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Ways of balanced use of vermiculture biotechnology in the conditions of anthropogenic load on the environment

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The high energy potential of organic waste allows its use in bioconversion technologies, where waste from one production cycle is a raw material for further production to produce environmentally friendly fertilizers, energy carriers and feed additives.

The article presents the results of experimental studies on the environmental efficiency of vermiculture on organic waste from livestock, crop production, gardening and forestry under anthropogenic load.

It is proved that due to the biological characteristics of vermiculture, which allows to consume a large amount of organic residues, enrich them with its own microflora, enzymes, biologically active substances and release them as processed products (coprolites), this technology to some extent solves the problems of balanced nature management.

It has been determined that in the conditions of intensification of production processes, secondary organic raw materials contain a number of pollutants - heavy metals and toxic metals that can accumulate in coprolites (vermicompost).

An approach is proposed that solves the problem of pollutant migration and involves the introduction of 3% zeolite from the Sokyrnytsia deposit in the Transcarpathian region into the vermiculture substrate.

Experimental and analytical determination of the environmental efficiency of the proposed approach has shown that its practical application in solving the problems of balanced nature management allows to reduce the accumulation of Plumbum by 13.6 % and Cadmium by 22.6 % in vermicompost, which improves the quality of this organic fertilizer and creates prerequisites for obtaining environmentally friendly products.

Key words: ecology, biotechnology, organic waste, red California worm hybrid, bioconversion, natural minerals, minimization of environmental pollution, sustainable environmental management.

Introduction. The intensification of anthropogenic activity leads to the generation of organic waste from livestock, crop production, gardening and forestry [1–4]. Traditional methods of managing such waste do not provide for the full use of the potential of organic raw materials and lead to the migration of pollutants in the biosphere [5–7].

The reduction in the number of livestock and the expansion of grain, corn and sunflower crops have changed the approach to the use of plant residues in the agricultural sector. Previously, crop residues were almost entirely used for livestock production, but now they are left on fields as fertilizer or burned together with stubble. Therefore, crop by-products are becoming increasingly important in balanced nature management [8].

Waste from horticulture and forestry is a renewable organic raw material that accumulates annually and can be used to produce fertilizers. The amount of waste of the lignified part of the phytomass of green spaces is systematically generated during the maintenance of green spaces by municipal enterprises when carrying out maintenance felling (clarification, clearing, thinning), sanitary felling (selective, fully sanitary, reforestation), felling associated with the reconstruction of low-value young trees and derivative stands, cutting of knots and parts of live lower branches, fire protection felling, maintenance of undergrowth and undergrowth, elimination of clutter, and crown pruning of urban trees and shrubs. The largest volumes of wood waste are generated by forest parks and forestry enterprises, some of which can be converted into fertilizer instead of being taken to landfills [9].

The most common method of managing waste from livestock farms and complexes is to use it as organic fertilizer in agroecosystems. However, from an environmental point of view, this method has disadvantages and leads to environmental pollution with heavy metals, pathogens and toxic metals [10-14].

One of the indicators of anthropogenic pressure on environmental components is the amount of production and consumption waste generated and accumulated in a certain territory (region). The processes of generation and accumulation of various wastes pose a threat to the state of all environmental components. The generation and, especially, accumulation of production and consumption waste inevitably leads to soil contamination. The problem of inefficient waste management is typical for the regions of Ukraine [15].

Sources of heavy metals in ecosystems include volcanic emissions, weathering and leaching of rocks, mining, fuel combustion, industrial and municipal waste, air emissions and wastewater pollution from the metallurgical, chemical and electrical industries. All of this, as well as the use of metal-containing pesticides and fertilizers, and runoff from contaminated soil, leads to contamination of food, feed and drinking water. It is important to note that the accumulation of heavy metals by ecosystem components is the result of rapid industrial development of society, increased chemicalization of agriculture and the use of metal-containing household products [15].

Once they enter ecosystems, heavy metals are constantly moving, changing from one form to another. The following systems of heavy metal translocation (transition) are distinguished: air to soil, soil to water, soil to plant, soil to plant to animal, soil to animal to plant to human, and soil to plant to human [15].

The constant intake of heavy metals into the soil leads to the formation of zones of increased environmental toxicity. Within these zones, the nature of element migration and some soil geochemical parameters change. The interaction of metals with soil is based on sorption, precipitation-dissolution, complexation and salt formation reactions. The speed and direction of the transformation processes depend on the reaction of the environment, the particle size distribution of the soil and the humus content [15].

The existence of negative consequences of human economic activity has forced scientists to pay considerable attention to their study, predicting the consequences of anthropogenic impact on nature and taking into account the findings in management decisions [19].

The main objective of sustainable environmental management as a scientific field is to organize and control the use of natural resources and environmental components (minerals, surface and groundwater, seawater, ocean water, air, soil, etc.), assess the levels of harmful impact of anthropogenic loads on them, and develop scientifically based recommendations for environmental protection and restoration measures [19].

The study of possible ways of balanced use of vermiculture biotechnology in the management of organic substrates obtained under conditions of anthropogenic pressure on the environment is of priority importance. The issue of biotransformation of organic waste from livestock, crop production, horticulture and forestry, generated under conditions of intensification of anthropogenic pressure on ecosystems, is not fully understood. This situation calls for the development of safe technologies and production facilities. Using the achievements of science, technological progress should be organized in such a way that production waste does not pollute the environment but is reintroduced into the production cycle as secondary raw materials [7].

Problem statement and analysis of recent research. Vermiculture is the cultivation of specialized worm species (biological name Eisenia foetida) under artificial conditions on various organic substrates. Vermiculture can be thought of as a complex biocenotic community limited to a specific habitat within a cultural landscape. Earthworms are the largest representatives of invertebrates that make up the soil macrofauna. They account for at least half of the total soil biomass. Their population density reaches an average of 120 individuals/m2, and their biomass is 50 g/m2 (with a body weight of 0.5–1.5 g per worm). In favorable periods, the density of earthworms in the soil can reach 400–600 individuals/m2. This area of bioconversion has emerged due to the search for alternative farming methods for agroecology that minimise environmental pollution by various organic wastes and ensure the cultivation of agricultural products free of harmful substances based on the use of biohumus and provide for the rational use of natural resources [4].

The results of the analytical search indicate that worms can accumulate heavy metals and metal toxicants. Studies conducted over a period of thirteen months have shown that populations of L. rubellus and A. caliginosa can be indicators of anthropogenic pressure on natural ecosystems and can be used to monitor the relative degree of metal pollution in different areas [23].

It has been reported that vermiculture on organic substrates (manure biomass, gardening waste) with heavy metal content above the maximum permissible concentration should be grown with the addition of 2 % lime by weight of the substrate. First of all, prepare a substrate of the following composition: plant residues; rotted sawdust; tree leaves; peat; lime (up to 2% by weight of the substrate). The substrate should be fermented for at least 3 months, 3–5 months in winter. The substrate can be stored for 8–10 months at a humidity of 70–80 % [4].

The readiness of the substrate for consumption is determined by the ratio of carbon to nitrogen – approximately 20 and pH 6–8. Raw vermicompost is collected twice a year. It is then used as fertilizer or recycled. If shredded branches are recycled, the complete extraction of vermicompost can be carried out in 1.5 years [4].

A group of researchers [17] studied the environmental efficiency of biotransformation of fallen leaves in urbanized settlements using the vermiculture method. For the cultivation of Eisenia foetida, a basic substrate (group BS I) was used, made from compost of fallen leaves from trees of different ecological zones: conditionally ecologically clean zone of the Bryukhovychi forestry, conditionally polluted zone within the maximum permissible concentration (MPC) – fallen leaves from trees of Stryi Park in Lviv (group BS II). Lviv (group BS II); conditionally contaminated area of the motorway with exceeded MPC – fallen leaves from the trees of K. Levytskoho Street, Lviv (group BS III). When forming the vermicompost, the area, weight of the substrate and the number of worms were taken into account. Substrate composition: 20 % livestock manure and 80 % compost of fallen leaves. The effect of heavy metals that may be contained in leaves contaminated with car exhaust on metabolic processes in Eisenia foetida was determined. According to the results of the study, it is proposed to activate bioconversion by introducing a mineral feed additive – fine zeolite flour in the amount of 6 % of the total mass of the culture medium by uniform mixing with the substrate.

In experimental studies [18], it was found that the addition of saponite to the nutrient medium for the red California worm hybrid in the amount of 2, 4, 6, 8, 10 and 12 % of its weight increases the content of Ferric, Magnesium and Zinc in the worm biomass by 2.4–75.7, 0.7–38.1 and 1.5–23.6 %, respectively. An increase in the concentration of Copper in vermiculture was observed in all experimental groups, except VI, and amounted to 2.9–34.3 %. In addition, in the experimental groups, the presence of saponite in the substrate causes a decrease in the body of oligochaetes of such toxicants as Cadmium and Plumbum – by 1.02–59.5 and 4.5–60.0 %, respectively.

It has been proven that the inclusion of saponite in the worms' nutrient medium at a concentration of 4 % by weight of the substrate provides an increase in biomass and the number of oligochaetes – by 7.9 and 8.3 % ($p<0.05$), respectively, and increases the activity of asparagine aminotransferase in the body of oligochaetes – by 11.8–36.9 % ($p<0.05$) [18].

The introduction of 4 % saponite to the substrate increases the content of Fe, Mg and Mn in vermicompost obtained from the II experimental group-bed by 52.1–78.1, 23.5–18.3 and 98.8–99.6 %, respectively ($p<0.05$). In addition, a decrease in the content of Cadmium and Plumbum was observed – by 7.09–9.07 and 8.2–19.2 % [18].

However, a number of issues remain unresolved today regarding the study of ways to use vermiculture biotechnology in a balanced manner under conditions of anthropogenic pressure on the environment [19]. The study of possible ways to protect nature, as a set of measures aimed at eliminating or mitigating the harmful effects of organic waste from livestock, crop production, gardening and forestry on the natural environment using vermiculture biotechnology, is a priority task [20–22].

Material and methods of research. The experiments were conducted in the vivarium of the Research Institute of Ecology and Biotechnology of Bila Tserkva National Agrarian University. To achieve this goal, a control group and four experimental groups were formed in the form of a microecosystem in glass containers. They are convenient because they allow observing the behaviour of a population or its individual individuals without destroying the microcosm [22].

The material for the study was the red California worm, which was used to populate microecosystems in the amount of 50 individuals [27]. The substrate for its cultivation was fermented cattle manure biomass (80 %) and 20 % fermented organic mixture of fallen leaves, dry grass and sawdust. The ratio of the fermented organic mixture was as follows: 10 % dry grass, 5 % fallen leaves and 5% sawdust. The experimental period was preceded by a preparatory period, during which the conditions in the microecosystems were levelled (in the control and experimental ones). Environmental conditions in all microecosystems were similar except for the factor under study.

According to the experimental design, zeolite from the Sokyrnytsia deposit of the Transcarpathian region was added to the vermiculture medium in the experimental microecosystems at doses of 1.5, 3.0, 4.5 and 6.0 % by weight of the substrate (Table 1).

Table 1 – **Scheme of the experiment**

Groups of microecosystems	Share of the studied factor in the nutrient medium medium
Control	OS (main substrate)
Experimental:	
I	OS + 1.5 % zeolite of Sokyrnytsia deposit
II	OS + 3.0 % zeolite of Sokyrnytsia deposit
III	OS + 4.5 % zeolite of Sokyrnytsia deposit
IV	OS + 6.0 % zeolite of Sokyrnytsia deposit

Vermiculture was carried out at a temperature of +20–25 °C and a substrate moisture content of 65–75 %. The experiment lasted 90 days.

The experiment lasted 90 days. At the end of the experiment, average samples of vermicompost were taken from each microecosystem. The samples were pre-dried and then insulated, gradually bringing the temperature to 450 °C. The metal content in the vermicompost was determined using atomic absorption spectrophotometry on an AAS-30 instrument.

The main research indicators were processed biometrically. The value of the Student's probability criterion at three thresholds $p<0.05$; $p<0.01$; $p<0.001$ was considered significant.

Results and discussion. The results of our research indicate that during the experiment, which lasted 90 days, the weight of vermiculture individuals changed in all microecosystems.

An indicator of vermiculture growth and development is an increase in their biomass and is considered an informative indicator of the efficiency of substrate biotransformation. The effectiveness of reproductive capacity can be assessed by the number of cocoons laid by the worm and the increase in the population, which is the mechanism that ensures the production of vermiculture biomass and determines the efficiency of bioconversion of organic substrate into vermicompost [27].

The analysis of the biomass growth dynamics showed that the largest increases were observed in the micro-ecosystem in which 3.0 % of zeolite from the Sokyrnytsia deposit in the Zakarpattia region was added to the organic substrate. The difference in the weight of worms in the second experimental group of the microecosystem compared to the control group was 2.8 %. There was also a positive trend in the number of cocoons laid. The number of cocoons in the second experimental group was 3.1 % higher than in the control group.

Cadmium and Plumbum are toxic metals. According to the hygienic regulations for the permissible content of chemicals in soil, approved by Order of the Ministry of Health of Ukraine No. 1595 dated 14.07.2020, Plumbum (Pb), Benz(a)pyrene, Arsenic (As), Mercury (Hg), Zinc (Zn), Molybdenum (Mo) and Nickel (Ni) are classified as carcinogenic (blastomogenic) compounds by the nature of their effects on the body. Plumbum (Pb) and Manganese (Mn) are mutagenic substances by the nature of their effects on the body. Mercury (Hg), Plumbum (Pb) and Manganese (Mn) show reproductive toxicity [26].

The results of our experimental studies (Table 2 and Table 4) show that an increase in the content of zeolites in the substrate leads to a decrease in the concentration of Plumbum and Cadmium in vermicompost.

Table 2 – **Plumbum content in vermicompost, mg/kg,** M±m, n=5

Groups of microecosystems	Plumbum content, mg/kg
Control	12,5±0,78
Experimental:	
I	11,1±0,49
II	10,8±0,53
III	10,6±0,61
IV	9,8±0,72*

Note: the difference is significant * – $p<0.05$; ** – $p<0.01$; *** – $p<0.001$.

In the selected samples of vermicompost of the control group, the content of Plumbum was 12.5±0.78 mg/kg. At the optimal concentration of zeolite from the Sokyrnytsia deposit of 3.0% in the nutrient medium, which provided the highest growth and development of worms, the content of Plumbum in the vermicompost was recorded at 10.8±0.53 mg/kg, which indicates a decrease by 13.6 % compared to the control group, where vermiculture was grown without the presence of zeolite. We also proved that the introduction of zeolite into the vermiculture substrate in the proportion of 6.0 % allows to reduce the content of the metal toxicant Plumbum in vermicompost by 21.6 % to 9.8±0.72 mg/kg at the level of probability ($p<0.05$). This trend is explained by the fact that the zeolite of the Sokyrnytsia deposit, due to its selective ability to bind heavy metals, adsorbs them on its surface.

The data on the background content of heavy metals in the soil of household plots are analysed and systematised in Table 3. Experimental studies [24] found that in the 0–10 cm soil layer, the content of plumbum varied from 5.4 to 6.31 mg/kg (Table 3). The average content of the pollutant was 5.66 mg/kg. When analyzing the content of Plumbum in the 11–20 cm soil layer, it should be noted that its content increased by an average of 0.15 mg/kg compared to the 0–10 cm layer.

Table 3 – **The content of heavy metals in soils of household plots in 2009-2011,** M±m, n=5 [24]

Soil layer	Heavy metal content, mg/kg	
	Pb	Cd
0-10 cm	5,66±0,52* 5,04–6,31	0,39±0,03 0,37–0,43
11-20 cm	5,80±0,82 4,65–6,51	0,44±0,05 0,38–0,5
21-30 cm	6,55±0,42 6,15–7,13	0,49±0,02 0,47–0,52

Note: * in the numerator is the average content, and in the denominator - the limits of variation of min and max values of heavy metals.

Comparing the results of our experimental studies with the results of monitoring studies by Stezhko O. [24], it should be noted that the use of vermicompost obtained from raw waste from livestock, crop production, horticulture and forestry as a fertilizer will not lead to a violation of the hygienic regulations for the permissible content of chemicals in soil, approved by Order of the Ministry of Health of Ukraine No. 1595 of 14.07.2020 [26]. The maximum permissible concentration (MPC), mg/kg, taking into account the background (Clark), for plumbum is 32 mg/kg. The content of Plumbum in vermicompost in the second experimental group at 10.8±0.53 mg/kg is 66.2 % of the MPC of this toxic metal in soil, and creates prerequisites for obtaining environmentally friendly products.

According to [25], with an increase in humus content to 2 %, mobile forms of Cu decreased by 45%, Pb – by 19 %, Co – by 40 %, Zn – by 45 %, Ni – by 38 %. The relationship between the content of mobile forms of the studied metals and the humus content in sod-podzolic soils was of medium closeness and the correlation coefficient was: for Pb – 0.68, Zn – 0.58, Cu – 0.58, Co – 0.67, and for nickel the relationship was close ($r=0.74$) [25]. The use of biohumus in the agroecosystem, obtained on the basis of balanced nature management using vermiculture biotechnology, is predicted to reduce the content of mobile forms of heavy metals in the soil – Cu, Pb, Zn, and Nickel.

The results of our research and the dynamics of Cadmium content in the control and experimental groups are shown in Table 4. Our studies have established a clear trend towards a decrease in the content of Cadmium in vermicompost, depending on the increase in the content of zeolite from the Sokyrnytsia deposit in the substrate.

Table 4 – **Cadmium content in vermicompost,** mg/kg, M±m, n=5

Groups of microecosystems Control	Cadmium content, mg/kg
Experimental:	0,97±0,079
Groups of microecosystems	
I	0,81±0,043
II	0,75±0,069
III	0,64±0,054*
IV	0,60±0,038**

Note: the difference is significant * – $p<0.05$; ** – $p<0.01$; *** – $p<0.001$.

The content of Cadmium in vermicompost on the 90th day of vermiculture in the control group was 0.97±0.079 mg/kg. In the experimental group, where the highest productivity indicators were determined with a zeolite content of 3.0 % in the substrate, the presence of Cadmium was 0.75±0.069 mg/kg, which is 22.6 % lower than in the control group.

The dynamics of Cadmium content shown in Table 4 indicates that the best adsorption properties of the Sokyrnytsia deposit celite were shown at its content in the vermiculture substrate of

6.0 %. We found a 38.1 % decrease in the Cadmium content in the IV experimental group compared to the experimental samples.

Comparing the value of the Cadmium content in the vermicompost of the II experimental group with the hygienic regulations for the permissible content of chemicals in soil, approved by the order of the Ministry of Health of Ukraine No. 1595 of 14.07.2020, it should be noted that it is 2 times lower than the established standards. The results of the studies presented in Tables 2 and 4 suggest that our approach is of practical importance, as it can solve the problems of balanced environmental management and the problems associated with the regulation of anthropogenic pressure on the environment.

When determining the correlations, it was found that the correlation between the mass fraction of zeolite from the Sokyrnytsia deposit in the Transcarpathian region in the vermiculture medium and the content of Plumbum and Cadmium in vermicompost is inversely strong (r> -0.75).

Conclusions. Increasing the level of use of secondary resources while saving primary raw materials plays a significant role in balanced nature management.

Modern production and economic activity is associated with the use of minerals, energy resources and substances of various origins. This causes a significant burden on the environment, reduces the living space for wildlife and facilitates the penetration of substances into the biosphere that are not typical for its natural cycle, and can cause serious environmental crises and disasters.

The intensification of anthropogenic activities leads to the generation of organic waste from livestock, crop production, gardening and forestry. Traditional methods of managing such waste do not allow for the full potential of organic raw materials.

The vermiculture technology is based on the biological characteristics of red California worms to biotransform organic waste into vermicompost and enrich it with its own microflora, enzymes, biologically active substances and prevent the development of pathogenic microflora in vermicompost.

To improve the environmental friendliness of the process of biotransformation of organic waste from livestock, crop production, horticulture and forestry into vermicompost, and to minimize the intake of Plumbum and Cadmium into agroecosystems, it is advisable to add 3.0 % zeolite from the Sokyrnytsia deposit in the Zakarpattia region to the vermiculture substrate.

The addition of 3.0 % zeolite to the vermiculture substrate leads to a decrease in the content of Plumbum in the vermicompost by 13.6 % and Cadmium by 22.6 %, respectively, which improves the quality of this organic fertilizer and creates prerequisites for obtaining environmentally friendly products.

Prospects for further research include the development of a scheme of integrated vermiculture and a technological scheme of mechanized technology for the production of vermicompost from organic waste from livestock, crop production, gardening and forestry.

REFERENCES

1. Ali, U., Sajid, N., Khalid, A., Riaz, L., Rabbani, M. M., Syed, J. H., Malik, R. N. (2015). A review on vermicomposting of organic wastes. Environmental Progress & Sustainable Energy, 34 (4), pp. 1050–1062. DOI:10.1002/ep.12100.

2. Thakur, A., Kumar, A., Kumar, C. V., Kiran, B. S., Kumar, S., Athokpam, V. (2021). A review on vermicomposting: By-products and its importance. Plant. Cell Biotechnol. Mol. Biol, 22, pp. 156–164. ISSN: 0972-2025.

3. Vukovi´c, A., Velki, M. Eˇcimovi´c, S., Vukovi´c, R., Štolfa Camagajevac, I., Lonˇcari´c, Z. (2021). Vermicomposting–Facts, Benefits and Knowledge Gaps. Agronomy. 11, 1952 p. DOI:10.3390/agronomy11101952.

4. Senchuk, M.M. (2021). Implementation of mechanized vermicomposting for the utilization of vegetable waste from horticultural farms. Collection of scientific works "Agrobiology", no. 2, pp. 137–145. DOI:10.33245/2310-9270-2021-167-2-137-145. (in Ukrainian).

5. Kharchyshyn, V. M., Vered, P. I., Zlochevskyi, M. V., Herasymenko, V. Yu. (2022). Resource and energy conservation: potential, environmental and economic efficiency of application in agriculture. Proceedings of the XIV International Scientific and Practical Conference (December 27–30, 2022) Prague, Czech Republic. pp. 26–32. DOI:10.46299/ISG.2022.2.14. (in Ukrainian).

6. Kharchyshyn, V. M., Vered, P. I., Zlochevskyi, M. V., Herasymenko, V. Yu. (2023). Alternative ways of handling organic waste from agricultural production: ecological and economic assessment. Current issues of science and integrated technologies. Proceedings of the I International Scientific and Practical Conference (January 10–13, 2023). Milan, Italy, pp. 22–30. DOI:10.46299/ISG.2023.1.1. (in Ukrainian).

7. Kharchyshyn, V. M., Onyshchenko, L. S., Zlochevskyi, M. V., Pertsovyi, I. V. (2023). Ecological and economic bases of low-waste and bioconversion technologies for handling organic waste from agricultural production. Application of knowledge for the development of science: proceedings of the VII International Scientific and Practical Conference (February 21–24, 2023). Stockholm, Sweden, pp. 16–24. Available at:http://rep.btsau.edu.ua/handle/BNAU/8437. (in Ukrainian).

8. Kaletnik, H. M., Bulhakov, V. M., Hrynyk, I. V. (2011). Scientifically based and practical approaches

to the use of straw and plant residues in agriculture. Collection of scientific works of the Vinnytsia National Agrarian University. no. 9, pp. 62–68. (in Ukrainian).

9. Pavlychenko, A. V., Borysovska, O. O., Parshutkin, M. A. (2012). Ways to solve the problem of plant waste management in the city of Dnipropetrovsk. Forum of miners - 2012: materials of the international conference, October 3–6, 2012. Dnipropetrovsk, Vol. 1, pp. 197–202. (in Ukrainian).

10. Herasymenko, V. H., Kharchyshyn, V. M. (2004). Intensification of agricultural waste utilization processes through the introduction of vermiculture biotechnology. Scientific Bulletin of the National Agrarian University. Issue 73, Part 1, pp. 33–38. Available at:http://rep.btsau.edu.ua/handle/BNAU/7798. (in Ukrainian)

11. Kharchyshyn, V. M., Melnychenko, O. M., Vered, P. I., Zlochevskyi, M. V. (2013). Innovations in solving the problems of organic waste utilization by the method of vermiculture: a collection of scientific papers. Bila Tserkva, Issue 10 (105), pp. 64–68. Available at:http://rep.btsau.edu.ua/handle/BNAU/2797. (in Ukrainian)

12. Kharchyshyn, V. M., Herasymenko, V. H. (2005). Composition of nutrient medium for hybrid California red worms: Utility Model Patent No. 9905. Available at:http://rep.btsau.edu.ua/handle/BNAU/7327. (in Ukrainian).

13. Kharchyshyn, V. M. (2021). The method of disposal of organic waste: utility model patent No. 148525. Available at:http://rep.btsau.edu.ua/handle/BNAU/6717. (in Ukrainian).

14. Kharchyshyn, V. M. (2005). The influence of the mineral composition of the nutrient medium on the content of metals in the biomass of worms. Agrarian news: a quarterly scientific and practical magazine. Bila Tserkva: BNAU, no. 1, pp. 8–9. Available at:.http://rep.btsau.edu.ua/handle/BNAU/8433. (in Ukrainian).

15. Chugai, A. V., Safranov, T. A. (2020). Manmade load on the components of the environment during the formation and accumulation of waste in the regions of the North-Western Black Sea. Environmental safety and nature management, 33 (1), pp. 5–17. DOI:10.32347/2411-4049.2020.1.5-17. (in Ukrainian).

16. Voitsitskyi, V. M., Khyzhniak, S. V., Danchuk, V. V., Midyk, S. V., Keppl, O. Yu., Ushkalov, V. O. (2019). Arrival and migration of heavy metals through terrestrial and aquatic ecosystems. Bioresources and nature management, 11, no. 1–2, pp. 59–68. DOI:10.31548/bio2019.01.007. (in Ukrainian).

17. Skip, O. S., Butsiak, A. A., Havryliak, V. V., Shved, O. V., Butsiak, V. I. (2018). Alternative use of fallen leaf substrates in vermiculture. Chemistry, Technology and Application of Substances. Lviv: Lviv Politechnic Publishing House, Vol. 1, no. 2, pp. 74–79. (in Ukrainian).

18. Merzlov, S. V. (2002). Increasing the productivity of vermiculture by introducing saponite into the substrate. Bulletin of Bilotserkiv State. agrarian university: 36. sciences, works. Bila Tserkva, Issue 22, pp. 110–115. (in Ukrainian).

19. Voitkiv, P. S., Ivanov, Ye. A. (2021). Balanced nature use: Educational and methodological guide. Lviv: LNU named after I. Franka, 182 p. (in Ukrainian).

20. Herasymenko, V. H., Kharchyshyn, V. M. (2006). Ways to optimize the quality of worm biomass. Agricultural news. Quarterly scientific journal, no. 1, pp. 16–18. Available at:http://rep.btsau.edu.ua/handle/BNAU/8621. (in Ukrainian).

21. Kharchyshyn, V. M., Onyshchenko, L. S., Zlochevskyi, M. V., Melnychenko, Yu.O. (2023). Natural zeolites: composition, properties and application in greening technologies and productions. The main directions of the development of scientific research: The 15th International scientific and practical conference (Finland, April 18–21, 2023). Helsinki, pp. 20–28. Available at:http://rep.btsau.edu.ua/handle/BNAU/8605. (in Ukrainian).

22. Kharchyshyn, V. M., Bitiutskyi, V. S., Melnychenko, O. M., Vered, P. I. (2021). Modeling and forecasting the state of the environment: methodological guidelines for practical work by students of the first (bachelor) level of higher education, specialty 101 "Ecology". Bila Tserkva: BNAU, 27 p. Available at:http://rep.btsau.edu.ua/handle/BNAU/7090. (in Ukrainian).

23. Morgan, J. E., Morgan, A. J. (2012). Seasonal changes in the tissue metal (Cd, Zn and Pb) concentration in two ecophysiologically dissimilar earthworm species, pollution monitoring implication. Environmental Pollution. Vol. 82, pp. 1–7. DOI:10.1016/0269-7491(93)90155-h.

24. Stezhko, O. V. (2012). Ecological assessment of the content of heavy metals in the soil of the Zhytomyr district. Bulletin of the Poltava State Agrarian Academy. no. 3, pp. 174–176. (in Ukrainian).

25. Dovbysh, L. L. (2002). Heavy metal contamination of sod-podzolic soils of forest-agrarian landscapes of Polissia: autoref. theses of the candidate of agricultural sciences: 03.00.16. State Agroecological University. Zhytomyr, 19 p. (in Ukrainian).

26. Hygienic regulations on the permissible content of chemical substances in the soil, approved by the order of the Ministry of Health of Ukraine No. 1595 dated 14.07.2020. Available at:https://zakon.rada.gov.ua/laws/show/z0722-20#Text. (in Ukrainian).

27. Horodnii, M.M., Tyvonchuk, S.O., Berri, E.S., Bykin, A.V. (1996). Bioconversion in the management of agroecosystems. Kyiv, 232 p. (in Ukrainian).

Шляхи збалансованого використання біотехнології вермикультивування в умовах антропогенного навантаження на навколишнє природне середовище

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Високий енергетичний потенціал органічних відходів дає можливість їх використання у біоконверсних технологіях, де відходи одного виробничого циклу є сировиною для подальших виробництв з одержанням екологічно чистих добрив, енергоносіїв та кормових добавок.

У статті наведено результати експериментальних досліджень із вивчення екологічної ефективності вермикультивування на органічних відходах тваринництва, рослинництва, садово-паркового та лісового господарств в умовах антропогенного навантаження.

Доведено, що завдяки біологічним особливостям вермикультури споживати велику кількість органічних решток, збагачувати їх власною мікрофлорою, ензимами, біологічно активними речовинами та виділяти у вигляді продуктів переробки (копролітів), ця технологія певною мірою вирішує проблеми збалансованого природокористування.

Визначено, що в умовах інтенсифікації виробничих процесів вторинна органічна сировина містить ряд полютантів – важкі метали та метали-токсиканти, які можуть накопичуватися у копролітах (біогумусі).

Запропоновано підхід, який вирішує проблему міграції полютантів та передбачає введення до субстрату вермикультури 3 % цеоліту Сокирницького родовища Закарпатської області.

Експериментально-аналітичне визначення екологічної ефективності запропонованого підходу показало, що практичне його застосування у вирішенні проблем збалансованого природокористування дозволяє зменшити накопичення у біогумусі Плюмбуму на 13,6 % та Кадмію – на 22,6 %, що підвищує якість цього органічного добрива і створює передумови для одержання екологічно чистої продукції.

Ключові слова: екологія, біотехнологія, органічні відходи, гібрид червоного каліфорнійського черв'яка, біоконверсія, природні мінерали, мінімізація забруднення навколишнього природного середовища, збалансоване природокористування.

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