus sands of forest lands under the influence of the recovery complex, an increase in biogenicity was observed by 1.9 times, while in the sample after fires due to armed conflict – by 9.9 times.

Consequently, military operations caused a sharp load on the soil, which affected the decrease in the number of microorganisms, inhibition of biological activity, and degradation of the microbiocoenosis.

The use of the recovery complex can be considered as an environmentally safe means and a stabilising factor that will activate the soil microbiota to play an important role in the restoration of both soils and soil ecosystems. The prospects for further research are to investigate the long-term impact of restorative complexes on the stability of microbiocoenosis, assess their effectiveness in various soil types and climatic conditions, and to develop optimal combinations of microorganisms and organic components to increase soil resistance to anthropogenic and military stresses. Special attention should be paid to determining the mechanisms of detoxification of pollutants and restoration of trophic chains, which will create scientifically based recommendations for the rehabilitation of affected agroecosystems and forest lands.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Abo-Alkasem, M.I., Hassan, N.H., & Elsoud, M.M.A. (2023). Microbial bioremediation as a tool for the removal of heavy metals. *Bulletin of the National Research Centre*, 47, article number 31. doi: 10.1186/s42269-023-01006-z.

[2] Balyuk, S., Vorotyntseva, L., Solovei, V., & Shymel, V. (2023). Realities of Ukrainian chornozem: Current state, evolution, preservation, and sustainable management. *Bulletin of Agricultural Science*, 101(3), 5-13. doi: 10.31073/agrovisnyk202303-01.

[3] Balyuk, S.A., *et al.* (2025). *Assessment of the impact of armed aggression on the state of black soils and measures for its restoration: Monograph*. Kyiv: Agricultural Science. doi: 10.31073/978-966-540-641-9.

[4] Danial, A.W., & Dardir, F.M. (2023). Copper biosorption by *Bacillus pumilus* OQ931870 and *Bacillus subtilis* OQ931871 isolated from Wadi Nakheil, Red Sea, Egypt. *Microbial Cell Factories*, 22, article number 152. doi: 10.1186/s12934-023-02166-3.

[5] Demydenko, O. (2021). Correlation links of physiological groups of microorganisms with fertility indicators of degraded chernozem for different fertilizer systems. *Bulletin of Agricultural Science*, 99(4), 20-27. doi: 10.31073/agrovisnyk202104-03.

[6] Dmitrenko, O.V., Demianiuk, O.S., Pohorila, L.P., Svidiniuk, N.L., Rozha, V.V., Kyryliuk, P.M., & Romanenko, V.M. (2023). Ecotoxicological assessment of sod-podzolic soil under the influence of military operations. *Agroecological Journal*, 4, 89-96. doi: 10.33730/2077-4893.4.2023.293758.

[7] Galkin, M.B., Strashnova, I.V., & Andryushchenko, A.V. (2024). Use of microorganisms in bioremediation of soils contaminated as a result of military actions. *Microbiology & Biotechnology*, 2(61), 28-55. doi: 10.18524/2307-4663.2024.2(61).310553.

[8] Goulart, P.W., Santini, A.T., Medina, L.R., Cerqueira, A.E.S., Gazolla, A.C., Silva, W.M., de Assis, I.R., Aniceto, D., de Paula, S.O., & da Silva, C.C. (2025). Microbial indicators show the rehabilitation flow of soil microbiota after the Brumadinho dam collapse. *Mining*, 5(1), article number 16. doi: 10.3390/mining5010016.

[9] Hryhorczuk, D., Levy, B.S., Prodanchuk, M., Kravchuk, O., Bubalo, N., Hryhorczuk, A., & Erickson, T.B. (2024). The environmental health impacts of Russia's war on Ukraine. *Journal of Occupational Medicine and Toxicology*, 19, article number 1. doi: 10.1186/s12995-023-00398-y.

[10] Jiang, S., Qu, H., Cheng, Z., Fu, X., Yang, L., & Zhou, J. (2025). Actinobacteria emerge as novel dominant soil bacterial taxa in long-term post-fire recovery of taiga forests. *Microorganisms*, 13(6), article number 1262. doi: 10.3390/microorganisms13061262.

[11] Johnsen, A.R., Boe, U.S., Henriksen, P., Malmquist, L.M.V., & Christensen, J.H. (2021). Full-scale bioremediation of diesel-polluted soil in an Arctic landfarm. *Environmental Pollution*, 280, article number 116946. doi: 10.1016/j.envpol.2021.116946.

[12] Kozar, S.F. (2021). Diazotroph activity regulating strategy under their introduction in agrocenoses. *Agricultural Microbiology*, 33, 33-43.

[13] Krell, T., Gavira, J.A., Roca, A., & Matilla, M.A. (2023). The emerging role of auxins as bacterial signal molecules: Potential biotechnological applications. *Microbial Biotechnology*, 16(8), 1611-1615. doi: 10.1111/1751-7915.14235.

[14] Levchuk, I., Iutynska, G., & Yamborko, N. (2022). *Stenotrophomonas maltophilia* IMV B-7288, *Pseudomonas putida* IMV B-7289 and *Bacillus megaterium* IMV B-7287 – new selected destructors of organochlorine pesticide hexachlorocyclohexane. *Archives of Microbiology*, 204, article number 611. doi: 10.1007/s00203-022-03220-1.

[15] Loboda, M., Biliavska, L., Iutynska, G., Newitt, J., & Mariychuk, R. (2024). Natural products biosynthesis by *Streptomyces netropsis* IMV Ac-5025 under exogenous sterol action. *Antibiotics*, 13(2), article number 146. doi: 10.3390/antibiotics13020146.

[16] Melnychuk, T.M., Vishovan, Yu.Yu., Samkova, O.P., Bogdanovich, R.P., Fedelesh-Gladynets, M.I., & Savchenko, E.A. (2025). Military impact on soil microbial biomass. In S. Shevchuk, O. Havryliuk & O. Tonkha (Eds.), *International scientific and practical conference "Food security in Ukraine. Preservation and restoration of soil and plant resources"* (pp. 154-157). Kyiv: National University of Life and Environmental Sciences of Ukraine. doi: 10.13140/RG.2.2.33546.58561.

[17] Peddle, S.D., *et al.* (2025). Practical applications of soil microbiota to improve ecosystem restoration: Current knowledge and future directions. *Biological Reviews*, 100(1), 1-18. doi: 10.1111/brv.13124.

[18] Rebai, H., Sholkamy, E.N., Abdelhamid, M.A.A., Thanka, P.P., Hassan, A.A., Pack, S.P., Ki, M.-R., & Boudemagh, A. (2024). Soil actinobacteria exhibit metabolic capabilities for degrading the toxic and persistent herbicide metribuzin. *Toxics*, 12(10), article number 709. doi: 10.3390/toxics12100709.

[19] Rieznik, S.V. (2021). Influence of different systems of crop farming on ecological and trophic groupings of microorganisms of typical chornozem in the conditions of the Left-bank Forest-steppe of Ukraine. *Agricultural Microbiology*, 33, 62-71.
[20] Tytova, L., Sergiienko, V., Pylypiuk, Y., & Iutynska, G. (2023). Effectiveness of the complex microbial formulation for disease protection and productivity enhancement of plants. *Agriculture (Poľnohospodárstvo)*, 69(4), 161-170. doi: 10.2478/agri-2023-0014.
[21] Universal Declaration on Bioethics and Human Rights. (2005, October). Retrieved from https://www.unesco.org/en/legal-affairs/universal-declaration-bioethics-and-human-rights?hub=66535.
[22] Vakhnyak, V., Khomovyi, M., Trach, I., Yavorov, V., & Petryshche, O. (2025). The role of restoring degraded soils in ensuring food security in the agro-industrial sector. *Scientific Horizons*, 28(2), 73-88. doi: 10.48077/scihor2.2025.73.
[23] Volkogon, V.V., *et al.* (2010). *Experimental soil microbiology*. Kyiv: Agrarian Science.

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Мілітарний вплив на біогенність чорнозему південного

Анотація. Серед низки значних проблем, що виникли в результаті воєнних дій на території України, є деградація ґрунтів, що потребує пошуку шляхів прискорення процесів їх відновлення після пошкодження. Метою дослідження було оцінити за показниками біогенності стан чорнозему південного і слабогумусованих пісків за мілітарного впливу та використання відновлювального комплексу, який складався з органічнного добрива Паросток і бактеріально-метаболічного препаратому Ультрачист. Методи дослідження включали лабораторний аналіз зразків, застосовуючи мікробіологічний посів на середовища, відповідні для мікроорганізмів еколого-трофічних, функціональних і таксономічних груп, та статистичну обробку даних для визначення достовірності розбіжностей. Проведені дослідження свідчать про значний негативний вплив на щільність популяцій ґрунтових мікроорганізмів чорнозему південного від ракетного влучання та слабогумусованих пісків від пожеж внаслідок воєнних дій. Кількість представників аборигенної мікробіоти у ґрунтах після мілітарного впливу зменшилася утричі. Показники біогенності чорнозему південного і слабогумусованих пісків зазнали зниження на 7,7 та 4,9 млн КУО/г сухого ґрунту (2,6 і 2,3 разів) відповідно, порівняно з контролем. Відновлювальний комплекс сприяв зростанню біогенності ґрунту в усіх варіантах досліду. У пошкоджених зразках зростання показників за дії відновлювального комплексу було вищим, ніж у контрольних. Застосування в умовах фонового чорнозему південного відновлювального комплексу забезпечило збільшення біогенності ґрунту в 4,2 разів, після ракетного влучання – в 6,1 разів. У слабогумусованих пісках лісових угідь під впливом відновлювального комплексу спостерігали зростання його біогенності в 1,9 разів, тоді як у зразку після пірогенного впливу в 9,9 разів. Запропонований відновлювальний комплекс на основі органічної речовини та корисних мікроорганізмів може розглядатись, як стабілізаційний чинник, що дозволить активізувати мікробіоту деградованого ґрунту для відновлення ґрунтових екосистем

Ключові слова: ґрунтові мікроорганізми; слабогумусовані піски; вплив воєнних дій; деградація мікробоценозу; відновлювальний комплекс