Production of biohumus by microbiological processing of forestry wastes

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Abstract. The article discusses the relevance and feasibility of biotechnology for the rehabilitation of ecosystems, in particular, rural areas. An integrated approach to the processing of agricultural and forestry wastes, such as bark dumps, is proposed in order to reduce the negative impact on the environment and obtain valuable products. The research was carried out in Perm Krai and included the stages of sorting, microbiological treatment of waste, and application of the resulting biohumus into the soil. As an example, the recycling of pulp and paper mill bark dump was considered, where a method of microbiological processing with vermiculture was developed. This allowed to reduce the volume of waste, reduce its fire hazard and obtain biohumus rich in humic acids. The obtained biohumus was successfully used as an organic fertiliser, which resulted in a 20-35% increase in the yield of barley, oats, wheat and vegetable crops compared to control plots. The research confirms the effectiveness of the proposed method for solving environmental problems and improving soil fertility, as well as its difference from traditional waste utilisation methods.

1 Introduction

Environmental problems such as soil and water pollution, climate change, loss of biodiversity and many others have become global and require immediate measures to solve them. In an attempt to find a way out of this situation, mankind turns to various approaches and technologies. Among them we can distinguish several main directions. Firstly, it is the reduction of resource consumption and waste by optimising production processes, introducing a circular economy and more responsible consumption. The main advantage of this approach is its focus on eliminating the very cause of the problem [1]. However, its implementation requires fundamental changes in production and consumer cultures, which is often associated with significant financial and organisational difficulties. Secondly, it is the development of waste treatment and recycling technologies. This approach makes it possible to neutralise or reduce the negative impact of already generated waste and return resources to the production cycle. Examples of such technologies are various methods of wastewater treatment, plastic recycling and recycling of various materials. The main advantage of this direction is its practical applicability and relative ease of implementation. At the same time, it does not solve the problem fundamentally and requires continuous investment in the creation and modernisation of treatment facilities. And thirdly, it is the development and implementation of new biotechnologies that make it possible to use natural mechanisms for cleaning and restoring the environment. This approach includes, for example, the use of microorganisms for waste treatment, the creation of biohumus and the use of phytoremediation for soil and water treatment. It is characterised by its environmental safety and focus on restoring the natural balance [2]. However, its implementation requires a deep understanding of biological processes and is often associated with the need for scientific research and adaptation of technologies to local conditions.

In this context, the direction proposed in the presented material, namely, the integrated application of new biotechnologies for the rehabilitation of natural ecosystems, seems particularly relevant and important. This is due to the fact that the proposed approach allows to simultaneously solve several problems: to reduce the volume of waste, recycle it into useful products and restore soil fertility and biodiversity [3]. Also, this direction allows the use of biological waste from agriculture and forestry, which are quite common and cause significant harm to the environment. This makes

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this approach especially relevant for regions with a developed agriculture and forestry sector. The use of biotechnology for waste processing allows not only to reduce their negative impact, but also to obtain valuable resources, such as biohumus, which can be used to improve soil fertility [4]. This is not only economically favourable, but also contributes to the transition to a more sustainable agriculture. Moreover, solving the problem of recycling wastes such as bark dumps with the help of biotechnology will improve the environmental situation, reduce fire hazards and increase the level of public confidence in the authorities [5].

The aim of the work is to substantiate the necessity and feasibility of integrated application of new biotechnologies for the rehabilitation of natural ecosystems in rural areas. The main emphasis is made on the possibility of using wastes of agricultural and timber industry complex as a source material for the rehabilitation of fertile land, as well as on the example of bark dump processing. The paper suggests ways to improve mechanisms and tools to reduce the negative anthropogenic impact on the environment and ensure sustainable development of rural areas through the introduction of environmentally safe and cost-effective technologies.

2 Method and materials

The research was carried out in the conditions of open terrain, on the territory of industrial enterprises and agricultural lands of Perm Krai. Experimental work included several stages: waste sorting, microbiological treatment, and application of the obtained biofertiliser. The crusher IR-100 was used for waste shredding, which provided a fraction of 1-5 cm, which is necessary for further processing. To accelerate the processes of waste processing, vermiculture technology was applied using earthworm culture Eisenia fetida. This technology involves the preparation of substrate by mixing shredded waste with nitrogen-containing additives in the form of manure and dung. The vermiculture process was carried out in special temperature-controlled containers, maintaining a temperature of 20-25°C. Standard laboratory instruments such as thermometer and moisture meter were used to monitor the decomposition and humification processes, as well as moisture control. To determine the chemical composition of the obtained biohumus and input materials, samples were analysed in a chemical laboratory using a spectrophotometer SF-46 and a pH meter. Application of the obtained biohumus into the soil in agricultural fields was carried out using standard agricultural machines such as fertiliser spreader. To evaluate the efficiency of biohumus application, plant growth and development were monitored and soil samples were analysed for nutrient and microbial content. All measurements and analyses were carried out according to the standards and methods used in agrochemical research.

3 Results and discussion

The conducted experimental work is aimed at developing an integrated approach to the rehabilitation of ecologically disadvantaged territories of the Perm Krai, with a focus on the utilisation of agricultural and forestry production wastes. The aim of the research was to create a waste-free technology that allows not only to reduce the negative impact on the environment, but also to obtain a valuable product for agriculture - biohumus. As a model object for the study, a pulp and paper mill bark dump was chosen, which is a serious source of pollution and fire hazard [6].

In the course of the study, the technology of microbiological processing of bark dump was developed and applied on the example of pulp and paper mill waste in the city of Krasnokamsk.

Earlier studies of the authors of this paper and other authors conducted on similar wastes show that the fractional composition of the bark dump can be quite diverse. In addition to wood residues, it often contains mineral impurities, the proportion of which can vary from 10 to 30%.

In this work, laboratory analyses have shown that the organic carbon to nitrogen ratio in the bark dump is approximately 60 to 1, which is a serious imbalance that prevents the natural decomposition of organic matter. In addition, studies have revealed the presence of lignin in the coring pond, which, when decomposed under oxygen deficient conditions, forms phenolic compounds that are hazardous to the environment and humans [7]. The experiment was conducted in several stages (Fig. 01). In the first stage, the bark dump waste was sorted, separating large fractions such as stones, logs and metal, which constituted up to 20% of the total mass. Then, the remainder was shredded to a 1-5 cm size fraction, which helped to increase the surface area for microbiological action. In the next step, the shredded substrate was mixed with nitrogen-containing wastes such as manure and litter in a ratio of 20 per cent by weight to the volume of the bark pile to balance the nutrients. The resulting mixture was treated with a specially designed microbial complex using EM vermiculture technology. During fermentation in a specially prepared container in the open air for 4-6 months, constant stirring of the substrate and control of the temperature, which was raised to 40-50 degrees Celsius due to exothermic reactions of microorganisms, were carried out. During this period, regular measurements of pH and humidity were carried out, which were maintained in the optimal range of 6.5-7.5 and 60-70%, respectively.

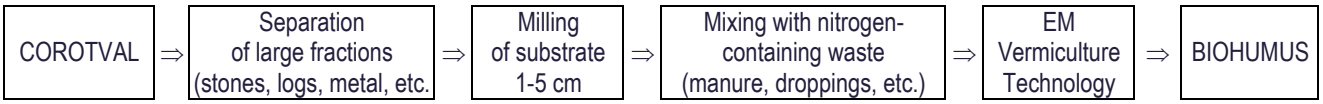

Figure 1. Recycling of pulp and paper mill bark dumps

As a result of the experiment, which lasted 12 months, it was found that microbiological treatment of forest industry waste, particularly bark dumps, can significantly reduce the risk of spontaneous combustion [8]. During observations of the control and experimental groups of bark dumps, it was noted that in the control groups, where no microbiological treatment was applied, the temperature in the depth of the dump reached 70-80°C during the summer months, which created prerequisites for ignition. In the experimental groups, on the contrary, the temperature inside the dump did not exceed 35-40°C, which indicated a decrease in the intensity of rotting processes and heat generation due to the active decomposition of organic matter by aerobic and anaerobic bacteria [9]. These results confirm that microbiological treatment is an effective method of preventing spontaneous combustion of bark dumps, which reduces the environmental and fire risk. Additionally, a significant reduction in waste volume was observed during the microbiological treatment process. The results of monitoring the volume of the bark dump before and after treatment showed a reduction of 12-14% throughout the experiment. This volume reduction was due to active decomposition of organic matter and its transformation into simpler compounds and humus acids. Initially the volume of waste was about 3500 cubic metres, at the end of the experiment the volume of waste decreased by 430 cubic metres. It should be noted that the bulk density decreased from a value of 350 kg/cubic metre to 280 kg/cubic metre, due to the reduction of cellulose and lignin content, which also confirms the success of the microbiological treatment. The transformation of waste by microbiological treatment resulted in a safe and useful product for agriculture - biohumus. Humification of the bark dump was confirmed visually by the change in the colour of the substrate. Initially, the dump had a light brown colour with bark and wood chips, but after processing the substrate became dark brown, almost black, indicating the formation of humic acids. In addition, laboratory tests showed an increase in humic acid content by 13-17% relative to the starting material. At the initial stage of the experiment the humic acid content was 11% and at the end of the experiment the content increased to 25%. The content of phenolic compounds decreased from 5 mg/kg to 0.03 mg/kg. The content of phenolic compounds was quite high in the initial corootwaste, indicating a potential environmental hazard, while in the obtained biohumus the content of these substances was insignificant and did not pose a threat to the environment. The analyses showed that the biohumus was a loose, dark mass, without any extraneous odour, with a neutral pH between 6.5-7.2. The salt concentration in the biohumus was 1.2-1.5 g/l, indicating its suitability for use in agriculture. The biohumus obtained, which was about 1500 cubic metres at the end of the experiment, was successfully applied as an organic fertiliser in the experimental plots [10]. Studies on experimental plots where barley, oats and wheat were planted showed an increase in yields by 22-27% compared to control groups where no fertiliser was applied. In the control plots, barley yields were 2.8 t/ha, oats 2.5 t/ha and wheat 3.0 t/ha, while in the plots treated with biohumus, barley yields were 3.6 t/ha, oats 3.3 t/ha and wheat 3.8 t/ha. Improvement in seed germination in the treated plots was also observed, indicating an improvement in soil fertility [11]. The yield of vegetable crops such as tomatoes and cucumbers increased by 30-35% compared to control plots. Tomato yield from control plots was 4.5 kg/m2 and from biohumus treated plots was 6 kg/m2, cucumber yield from control plots was 5.1 kg/m2 and from biohumus treated plots was 7 kg/m2. Thus, the results of the conducted research confirm the feasibility and effectiveness of microbiological processing of bark dump for solving ecological and agronomic problems. Microbiological processing allows not only to reduce the environmental hazard of waste, but also to obtain a valuable organic product that increases soil fertility and crop yields, which makes this technology promising for wide application.

Analysis of the obtained data allows us to conclude that microbiological processing of bark dump is a promising technology for waste utilisation and reclamation of contaminated territories. The proposed method allows not only to reduce the environmental load, but also to obtain a valuable product for agriculture. This approach is fundamentally different from traditional methods, which are often reduced to waste burial or incineration, which leads to further pollution of the environment. In addition, the proposed technology provides an opportunity to involve waste in a new production cycle, which contributes to the realisation of the principles of cyclic economy.

Comparing the results of the study with other works, it can be noted that the use of microbiological waste processing is a worldwide trend in the field of environmental protection. Many researchers have noted the high efficiency of this method in the processing of various types of organic waste, including wood waste. In particular, studies conducted in European countries have shown that the use of biohumus derived from wood waste helps to increase crop yields by 15-20%. This is consistent with the data obtained [12]. The results of the work emphasise the importance of using biohumus to improve soil fertility.

Nevertheless, it should be noted that the effectiveness of the proposed technology depends on a number of

factors such as waste composition, storage conditions and microbiological diversity of the microbial consortium of microorganisms used [13]. Further research should be aimed at optimising the treatment process and adapting the technology to different waste types and conditions. In addition, it is necessary to carry out an economic evaluation of the proposed technology to determine its economic feasibility and the possibility of industrial implementation.

It is also necessary to take into account that on the territory of Perm Krai there is a large number of industrial facilities and dumps that require ecological rehabilitation, so it is necessary to actively implement waste-free technologies in the regions, and not to be limited to one-off projects. In particular, it is necessary to create a set of measures for the processing of livestock and poultry waste, which are also a large source of environmental pollution [14]. Only with an integrated approach to waste utilisation, it will be possible to count on sustainable environmental development of the region [15].

As a result of the study, it can be concluded that the application of microbiological waste recycling is a promising method that will not only solve environmental problems, but also obtain valuable products for agriculture. The development and implementation of these technologies is an important step towards sustainable development and environmental conservation.

4 Conclusion

In the course of work, a technology for microbiological processing of barkwaste using a complex of microorganisms and vermiculture was developed. This technology includes waste grinding, mixing with nitrogen-containing additives and fermentation under specially prepared conditions. The research results showed that microbiological treatment allows to significantly reduce the risk of spontaneous combustion of landfills, reduce their volume, and obtain biohumus rich in humic acids and nutrients. The biohumus obtained was successfully applied as an organic fertiliser in experimental plots, where an increase in crop yields by 22-35% was observed compared to control groups [16].

Thus, the conducted study confirms the effectiveness and feasibility of microbiological processing of bark dumps for waste disposal and remediation of contaminated territories. The proposed approach not only solves environmental problems, but also contributes to the development of a cyclic economy, allowing the involvement of waste in a new production cycle. Unlike traditional methods such as landfilling or incineration, this method is environmentally friendly and economically viable, which makes it promising for wide application. The article also notes the importance of further research to optimise the recycling process and adapt the technology to different types of waste.

References

1. V. Langraf, K. Petrovičová. Morphometric variability of specimens in Ground Beetle (Carabidae) communities in agrarian landscape forests and protected areas. Rev. Soc. Entomol. Argent., **83,** 1-8 (2024). DOI: 10.25085/rsea.830401.
2. V.V. Bukhtoyarov, V.Y. Konyukhov. Circular Mining Wastes Management for Sustainable Production of Camellia sinensis (L.) O. Kuntze. Sustainability (Switzerland), **15,** 11671 (2023). DOI: 10.3390/su151511671.
3. S. Bamidele. BRICS Revolution: The Global Agrarian Shift Sparked by Emerging Economies. India Q., **4,** 21–29 (2025). DOI: 10.1177/09749284241307937.
4. L. M. Tatarintsev, F. K. Ermekov, Yu. S. Lisovskaya. Agroecological condition assessment of agricultural landscapes for their sustainability increase. Sustainable Development of Mountain Territories, **14,** 76–86 (2022). DOI: 10.21177/1998-4502-2022-14-1-76-86.
5. H. Cochet, O. Ducourtieux, N. Garambois. Agrarian systems and climate change: Journeys of adaptation in the global south. Agrar. Syst. Clim. Change: Journeys Adapt. Glob. South, **1-**208 (2024). DOI: 10.1079/9781800628137.0000.
6. A. T. Beristenov, L. V. Lebedeva, L. M. Tatarintsev, V. L. Tatarintsev. Assessment of the agroecological potential of anthropogenic landscapes in the dry steppe of the south of Western Siberia. Sustainable Development of Mountain Territories, **16,** 975–987 (2024). DOI: 10.21177/1998-4502-2024-16-3-975-987.
7. D. D. Duisenova, K. M. Tireuov, L. M. Tatarintsev, L. V. Lebedeva. Ecological typization of agricultural land and modeling of sustainable agrolandscape at the local level. Sustainable Development of Mountain Territories, **16,** 94–110 (2024). DOI: 10.21177/1998-4502-2024-16-1-94-110.
8. L. V. Lebedeva, G. D. Syzdykova, D. S. Inkarov. Management of agricultural land use sustainability at the local level using GIS technologies and special map material. Sustainable Development of Mountain Territories, **15,** 864–876 (2023). DOI: 10.21177/1998-4502-2023-15-4-864-876.
9. J. Rodzik, R. Kołodyńska-Gawrysiak, Ł. Franczak, W. Zgłobicki, J. Poesen. IMPACT OF LAND USE CHANGES ON COLLAPSED PIPES DEVELOPMENT IN THE LOESS GULLY (LUBLIN UPLAND, EAST POLAND). Quaest. Geogr., **43,** 17-33 (2024). DOI: 10.14746/quageo-2024-0042.
10. F. K. Ermekov, Yu. S. Lisovskaya. Agroecological condition assessment of agricultural landscapes for their sustainability increase. Sustainable Development of Mountain Territories, **14,** 76–86 (2022). DOI: 10.21177/1998-4502-2022-14-1-76-86.
11. B. Aparecida da Silva, R. Evangelista de Oliveira, A. Cavalieri Sais, E. Cardoso leite. Family farmers and trees: ecological functions, ecosystem services and food

production in agrarian reform settlements in Brazil. Agroecol. Sustain. Food Syst., **49,** 4-21 (2025). DOI: 10.1080/21683565.2024.2405515.
12. T. Bandara, B. Marambe, G. Pushpakumara, P. Silva, R. Punyawardena, L. Manawadu, S. Premalal, G. Miah, K.R. Dahal. Adapting mountain-farming systems to climate change by reducing food-nutrition-health vulnerability. Mitig. Adapt. Strateg. Glob. Change, **29,** 88 (2024). DOI: 10.1007/s11027-024-10181-x.
13. M. N. Nurpeisov, K. V. Ruchkina, V. A. Androkhanov, S. K. Makenova. Assessment of geoecological factors and conditions affecting sustainability of agricultural land use in the forest-steppe zone of Altai Krai. Sustainable Development of Mountain Territories, **15,** 419–430 (2023). DOI: 10.21177/1998-4502-2023-15-2-419-430.
14. V.Yu Konyukhov, I.Y. Matasova. Ecologization of underground coal mining by means of ash use in backfill preparation. Min. Inform. Anal. Bull., **10,** 123-135 (2024). DOI: 10.25018/0236_1493_2024_10_0_123.
15. A. G. Terekhov, G. N. Sagatdinova. Spectral characteristics of saline arable land in the foothill catchment Zailiisky Alatau ridge (Northern Tien-Shan) during 2016-2022 using Sentinel-2 data. Sustainable Development of Mountain Territories, **16,** 143–155 (2024). DOI: 10.21177/1998-4502-2024-16-1-143-155.
16. N.A. Zhirov. Socio-Economic Development of the Black Soil Village in the XIX–early XX centuries: from the Prosperous Granary of Pre-Reform Russia to the Demo-Ecological Crisis of Rural Settlements. Bylye Gody, **19,** 1605-1614 (2024). DOI: 10.13187/bg.2024.4.1605.