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COMPARATIVE ANALYSIS OF THE STUDY RESULTS ON THE COMPONENT COMPOSITION OF MUNICIPAL WASTE IN SETTLEMENTS OF TOWNSHIP AND VILLAGE TYPE IN THE POLTAVA REGION

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Abstract. This paper presents the results of a comparative analysis of collected data on the component (morphological) composition of municipal waste generated in the township and village type settlements of the Poltava region. Moreover, it includes the authors' own research findings from sorting analyses conducted in the settlement of Kotelva, Poltava region. The conclusions of these studies were obtained as a result of sorting analyses conducted for four seasons, following the guidelines outlined in the Ukrainian *Methodological Recommendations for Determining the Morphological Composition of Municipal Waste* as well as European approaches, the *European Guidelines for Conducting Residual Waste Sorting Analyses ("Leitfaden für die Durchführung von Restmüll-Sortieranalysen").* The conclusions gained from these studies have allowed the authors to create a more comprehensive components list, which they recommend for use in sorting analyses. This aims to accurately identify the component composition of municipal waste and to inform effective waste management and strategic economic solutions accurately.

Keywords: municipal waste, component (morphological) composition of waste, resource potential.

1. Introduction

The current wartime conditions have revealed numerous issues affecting national security in our country, particularly in the realm of energy security. This is a fundamental need for society, alongside food supply and environmental safety. The vulnerability of the looped gas transportation and electricity networks, as well as the dependence of large industrial enterprises and public utility services on continuous energy and fuel supply, are significant weaknesses in our national energy system that have become evident during the full-scale war. These challenges call for rational solutions.

Ensuring the independence of heating and energy systems for private households, public dining and trade establishments, administrative and public institutions, healthcare and educational facilities, hotels, dormitories, and sanatoriums requires the use of autonomous energy sources. Such solutions allow

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consumers to choose the most convenient and economically viable heat and energy supply options.

The impacts and consequences of military actions necessitate the search for alternative heating and energy solutions, the development of new fuel types, and the creation of more efficient, autonomous, and ideally independent systems for the public utility sector. Additionally, these challenges align with sustainable development goals, such as reducing greenhouse gas emissions, minimizing the use of non-renewable fossil fuels, and decreasing the volume of municipal waste and the land occupied by landfills through the utilization of resource-valuable waste components waste and the area occupied by landfills and dumps by using resource-rich waste components (Holik et al., 2023).

The *purpose of this study* is to analyze and summarize the results of existing and original research on the component composition of municipal waste (hereinafter referred to as MW) in settlements of township and village type of the Poltava region. This includes assessing the resource potential of MW for possible use as raw material for example, for small-scale energy facilities and/or the possibility of replacing the corresponding volumes of traditional resources with alternative ones, which are separate fractions of municipal waste.

2. Theoretical part

The constant growth of waste generation in the Poltava region, along with the prevalent use of waste disposal technologies, has led to the expansion of landfills. This results in significant land contamination and higher emissions of pollutants into various environmental components. Moreover, by disposing of MW in landfills, we lose potentially valuable materials that could serve as secondary raw materials and replace traditional non-renewable natural resources. In this context, transitioning to new waste management strategies focused on waste recovery technologies is becoming increasingly important. Such approaches aim to optimize the resource potential of waste and reduce its environmental impact (Illyash, Holik, 2023).

One of the prerequisites for the effectiveness of the waste management system is the availability of objective data on the component (morphological) composition of MW typical for a certain type of settlement, to plan the infrastructure for the collection and subsequent management of individual components of household waste.

Determination of the component composition of municipal waste is currently carried out in two directions: 1) determining the component composition of MW; and 2) assessing the resource and energy characteristics of MW components.

3. Methods and Materials

This study employed methods of comparative analysis, systematization, and qualitative evaluation of collected data and analytical results. The research included planning and conducting a series of sorting analyses of MSW within the Kotelva community in the Poltava region, Ukraine. These analyses were guided by Ukrainian *Methodological Recommendations for Determining the Morphological Composition of Solid Household Waste* (Order of the Ministry of Housing and Communal Services, 2010; Order of the Ministry of Community Development, Territories, and Infrastructure of Ukraine, 2024), as well as the *European Guidelines for Conducting Residual Waste Sorting Analyses* ("Leitfaden für die Durchführung von Restmüll-Sortieranalysen") (Guideline for Conducting Residual Waste Sorting Analyses, 2021).

The morphological composition of MSW is significantly influenced by the socio-economic characteristics of the settlement, demographic indicators, urbanization level, dietary habits, and other factors. In European practices, a classification approach known as the "stratification factor" is used to better compare conditions that affect the composition of MSW.

This study, therefore, focused on collecting and systematizing data on the morphological composition of MSW from research conducted in 2022–2023 in the township and rural areas of the Poltava region, about which there is limited but important information. The studies were carried out following the *Methodological Recommendations for Determining the Morphological Composition of Solid Household Waste,* approved by the Ministry of Housing and Communal Services of Ukraine on February 16, 2010, No. 39 (Order of the Ministry of Housing and Communal Services, 2010), valid at the time of the study. These recommendations classified MSW into 11 components. The compiled results of these studies are shown in Table 1.

Table 1

The Results of the Study on the Morphological Composition of Municipal Waste in Settlements of Township and Village Type in the Poltava Region for 2022–2023

Name of the sample component	Name of the settlement				
	village Kharsiki of Chornukhy community[1]	village Yatsyny of Pyriatyn community[2]	village Oleksandrivka of Hrebinkivska community[3]	Novoorzhytske urban-type settlement of the Novoorzhytska community[4]	Opishnia urban-type settlement of the Opishnia community[5]
	Percentage of total weight, %				
Food waste	16.3	26	28.6	11.6	24
Paper and cardboard	9.7	3.8	18.8	14	8
Polymers	22.7	7.7	23.3	15.1	13
Glass	13.7	2,2	10.3	9.5	18
Ferrous metals	–	–	–	4.9	0.95
Non-ferrous metals	–	–	1.3		
Textile	10.1	6.7	2.9	6.9	3.5
Wood	18.2	0	0	12	1.15
Hazardous waste	–	7.6	–	–	0.55
Bones, leather, rubber	–	3.4	–	18.1	3.1
Residue of MW after extraction of components	4.2	42.4	14.7	7.2	27.75
Total weight of MW	100	100	100	100	100

Explanation of the Table:

[1] The results of the study (rapid analysis) of the morphological composition of MW, were conducted at the landfill near the village of Kharsiki, Chornukhy community on August 17, 2022 (Analytical Materials on the Operation Status of Landfills in the Chornukhynska Territorial Community, 2022).

[2] The results of the study (rapid analysis) of the morphological composition of MW conducted at the landfill near the village of Yatsyny, Pyriatyn community, on August 21, 2022 (Analytical Materials on the Operation Status of Landfills in the Pyriatynska Territorial, 2022)..

[3] The results of the study (rapid analysis) of the morphological composition of MW conducted at the landfill in Oleksandrivka village of the Hrebinkivska community on August 14, 2022 (Analytical Materials on the Operation Status of Landfills in the Hrebinkivska Territorial Community, 2022).

[4] the results of the study (rapid analysis) of the morphological composition of MW conducted at the landfill of Novoorzhytske township of the Novoorzhytska community on August 12, 2022 (Analytical Materials on the Operation Status of Landfills in the Novoorzhytska Territorial Community, 2022).

[5] data from the materials *"Sanitary cleaning scheme for Opishnia township, Popivka village and Mali Budyshcha village of Opishnia territorial community of Poltava region"*, 2023 (Contract No. 0012/23, 2023).

Based on the analysis of the data provided in Tabl.1, the following observations can be highlighted:

Food waste (vegetables, fruits, gardening waste, etc.) makes up the majority of the total waste, ranging from 11.6 to 28.6 %. The fluctuation of this indicator is related to the food and household management traditions inherent in the population of urban and rural communities.

The content of *paper and cardboard* in the total weight of MW varies significantly, ranging from 3.8 to 18.8 %. The lowest level of paper and cardboard waste is inherent in one-storey buildings in the private sector, where this resource is used for economic purposes, in particular for energy needs. Higher levels of paper waste are typical for apartment buildings.

The percentage of *waste polymers* is quite high and also varies in a wide range from 7.7 to 23.3 %. This is due, firstly, to the high demand for food products in polymeric packaging materials, and secondly, to the absence or insufficient organization of containers for separate collection of polymeric packaging in certain communities and settlements.

Glass waste in the total weight of MW ranges from 2.2 to 18 %, due to the predominant lack of glass container collection points in communities and/or insufficient containers for separate collection of glass waste.

The content of *ferrous and non-ferrous metals* traditionally varies from a low level of less than 1 to 4.9 %, depending on the availability of small businesses in the communities that collect metal waste and transfer it for recycling.

The content of *wood waste* also has a significant range of fluctuations from 0 to 18.2 %, which can potentially be associated with the generation of wood waste during the maintenance of forest belts and public green spaces in the territories of the respective communities.

Waste components such as *textiles, leather, rubber, and bones* traditionally have a significant range of variation from about 3 % to 18.1 %.

In the township and village areas, hazardous waste (e.g., batteries, dry and electrolytic accumulators, solvent and paint containers, mercury lamps, TV screens) typically constitutes less than 1 %. This is attributed to the gradual establishment of collection systems for hazardous waste through public collection points and transfer to specialized facilities via regional services like the *EcoBus*. However, levels as high as 7.6 % indicate the inclusion of a broader range of waste types under "hazardous waste", such as discarded electronic devices.

The significant variation in the residual waste content after the removal of components (ranging from 4.2 to 42.4 %) is due to differing thoroughness in the sorting analyses and the specific locations where these analyses were conducted (e.g., landfills, collection trucks, or containers).

Therefore, the data collected regarding the composition of MW from different rural and township settlements in the Poltava region reveal substantial variability across nearly all waste components. This can be explained by:

– First, by non-systematic and episodic nature of studies conducted in these areas, often limited to one-off or rapid analyses.

– Secondly, the choice of different locations for sorting analyses (landfills, containers of different capacities).

– Thirdly, conducting research in different seasons of the year is logical and leads to an increase in the range of fluctuations in the content of individual components, especially food waste, plastic, paper and cardboard).

Consequently, the data presented in Table 1 do not provide an objective assessment of MW composition but serve only as indicative Figures.

Therefore, to obtain more objective information on the morphological composition of MW, a series of our studies (sorting analyses) of the composition of household waste in the territory of the Kotelevka settlement community of Poltava region in the period 2023–2024 was conducted as part of this work. The first two stages of the study (in the autumn and winter seasons of 2023) were conducted following *the Methodological Recommendations of 2010* (Order of the Ministry of Housing and Communal Services, 2010). The next two stages (in the spring and summer seasons of 2024) were carried out according to the new *Methodological Recommendations*, which came into effect on May 3, 2024 (Order of the Ministry of Community Development, Territories, and Infrastructure of Ukraine, 2024), according to which the morphological composition of the MW was determined by 14 components.

The summarized results of the study of the composition of the MW, conducted in the urban type Kotelva, Poltava region, for 4 seasons are presented in Table 2.

Table 2

Generalized Results of the Studies on the Component (Morphological) Composition of Municipal Waste in the Township of Kotelva, Poltava Region, Conducted in 2023–2024

Name of the sample component	urban-type settlement Kotelva of the Kotelva community (generalized data from 4 seasonal surveys)
	Percentage of total weight, %.
1	2
Bio-waste (food waste, vegetables, fruits, horticultural waste, greenery waste etc.)	28.83–62.2
Paper and cardboard	3.3–5.5
Plastic (plastics and other polymers)	5.49–12.14
Glass	2.13–7.93
Metals (ferrous and non-ferrous)	0.43–3.82
Textile	0.63–10.6
Wood	0.02–0.16

Continuation Table 2

1	2
Hazardous waste (solvent and paint containers, mercury lamps, expired medicines, poisons, chemicals, herbicides and pesticides, hygiene products, diapers etc.)	3.23–9.39
Bones, leather, rubber	0.73–4.72
Residual MW after extraction of components	0.97–3.9
Combined packaging (packaging that may contain different combinations, such as cardboard and metals)	0.82–1.49
Waste electrical and electronic equipment (telephones, computers, TVs, refrigerators, irons, radios etc.)	0.11
Waste batteries and accumulators (finger, car etc.)	0.01
Bulky household waste (furniture, mattresses etc.)	–
Household renovation waste (bricks, plaster, wallpaper etc.)	13.55
The total relative weight of the MW sample	100

In parallel, as part of these studies, sorting analyses of municipal waste in the township settlement of Kotelva were conducted, following the European approach. This approach includes the European specification and specific recommendations from the Methodology for the Analysis of Solid Waste (SWA-Tool) and Sorting Catalogue (Annex I) (Annex I) (SWA-Tool, 2024), as well as certain provisions of the Austrian methodology "Leitfaden für die Durchführung von Restmüll-Sortieranalysen" (Guideline for conducting residual waste sorting analyses, 2021). According to European guidelines, sorting analyses are divided into 24 components. The results are presented in Table 3.

Table 3

Results of sorting analyses of MW composition according to the Austrian methodology

Item No.	Name of the sample component	Share of total household waste, %
1	Organics (except food waste)	18.1
2	Kitchen waste	23.1–45.09
3	Food waste that can be avoided	1.07–5.82
4	Packaging paper and cardboard and corrugated cardboard	2.19–2.98
5	Paper and cardboard (printed paper)	0.32–3.27
6	Lightweight plastic packaging PET (beverage containers)	1.35–3.79
7	Lightweight polymer packaging	1.97–4.99
8	Other plastic	0.34–2.13
9	Other packaging	0.72–1.42
10	Glass packaging	2.13–4.61
11	Other glass	0.244
12	Metal packaging	0.43–3.82
13	Non-packaging metals	0.35
14	Plastics other	0.02–1.35
15	Wood	0.02
16	Hygiene products	4.15–8.88
17	Textile	0.63–10.6
18	Footwear	1.89–17.41
19	Waste electrical and electronic equipment	0.11–0.217
20	Batteries, including batteries	0.023
21	Hazardous substances (medicines, paints, varnishes, oil filters, detergents etc.)	0.26–2.66
22	Inert substances (construction waste)	2.44–13.55
23	Other waste (leather, rubber, toys and tools made of various materials, soft toys, cigarette butts, bones etc.)	0.07–6.34
24	Sorting residue (cannot be identified)	0.17–3.9
	The total relative weight of the sample of the MW	100

4. Results and Discussion

The component (morphological) composition of modern municipal solid waste (MSW) has significantly evolved compared to several decades ago. The widespread use of packaging materials and convenience foods in the daily lives of most residents has led to a simultaneous increase in the content of paper and polymers. The composition of solid waste primarily depends on the specifics of the sources of its generation; it changes significantly not only over time but also depends on the specific area where waste is collected (city, rural area, mixed zone). In addition, climatic conditions, living standards, and the level of development of the secondary raw materials market are important external factors that affect the composition of MW (Project "Regional Waste Management Plan in Poltava Region until 2030", 2024).

The results of the comparative analysis of the collected data on the component composition of MW and the data from the sorting analyses of MW in the township settlement of Kotelva, Poltava region, according to Ukrainian methodological recommendations (Order of the Ministry of Housing and Communal Services, 2010; Order of the Ministry of Community Development, Territories, and Infrastructure of Ukraine, 2024) and Austrian methodology (Guideline for Conducting Residual Waste Sorting Analyses, 2021) are as follows:

− According to the results of our sorting analyses, the content of biowaste (food waste, fruits, vegetables and their residues) in the total MW mass is much higher (28.83–62.2 %) compared to the data of all previous studies. Their significant share in the total mass of municipal waste is explained by the specifics and eating habits of the local population of Kotelva, which is typical for most settlements of Ukraine of urban and rural types;

− gardening waste (tree trimmings, branches) in the urban-type settlement of Kotelva is collected separately and accounted for separately, so it was not included in the studied sample of household waste in the container during sorting analyses, which is a specificity of this settlement that is not widespread;

− the range of paper and cardboard content of 3.3–5.5 % established in Kotelva is more logical for a settlement where private individual construction prevails;

− a lower level and a smaller range of fluctuations are characteristic of plastic waste, which was studied in Kotelva (5.5–12.14 %);

− a much smaller range of fluctuations in glass waste (2.13–7.93 %) was recorded during our sorting analyses;

− a very low level of wood waste (0.02–0.16 %) was determined during the sorting analyses, which indicates the predominant use of this waste as a fuel resource in private homes;

− the content of hazardous waste, which was established during the sorting analyses by the authors, was, on the contrary, much higher (3.23–9.39 %) than previously published data;

– the results of the comparative analysis of the data on the component composition of MW obtained during our 4-seasonal studies in the urban-type settlement of Kotelva and the collected data on the composition of MW in other settlements of the Poltava region, mentioned in paragraph 1, prove the necessity of determining the composition of household waste by conducting a full series of field sorting analyzes in different seasons of the year, taking into account the specifics of a particular settlement;

– the established list of 11 and currently 14 mandatory components that determine the composition of household waste in Ukraine according to the "Methodological Recommendations for Determining the Morphological Composition of Household Waste" does not currently meet the current specifics of household waste and, accordingly, is difficult to comply with the European approach, in particular, with the requirements of the Austrian methodological recommendations "Leitfaden für die Durchführung von Restmüll-Sortieranalysen" (Guideline for Conducting Residual Waste Sorting Analyses, 2021);

– the research results presented in Table 3 indicate that the list of studied components identified during the sorting analyses of the composition of MW in the urban-type settlement of Kotelva covers the entire spectrum of the modern composition of household waste, which is typical for a settlement of a village type. That is, 19 components, sorted following European requirements (Guideline for Conducting Residual Waste Sorting Analyses, 2021), were represented in the total mass of the sample studied municipal waste in the urban-type settlement of Kotelva at the level of more than 1 %;

– after conducting field sorting analyses, the average indicator of the share of sorting residue that cannot be identified, according to the results of 4 seasonal studies, was quite low at the level of 0.97–3.9 %, which indicates the objectivity of this approach to sorting the MW and corresponds to the interval of up to 10 % recommended by the European methodlogy.

5. Conclusions

Based on the results of the above studies and their comparative analysis, the following conclusions can be drawn:

– for a thorough further selection of the optimal technological solution for the processing (recovery) of municipal waste, it is necessary to conduct sorting analyses of the composition of MW according to an expanded list of municipal waste components, namely:

1) bio-waste (gardening waste, waste from green spaces, including branches and trunks of trees/shrubs);

2) biowaste (kitchen waste and avoidable food waste);

3) paper and cardboard (packaging and corrugated cardboard, printed);

4) plastic containers and plastic lightweight packaging;

5) plastic and other plastics;

6) other (combined) packaging;

7) glass containers;

8) other glass;

9) metal containers and non-packaging metals;

10) wood (furniture wood, chipboard, fiberboard, MDF etc.);

11) textiles;

12) waste electrical and electronic equipment;

13) batteries, including accumulators;

14) hazardous waste or problematic substances (containers of solvents, paints, mercury lamps, expired medicines, poisons, chemicals, herbicides and pesticides, hygiene products, diapers etc.);

15) household repair waste and inert substances (construction waste, bricks, plaster, wallpaper, ceramic dishes etc.);

16) bulky household waste (furniture, mattresses etc.);

17) other waste (leather, rubber, footwear, products made of combined materials);

18) unsorted residue (bones, stones, street litter etc.);

– based on the results of such sorting analyses, for each settlement, taking into account its specifics, it is necessary to develop a system of separate collection of MW and the creation of recycling collection points, which should be accompanied by constant educational work among the population to understand the importance of separating and collecting waste with resource value;

– objective data on the composition of municipal waste will enable local authorities to find effective and rational solutions to urgent problems: energy autonomy through the creation of small municipal energy facilities using alternative fuels and the development of local entrepreneurship in the field of municipal waste management.

Realizing the value of resources containing municipal waste and assessing their material and energy potential becomes possible only after obtaining objective data on the component composition of waste specific to a particular settlement or settlements of a certain type, which will make it possible to choose rational management and technical and economic solutions.

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