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Sustainable Development of Regions Under Martial Law: Challenges and Approaches in Waste Management

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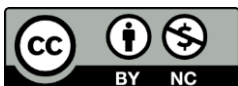
ABSTRACT

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The article examines ways to ensure the sustainable development of regions under the growing challenge of waste management, including waste generated as a result of war-related destruction. The purpose of the study is to identify directions for improving the waste management system under martial law from the perspective of regional sustainable development. The research emphasizes that effective solutions to this issue are possible only through the introduction of a systemic and legally regulated approach that will prevent waste accumulation, minimize risks of negative impacts, and avoid long-term environmental pollution. It has been found that a systemic approach to waste management in wartime conditions will prevent long-term regional contamination and facilitate rapid recovery by enabling resource reuse, in line with the principles of the “circular economy”. The provisions of the circular economy are considered a key instrument for achieving sustainable regional development and strengthening resilience to future challenges. In the current context, one of the leading topics of Ukrainian scholarly discourse is the post-war recovery of the state. This issue gains particular significance given the large-scale infrastructure destruction, substantial human and material losses, and the need to shape a new model of national development. The study highlights that the problems of processing war-related waste are especially urgent today, granting strategic importance to the implementation of circular economic models for ensuring Ukraine’s sustainable development in the long term. It is concluded that sustainable regional development in the context of waste management must be based on international standards and national programs with the involvement of relevant experts and donor organizations, which will serve as a decisive factor for achieving sustainability in the post-war period.

KEYWORDS

sustainable development, regions, war-related destruction waste, circular economy, waste management.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Сталий розвиток регіонів в умовах воєнного стану: виклики та підходи у сфері поводження з відходами

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СТАТТЯ

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У статті розглядаються шляхи забезпечення сталого розвитку регіонів в умовах загострення проблеми поводження з відходами, у тому числі тих, що виникають унаслідок воєнних руйнувань. Мета дослідження – визначення напрямів удосконалення системи управління відходами в умовах воєнного стану з позицій сталого розвитку регіонів. У межах дослідження відзначається, що ефективно вирішення даної проблеми можливе лише за умови запровадження системного і нормативно врегульованого підходу, який дозволить уникнути накопичення відходів, мінімізувати ризики їх негативного впливу та запобігти довготривалому забрудненню довкілля. Досліджено, що системний підхід до управління відходами в умовах воєнного стану унеможливить довгострокове забруднення регіонів та сприятиме їх оперативній відбудові завдяки повторному використанню ресурсів, що відповідає принципам «циркулярної економіки». Положення «циркулярної економіки» розглядаються як ключовий інструмент досягнення сталого розвитку регіонів та підвищення стійкості до майбутніх викликів. У сучасних умовах однією з провідних тем українського наукового дискурсу є проблематика післявоєнного відновлення держави. Це питання набуває особливої ваги з огляду на масштабні руйнування інфраструктури, значні людські та матеріальні втрати, а також потребу у формуванні нової моделі розвитку країни. Показано, що надзвичайно актуальними сьогодні є проблеми перероблення відходів воєнної руйнації, що надає питанню запровадження циркулярних моделей управління економікою стратегічного значення для забезпечення сталого розвитку України у довгостроковій перспективі. Зроблено висновок, що сталий розвиток регіонів в контексті поводження з відходами повинен базуватися на міжнародних стандартах і національних програмах із залученням відповідних фахівців і донорських організацій, що стане вирішальним чинником сталого розвитку регіонів у післявоєнний період.

КЛЮЧОВІ СЛОВА

сталий розвиток, регіони, відходи руйнації війни, циркулярна економіка, управління відходами.

1. Introduction

In modern scientific research on waste management, the main emphasis is placed on the possibilities of recycling and reuse. The public and experts draw the attention of society to the environmental and material advantages of introducing a circular economy. The importance of the political and value dimension of this process is especially emphasized, taking into account the European integration prospects of Ukraine. National policy should be aligned with EU policy, in particular aimed at transforming the economy for sustainable development in accordance with the provisions of the European Green Deal.

Despite the obvious relevance, the processing of waste from the destruction of war on an industrial scale is still rather an exception. Individual Ukrainian projects are implemented mainly at the expense of donor funding. The current state in this area is due to a number of factors, first of all, the unprecedented level of destruction and the lack of previous experience in working with waste of this nature and volume.

War risks and losses have an additional impact. The situation is determined by both the pre-war waste management strategy and modern attempts at reform. Representative and executive bodies of local self-government in the regions are forced to adapt to new conditions and challenges. Understanding their needs and challenges is key to a prompt and effective system upgrade. First of all, it concerns problems in the field of legal regulation, financing, organization, technical and technological support, as well as information support.

2. Literature Review

Today, one of the key directions in the Ukrainian scientific discourse is the study of the problems of post-war restoration of the state on the basis of sustainable development. Improving environmental safety and forming long-term strategies for the restoration of Ukraine, as an important factor in ensuring the sustainable development of regions, is considered in the works of such scientists as M. Bortnikova et al. [1], N. Horbal, & S. Slipachyk [2], O. Ivanov [4], O. Kolesnichenko [5], A. Kozlova [6], M. Potip [8], T. Safranov et al. [9] pay special attention to environmental problems of the peculiarities of construction and demolition waste management in the regions of Ukraine during the war, and S. Sychanskyi [10] studies the legal regime of war waste generated as a result of hostilities in Ukraine.

Information from various sources within the chosen topic was analyzed and structured. Despite the existing studies on the problems of sustainable development of regions in the context of waste management during martial law, there is a lack of comprehensive improvements that would take into account the long-term benchmarks of post-war recovery.

3. Problem Statement

The purpose of this study is to analyze the dynamics of waste generation and forecast their volumes under martial law, as well as to outline possible areas for improving the waste management system from the standpoint of ensuring sustainable development of regions. To achieve this goal, the following tasks will be performed: to investigate modern methods of waste management; to show the current state of waste management in the regions; to focus on the problems of regional waste management; to develop recommendations that contain the main tasks of regional policy on the development of the waste management system, taking into account the specifics of war destruction waste.

4. Methods and Materials

The methodology of the study of sustainable development of regions in the context of waste management is based on a complex combination of quantitative and qualitative methods of analysis. In the process of work, systematization and critical review of scientific literature, official reports of state and international institutions, as well as materials of practical research covering current trends and problems in the field of waste management, are carried out. This approach makes it possible to identify

both general patterns and specific regional features that affect the effectiveness of sustainable development strategies. Special attention is paid to the analysis of institutional mechanisms, economic tools and environmental practices that can be applied to increase the resilience of regional systems in the post-war period. The combination of quantitative methods aimed at assessing the indicators of waste generation and dynamics, with a qualitative analysis of adaptation strategies, provides a comprehensive vision of the problem, allows you to assess potential risks and form scientifically based recommendations for improving the waste management system on the basis of sustainable development.

The study of the development of waste management processes in the regions of Ukraine is methodically planned to be carried out through a synergistic combination of assessment, monitoring and forecasting processes.

5. Results and Discussion

The 2022–2023 analysis of the state of household waste management in Ukraine was based on data from regional military administrations, excluding the temporarily occupied territories and most of the eastern and southern regions, where it was impossible to collect statistics due to the military aggression of the Russian Federation. During this period, waste removal services covered about 80% of the population. In 1,440 settlements, a separate collection system has been introduced, which is 72% of residents, but in general in the country, this figure reaches only 30%. Collection technologies involve the use of 2–5 containers: in small settlements, 1 container for PET bottles or plastic is common, in cities, 2–3 containers for paper, plastic, glass, metal and dry fraction. Household waste management in Ukraine is mainly based on low-tech disposal methods. There are 31 waste sorting lines in 26 settlements, and disposal is carried out only at one incineration plant in Kyiv. There are approximately 5,700 landfills and waste disposal sites with a total area of almost 8,000 hectares, of which about 40% require reclamation

According to the Ministry of Communities and Territories Development, in 2023, more than 51 million m³ of household waste were buried in Ukraine on almost 6,000 hectares. landfills and landfills, a significant part of which is overloaded or does not meet environmental standards. The field of solid waste management is characterized by an increase in waste volumes, a low level of recycling (less than 8%), poor coverage of the rural population with services and the predominance of landfill over other disposal methods. Most of the landfills are outdated, which threatens the environment and public health.

The current state of waste management is characterized by the following indicators: the volume and structure of waste, the level of its processing, infrastructure development and disposal features. It should be noted that some of these indicators are missing in the state statistical reporting, and in our country, there is not enough experience in implementing standard approaches to waste management, which would allow estimating specific costs depending on the scale and depth of waste processing, which is an obstacle to conducting thorough research. Table 1 shows the characteristics of waste processing methods in the EU [17].

Table 1. Technical and economic characteristics of waste processing methods

Method/Indicator	Collection and recycling of mixed waste	Recycling with separate collection (organic waste)	Recycling with separate collection	Biogas production from organic biomass	Composting (aerobic digestion)	Waste incineration with energy production
1. Possible recycling rate, %	5–20	15–30	30–40	20–30	30–40	80–85
2. Specific investment, €/ton	100–250	200–300	300–400	300–500	400–600	800–1,200

Source: Systematized by the authors according to the data given in [12; 17].

Modern methods and technologies in the field of household waste management have been introduced in Ukraine. On the territory of 1,557 settlements and territorial communities, there is a system of separate collection of household waste [7; 11]. Implementation of modern methods of household waste management in Ukraine by directions and state of implementation, with examples given in Table 2.

Table 2. Implementation of modern methods of household waste management in Ukraine

Direction	Implementation status	Examples/Details
1. Separate waste collection	1,557 settlements and communities	Coverage of various regions, except for temporarily occupied territories and war zones
2. Waste sorting	41 waste sorting lines in 30 settlements	Kyiv (10 lines), Vinnytsia, Kryvyi Rih, Kramatorsk, Lviv region (Stryi, Chervonograd, Zolochiv), Chernivtsi, Sumy
3. Heat treatment	1 incinerator	Kyiv
4. New objects	9 sorting complexes, 1 mechanical and biological processing, 1 incineration plant, 1 transshipment station	In the process of construction
5. Logistics	Purchase of 31 thousand tons. containers (3.3 thousand for separate collection) and 172 garbage trucks	Financing: UAH 204 million (containers), UAH 402 million (transport)
6. Leachate collection and disinfection systems	53 landfills (47 equipped with installations)	Others have storage tanks for later removal
7. Biogas utilization	16 polygons	Kremenchuk, Kharkiv – flare burning; Lutsk, Kyiv, Kryvyi Rih, Odesa, Chernivtsi – cogeneration plants

Source: Systematized by the authors according to the data given in [17].

The volume of destruction waste generated in Ukraine as a result of russia's military aggression is already comparable to the average annual generation of solid household waste in the country – approximately 10–12 million tons. The exact figures can be determined after the liberation of the entire territory of Ukraine [16]. Let us consider the algorithm for managing war destruction waste for the population in the regions (Table 3).

Table 3. Algorithm for handling war destruction waste in territorial communities

Stage	Content of actions	Executors / Responsible
1. Security check	Prompt inspection of destroyed objects for their safety	Special services, local authorities
2. Organization of dismantling	Search for resources for dismantling; hiring employees, attracting volunteers, creating public associations	Local authorities
3. Initial sorting	First waste sorting within households	Citizens
4. State support	Financing of dismantling and removal; stimulating households to sort and hand over secondary raw materials	Government Bodies
5. Organization of infrastructure	Creation of containers and temporary sorting sites; in the case of unsorted waste, involvement of employees, volunteers, and businesses for sorting	Local authorities, businesses, and volunteers
6. Logistics	Dismantling, loading and removal of waste; provision of consultants to support processes	Utilities
7. Reuse	Creation of “hypermarkets/waste banks”; popularization of reuse; Cooperation with businesses for recycling	Local authorities, business, and community
8. Innovation and international experience	Study of EU practices, search for investors/donors; Financing of waste recycling projects	State bodies, local authorities
9. Raw material collection points	Organization of collection points for glass, plastic, metals, etc.	Local authorities, utilities

Source: Systematized by the authors according to the data given in [17].

Although according to the content of the table, the vast majority of responsibilities belong to state and local authorities, it should be taken into account that private businesses can also effectively engage in waste removal, fulfilling contractual obligations, as well as managing waste responsibly. The optimal model of waste management from the destruction of war can be based on four principles: responsibility of the authorities and utility companies, clear communication of procedures and deadlines, sorting and recycling of waste.

Today, work with waste generated as a result of the war is regulated by the following basic regulatory documents [14–16]:

1. Law No. 2320-IX “On Waste Management” (2022);
2. Resolution of the Cabinet of Ministers of Ukraine No. 1073 of 27.09.2022 “On Approval of the Procedure for Handling Waste Generated in Connection with Damage (Destruction) of Buildings and Structures as a Result of Hostilities, Terrorist Acts, Sabotage or Work to Eliminate Their Consequences”, in particular regarding the creation of temporary storage sites for destruction waste;
3. Resolution of the Cabinet of Ministers of Ukraine No. 473 (2022) “On Approval of the Procedure for Performing Urgent Work to Eliminate the Consequences of the Armed Aggression of the Russian Federation Related to the Damage to Buildings and Structures”;
4. Resolution of the Cabinet of Ministers of Ukraine No. 600 (2023) “On Approval of the Procedure for Providing Compensation for Destroyed Real Estate Objects”;
5. Law of Ukraine No. 2189-VIII “On Housing and Communal Services” (2022);
6. Rules for the operation of landfills.

Experts note that the most problematic for practical implementation is the new Law “On Waste Management”, since it was developed without taking into account realities. It is difficult for performers to understand how to apply it in practice: the prescribed requirements are often unrealistic, which can lead to the collapse of the system or to its operation outside the legal field [14].

Funding for the removal, sorting and disposal of war waste in Ukraine is currently carried out at the expense of territorial communities, the Recovery Agency, volunteers and donors. The main problems of financing in the field of waste management:

- Lack of funds in community budgets to pay for contractors’ services. The frontline and de-occupied communities of Kherson, Kharkiv and Kyiv regions, where the scale of destruction is the greatest, need significant resources to eliminate the consequences, while taxpayers are partially lost.
- The resolution on directing the personal income tax to the state budget hurt local budgets.
- Hostilities allowed the population not to pay utility tariffs, which did not increase during the three years of the war, making utility companies unprofitable.

The lack of an economically justified tariff for the removal and disposal of waste led to direct dependence of utility companies on community budgets and limited the possibilities for planning and development. In addition, local authorities note the high costs of design and estimate documentation for the dismantling of high-rise buildings [5; 6].

Organizational and security issues:

- Workers and equipment often work near the front line, being at risk of shelling (especially in the Kherson region).
- There is a shortage of personnel, in particular in frontline and de-occupied settlements, where about 5% of the population, mainly of retirement age, remains.
- Local authorities complain about the inflated cost of waste disposal due to the monopolization of landfills that are privately owned and have no competitors.
- Waste removal companies are often forced to perform work outside of contracts, including working with construction waste, although their contracts only apply to municipal solid waste.

Technological problems: lack of special equipment: forklifts, waste removal machines, bulldozers, tractors, shredders and composters; repair of equipment is complicated due to lack of funding; donor support does not cover all needs; There are not enough sorting lines in large cities. Technologies are needed to recycle waste into construction raw materials (e.g., concrete blocks into new blocks) and improve waste testing for explosive elements for safe sorting and recycling.

Information problems: insufficient understanding of the potential benefits of waste recycling, lack of pilot projects and examples, as well as a shortage of specialists who could find ways to reuse waste; lack of access to successful experience and inability to scale successful projects of local communities.

According to experts, communities in frontline regions have the potential to implement the principles of the circular economy in the future [1]. However, large-scale projects, such as large waste processing plants, currently remain a distant prospect – after the end of the war, the elimination of the threat of occupation, the cessation of shelling and the emergence of investors or financing for the purchase of technological equipment. The exception is the Kyiv region, which is already attracting the attention of European investors. Currently, community residents see potential in the development of

local initiatives and private businesses that process secondary raw materials for their own needs, in particular building materials, metal, glass, or plastic [2; 3].

Forecasts of waste generation in Ukraine are based on the population and the level of development of production potential, transport and social infrastructure. Using data from the State Statistics Service, the Institute of Demography and Social Research of the National Academy of Sciences of Ukraine, UNHCR and the Office of the United Nations High Commissioner for Refugees, taking into account trends and development factors, two population scenarios for 2023–2035 have been developed:

- The optimistic scenario assumes the preservation of existing trends in demographic and migration processes. 50% of refugees are expected to return in 2023–2026, mainly women of fertile age and children. By the beginning of 2035, the population will be 30.76 million people (74.7% of the pre-war level of 2022).

- The pessimistic scenario assumes a decrease in natural growth and an intensification of migration processes, with the return of 25% of refugees in 2023-2026. At the end of the period, the population will be 25.20 million people (61.2% of the pre-war level of 2022).

The average Ukrainian produces 1.04 kg of household waste per day, including waste from local green areas, which gives about 379.6 kg per year. Added to this is approximately 38 kg of bulky, repair and construction waste per year. These indicators are used as a base for making forecasts of waste generation, taking into account the average annual growth rate: 1.38% according to the Institute of Environmental Economics and Sustainable Development of the National Academy of Sciences of Ukraine, 1.69% for large cities and 0.9% for other settlements according to the National Institute of Environmental Economics and Sustainable Development of Ukraine. It is predicted that in 2025, 13.51 million tons will be generated, and in 2030, 13.65 million tons of household waste from households and other sources that generate waste of similar composition (Table 4).

Table 4. Forecast of solid waste generation by the population according to optimistic and pessimistic scenarios (2023–2035, million tons/year)

Year	Optimistic forecast												
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Population, million Persons	34.43	34.76	35.27	35.57	35.00	34.44	33.89	33.35	32.81	32.29	31.77	31.26	30.76
Generated solid waste, million tons/year	13.07	13.19	13.39	13.50	13.29	13.07	12.86	12.66	12.45	12.26	12.06	11.87	11.68
Year	Pessimistic forecast												
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Population, million Persons	34.40	33.80	33.50	32.80	31.90	30.90	30.00	29.20	28.30	27.50	26.70	25.90	25.20
Generated solid waste, million tons/year	13.06	12.83	12.72	12.45	12.11	11.73	11.39	11.08	10.74	10.44	10.14	9.83	9.57

Source: Systematized by the authors according to the data given in [4].

For the implementation of the National Waste Management Plan for 2024–2035, priority goals have been identified:

1. Improvement of legislation – bringing national regulations in line with EU requirements and implementation of the provisions of the Association Agreement between Ukraine and the EU in the field of waste management.

2. Implementation of economic mechanisms to improve waste management.

3. Development of the institutional structure and increase of human resources in the field of waste management.

4. Modernization of the information support system for waste management.

5. Development and modernization of infrastructure in the field of waste management.

6. Raising public awareness of effective waste management.

To achieve European standards for reducing the disposal of household waste, by 2030, its disposal must be reduced to 30% of the total mass of waste (an indicator of the National Waste Management Strategy until 2030) [15].

Thus, we will formulate recommendations that contain the main tasks of regional policy on the waste management system, taking into account the specifics of war destruction waste: analyze waste generated at the regional level and develop programs to prevent its generation, taking into account local conditions; encourage public participation through information and education campaigns; minimize waste during public works and increase the use of recycled building materials in public procurement; familiarize local businesses with environmental management systems (EMAS) to help reduce waste in business activities.

6. Conclusions

Therefore, the main challenges for the sustainable development of regions under martial law are the increase in the volume of waste generated, in particular that arising from military aggression, which is a serious environmental problem. Solid domestic and industrial waste, as well as construction waste, cause air and water pollution, increase greenhouse gas emissions, release hazardous gases and leachate, lead to the loss of land resources and the spread of harmful chemicals. Reducing the negative impact of waste on the environment is a key principle of sustainable development in the region.

As for approaches to waste management, the state today pays attention not only to economic and social aspects of reconstruction, but also to environmental challenges, in particular, the processing of destructive waste and optimization of methods of its disposal. In this context, it is important to implement the principles of the circular economy, which involves the reuse of resources, the reduction of waste and the minimization of harmful effects on the environment.

The role of the state is to form a national strategy, legislative regulation and financial stimulation of business. Local authorities initiate a dialogue with the community on waste recycling and create favorable conditions for investors. Business can become the main investor and executor of projects, while the community is responsible for the initial sorting of waste, its reuse where possible, and active participation in public initiatives – cooperation with the authorities, attracting grants and volunteer projects.

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