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MEDICAL AND SANITARY ANALYSIS OF BIOMASS AND BIOGAS PRODUCTION WASTE IN THE UTILIZATION OF ORGANIC RAW MATERIALS ACCORDING TO EUROPEAN SAFETY CRITERIA

ANALIZA MEDICO-SANITARĂ A DEȘEURILOR DIN PRODUCȚIA DE BIOMASĂ ȘI BIOGAZ ÎN CADRUL UTILIZĂRII MATERIILOR PRIME ORGANICE, CONFORM CRITERIILOR EUROPENE DE SIGURANȚĂ

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ABSTRACT

Objectives. In Ukraine, soil degradation has become an acute problem because of the destructive effects of the war. Organic fertilizing materials may support the restoration of soil structure and humus balance through agrochemical and remediation effects. To conduct a medical and sanitary assessment of biogas production waste, determine biomass safety indicators, and compare them with European criteria for use without unacceptable risks to human health, agricultural product quality, or the environment.

Methods. Physicochemical, sanitary-helminthological, and bacteriological indicators of biomass were investigated and evaluated by hygienic analysis, taking into account the toxicological properties of hazardous components.

Results. The physicochemical indicators did not exceed the applicable threshold values. However, the untreated substrate presented an infectious hazard: the E. coli titer was 0.0001, and the thermophilic bacteria count was 40,000–500,000 CFU/g. These findings indicate the need for pasteurization or composting, followed by confirmatory microbiological testing, before use.

Conclusions. Safe use of waste generated from processed organic raw materials as an organic fertilizer requires treatment and mandatory monitoring of safety and quality indicators in accordance with European medical and sanitary requirements.

Keywords: soil, fertility restoration, biomass, substrate, digestate, biowaste, safety indicators, heavy metals, pathogens, organic fertilizers, European criteria, medical and sanitary assessment

REZUMAT

Obiective. În Ucraina, degradarea solurilor a devenit o problemă acută din cauza efectelor distructive ale războiului. Materialele fertilizante organice pot contribui la refacerea structurii solului și a echilibrului humic prin efecte agrochimice și de remediere. Evaluarea medico-sanitară a deșeurilor rezultate din producerea biogazului, determinarea indicatorilor de siguranță ai biomasei și compararea acestora cu criteriile europene pentru utilizare fără riscuri inacceptabile pentru sănătatea umană, calitatea produselor agricole sau mediu.

Metode. Au fost investigați indicatorii fizico-chimici, sanitaro-helmintologici și bacteriologici ai biomasei și a fost efectuată analiza igienică, luând în considerare proprietățile toxicologice ale componentelor periculoase.

Rezultate. Indicatorii fizico-chimici nu au depășit valorile-prag aplicabile. Totuși, substratul netratat a prezentat un pericol infecțios: titrul E. coli a fost 0,0001, iar numărul bacteriilor termofile a fost de 40.000–500.000 CFU/g. Rezultatele indică necesitatea pasteurizării sau compostării, urmată de testarea microbiologică de confirmare înainte de utilizare.

Concluzii. Utilizarea în siguranță ca îngrășământ organic a deșeurilor provenite din prelucrarea materiilor prime organice necesită tratare și monitorizarea obligatorie a indicatorilor de siguranță și calitate, în conformitate cu cerințele medico-sanitare europene.

Cuvinte-cheie: sol, refacerea fertilității, biomasă, substrat, digestat, biodeșeuri, indicatori de siguranță, metale grele, agenți patogeni, îngrășăminte organice, criterii europene, evaluare medico-sanitară

Introduction

In Ukraine, soil degradation attracted particular public attention following the onset of the war, which revealed the destructive effects of direct combat operations, mining, and the contamination of agricultural land caused by shelling. Large-scale land damage will require long-term efforts to restore war-damaged soils and ensure their sustainable health. In the context of European integration, the preservation of soil health and its sustainable management to ensure the quality of agricultural products are gaining particular significance.

One of the most effective methods for restoring soil structure and humus balance is the application of organic fertilizing materials. These materials are suitable for sustainable farming systems in Ukraine, providing both agrochemical and remediation effects and thus representing a key element in the strategy for restoring soil fertility in the post-war period [1-3]. Their use also aligns with the EU Biodiversity Strategy for 2030. Regulation (EU) 2019/1009 establishes requirements for component and derivative materials used in fertilizer production and for the technological approaches to their treatment, with the aim of maintaining appropriate physicochemical parameters and final product quality [4]. Given the absence of a comparable regulatory document in Ukraine, we conducted a medical and sanitary assessment of biomass derived from the treatment and disposal of organic waste and its mixtures to evaluate the feasibility of adopting European approaches [5, 6].

Objective. To conduct a medical and sanitary assessment of biogas production waste, determine biomass safety indicators, and compare them with European criteria for use without unacceptable risks to human health, agricultural product quality, or the environment.

Materials and methods

Biomass samples were collected from two open-air temporary storage sites using the envelope method, from 15 points at different depths, and then pooled. A 1.5 kg composite sample was divided into three subsamples for bacteriological, helminthological, and sanitary-chemical testing. Samples for bacteriological and helminthological analyses were packed in sterile glass containers. Physicochemical, helminthological, and sanitary-bacteriological indicators were determined. Sampling was conducted in May–June 2022.

Heavy metal content was determined by atomic absorption spectrometry. Samples were prepared by acid digestion, and mobile forms of heavy metals were extracted using ammonium acetate buffer at pH 4.8. Heavy metal concentrations were measured using a KAS-120.1 (S-115M) atomic absorption spectrometer with electrothermal atomization. Instrument sensitivity ranged from 0.008 to 0.1 mg/dm^3.

The pH was determined according to DSTU ISO 10390:2007 (ISO 10390:2021, IDT). Geohelminth indicators in organic fertilizers were determined by microscopy using an XSP-139T LED digital biological microscope. Appropriate culture media were used for the qualitative identification of pathogenic organisms. All instruments had calibration certificates, and the laboratories held certificates confirming measurement capability in accordance with DSTU ISO 10012:2015. The assessment used hygienic analysis, considered toxicological data for hazardous biomass components, and compared the findings with European suitability criteria.

Results and discussion

The biomass investigated was a byproduct of biogas production from organic feedstock. The technology uses aceto-methanogenic fermentation, during which complex organic matter is converted into simple organic compounds, mineralized substances, microbial biomass, and biogas containing methane (55%-70%) and carbon dioxide (30%-45%). The principal feedstock was fresh or fermented beet pulp, a byproduct of sugar beet processing. Additional feedstocks included the liquid fraction of cattle manure, vegetable and seed oils (soybean and sunflower), soybean oil hydrofuse, chicken manure, and beet molasses. The process occurred in a specialized anaerobic digestion unit comprising an acetic acid system (hydrolysis, acidogenesis, and acetogenesis) and a methane system (syntrophic microorganisms and methanogens). The operating parameters were a mesophilic temperature of 37 °C, pH 7.2-7.6, and a minimum retention time of 25 days. The substrate was continuously agitated and mixed. Measured doses of nutrients containing Fe, Co, Mo, Ni, Mn, Cu, and Zn were added to support the active biomass. During methanogenesis, unpurified biogas was released, and the methane slurry flowed continuously into digesters beneath a membrane roof. The total fermentation and digestion period was approximately 30 days. The resulting methane slurry was decanted and separated into liquid and solid digestate fractions.

Digestate is the organic material remaining after anaerobic digestion during biogas production. It is rich in nitrogen (2.3-4.2 kg/t), phosphorus (0.2-1.5 kg/t), potassium (1.3-5.2 kg/t), and micronutrients such as calcium and magnesium. The nutrients are readily available to plants. Digestate may therefore be used as a fertilizer that supports soil structure and fertility. Its liquid and solid fractions are separated to facilitate application. Because anaerobic treatment alone does not necessarily ensure sanitization, physicochemical, sanitary-helminthological, and sanitary-bacteriological testing was conducted on the solid component, followed by a medical and sanitary safety assessment.

On visual inspection, the waste appeared as a solid, grey-brown, odorless granular substrate with particles measuring 0.1-2.0 cm. The physicochemical characteristics were pH 8.23, moisture content 13.5%, organic matter 87%, and mineral content 13%. The heavy metal results presented in Table 1 were used to assess the waste hazard category based on acute toxicity parameters and the relationship between physicochemical properties and acute toxicity data.

Table 1. *Concentrations of chemical elements in the biomass sample.*

Element	**Concentration, mg/kg**	**% by mass in biomass**	**MPC in soil*, mg/kg**	**Limit value**, mg/kg**
Pb	2.56	0.000256	32.0	120.0
Cd	0.28	0.000028	1.5	-
Cr	1.68	0.000168	0.05 (Cr VI) / 6.0 (Cr III)	2.0 (Cr VI)
Ni	0.81	0.000081	4.0	50.0
Zn	36.29	0.003629	23.0	800.0
Mn	41.86	0.004186	1500.0	-
Cu	1.92	0.000192	3.0	300.0
Hg	below detection limit	-	2.1	1.0
Fe	109.0	0.0109	-	-

**Ukrainian standard: Hygienic Regulation of the Permissible Content of Chemical Substances in Soil, Order of the Ministry of Health of Ukraine No. 1595 of July 14, 2020 [7]. **European standard: Commission Regulation (EU) No. 142/2011 [8].*

Because both the feedstocks and the substrate are biowaste, their indicators were assessed in accordance with the Procedure for Waste Classification, approved by Resolution of the Cabinet of Ministers of Ukraine No. 1102 of October 20, 2023, which implements the principal provisions of Directive 2008/98/EC, Regulation (EC) No. 1272/2008, and Commission Regulation (EU) No. 1357/2014 [9-11]. The combined concentration of toxic elements was 0.01944% of the 13% mineral component, distributed as follows:

• Toxicity class I (Pb, Cd, Cr, and Hg): 0.000452% (<0.1%);

• Toxicity class II (Ni, Mn, and Cu): 0.004459% (<0.25%);

• Toxicity class III (Zn and Fe): 0.014529% (<5%);

• the combined concentration of toxicity class I and II substances was 0.004911% (<0.1%), which did not exceed the threshold value.

On this basis, the biomass substrate generated during biogas production was classified as non-hazardous with respect to the evaluated chemical indicators. A probable infectious hazard (HP 9) remained, as shown by the helminthological and microbiological findings.

This study applied domestic approaches to assessing soil purity using microbiological indicators in accordance with the soil sanitary status assessment scale, taking into account their hygienic significance [12, pp. 237–238]. Geohelminth eggs were not detected. Microbiological analysis showed that the E. coli titer was 0.0001, corresponding to the "heavily polluted" category, while Salmonella spp. was not detected. The thermophilic bacteria count ranged from 40,000 to 500,000 CFU/g. When expressed as the corresponding reciprocal titer, the limiting values extend from approximately 0.000025 to 0.000002 and therefore span the "weakly polluted" to "heavily polluted" categories of the Bardov scale [12, pp. 237–238]. Because individual determination results were not available, no single overall contamination category was assigned on the basis of this indicator. The mesophilic anaerobic digestion temperature of 37–38 °C may allow microorganisms to remain viable or multiply. Despite this, the substrate is a potentially valuable organic raw material and can be used for the production of organic fertilizers after decontamination under microbiological control.

The substrate was generated primarily from sugar beet pulp, with liquid cattle manure and poultry manure as additional feedstocks. Its composition is consistent with the input-material provisions for anaerobically obtained digestate under Regulation (EU) 2019/1009 [4]. However, further treatment is required to eliminate bacteriological contamination because mesophilic anaerobic digestion at 37-40 °C is only the first stage. Production of an organic fertilizer material requires pasteurization in accordance with Commission Regulation (EU) No. 142/2011 [8] or composting.

Under Regulation (EU) 2019/1009, composting following mesophilic anaerobic digestion should meet one of the following temperature-time profiles: at least 70 °C for 3 days, 65 °C for 5 days, 60 °C for 7 days, or 55 °C for 14 days [4]. Compliance with these treatment requirements is expected to sanitize the organic material and permit its use for soil fertilization, subject to confirmatory testing. The applicable microbiological criteria include absence of Salmonella spp. and limits for Escherichia coli or Enterococcaceae. The digestate must also comply with limits for macroscopic impurities and PAH16 in dry matter [4, 8].

The medical and sanitary analysis showed that the untreated biomass met the evaluated chemical and helminthological criteria but did not meet microbiological safety requirements because of E. coli and thermophilic bacterial contamination. Following the required pasteurization or composting, compliance with Regulation (EU) 2019/1009 and the applicable Ukrainian hygienic regulation must be confirmed by repeat laboratory testing [4, 7].

Organic fertilizer materials, including organic and organo-mineral fertilizers and soil improvers, may support the restoration of degraded soils and reduce dependence on conventional mineral fertilizers. In post-war landscape restoration, their value may extend beyond nutrient supply to the binding of toxic compounds, reduction of contaminant mobility, and restoration of the humus layer. Ukrainian legislation requires organic fertilizers placed on the market to meet safety requirements for heavy metals, pathogenic bacteria, and helminth eggs; however, the manuscript identifies gaps in specific medical and sanitary limits for fertilizing materials. Establishing composition and quality criteria could expand production of safe fertilizer mixtures and provide clear parameters for quality control, thereby supporting the restoration of degraded and war-damaged soils while protecting public health, agricultural products, water resources, and the environment.

Conclusions

The biomass generated by mesophilic anaerobic digestion of organic raw materials during biogas production met the evaluated chemical and helminthological criteria but required further sanitization because of microbiological contamination. Following composting or pasteurization, its suitability for use as an organic fertilizing material should be confirmed by repeat safety and quality testing.

Residues from processed organic raw materials may be used as organic fertilizing materials only after appropriate treatment, with mandatory monitoring of safety and quality indicators.

Clearly defined national criteria for the safe use of fertilizing materials in soil restoration, aligned with relevant European safety requirements, are needed to minimize potential risks to public health and the environment.

Bibliography

1. Kakura I, Stankevych V, Kostenko A, Fedoryshyna O. Medyko-sanitarni aspekty bezpechnoho vykorystannia orhanichnykh dobryv dlia vidnovlennia hruntiv [Medical and sanitary aspects of the safe use of organic fertilizers for soil restoration]. In: Science, Technology, Innovation: Global Trends and Regional Aspect. Tallinn, Estonia; 2024:133-138. https://isg-konf.com/uk/science-technology-innovation-global-trends-and-regional-aspect/
2. Kakura IV, Stankevych VV, Kostenko AI, Fedoryshyna OM. Perevahy vykorystannia orhanichnykh dobryv dlia vidnovlennia rodiuchosti porushenykh viinoiu hruntiv [Advantages of using organic fertilizers to restore the fertility of soils damaged by war]. Hihiena Naselenykh Mists. 2024;74:39-48. doi:10.32402/hegiene2024.74.039
3. Kakura IV, Stankevych VV, Kostenko AI, et al. Medyko-sanitarnyi porivnialnyi analiz naibilsh poshyrenykh v Ukraini hrup dobryv [Medical and sanitary comparative analysis of the most common groups of fertilizers in Ukraine]. Dovkilla Zdorovia. 2025;3(116):63-75. doi:10.32402/dovkil2025.03.063
4. European Parliament and Council of the European Union. Regulation (EU) 2019/1009 of June 5, 2019 laying down rules on the making available on the market of EU fertilising products. Off J Eur Union. 2019;L170:1-114. Accessed August 10, 2026. https://eur-lex.europa.eu/eli/reg/2019/1009/oj/eng
5. Kostenko AI, Stankevych VV, Fedoryshyna OM, Kakura IV, Humennykova NM. Medyko-sanitarni aspekty upravlinnia vidkhodamy orhanichnoho pokhodzhennia dlia vidnovlennia hruntiv, porushenykh vnaslidok boiovykh dii [Medical and sanitary aspects of organic waste management for the restoration of soils damaged by hostilities]. In: Aktualni pytannia hromadskoho zdorovia ta ekolohichnoi bezpeky Ukrainy. Kyiv, Ukraine; 2025:116-117. https://health.gov.ua/events/conferences/conference-proceedings/
6. Stankevych VV, Kostenko AI, Trakhtenherz HYa, Cherevko OM. Harmonizovanyi pidkhid zastosuvannia vymoh dyrektyv YeS dlia vyznachennia bezpechnosti vykorystannia dobryv ta udobriuvalnykh pozhyvnykh rechovyn [Harmonized approach to applying EU directive requirements to determine the safety of fertilizers and fertilizing nutrients]. Hihiena Naselenykh Mists. 2021;71:87-94. doi:10.32402/hegiene2021.71.087
7. Ministry of Health of Ukraine. Hygienic Regulation of the Permissible Content of Chemical Substances in Soil. Order No. 1595. Issued July 14, 2020. https://zakon.rada.gov.ua/laws/show/z07222-20#Text
8. European Commission. Commission Regulation (EU) No. 142/2011 of February 25, 2011 implementing Regulation (EC) No. 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption. Off J Eur Union. 2011;L54:1-254. Accessed August 10, 2026. https://eur-lex.europa.eu/eli/reg/2011/142/oj/eng
9. Cabinet of Ministers of Ukraine. Procedure for Waste Classification. Resolution No. 1102. Issued October 20, 2023. https://zakon.rada.gov.ua/laws/show/1102/-2023-п#Text
10. European Parliament and Council of the European Union. Directive 2008/98/EC of November 19, 2008 on waste and repealing certain directives. Off J Eur Union. 2008;L312:3-30. Accessed August 10, 2026. https://eur-lex.europa.eu/eli/dir/2008/98/oj/eng
11. European Parliament and Council of the European Union. Regulation (EC) No. 1272/2008 of December 16, 2008 on classification, labelling and packaging of substances and mixtures. Off J Eur Union. 2008;L353:1-1355. Accessed August 10, 2026. https://eur-lex.europa.eu/eli/reg/2008/1272/oj/eng
12. Bardov VG, ed. Hihiiena ta ekolohiia [Hygiene and Ecology]. Nova Knyha; 2020:237–238. ISBN 978-966-382-830-5. https://emed.library.gov.ua/hihiiena-navkolyshnoho-seredovyshcha/hihiiena-ta-ekolohiia-3/

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