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BIOCONVERSION OF SLUDGE DEPOSITS FROM ABANDONED DRAINAGE CANALS INTO GRANULATED ORGANIC-MINERAL FERTILIZERS

Ukraine's neglected reclamation systems have accumulated significant volumes of sludge deposits representing both environmental challenges and potential agricultural resources. Modern sustainable agriculture development requires innovative approaches to organic waste utilization while simultaneously providing agriculture with environmentally safe fertilizers. This study presents a comprehensive investigation of bioconversion technology for transforming sludge deposits from abandoned drainage canals into granulated organic-mineral fertilizers.

The scientific novelty lies in a systematic approach to bioconversion considering three key components: detailed raw material characterization, technological parameter optimization, and comprehensive risk management. Unlike existing research focusing primarily on organic matter transformation, this work integrates knowledge from biotechnology, agrochemistry, ecology, and bioprocess engineering to create effective technological solutions with stable quality assurance during industrial scaling.

Sludge deposits were collected from abandoned drainage canals in Dnipropetrovsk Oblast using standardized sampling protocols from systems inactive for over five years to minimize recent anthropogenic contamination. Comprehensive chemical characterization was conducted at the Biogeochemistry Laboratory, Department of Earth Sciences, Zhytomyr Polytechnic State University, utilizing established analytical methodologies including spectrophotometric, titrimetric, and atomic absorption techniques for macroelements, physicochemical parameters, microelements, and water-extractable components.

The bioconversion process involved multi-stage processing combining thermal treatment at 105°C for 24 hours for pathogen elimination, mechanical processing through 2mm sieves, and drum granulation technology. Microbial bioconversion enhancement utilized selected bacterial consortia with high destructive activity under controlled temperature (50-65°C), moisture (50-60%), and pH (6.5-8.0) conditions. Fertility assessment employed standardized bioassay protocols using common oat (Avena sativa L.) as indicator species across five treatment concentrations: 0% (control), 5%, 10%, 20%, and 50% sludge amendments.

Chemical analysis revealed exceptional agricultural potential with organic matter content of 23.0% in humic-fulvic complexes, optimal pH values of 7.3 (water extract) and 6.4 (salt extract), and cation exchange capacity of 40.0 $mmol(+)\cdot 100g^{-1}$ indicating excellent nutrient retention capability. Base saturation degree of 96.1% confirmed outstanding fertility potential. Macronutrient analysis demonstrated adequate phosphorus availability (79.0 $mg\cdot kg^{-1}$ P_2O_5 mobile) and moderate potassium content (53.0 $mg\cdot kg^{-1}$ K_2O mobile). Micronutrient composition was exceptionally balanced with optimal concentrations of boron (4.830 $mg\cdot kg^{-1}$), zinc (3.260 $mg\cdot kg^{-1}$), and manganese (5264.000 $mg\cdot kg^{-1}$). Salinity evaluation confirmed minimal salt stress potential with electrical conductivity of 0.50 $mS\cdot cm^{-1}$, well below problematic thresholds.

Comparative analysis of multiple growth parameters enables comprehensive evaluation of fertilizer effectiveness across different physiological processes. Integration of germination, morphological, and biomass data provides a holistic understanding of concentration-dependent responses and facilitates identification of optimal application strategies.

The integrated analysis demonstrates that optimal fertilizer concentration (20%) maximizes performance across all evaluated parameters, supporting its identification as the most effective application strategy.

Bioassay results demonstrated clear dose-response relationships across all measured parameters. Control treatment established baseline performance with 58.0±6.2% germination, 141.6±5.4mm stem length, 84.0±3.6mm root length, and 0.125±0.014g biomass accumulation. Application of 5% sludge concentration resulted in measurable improvements to 72.0±8.1% germination, representing 24.1% enhancement.

Progressive increases to 10% and 20% concentrations yielded further enhancements, with optimal 20% treatment achieving maximum performance: 82.5±7.3% germination, 195.4±8.2mm stem length, 125.6±6.0mm root length, and 0.218±0.025g biomass. These values represent improvements of 42.2%, 38.0%, 49.5%, and 74.4% respectively compared to control conditions. However, escalation to 50% concentration resulted in decreased performance (76.0±9.5% germination), confirming concentration-dependent phytotoxicity at excessive application rates.

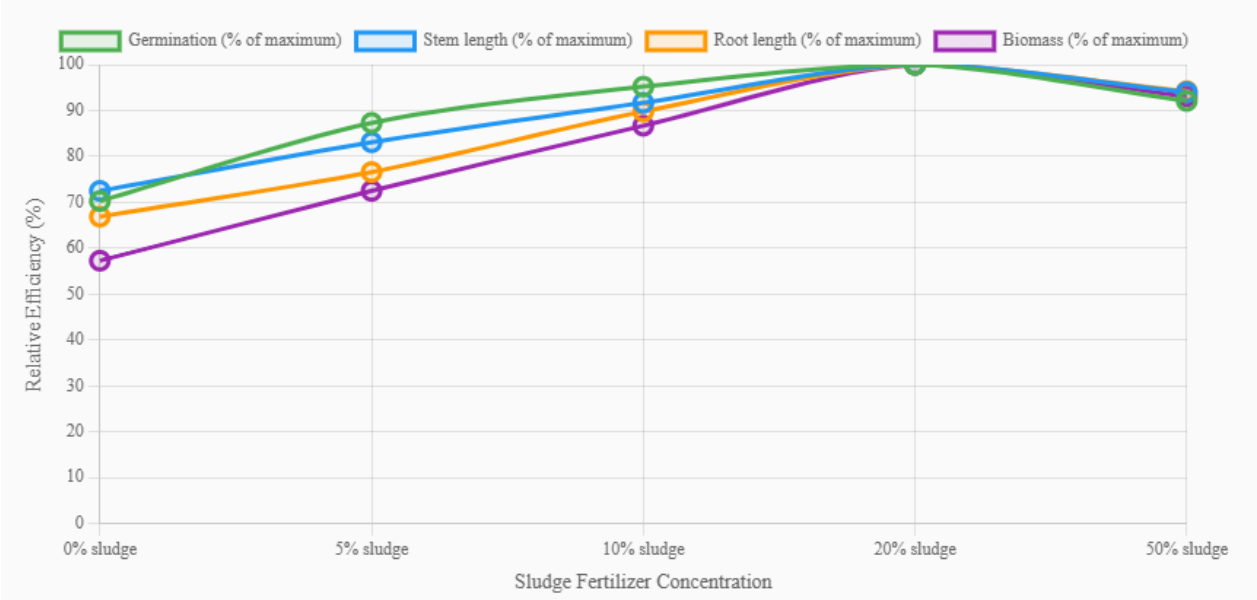

Fig. 1. Comparative dynamics of plant growth parameters under different sludge concentrations

Conclusions. The comprehensive study confirms high potential of sludge deposit bioconversion technology for sustainable agricultural development. Chemical analysis revealed exceptional agricultural potential with 23.0% organic matter content, optimal pH values (7.3 water extract), and excellent cation exchange capacity (40.0 mmol(+)·100g^{-1}). Bioassay results demonstrated clear dose-response relationships with optimal 20% sludge concentration achieving maximum improvements: 42.2% germination enhancement, 38.0% stem length increase, 49.5% root development improvement, and 74.4% biomass accumulation increase compared to control conditions. The developed technological scheme integrating controlled biofermentation at 50-65°C with comprehensive risk management provides scientific foundation for industrial implementation. Economic analysis confirms technology attractiveness through free raw materials utilization, local production establishment, and import substitution benefits. Implementation addresses multiple challenges simultaneously including environmental waste elimination, agricultural productivity enhancement, and rural development promotion, establishing this bioconversion approach as viable solution for sustainable agriculture advancement.

References:

1. Kominko, H., Gorazda, K., & Wzorek, Z. (2021). Formulation and evaluation of organo-mineral fertilizers based on sewage sludge optimized for maize and sunflower crops. Waste Management, 136, 57-66. https://doi.org/10.1016/j.wasman.2021.09.040
2. Lamastra, L., Suciu, N.A. & Trevisan, M. (2018). Sewage sludge for sustainable agriculture: contaminants' contents and potential use as fertilizer. Chemical and Biological Technologies in Agriculture, 5, 10. https://doi.org/10.1186/s40538-018-0122-3
3. Kapelista, I., Kireitseva, H., Tsyhanenko-Dziubenko, I., Khomenko, S., & Vovk, V. (2024). Review of innovative approaches for sustainable use of Ukraine's natural resources. Grassroots Journal of Natural Resources, 7(3), 378-395. DOI: 10.33002/nr2581.6853.0703ukr19
4. Kireitseva, H., Tsyhanenko-Dziubenko, I., Khomenko, S., & Palii, O. (2025). Integral assessment of the effectiveness of water resource management in communities for sustainable development. Ecological Safety and Balanced Use of Resources, 16(1), 27-38. DOI: 10.69628/esbur/1.2025.27
5. Tsyhanenko-Dziubenko, I., Kireitseva, H., Shomko, O., Gandziura, V., & Khamdosh, I. (2025). Analytical assessment of heavy metals polyelement distribution in urbanized hydroecosystem components: spatial differentiation and migration patterns. Journal Environmental Problems, 10(2), 135-144. DOI: 10.23939/ep2025.02.135