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REGIONAL SPECIFICS OF USING COMMUNITY BINS IN WASTE MANAGEMENT: A CASE STUDY OF RURAL COMMUNITIES IN POLTAVA REGION (UKRAINE)

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Background: The growing waste amount generation and its negative impact on the environment have become a serious problem. Many regions of Ukraine are not ready for modern challenges in the field of municipal solid waste (MSW) management. Inadequate waste management strategies at the regional level, taking into account local technical and economic features, require the attention of researchers. In particular, the technological component of local and regional MSW management systems in rural communities of the Poltava region (Ukraine) needs to be analysed and modernized, as well as the development of a technology for the use of specialized community bins to ensure environmental safety and efficient waste management. **Objectives:** This study aims to improve the efficiency of MSW management at the regional level by optimizing the waste collection system through the use of specialized community bins. A step-by-step approach was used to achieve the stated goal. **Methods:** The study was conducted using methods of system and factor analysis, as well as methods of structural-genetic synthesis. **Results:** It was revealed that the vast majority of rural settlements in the Poltava region were deprived of such an organizational structure as community waste systems; there was an irrational placement of special sites for community urns, which prevented the full collection of household waste from the population. The study found that the priority direction for optimizing the use of public household bins is the use of the entire range of bin capacities from 0.12 to 1.1 m^3, which will reduce capital costs. **Conclusion:** The stated objective was successfully achieved, providing a scientifically based concept for the optimal planning of community bin systems as a component of waste management with an emphasis on local and regional characteristics of the region under study. The study filled a gap in organizational approaches to the development of solid waste management systems in rural areas and communities of the Poltava region, which increases the efficiency of waste collection from the population and reduces capital costs for organizing the process.

Keywords: households; urbanization; circular economy; waste collection optimization; waste transportation; sustainable management.

INTRODUCTION

Solid waste management is a multifaceted task that includes generation, source separation, storage, collection, transfer, transportation, recycling and disposal (Ahmed et al., 2024; Sevda & Chauhan, 2024). The growing waste amount generation and its adverse impact on the environment has become a major concern for leaders of many countries of the world. These problems are caused by a number of factors, including inadequate infrastructure, lack of environmental legal framework, indiscriminate dumping of solid waste, population growth, urbanization resulting from rural-urban migration, limited funding for solid waste management processes, and lack of advanced waste management technologies (Abdel-Shafy & Mansour, 2018). Current situation with municipal waste is a serious problem for almost all developing countries in the world. Ukraine is no exception, since many regions are not ready for modern challenges in the field of municipal solid waste management (MSWM).

Inadequate waste management strategies at the regional level, taking into account local technical and economic characteristics, require the attention of authorities and researchers. Within the framework of the ecological modernization theory and the circular economy model, resource recovery from waste streams becomes a practical solution, dependent on an effective waste management system. Moreover, these strategies should cover all stages of waste management, including waste collection, transportation and recycling. In this regard, in the last decade, an important task has become to determine the optimal waste management process depending on the amount and characteristics of the generated waste (Han et al., 2018). This problem requires studying specific local conditions and many important factors related to various elements of the waste management system, such as waste production and collection, waste transportation and disposal, treatment, disposal and recycling of waste (Zurbrügg et al., 2012).

Among the regions that have not mastered modern effective approaches in the field of household waste management is Poltava region (Ukraine).

The effectiveness of regional and local waste management systems depends on many factors. Some of them are technical equipment and logistical planning of waste collection processes (Bredun et al., 2022). In many cases, technical equipment means special transport. However, an important element of the technological chain is special sites. The technical and economic characteristics of the entire waste management program largely depend on their optimal selection and operation. Currently, in most villages and rural settlements of Poltava region and Ukraine as a whole, modernization of sanitary cleaning plans of existing settlements and development of new plans are underway. In rural settlements, sanitary cleaning plans are practically absent. In many villages, the organization of local solid waste collection systems is immature. In this situation, optimization of the choice of community bin facilities for sanitary cleaning is a very urgent and important task.

BACKGROUND

MSWM is recognized globally as the most complex environmental service, requiring multidisciplinary methods for effective implementation. Most of the problems associated with municipal waste management in developing countries are the result of a lack of financial resources (funds), inadequate infrastructure, and weak political and institutional capacity for waste collection and management(Ampong et al., 2024). Most studies analysed economic factors, population participation in waste collection and segregation, and social factors of attitudes towards modern waste management methods, analysed quantitative composition and production of waste (Burnley,

2007; Alvarez et al., 2008), as well as specific case studies, collection and treatment options (Rivers et al., 2024).

The role of community bins in waste management

MSWM includes at least three stages: collection, transportation, and recycling. The most problematic aspect of waste management is its collection (Wekisa & Majale, 2020). Although the costs depend on population size, population density, geographic location, labour costs, and many other factors, waste collection has been reported to account for more than 40% of total waste management costs (Jaunich et al., 2016). In low-income areas, waste disposal costs account for 50 – 80% of the waste management budget (Das et al., 2024). In middle-income areas, this share is 80 – 90% (Kallel et al., 2016). These arguments motivate decision makers and researchers to conduct general studies on all possible optimization aspects in waste management approaches to achieve cost-effectiveness (Kinobe et al., 2015).

The analysis of scientific publications demonstrates the prevalence of research in the field of solid waste management, studying the environmental safety of waste and methods of processing, associated with the development of cost-effective routes for the transportation and sorting of waste by composition. Previous studies have mainly focused on the following design stages:

– Life Cycle Assessment (LCA)-based optimization has been applied to the environmental impacts of SWM systems, although its application in social sustainability has been more limited (Gutierrez-Lopez et al., 2024);

– comparison of operational efficiency and effectiveness of formal and informal waste pickers in a municipal waste management system(Ampong et al., 2024);

– implementation of computing-intensive technologies to create smart cities to overcome the waste crisis due to rapid urban sprawl (Ahmed et al., 2024). IoT-enabled waste management has been the subject of much recent research, although it is not sufficient for economically weak countries and their regions;

– using AI to address issues such as overflowing waste bins, high operating costs, and inefficient collection schedules. Integrating AI into the management system allows data analysis to improve waste collection routes and schedules, thereby reducing the negative impact of cities on the natural environment (Ahmed et al., 2024). However, there are challenges in implementing this approach in the context of small rural communities in the Poltava region;

– using GIS to optimize MSW collection and transportation. Ghose et al. (2006) proposed a model that includes collection bin allocation, vehicle load balancing and optimal route generation based on GIS. Tavares et al. (2009) pointed out a GIS-based model that takes into account the terrain when calculating and optimizing vehicle fuel consumption. In the study by Vicentini et al. (2009), the authors proposed an innovative and cost-effective solution for waste monitoring and treatment: a sensor waste collection bin to assess the content and optimize collection in order to design and implement a suitable MSW bin system taking into account factors such as the city's urban characteristics, season, population served, etc. At the same time, in the context of a weak economy and low technical equipment of regional waste management centres, such an approach is extremely difficult to implement;

– management of community bin placement based on population parameters such as age, gender, education level, etc., which should ensure more complete waste collection. In terms of waste disposal, preferences for nearby community bins over open space depend significantly on gender. Respondents aged 46 – 64 were 604 times more likely to use the nearest bin (Zen & Siwar, 2015). Men were 7.55 times less likely than women to choose nearby community bins over open spaces. For each additional family member, the likelihood of choosing a nearby community bin decreases by 45%. Pensioners are less likely to use home waste collection services than government employees (Taye et al., 2024).

At the same time, specific areas of research, such as the use and maintenance of community bins, remained outside the scope of active research.

MSW collection has several environmental impacts due to the production and use of different types of bags and community bins, the use of vehicles, and the construction, maintenance, and dismantling of transfer stations.

Among the waste management models implemented in the world, a significant part is made up of those that use community bins (Guerrero et al., 2013). Data on the environmental impact of various MSW disposal systems and their stages is very extensive, but information on specific aspects, such as the use of community bins, is very scarce (Chang et al., 2011). In addition, it has been noted that today, when an enterprise purchases a particular type of waste bins, it is mainly guided by economic or aesthetic criteria and never by environmental ones.

Effective solid waste management systems must be simple, cost-effective, and financially, environmentally, and socially sustainable (Odonkor et al., 2020). Equitable service delivery is necessary to serve both economically disadvantaged and affluent households (Lema et al., 2019).

Problem statement and study objectives

The technological component of local and regional solid waste management systems in rural communities of Poltava region (Ukraine) needs to be analysed and modernized, and the development of technology for the use of specialized community bins to ensure environmental safety and efficient waste management is also required. To fill this gap, the current study aims to improve the efficiency of solid waste management at the regional level by optimizing the waste collection system through the use of specialized community bins. The following stages of the study contributed to the step-by-step achievement of the goal:

– primary analysis of the provision of municipal services of territorial communities of Poltava region with community bins for collecting solid municipal waste;

– study of real modes of using community bins in the process of collecting solid municipal waste;

– identification of modern trends in providing community bins to territorial communities of Poltava region in the general waste management system;

– development of technology for using specialized community bins to ensure environmental safety and effective waste management.

MATERIALS AND METHODS

Study area

Poltava region is the central part of Ukraine, located on the Dnieper Lowland, on the Vorskla River according to the geographic coordinates 49°38′35″ N; 34°29′32″ E, and with the administrative centre in Poltava. Poltava urban community includes 1 city, 55 villages and has an area of 550.3 km², population – 309,647 people.

Research methods

The study was conducted using methods of system and factor analysis, as well as methods of structural-genetic synthesis.

RESULTS AND DISCUSSIONS

Current situation with the provision of community bins to the population for collecting MSW (territorial communities of Poltava region)

The efficiency of solid municipal waste collection in community bins depends on technical equipment and logistics schemes (Singh et al., 2024). In real life conditions in different communities of Poltava region, these two aspects are often interconnected, since technologies determine the nature of logistics planning. A thorough study of this interaction using waste management project schemes in Poltava region communities will help to increase the efficiency of this process.

The investigation was conducted on the example of the following rural communities: Hadiach, Lokhvitsa, Kotelva and Opishnya. Each of these communities has its own specific features in waste management as well as common aspects.

Thus, in Hadiach territorial community, a combined approach to solid municipal waste collection is used, which involves the use of various community bins in accordance with the types of zones (SSC HCUTC, 2020).

For areas where households are located, community bins with a capacity of 0.12 m^3 are used, while for areas with multi-apartment buildings and community centres, community bins with a capacity of 0.75 m^3 are used. Bins made of metal mesh for recycling PET bottles and similar bins for glass waste are installed throughout the city. In Hadiach territorial community, there are 89 community bins with a capacity of 0.75 m^3 and 0.12 m^3 at 28 sites near multi-apartment buildings, as well as one site with three community bins with a capacity of 0.75 m^3 for households.

The spatial arrangement of sites for community bins is not always optimal. Garbage trucks operate during the day, covering the entire territory of the settlement according to the approved schedule of the KP "Hadiach-Zhilye". In the Lokhvitsa city, a planned household-by-household method is used (SSC Lohvytsa city, 2019), where community bins of different capacities are used for different zones: for households – 0.12 m^3, for multi-apartment buildings and community centres – 1.1 m^3. Currently, in Lokhvitsa and the villages of the Lokhvitsa territorial community, 1,547 community bins with a capacity of 0.12 m^3 have been installed in households. On some streets, the community bin coverage ranges from 20% to 80%. Also, In Lokhvitsa, there are 32 collective sites with community bins with a capacity of 1.1 m^3.

However, the location of these sites with community bins is not always optimal, which increases the time required for garbage trucks to collect garbage. Therefore, during the day, garbage trucks move around the territory of the settlement, collecting bags of garbage from households in those areas where there are no community bins.

The choice of the collection system and type of garbage truck is determined by the architectural and planning features of the settlements (Topaloglu et al., 2018). For example, the width of the streets in the village can be 6 m between the boundaries of households, and the width of the asphalt part is no more than 3 m. This creates restrictions on the placement of sites with community bins and the movement of special vehicles.

In the Kotelva urban-type settlement and in the villages of the Kotelva territorial community, most houses are households, which is typical for most communities in the Poltava region. Therefore, a planned-yard method is used to collect household waste with community bins of 1.1 and 0.75 m^3 (SSC KSTC, 2023). Waste is removed using a system of "unchangeable" community bins according to an agreed schedule.

According to Kotelva territorial community there are 111 sites with community bins in the Kotelva urban-type settlement, 13 in the Bilsk village, and 14 in the Derevki village. Another 39 sites have community bins for use by enterprises and organizations. However, the location of some sites is not optimal. In addition, out of 11 settlements in the community, only three are equipped with community bins.

A system for separate collection of recyclable materials is being introduced in the Kotelva urban-type settlement: glass, plastic, paper, and cardboard.

In the Opishnya village and the settlements of Malye Budyshche and Popivka, which are part of a single agglomeration with the Kotelva village, most residential buildings belong to households (SSC OTC, 2023). Therefore, for the collection of solid municipal waste, the local population uses the planned-yard method using community bins with a capacity of 1.1 m^3. The solid waste removal system in these areas is based on the use of "fixed" community bins, whereby waste from community bins is unloaded into garbage trucks operating on a pre-agreed schedule.

The current situation in the Opishnya city and the Malye Budyshcha and Popivka villages is that there are 53 common sites with community bins for waste collection, where 71 community bins of 1.1 m^3 are located, as well as 8 sites equipped by enterprises and organizations, where 9 community bins of 1.1 m^3 are installed. However, the location of these sites is not always optimal.

Three times a week during the day, garbage trucks drive around the settlements and remove waste from the community bins.

For the improvement of the Opishnya city, 71 community bins of 1.1 m^3 were purchased for the purpose of placing them at 53 sites to ensure a more complete collection of solid waste. In addition, 5 community bins and 14 community bins made of metal mesh for collecting plastic and glass are located at the sites.

Modes of using community bins for collecting solid waste from the population

The for collecting and removing mixed waste in the residential sector of the region under study are implemented in the following ways.

1. In the households and on the territories of apartment buildings and in the area of the public centre for mixed waste, standard community bins with a capacity of 0.12 to 1.1 m^3 are used to collect mixed waste from the population, which is placed in specially equipped areas.

2. In the households, mixed waste can be collected in individual bins with a capacity of 0.12 m^3, which are installed in courtyards (when specialized transport passes), as well as in community bins with a capacity of 0.12 to 1.1 m^3, placed in specially equipped areas. On the territories of apartment buildings and in the area of the public centre, mixed waste is collected in standard community bins with a capacity of 0.24 to 1.1 m^3.

The choice of the method of collecting mixed waste in community bins of different capacities (0.12 m^3 or 0.24 to 1.1 m^3) depends on the operating costs of servicing the relevant community bins and the convenience for the population to use one or another option.

In each case, municipal services remove mixed waste by garbage trucks in accordance with a planned-regular system along established routes in accordance with the sanitary cleaning plan. The garbage removal plan is agreed upon with the contractor who performs the service and with the population that generates the waste.

Prospects for organizing separate collection of solid waste in communities of Poltava region

In the villages and especially rural settlements of the Poltava region, the separate collection system of solid household waste is still insufficiently developed.

At the same time, for the implementation of a separate waste collection system, it is recommended to use well-proven technological schemes, including the following options:

– two-bins scheme (process scheme No. 1);

– three-bins scheme (process scheme No. 2);

– four-bins scheme (process scheme No. 3);

– five-bins scheme (process scheme No. 4).

For example, the first scheme assumes the installation of two community bins:

– the first community bin, painted blue and designated as "Secondary raw materials", is intended for collecting secondary raw materials, with the exception of organic components of household waste;

– the second community bin, grey, is intended for collecting the remaining mixed waste, including organic components of the household waste.

Technological scheme No. 2 provides for separate collection of cases when one of the waste types as secondary raw materials does not require additional processing and can be separately taken to a processing plant. Other waste that requires additional processing and meets certain quality standards is centrally transported to processing facilities. Thus, for this scheme, it is recommended:

– using one community bin for separate collection of a specific type of secondary raw materials;

– using a second community bins for other types of secondary raw materials;

– using a third community bins for collecting mixed waste.

For example, you can install a yellow community bin with the inscription "Polymers" for sorting polymer waste, a green one for glass and a blue one for paper.

Also, according to technological scheme No. 2, you need to install one blue community bin with the inscription "Secondary raw materials" for other secondary waste and one grey community bin for mixed waste.

The organization of separate collection of MSW according to the technological scheme No. 3 is possible when two types of secondary raw material waste can be taken directly to the processing facilities without additional processing. Other secondary raw material waste that requires additional processing is transported to enterprises for sorting or processing of municipal solid waste.

Therefore, according to the technological scheme No. 3, it is necessary to provide for separate collection of different types of secondary raw materials in one community bin, and in another – other waste as secondary raw materials, as well as a community bin for mixed waste.

Therefore, it is possible to organize separate community bins for collecting two selected types of waste as secondary raw materials as follows:

1) two separate community bins are installed:

– a yellow community bin with the inscription "Polymers" is intended for polymer waste.

– a green community bin with the inscription "Glass" is used for collecting glass.

– a blue community bin with the inscription "Paper" is intended for collecting paper;

2) a single blue community bin with the inscription "Secondary raw materials" is intended for other secondary raw material waste;

3) a single grey community bin is intended for collecting mixed waste.

When using process flow chart No. 4 for separate collection of MSW, this is done in separate community bins placed on the special site:

– yellow community bin for polymer waste;

– green community bin for glass;

– blue community bin for paper;

– brown community bin for the organic component of household waste;

– grey community bin for mixed MSW.

There are two options for implementing segregated waste collection for the Hadiach city and the villages of the Hadiach territorial community.

The first option involves the use of process flow chart No. 1, which provides for the separate collection of solid municipal waste using community bins. This scheme provides for the use of two community bins: one for secondary raw materials, except for organic waste, and the other for other mixed waste, including the organic component.

The second option involves sorting solid municipal waste according to process flow charts No. 2 or No. 3, followed by segregation of types of secondary raw materials. This waste is transferred for processing to specialized enterprises under concluded contracts. Recycling collection points for glass, plastic, waste paper and metals are also organized, the network of which covers all settlements of the Hadiach territorial community, both multi-storey buildings and households.

At the promising stage of implementing the sanitary cleaning scheme of 15 – 20 years, a possible option is to use process flow chart No. 4. However, given the specifics of the Hadiach city and rural settlements of the Hadiach territorial community, it is more appropriate to collect residual mixed waste in community bins for organic waste.

For the Lokhvitsa urban-type settlement, the next stage within 3 – 7 years is rational to implement the technological scheme No. 1 of separate container collection of solid waste. This includes the organization of two community bins: for secondary raw materials, with the exception of organic components of household waste, and for other mixed waste, including organic components of household waste.

In the Kotelva urban-type settlement and the Opishnya urban-type settlement, the implementation of separate collection of solid waste has already begun. In this regard, two options for

the development of the waste management system of the Kotel and Opishnya territorial communities can be proposed.

The first option provides for the separate collection of solid waste in community bins at centralized collective sites with distribution into organic and mixed waste and resource components related to secondary raw materials. It is planned that this scheme will be implemented in the period 2023 – 2027. The second option provides for separate collection of solid municipal waste with collection of organic and mixed waste in individual and community bins, and secondary raw materials - only in community bins at organized special sites. It is planned that this scheme will be partially implemented in the period 2023 – 2027 and will take a stronger position in the waste management system of the Kotelva and Opishnya territorial communities from 2027 – 2040, after the implementation of the first scheme.

Taking into account the above-mentioned principles of sanitary cleaning of settlements of Kotelva and Opishnya territorial communities, it is proposed to implement a waste management system according to the following criteria:

1) inclusion of all settlements of the community in the solid municipal waste collection system;

2) in planning for the current and long-term period, implement a scheme for sorting solid municipal waste in all settlements of the community with separate collection of mixed waste and three groups of useful components: glass, plastic, paper. Thus, within the framework of sanitary cleaning, we are considering quite reasonable options for managing solid municipal waste in the Kotelva and Opishnya territorial communities:

– implementation of a two-bin technological scheme for collecting solid municipal waste, including separate collection of mixed waste and its collection in one container together with all useful components;

– implementation of a four-bin technological scheme for collecting MSW, which provides for separate collection of mixed waste and its separate collection in appropriate containers for each useful component: glass, plastic, paper.

Possibilities of technological optimization to improve waste management efficiency

In the Hadiach and Lokhvitsa territorial communities, it is considered appropriate to introduce a mixed system of container waste collection, using individual and community bins with a capacity of 0.12 m^3 and 1.1 m^3, respectively. In total, households received more than 2,000 bins with a capacity of 0.12 m^3, for each of which a corresponding service agreement was concluded. Such an organization of the household waste collection system contributed to some negative consequences:

– a significant decrease in the speed of route servicing, since garbage trucks are forced to stop at almost every yard, and in some areas to move in reverse. In this regard, the average speed of movement along the route is 5 – 10 km/h;

– an increase in the time of route servicing due to a large number of loading and unloading operations;

– significant fuel consumption, since the control fuel consumption for garbage trucks of the AT-2121 type at a speed of 60 km/h is about 16 L/100 km, and operating costs on the route, according to specialists from public utilities in other settlements of the Poltava region, reach 48 L/100 km.

This is consistent with the findings of (Das et al., 2024), where the authors report that the main goal of route optimization, in addition to reducing the number of vehicles involved and their cost, is to optimize the distances travelled. The authors of another study found that route planning can reduce the number of weekly trips by 19% and the weekly travel distance by 36% (Rambandara et al., 2022).

At the promising stage of implementing the scheme (15 – 20 years) for separate collection of household waste, it is recommended to use technological scheme No. 4, in which three types of waste will be collected in separate community bins: 1 – paper and cardboard; 2 – plastic; 3 – glass.

To install community bins with a capacityof 1.1 m^3, intended for unitary collection of municipal solid waste (MSW), it is necessary to organize special sites in accordance with the requirements of the State Sanitary Norms and Rules for the territories of settlements. According to these standards, such special sites should be located at a distance of at least 20 m from the boundaries of land plots where educational and medical institutions, walls of residential and public buildings and structures, as well as playgrounds and recreation areas for the population are located.

Taking into account the developed layout of the specified sites for collecting solid waste and the availability of sites with the possibility of installing additional community bins for recyclable materials with a capacity of 1.1 m^3, the planned number of community bins is 434 pieces. However, this approach may be irrational due to the significant capital costs of purchasing bins.

Also, it is important to consider the results of previous studies where it was calculated that although one small community bin occupied less space in a dedicated area or on the street than a larger community bin, due to the fact that the amount of waste is large and several small community bins are required to satisfy the functional unit, as a result, a significantly larger surface area is required to accommodate several small bins compared to the area required for a larger bin. That is, a system consisting of 1.7 m^3 bins occupied only 12.8 m^2 compared to 52.3 m^2 occupied by a system of small 0.6 m^3 bins (Rives et al., 2010).

Reducing the capital costs of purchasing community bins and their subsequent maintenance is possible by reducing the period of accumulation of recyclable waste and using community bins of different capacities (Oteng-Ababio, 2014). This approach allows minimizing the costs of purchasing community bins. Therefore, to organize separate collection of solid waste, an option is used using bins of different capacity, such as 0.12 m^3, 0.24 m^3, 0.75 m^3 and 1.1 m^3.

If community bins are to be purchased, one environmental factor to consider is the material of the community bins. A study found that MSW collection systems using steel community bins for significant amounts of waste, such as 1.7 m^3 and 2.4 m^3, had the lowest environmental impact across several assessment factors compared to steel community bins for less waste, such as 0.6 m^3 and 0.8 m^3. The most important justification for this is the longer service life of the steel community bins. In addition, the bin material should be considered – steel is a raw material, 40% of which can be recycled, while high-density polyethylene (HDPE), which is derived from petroleum, is a virgin material (Rives et al., 2010).

In some areas of Hadiach and Lokhvitsa citys, as well as the villages of Opishnya territorial community, due to their architectural and planning features, such as narrow streets and dense buildings, it is impossible to organize sites for placing community bins. In these cases, a combined waste collection scheme is used, which provides for both collection in bins and collection directly into cars. However, this technology also has the disadvantages described above.

The waste collection plan in the Kotelva territorial community is unique compared to other studied areas. A system of separate collection of household waste in community bins is already in place here. Unlike other communities, such as Lokhvitsa and Hadiach, the Kotelva territorial community organized the installation of common community bins at special sites. Waste amount estimates, taking into account the peculiarities of village and rural life, demonstrate that:

– technological scheme No. 1 is advisable to apply in all populated areas;

– technological scheme No. 2 is advisable to use for glass and plastic in the Kotelva urban-type settlement and the Belsk village, and for paper – only in the Kotelva urban-type settlement.

Since the general plan of the Kotelva urban-type settlement and the villages does not provide for significant changes in the street network, especially in already built-up areas, when developing a scheme for collecting solid waste in bins, it is necessary to take into account the existing organizational and technological limitations. Taking this into account, it is advisable to use a combined system for using bins of different capacities from 0.12 to 1.1 m³.

The planned scheme includes 321 sites for community bins, namely: in the Kotelva urban-type settlement – 205 such sites, the Belsk village – 43, the Melnitsy village – 9, the Derevye village – 25, the Lyubka village – 4, the Mikhaylovka Pervaya village – 13, the Cherneshchina village – 2, the Sidorye village – 10, the Mikhailovo village – 7, Kaminny village – 3. According to design calculations, 415 community bins should be installed there for collecting mixed waste, the main part of which consists of bins with a capacity of 0.77 and 1.1 m³.

In the case of distributed waste collection according to the first technological scheme, it is necessary to install 336 community bins with a capacity of 0.77 m³ and 1.1 m³, and according to the third scheme – 967 community bins with a capacity of 0.12 m³. This requires an appropriate selection of community bins for each site, ensuring compliance with the waste amount. The total number of community bins is determined not only by the waste amount, but also by the service radius and coverage of the territory.

For the Popivka and Malye Budyshche urban-type settlements, various technologies for the collection and removal of household waste are recommended. At a later stage of the scheme implementation (15 – 20 years), it is recommended to use the second technological scheme, where glass, plastic and mixed MSW are collected in separate bins.

One of the options for collecting MSW is a combined system, where recyclable materials are collected at collective sites in community bins of different capacities, and mixed MSW is collected mainly in households. At the same time, the number of bins increases significantly, especially according to the second technological scheme – up to 1391 community bins. In the future, it is planned to purchase community bins with a capacity of 0.12 m³ and distribute them among private plots with the conclusion of service contracts. This situation requires the development of a system for collecting solid waste in the short and medium term in the Opishnya urban-type settlement and the Popivka and Malye Budyshcha villages using purchased community bins. There are two possible options:

1) construction of the required number of collective sites and installation of community bins with a capacity of 0.12 m³ – 1.1 m³ for separate collection of mixed waste and secondary raw materials from private households, which was initially proposed by Opishnya community;

2) combined service, which includes continuing to service community bins at collective sites with collection of secondary raw materials and mixed MSW in areas where it is impossible to organize collection from individual bins due to architectural and planning conditions and the lack of hard road surfaces; collection of mixed MSW from individual bins by households in accordance with concluded agreements.

The materials show that some communities plan to distribute 12 m³ bins to households, while other communities plan to build collective sites with community bins with a capacity of 0.12 to 1.1 m³. The choice of technology is determined primarily by two factors: the architectural and planning features of populated areas that affect the possibility of establishing special sites for placing community bins, and the presence or planning of a system for concluding contracts between the utility company and consumers of services based on the experience of collecting payments for waste removal services in each community. The current situation in the field of waste management in the region shows that from an economic and technological point of view, a more rational option is to install community bins of different capacities at collective sites. This will effectively reduce capital costs for the purchase of equipment. At the same time, specific requirements arise for vehicles, since the mechanism of the loading system of a garbage truck must be able to work with any type of container. Modern models of garbage trucks (Bereziuk, 2020), in particular those with rear loading and more practical for use on narrow streets, are already equipped with such loading systems. Some problems may arise with respect to older models of garbage trucks with side loading, but modern service companies are ready to re-equip their gripping devices to work with bins of different capacities. Therefore, it can be stated that the problem of compatibility of bins and specialized transport is practically solved. Replacing old bins with a capacity of 0.75 m³ that have lost their operational properties with community bins made of modern materials and an effective design is advisable, since modern bins have special wheels for transportation, which simplifies loading waste into the car body. Various models of such bins are already available on the Ukrainian market.

CONCLUSION

The current study has successfully achieved its objective by providing a scientifically based concept for the optimal planning of community bin systems of local waste management schemes highlighting the local and regional characteristics of the study region, namely:

– the current state of community bin systems in most communities of the Poltava region (Ukraine) did not meet the modern needs of local and regional levels of solid waste management;

– the vast majority of rural settlements of the Poltava region were deprived of such an organizational structure as community bin systems;

– in most rural settlements, irrational placement of special sites for community bins was identified, which prevented the complete collection of household waste from the population and contributed to a negative impact on the environment;

– bin systems with a capacity of 1.2 m³ in households for collecting solid household waste, which are used in individual communities of the Poltava region in the current study were recognized as irrational in technical and economic indicators compared to systems based on community bins located on special sites;

– a capital excess of expenses for the organization of the household waste collection system was revealed due to the irrational range of community bins used by most communities, which consists of bins with a capacity of 0.75 m^3 and 1.1 m^3;

– the study showed that the priority direction for optimizing the use of community bin systems is the use of the entire range of bin capacities from 0.12 to 1.1 m^3, which will reduce capital costs;

– for the purpose of technological optimization of solid waste collection processes associated with the renewal of the fleet of garbage trucks, it is advisable for communities to switch to modern types of containers designed for loading devices of European DIN standards.

Thus, the gap in organizational approaches to the development of a solid municipal waste management system in rural settlements and communities of the Poltava region was filled, which increases the efficiency of waste collection from the population and reduces capital costs for organizing the process. The implementation of the research results contributes to the gradual approximation of waste management technologies at the regional level, and subsequently at the national level, to European standards in the area of activity under study.

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Author's statements

Contributions

Conceptualization: V.B.; Data curation: V.B.; Investigation: V.B., R.C., A.K.; Methodology: V.B., R.C., A.K.; Resources: V.B., R.C., A.K.; Supervision: V.B., A.K.; Validation R.C.; Writing – original draft: V.B., R.C.; Writing – review & editing: V.B., R.C., A.K.

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REFERENCES

Ahmed, K., Kumar Dubey, M., Kumar, A., & Dubey, S. (2024). Artificial intelligence and IoT driven system architecture for municipality waste management in smart cities: A review. *Measurement: Sensors*, 36, 101395. https://doi.org/10.1016/j.measen.2024.101395.

Ampong, R. O., Miezah, K., Banunle, A., Amuah, E. E. Y., & Amoah, E. G. (2024). Comparative analysis of the effectiveness and efficiency of formal and informal waste collectors in urban waste management system. *Heliyon*, 10(20), e39017. https://doi.org/10.1016/j.heliyon.2024.e39017.

Bereziuk, O. V. (2020). Analytical study of the improved mathematical model of the vibration drive for solid household waste additional compaction in the dust cart (Eng). *Scientific Works of Vinnytsia National Technical University*, 1. https://doi.org/10.31649/2307-5392-2020-1-35-45.

Bredun, V., Smoliar, N., & Sarkarli, A. (2022). Logistic Component of Regional Waste Management Systems Efficiency Improvement (pp. 467–475). https://doi.org/10.1007/978-3-030-85043-2_44.

Chang, N.-B., Pires, A., & Martinho, G. (2011). Empowering Systems Analysis for Solid Waste Management: Challenges, Trends, and Perspectives. *Critical Reviews in Environmental Science and Technology*, 41(16), 1449–1530. https://doi.org/10.1080/10643381003608326.

Das, S., Baral, A., Rafizul, I. M., & Berner, S. (2024). Efficiency enhancement in waste management through GIS-based route optimization. *Cleaner Engineering and Technology*, 21, 100775. https://doi.org/10.1016/j.clet.2024.100775.

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, 33(1), 220–232. https://doi.org/10.1016/j.wasman.2012.09.008.

Gutierrez-Lopez, J., McGarvey, R. G., Noble, J. S., Hall, D. M., & Costello, C. (2024). Quantification of social metrics for use in optimization: An application to solid waste management. *Journal of Cleaner Production*, 480, 144111. https://doi.org/10.1016/j.jclepro.2024.144111.

Han, Z., Liu, Y., Zhong, M., Shi, G., Li, Q., Zeng, D., Zhang, Y., Fei, Y., & Xie, Y. (2018). Influencing factors of domestic waste characteristics in rural areas of developing countries. *Waste Management*, 72, 45–54. https://doi.org/10.1016/j.wasman.2017.11.039.

Lema, G., Mesfun, M. G., Eshete, A., & Abdeta, G. (2019). Assessment of status of solid waste management in Asella town, Ethiopia. *BMC Public Health*, 19(1), 1261. https://doi.org/10.1186/s12889-019-7551-1.

Odonkor, S. T., Frimpong, K., & Kurantin, N. (2020). An assessment of house-hold solid waste management in a large Ghanaian district. *Heliyon*, 6(1), e03040. https://doi.org/10.1016/j.heliyon.2019.e03040.

Oteng-Ababio, M. (2014). Rethinking waste as a resource: insights from a low-income community in Accra, Ghana. *City, Territory and Architecture*, 1(1), 10. https://doi.org/10.1186/2195-2701-1-10.

Rives, J., Rieradevall, J., & Gabarrell, X. (2010). LCA comparison of container systems in municipal solid waste management. *Waste Management*, 30(6), 949–957. https://doi.org/10.1016/j.wasman.2010.01.027.

Scheme of sanitary cleaning (SSC) of the Hadiach city united territorial community (HCUTC), agreement of 2020.

Scheme of sanitary cleaning (SSC) of the Lohvytsia city of the Poltava region, agreement of 2019.

Scheme of sanitary cleaning (SSC) of the Opishnyan territorial community (OTC), agreement of 2023.

Scheme of sanitary cleaning (SSC) of the Kotelev settlement territorial community (KSTC), agreement of 2023.

Sevda, S., & Chauhan, G. (2024). *Solid Waste Management*. CRC Press. https://doi.org/10.1201/9781003229919.

Singh, D., Dikshit, A. K., & Kumar, S. (2024). Smart technological options in collection and transportation of municipal solid waste in urban areas:

A mini review. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, 42(1), 3–15. https://doi.org/10.1177/0734242X231175816.

Taye, A., Assefa, E., & Simane, B. (2024). Analysis of practices and factors of solid waste management among urban households of Addis Ababa city, Ethiopia. *Environmental Challenges*, 14, 100811. https://doi.org/10.1016/j.envc.2023.100811.

Topaloglu, M., Yarkin, F., & Kaya, T. (2018). Solid waste collection system selection for smart cities based on a type-2 fuzzy multi-criteria decision technique. *Soft Computing*, 22(15), 4879–4890. https://doi.org/10.1007/s00500-018-3232-8.

Zen, I. S., & Siwar, C. (2015). An analysis of household acceptance of curbside recycling scheme in Kuala Lumpur, Malaysia. *Habitat International*, 47, 248–255. https://doi.org/10.1016/j.habitatint.2015.01.014.

Zurbrügg, C., Gfrerer, M., Ashadi, H., Brenner, W., & Küper, D. (2012). Determinants of sustainability in solid waste management – The Gianyar Waste Recovery Project in Indonesia. *Waste Management*, 32(11), 2126–2133. https://doi.org/10.1016/j.wasman.2012.01.011.