EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2023, 24(1), 55–66
https://doi.org/10.12912/27197050/154918
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Received: 2022.09.15
Accepted: 2022.10.10
Published: 2022.11.01

A Strategic Analysis of the Prerequisites for the Implementation of Waste Management at the Regional Level

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ABSTRACT
In most settlements of Ukraine there are no existing programs for municipal solid waste management (MSW) and schemes for sanitary cleaning of settlements, there are no registers of waste generation, treatment and disposal and disposal sites, which leads to the formation of landfills, deteriorating sanitation settlements and increase the level of environmental danger in the region. The article presents the results of research that indicate that the existing structure of the MSW management system in Ukraine at the regional level (on the example of Zhytomyr region) is imperfect. It is characterized by fragmentation, disunity and heterogeneity. The peculiarity of the system is the lack of interaction between government agencies, environmental services and the local community, which does not provide a sufficient level of control over the sanitary condition of territories, as well as collection, transportation, disposal and disposal of solid waste. The aim of the study is to strategically analyze the preconditions for the implementation of municipal solid waste management systems to increase the level of environmental safety in the united territorial communities through the introduction of environmental logistics and crowdsourcing mechanisms. The methodological basis for assessing and selecting methods and ways to improve the environmental safety of the study region by improving the waste management system (hereinafter - waste management) is a systematic approach that allows analysis of the problem and ensures search efficiency for management decisions. The SWOT and PEST analysis identified the strengths and weaknesses of the existing waste management system and the prerequisites for the implementation of a modern system of solid waste management. The increase in the number of business structures that are ready and able to implement modern methods of waste disposal and identified the availability of modern innovative management methods in public authorities and local governments. However, the low efficiency of the existing waste management system, the lack of communication and coordination of actions between stakeholders in solving the problem pose a threat to maintaining the environmental security of the region.

Keywords: municipal solid waste, waste management system, waste management model, SWOT-analysis, PEST-analysis, territorial community, regional level.

INTRODUCTION

Adopted in 2017, the National Waste Management Strategy for Ukraine until 2030 (National Waste Management Strategy, 2017) creates conditions for improving living standards by introducing a systematic approach to waste management at the state and regional levels, reducing waste generation and increasing its recycling and reuse. The strategy (National Waste Management Strategy, 2017) identifies the main directions of state regulation in the field of waste management in the coming decades, taking into account European approaches to waste management, based on the provisions (Directive, 2008; Directive, 2006; Council Directive, 1999) and other EU regulations. Accordingly, Regional Waste Management Plans are being developed. The implementation of the measures provided for in these documents is carried out, first of all, at the local level by united territorial communities (UTC) and at the municipal level – in cities of regional or district significance. Thus, community-based waste management is an important element of the management system, however, the current crisis in the provision of public utilities has affected municipal solid waste management. Waste management companies are unable to provide high-quality utilities to the community. Their equipment is mostly obsolete and worn out. Only a small proportion of MSW from households is harvested separately and recycled. There are some successful enterprises in Ukraine, but their number is quite small. Therefore, the analysis of the preconditions for the implementation of the waste management system at the regional level is a topical issue today (Gangolells et al., 2014; Safranov et al., 2021; Khrutba et al., 2021a).

However, despite the results obtained by scientists, the problems associated with the accumulation, disposal and recovery of household (municipal) waste in Ukraine remain acute and complex due to the imperfection of the waste management system (Kotsiuba et al., 2018), low efficiency of interaction between all stakeholders (Morozova et al., 2019; Terrones-Saeta et al., 2020), which are involved in all waste management processes (Saheed et al., 2015; Frolov & Bilopilska, 2013; Kolodiichuk et al., 2021). The lack of scientifically system developments for the formation of a methodological apparatus that can combine modern innovative management solutions with technical and technological features of the solid waste management system does not allow to implement an effective waste management system at the regional level for united communities.

Thus, the direction of the presented research is the formation of a new approach to creating a modern effective management system for the management of solid waste through the introduction of innovative management mechanisms of environmental logistics and crowdsourcing (Bienvenu et al., 2017) to ensure economic and environmental security of Ukraine and the country as a whole.

The scientific novelty consists in the formation of the methodology for implementing the integrated strategy of solid waste management of the united territorial communities: revealed the essence of the theoretical prerequisites and methodological foundations for the implementation of an integrated municipal solid waste management system; the concepts of introduction of ecological logistics and ecological crowdsourcing in the waste management system are substantiated; substantiated and developed a methodological approach to the creation of models and methods designed to modernize the management system of municipal solid waste management.

The aim of the study is a strategic analysis of the prerequisites for the implementation of municipal solid waste management system to improve environmental safety in the united territorial communities through the introduction of environmental logistics and crowdsourcing mechanisms.

To achieve this goal the following tasks are set:

- to conduct a strategic analysis of the preconditions for the implementation of the waste management system at the regional level.
- to develop a conceptual model of a regional waste management program based on a logistic approach and to propose methods, techniques and tools for theoretical and experimental research.

The object of research is the processes of waste management system management in the united territorial communities.

The subject of the study is the relationship and interaction of factors influencing on waste generation in integrated territorial communities, factors influencing on environmental components of landfills and waste management system through the introduction of innovative management methods of environmental logistics and environmental crowdsourcing.

RESEARCH METHODS

Scientific methods of theoretical (Kotsiuba et al., 2020) and empirical research are used in the work, the main of which are system approach, methods of analysis and synthesis (abstraction, formalization, analogy, classification, etc.), structural analysis, expert evaluation, modeling, including mathematical, simulation, statistical and graphic (Podchashinskiy et al., 2017). The methodological basis of the work consists of general scientific principles of research, theoretical and methodological foundations of systemic and process approaches (Kotsiuba et al., 2019; Khrutba et al., 2021a; Ojha et al., 2012). The theoretical basis of the work are the fundamental provisions of environmental safety (Hewelke & Wiśniewska, 2018; Shamrai et al., 2017) and environmental management. The information base of the study is statistical information on the state of the environment and waste management system, the results of own research (Delehan-Kokaiko et al., 2020; Khrutba et al., 2021b; Suryawan et al., 2022; Trofymchuk et al., 2021; Terrones-Saeta et al., 2020).

The study used innovative methods of modern environmental safety management in terms of waste management (for strategic analysis of the regional waste management program); systems theory and systems analysis (for formalization of waste management processes, development of system models, parametric description of systems); methods of mathematical and simulation modeling for processing experimental data and forecasting the state of the waste management system; methods of environmental logistics and strategic crowdsourcing for the formation of a modern innovative waste management system), field modeling (verification of developed concepts and use of models for municipal solid waste management in the united territorial communities of Zhytomyr region).

Processing of the results of experimental studies was performed using correlation-regression analysis.

RESULTS

To form a system model of waste management for united territorial communities taking into account the interests of stakeholders, we denote the set of basic parameters of mathematical representation of waste management system (input, output and state) through T which we denote by the corresponding tuple:

$$T = <X, Y, U> \quad (1)$$

where: X, Y, U set of input, output and system status values.

The elements of the set X^T, that is to say the set of mappings from T to X, are denoted as $x\,(*)$ and will be considered as input parameters of the system, which determine the initial state of the waste management system in a particular region. Each system is characterized by its set of inputs, which we denote by

$$x\,(*) \subset X^T \quad (2)$$

The set of inputs x_i may include variables such as the amount of waste generated, quantitative indicators of waste composition (morphological composition, indicators of mass and size characteristics), quantitative indicators of the properties of solid waste (physicochemical, mechanical, technological, operational, etc.), hazard indicators, hazard class, carcinogenicity, mutagenicity, biological stability, fire hazard, nuclear and radiation hazard, ability to silt reservoirs and others over time, etc.), available waste management methods and technologies for different stakeholder groups, etc.

The set of mappings $x\,(*)$ on the interval $[t_1, t_2]$ is denoted by $x\,[t_1, t_2]$. We assume that the set $x\,(*)$ is not empty and the system is not isolated from other systems. We will also assume that if $x_1(\cdot) \in X(\cdot)$ and $x_2(\cdot) \in X(\cdot)$, then for anyone $t_1 < t_2 < t_3$ it is possible to specify such $x(\cdot) \in X(\cdot)$, that $x\,[t_1, t_2] = x_1\,[t_1, t_2]$ and $x\,[t_2, t_3] = x_2\,[t_2, t_3]$.

Therefore, the set of input parameters includes the following sets:
- The set of qualitative and quantitative indicators MSW;
- The set of methods of waste management that can be implemented in integrated territorial communities;
- The set of stakeholders in the TCB management system of the united territorial communities, which includes state structures / local governments, business structures / entities and the local community / households. The scheme of communication between stakeholders is presented in Figure 1. Characteristics of the main stakeholders were given in Table 1.

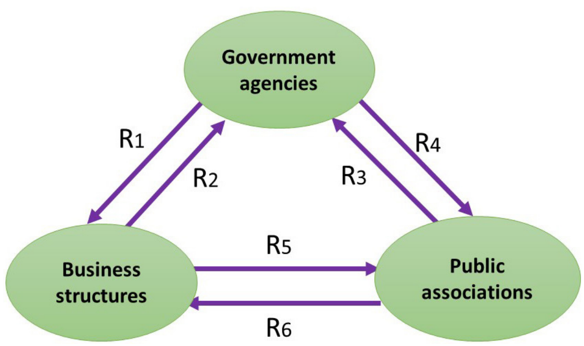

Figure 1. Scheme of communication between stakeholders, where R_i – cross-links of controlled influences

Table 1. The main participants in the waste management system

No.	The main performers	Functions	Objectives
1	Ministry of Environmental Protection and Natural Resources of Ukraine	Licensing and monitoring of the full range of services, assessment of technical, sanitary and environmental safety of existing facilities, as well as control of documentation on the generation, collection, treatment, disposal and disposal of waste; coordination of limits on waste generation and disposal, control of keeping logs of objects	Coordination of specially authorized bodies in matters of MSW management
2	Ministry of Development of Communities and Territories of Ukraine	Coordination of activities carried out by local executive bodies in the field of household waste; preparation of normative and procedural recommendations on household waste management; development and approval of state standards, norms and rules on household waste management, sanitation schemes of settlements	Policy implementation and implementation of state programs in the field of solid waste management
3	Local state administrations	Management of the solid waste management process (planning, coordination, control). Organization of garbage collection and removal from the territory of the settlement. Coordination of waste collection, processing, utilization and disposal. Compilation and maintenance of the register on waste generation, processing and utilization, as well as the register of waste disposal facilities	Timely transportation of waste. Affordable price for transportation. Quality transportation. Introduction of separate collection. Convenience of placing collection points. Compliance with the legal framework. Feedback from the public
4	Bodies of state ecological management	Issued to legal entities (enterprises, associations and organizations) and individuals licenses to carry out under the control of state bodies work on integrated waste disposal and certain activities that require a special permit in accordance with applicable law	Minimum emissions from motor vehicles of carriers. Timely garbage collection. Minimum ecological and economic burden on the environment. Separate collection. Waste recycling. Possibility of creating thermal energy for residents by burning garbage. Minimum emissions of pollutants from the incinerator. Minimum landfill load
5	Manufacturers of solid waste (households)	Collect generated waste, pay for services for their treatment. Direct ownership of waste. Obligation not to allow negative impact on the environment	Introduction of separate collection. Minimum amount of garbage. Compliance with the legal framework
6	Housing and maintenance organizations	Proper operation of infrastructure and provision of services for the collection, removal and disposal of waste for a fee. Responsible for the sanitary maintenance of the territory, including the cleanliness of container sites	Introduction of separate collection. Convenience of placing collection points. Compliance with the legal framework. Feedback from the public. Prevention of complaints from the population
7	Secondary resource collection points	Proper operation of infrastructure and provision of services for the collection, removal and disposal of waste for a fee. Accept from waste producers separate fractions of solid waste which are subject to reuse after the corresponding processing or without such, deliver the collected secondary resources to their consumers	Introduction of separate collection. Compliance with the legal framework. Feedback from the public. Prevention of complaints from the population
8	Specialized transport companies	Proper operation of infrastructure and provision of services for the collection, removal and disposal of waste for a fee. Conclude contracts for the removal of solid waste, transport utility containers from container sites to recycling plants or landfills	Minimize costs. Traffic route optimization. Profit maximization and production automation. Reducing the cost of the company's fleet, fuel, communications. Separate garbage collection. Availability of own landfill, sorting station, qualified production and technical staff, repair base, car wash, own garbage containers, recycling of waste or incinerator
9	Incinerators and recycling companies	Proper operation of infrastructure and provision of services for the collection, removal and disposal of waste for a fee. Carry out the accounting of the accepted waste and registration of the accounting documents containing the information on actually accepted for processing solid waste, process the accepted waste according to the existing technology	Separate collection. Maximum amount of waste. High price per 1 m^3 of secondary raw materials. Qualitatively selected waste
10	Landfills	Carry out the accounting of the accepted waste and registration of the accounting documents containing the information on actually accepted for burial solid waste, place the accepted waste on the landfill according to existing technologies of burial	Separate garbage collection. Organic composition of garbage. Minimum amount of garbage
11	Public organizations and educational institutions	Carry out educational activities in the field of environmentally friendly waste management	The amount of information disseminated. Population sorting MSW

The elements $y(\cdot)$ of the set Y^T are the initial parameters of the system. The set of all reactions of the system, as the set of initial parameters that are characteristic of the system, is denoted by $Y(\cdot) \in Y^T$. The initial parameters of the system are the ecological and economic indicators of the system of solid waste management of the united territorial community. As defined earlier, the specific output $y(\cdot) \subset Y(\cdot)$ at every moment t completely determined by the state of the system at this time t. Let us denote this state by $x(t)$; then there is a reflection η: $T \times X \rightarrow Y$, such that the relation is fulfilled:

$$y(t) = \eta[t, x(t)],\ t \in T \qquad (3)$$

Dependence of display η from t means that the nature of the dependence of the exit on the state over time may change. Thus, the introduction of modern innovative models of waste management system will determine the optimal parameters of management processes.

The elements $u(\cdot)$ of the set U^T can denote processes in the state space. Waste management system process parameters $(\cdot)$, for example, at some point, $\epsilon\ u(t) \in U$. The aim of the system is to prevent the harmful effects of waste on the environment and public health by implementing measures to prevent waste generation, reduce waste, optimize waste flows by restoring their value, reuse, recycling, disposal and control of waste disposal facilities. One of the important conditions for ensuring the effectiveness of waste management system management is the effective management of waste management processes.

At the same time, the management system receives information about changes in its current state from waste disposal facilities. The decision maker receives information, takes into account and analyzes to identify deviations from the required state and determines the need for change. If you denote the set of MSW that can be controlled, through $G(s)$, and waste that cannot be managed through $G_d(s)$, then the system management process will look like:

$$y(s) = G(s) \cdot u(s) + G_d(s) \cdot d(s) \qquad (4)$$

where: $d(s)$, $u(s)$, $y(s)$ – perturbation, control, and output vectors, respectively.

$$d(s) = \begin{bmatrix} d_1(s) \\ d_2(s) \\ \cdots \\ d_k(s) \end{bmatrix};\ u(s) = \begin{bmatrix} u_1(s) \\ u_2(s) \\ \cdots \\ u_k(s) \end{bmatrix};\ y(s) = \begin{bmatrix} y_1(s) \\ y_2(s) \\ \cdots \\ y_k(s) \end{bmatrix} \qquad (5)$$

In the matrix form of the function of changing the volume of MSW, which can be controlled (s), and unmanageable amounts of waste $G_d(s)$ have the appearance:

$$d(s) = \begin{bmatrix} g_{11}(s) & g_{12}(s) & & g_{1n}(s) \\ g_{21}(s) & g_{22}(s) & \cdots & g_{2n}(s) \\ \cdots & \cdots & & \cdots \\ g_{k1}(s) & g_{k2}(s) & & g_{k}(s) \end{bmatrix};$$

$$G_d(s) = \begin{bmatrix} g^d_{11}(s) & g^d_{12}(s) & & g^d_{1n}(s) \\ g^d_{21}(s) & g^d_{22}(s) & \cdots & g^d_{2n}(s) \\ \cdots & \cdots & & \cdots \\ g^d_{k1}(s) & g^d_{k2}(s) & & g^d_{k1}(s) \end{bmatrix} \qquad (6)$$

Formation of control influence $u(s)$ will be determined by the multidimensional controller $G_c(s)$ taking into account the error of discrepancy:

$$\varepsilon(s) = y^*(s) - y(s) \qquad (7)$$

$$\varepsilon(s) = [\varepsilon_1(s), \varepsilon_2(s), \ldots, \varepsilon_n(s)]^T \qquad (8)$$

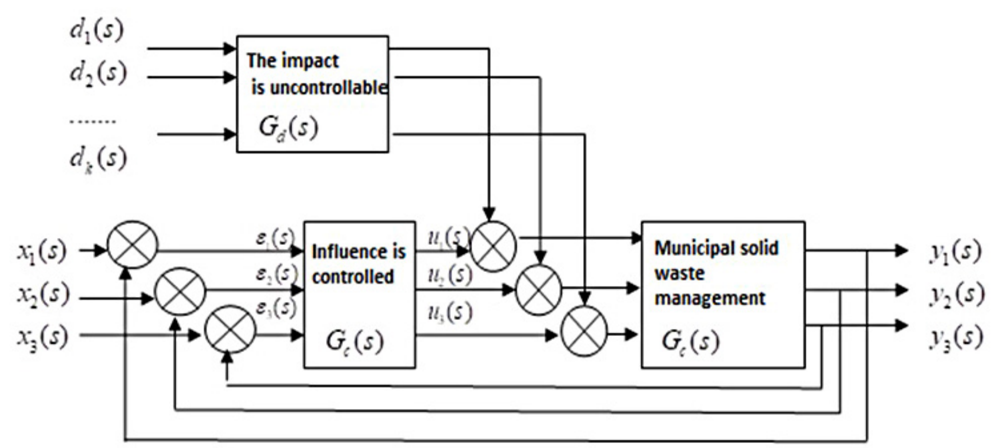

Figure 2. Structural model of the waste management system

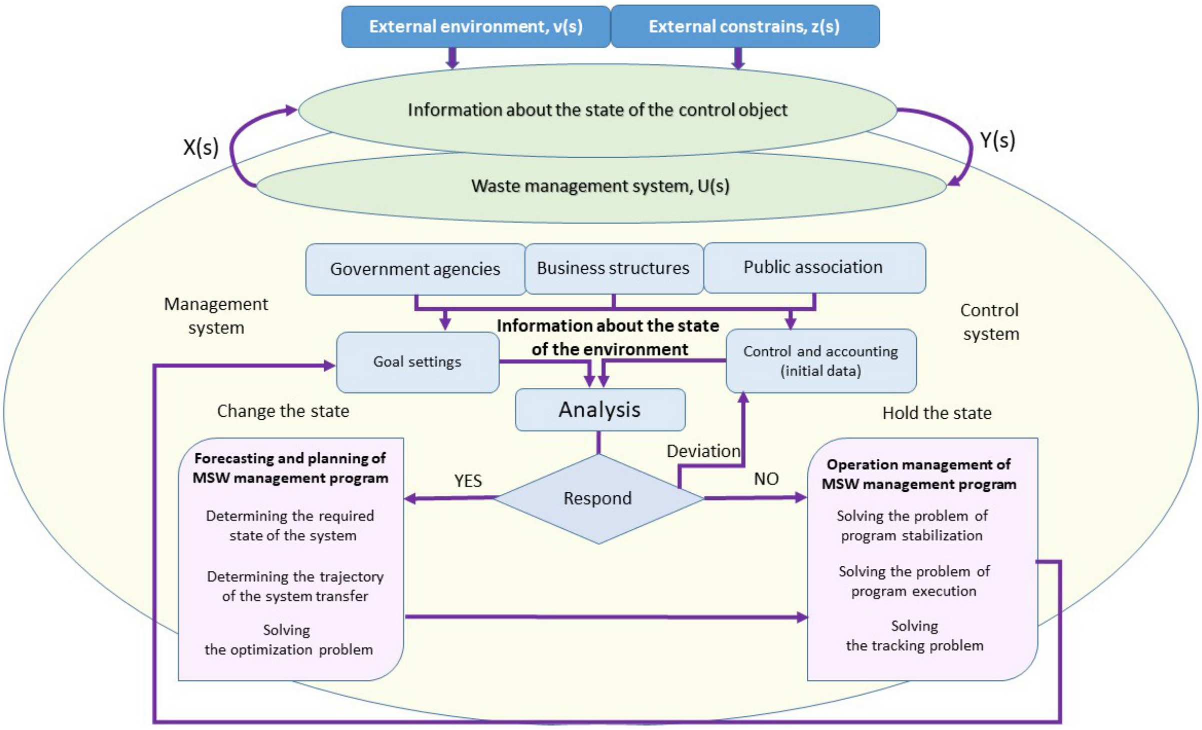

Figure 3. System model of waste management

Taking into account the change in the quantitative and qualitative characteristics of the MSW, the generalized scheme of the waste management system (1) will look like in Figure 2.

An improved system model for the management of MSW is shown in Figure 3. It includes sets of input and output parameters, constraints, controlled and uncontrolled parameters.

The system is a rigid hierarchical structure, which complicates the possibilities of effective management. The large number of stakeholders with different goals of the management process complicates the functioning of the system. The system model of MSW management for the united territorial communities can be presented in the form of Table 2.

The volume of MSW in a separate local space UTC, region or city is formed by many parameters, which primarily takes into account the population, level of consumption, the amount of housing as an indicator of the development of the settlement. The dynamics of waste generation is influenced by factors that characterize the development of society and the welfare of the population, namely, the volume of industrial production, cash income, retail turnover, including catering, which forms a significant share of solid waste and others.

To improve the management system of MSW, it is necessary to apply an integrated approach that allows to reconcile the interests of stakeholders.

Thus, the system approach allowed to develop a system model for waste management, which translates the input state of the system $x(s)$ into the output $y(s)$ using control effects $u(s)$ subject to external constraints $v(s)$ and risk taking

Table 2. System model of management of MSW management for the united territorial communities

Input parameters	$x(s) = \{x_1, x_2, ..., x_n\}$, where $x_1, x_2, ..., x_n$ – indicators of the waste management system of the united territorial community
Output parameters	$y(s) = \{y_1, y_2, ..., y_n\}$, where $y_1, y_2, ..., y_n$ – indicators of the waste management system and environmental safety of the united territorial community
Limitation	$v(s) = \{v_1, v_2, ..., v_n\}$, where $v_1, v_2, ..., v_n$ – quantitative values of maximum permissible levels and other restrictions set by the legislation for anthropogenic impact on the environment
Control parameters	$u(s) = \{u_1, u_2, ..., u_n\}$, where $u_1, u_2, ..., u_n$ – set of stakeholders, regulatory, organizational, technological, financial and economic, information indicators of the system
Unmanaged settings	$z(s) = \{z_1, z_2, ..., z_n\}$, where $z_1, z_2, ..., z_n$ – many indicators of political influences, social factors, financial and other risks caused by external factors.

into account uncontrolled influences $z(s)$. The governance process in the united territorial communities is provided by state structures / local self-government bodies, business structures / economic entities and the local community / households. To develop an effective waste management system at the regional level, we will analyze innovative methods of modern environmental safety management in terms of waste management.

In order to successfully implement an environmentally safe waste management system in the long run, it is necessary to forecast the situation and the difficulties that may arise in the future. Therefore, studying the external environment, strategic management focuses on finding out what threats and what opportunities are hidden in the external environment. In addition, the strengths and weaknesses of the internal environment also determine the conditions for the successful implementation of any long-term program.

Thus, strategic analysis is the basis for ensuring the complexity of solid waste management processes in the region, used for structural design of an effective regional waste management program, based on innovative methods of modern management and the formation of a single information space that affects sustainable development. PEST and SWOT analysis technology is an important tool that brings together the strengths and weaknesses of a business, opportunities and threats to the environment and conducts analysis. The results of determining the situation with the waste management system by the method of PEST-analysis are given in Table 3.

The regulatory framework for waste management is in the process of formation. The national strategy for the management of solid waste by 2030 is not fully implemented. Regional programs in most regions of Ukraine have not been approved or need significant changes. Low efficiency of executive discipline during the implementation of programs and low level of interest of stakeholders are unfavorable factors for solving the problem in Zhytomyr region. Not all of these economic indicators have a positive effect.

Some of them are unfavorable due to the unwillingness of the population of the region to reduce the level of waste generation and separate collection of solid waste. Social indicators are favorable for the implementation of an effective and environmentally safe system of solid waste management in the region. All technological indicators are a positive factor for solving the problem. The results of the PEST analysis of the MSW management system show that the least favorable for an effective solution to the problem are political conditions.

Table 3. PEST-analysis of the control system of MSW management

Political – political indicators	Economical – economic indicators
• Imperfect regulatory framework of waste management. • Low interest of the population, enterprises-carriers in the joint decision of a problem. • Opportunity to involve the general public in the implementation of projects and programs for waste management through public organizations and associations. • Low level of interest in the results of solving the problem of senior officials of Zhytomyr region.	• Insufficient funding of the waste management system. • Availability of additional sources of funding, including international funds, EBRD loans, public budget projects. • High cost of implementing waste management technologies and low cost of waste as a secondary raw material. • Reducing the prevention of environmental damage by reducing environmental damage.
Social – social indicators	**Technological – technological indicators**
• The number of MSW is constantly growing, especially in cities. • Constantly informing the population through the media and social networks about the negative impact of waste on the environment and related health problems. • Promotion of waste recycling, the need to reduce waste, the use of waste as a secondary resource in the media and social networks. • Low level of understanding of the problem by the population of the region. • Readiness of a certain part of the population to actively cooperate with local governments in reducing the impact of MSW on the environment.	• Widespread introduction of waste recycling technologies, reducing waste generation, use of waste as a resource in European countries. • Existence of modern and effective technologies of waste recycling, their processing as secondary raw materials. • Availability of some successful projects to address the problem of reducing the impact of solid waste on the environment. • Lack of efficient logistics systems used in waste management. • Low level of implementation of effective technologies of modern management.
The presence of perspective. Increasing the level of interaction between all participants in the waste management system. Improving the general culture of the population in matters of waste management. Reduction of waste generation. Optimization of economic and environmental indicators through the introduction of environmental logistics systems. Conservation of natural and energy resources through the use of waste as a secondary raw material. Improving the health of the region's population.	

Summing up the results of PEST-analysis, it should be noted that the current conditions in most regions of Ukraine are favorable for the implementation of modern innovative programs for the management of solid waste management.

SWOT-analysis allows you to identify opportunities and threats to the implementation of the management system of solid waste in the region, identify the likelihood of use and the impact of selected opportunities and threats to the results. Similarly, the analysis of threats and consequences of the implementation of modern innovative programs for the management of solid waste management in the region. Also carry out is an assessment of environmental factors. The analysis of the factors of the internal and external environment of the waste management system allows to form a specific list of its weaknesses and strengths, as well as threats and opportunities. The results of the SWOT-analysis of the preconditions for the implementation of innovative waste management programs are given in Table 4.

The final stage of the SWOT-analysis is a quantitative expert assessment and construction of a matrix of results of the prerequisites for the implementation of the program. We will conduct a quantitative expert assessment on the example of the regional waste management program in the Zhytomyr region. Experts from various stakeholders were involved in the expert assessment, namely representatives of: government agencies (local governments, environmental management, state environmental inspection, etc.); business structures (carriers, waste sorting stations, housing and communal services, etc.); public (public organizations, associations, parties, etc.); population living in the region.

The results of the survey of experts allowed to build a matrix of SWOT-analysis of the preconditions for the implementation of the regional waste management program in the Zhytomyr region. At the intersection of columns and rows – Opportunities / Strengths, Opportunities / Weaknesses, Threats / Strengths, Threats / Weaknesses - an expert assessment of their mutual influence in points ranging from -1 to +1. Moreover, a score of +1 corresponds to a strong mutual influence, and a value of -1 – a complete lack of influence.

The consistency of experts' opinions and the non-random nature of the agreemen were assessed according to the concordance coefficient W_i and Pearson's statistical criterion χ^2.

Table 4. SWOT-analysis of the preconditions for the implementation of innovative waste management programs

Environment	Positive impact	Negative influence
	Strengths	Weaknesses
Internal environment	A_1. Implementation of the waste management program will increase the level of environmental safety of the region. A_2. Awareness of the top management of the region of the need to address the problem of efficient waste management. A_3. Changing the vector of solving the problem from the concept of combating the effects of waste on the environment to the concept of developing technologies for low-waste and non-waste production, recycling, recycling and reuse. A_4. Increasing the number of business structures that are ready and able to implement modern methods of MSW disposal	B_1. Developed National Waste Management Program until 2030, is implemented only partially, which complicates the formation of regional programs, reduces the effectiveness of new management methods. B_2. The region maintains a functional hierarchy of management, which makes the effectiveness of the program dependent on the management decisions of senior management. B_3. Low efficiency of the existing waste management system in the region. B_4. Insufficiently developed market for waste processing and disposal.
	Opportunities	Threats
External environment	C_1. Growing number of public organizations and the population that are ready and able to participate in solving this problem. C_2. Waste disposal methods are constantly being improved in both domestic and international practice. C_3. Waste management programs implemented at the national, regional or local level are based on the existing waste management system of the country, region, city or enterprise. C_4. Introduction of modern innovative management methods in public authorities and local governments. C_5. In the cities of the region there are opportunities to form a modern infrastructure for waste management. C_6. The region has the conditions to create a competitive market for waste management.	D_1. Increasing the amount of waste and increasing their impact on the environment, the threat of environmental catastrophe. D_2. Threat of social and political dangers due to increased waste disposal fees and increased fines. D_3. Lack of developed regional waste management programs based on modern management methods. D_4. Low level of social environmental awareness and culture of MSW management. D_5. Lack of communication and coordination of actions between stakeholders in solving the problem. D_6. The presence of a conflict of interest and unwillingness to take responsibility for solving the problem.

The concordance coefficient W allows us to estimate how consistent the rankings of n objects built by a group of m experts are.

$$\|r_{ij}\| \; j = (1, ..., m; i = 1, ..., n)$$

where: r_{ij} – rank given by the j-th expert of the i-th object. It is defined as the ratio of D, which describes the variance between the rankings to the value of D_{max}, which is the maximum possible variance and is calculated by the formula:

$$W = \frac{D}{D_{max}} = \frac{12 \cdot S}{m^2(n^3 - n)'} \quad (9)$$

where: m – number of experts; n – number of listeners.

To calculate the sum of squares of deviations of ranks from the average value S:

$$S = \sum_{i-1}^{n} \left(\sum_{j-1}^{m} r_{ij} - r \right)^2 \quad (10)$$

The coefficient W is measured in the range from 0 to 1 and the group estimate is considered sufficiently reliable when $W > 0.7$. If the concordance coefficient is zero, then there is an absolute discrepancy between the opinions of experts. If the concordance coefficient is equal to one, then there is a full consensus of experts' opinions on the results of the survey.

The statistical value of the concordance coefficient is checked by Pearson's criterion χ^2**,** which is calculated by the formula:

$$\chi^2_{\phi} = m(n - 1) \cdot W \quad (11)$$

According to the level of significance α and the number of degrees of freedom $q = n - 1$ in Pearson's tables are critical χ^2_{kp}.

If $\chi^2_{\phi} > \chi^2_{kp}$, then the concordance coefficient can be trusted and obtained, its main conclusions are reliable.

The found value of χ^2 is compared with the tabular χ^2 for the number of degrees of freedom $n - 1$ and the level of significance α. If the value of χ^2 is greater than χ^2 of the table, the hypothesis of non-random agreement of experts' opinions is not rejected. If the concordance coefficient W and Pearson's criterion χ^2 are unsatisfactory, experts re-evaluate the materials.

The results of the SWOT-analysis of the preconditions for the implementation of the regional waste management program in the Zhytomyr region are presented in Table 5.

Concordance coefficient $W = 0.7892$, which indicates sufficient consistency of experts' opinions.

Table 5. Results of the SWOT-analysis of the preconditions for the implementation of the regional waste management program in Zhytomyr region

Opportunities / Strengths	C_1	C_2	C_3	C_4	C_5	C_6
A_1	1	0.9	0.7	0.6	1	0.9
A_2	0.5	0.9	0.9	0.5	0.8	0.7
A_3	0.6	0.1	0.1	0.9	0.1	0.8
A4	1	0.2	0.7	0.7	0.1	0.2
Opportunities / Weaknesses	C_1	C_2	C_3	C_4	C_5	C_6
B_1	0.7	0.7	0.6	0.5	0.7	0.4
B_2	0.2	0.2	0.1	0.1	0	0.1
B_3	0.3	0.8	0.7	0.6	0.9	0.9
B4	0.1	0.8	0.2	0.8	0.5	0.5
Threats / Strengths	D_1	D_2	D_3	D_4	D_5	D_6
A_1	-0.6	-0.7	0	-1	-0.8	0.1
A_2	-0.7	-0.6	0.1	-0.5	-0.6	-0.4
A_3	-0.7	-0.8	0.1	-1	-0.6	0.2
A_4	0.2	0.3	0.3	-0.5	-0.4	-0.2
Threats / Weaknesses	D_1	D_2	D_3	D_4	D_5	D_6
B_1	-0.7	-0.6	-0.4	-0.3	-0.4	-0.2
B_2	-0.1	-0.4	-0.1	-0.3	-0.5	-0.6
B_3	-0.6	-0.8	0.1	-0.3	-0.6	-0.4
B_4	-0.3	-0.9	0	-0.2	-0.7	-0.6

Table 6. General results of the SWOT-analysis of the preconditions for the implementation of the regional waste management program in the Zhytomyr region

Strength codes	A_1	A_2	A_3	A_4
The total amount of estimates	2.1	1.6	-0.2	2.6
Weakness codes	B_1	B_2	B_3	B_4
The total amount of estimates	1	-1.3	1.6	0.2

Opportunity codes	C_1	C_2	C_3	C_4	C_5	C_6
The total amount of estimates	4.4	4.6	4	4.7	4.1	4.5
Threat codes	D_1	D_2	D_3	D_4	D_5	D_6
The total amount of estimates	-3.5	-4.5	0.1	-4.1	-4.6	-2.1

The estimated value of Pearson's statistical criterion χ^2 is equal to 14.86, which at a degree of freedom of 14 and a significance level of $\alpha = 0.01$ is greater than the tabular value ($\chi^2 = 14.4$). Thus, the ranking of experts at $\alpha = 0.1$ can be considered consistent.

The general results of the SWOT-analysis of the preconditions for the implementation of the regional waste management program in the Zhytomyr region are given in Table 6.

A generalized analysis of the strengths shows that the region has all the conditions to address waste management on the basis of modern innovative management methods, but there are significant risks associated with lack of communication and coordination between stakeholders in addressing this issue.

CONCLUSIONS

Thus, as the results of the SWOT analysis showed, the strongest aspect of the implementation of a modern waste management system is the increase in the number of business structures that are ready and able to implement modern methods of waste disposal. The weakest point is the low efficiency of the existing waste management system in the region. External opportunities that contribute to change are the availability of modern innovative management methods in public authorities and local governments. The biggest threat is the lack of communication and coordination between stakeholders in solving the problem. The obtained results are the basis for the implementation of regional waste management programs based on the provisions of the circular economy.

The application of systems analysis allowed to develop a system model of waste management, which translates the input state of the system $x(s)$ to the output $y(s)$ using control effects $u(s)$ subject to external constraints $v(s)$ and taking into account the risks of uncontrolled impacts $z(s)$. Sets of input parameters include a set of qualitative and quantitative indicators of MSW; many methods of waste management that can be implemented in integrated territorial communities; many stakeholders in the MSW management system of the united territorial communities. The initial parameters of the system are the ecological and economic indicators of the system of solid waste management of the united territorial community. The task of the system is to prevent the harmful effects of waste on the environment and public health through the implementation of measures to prevent waste generation, reduce its amount, and optimize waste flows by restoring their value, reuse, recycling, disposal and control of waste disposal facilities.

A conceptual model for the implementation of an environmentally friendly innovative logistics management system for waste management is proposed, which includes the involvement of a coordinating agent as a separate entity that manages all waste generated in a given area. The implementation of a logistical approach in regional waste management programs covers the entire life cycle of the MSW from the formation to the creation of a new product or subsequent disposal or safe storage in the environment. The main condition for the implementation of waste management system is any technologies and measures, including reducing the amount of waste, their recovery or disposal, disposal, etc. are developed in combination with each other.

REFERENCES

1. Bienvenu, M., Mulaji, K.C., Mpiana, P.T., Elongo, V., Otamonga, J.P., Biey, E., Wildi, W., Poté, J., Giuliani, G. 2017. Citizen sensing of solid waste disposals: crowdsourcing as tool supporting waste

management in a developing country. https://www.researchgate.net/publication/326668626_Citizens_as_Sensors_Human_Sensors_as_a_Smart_City_Data_Source

2. Council Directive 1999/31/EC of 26 April 1999 on waste disposal. 1999. https://zakon.rada.gov.ua/laws/show/994_925#Text
3. Delehan-Kokaiko, S., Slabkiy, G., Lukianova, V., Anpilova, Y. 2020. Effect of landfill sites on disease and disease distribution among rural population (Vplyv smittyezvalyshch na pokaznyky zakhvoryuvanosti silʹsʹkoho naselennya ta poshyrenosti sered nʹoho khvorob). Environmental safety and natural resources, 34(2), 43–52. https://doi.org/10.32347/2411-4049.2020.2.43-52. (in Ukrainian)
4. Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC - Statement by the European Parliament, the Council and the Commission. 2006. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32006L0021&qid=1644248389129
5. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. 2008. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0098
6. Frolov, S.M., Bilopilska O.O. 2013. Assessment profile of waste management system in Ukraine based on the stage model of development. Маркетинг і менеджмент інновацій, 2, 220–229. https://mmi.fem.sumdu.edu.ua/sites/default/files/mmi2013_2_220_229.pdf
7. Gangolells, M., Casals, M., Forcada, N., Macarulla, M. 2014. Analysis of the implementation of effective waste management practices in construction projects and sites. Resources, Conservation and Recycling, 93, 99–111. https://doi.org/10.1016/j.resconrec.2014.10.006
8. Hewelke, E.A., Wiśniewska, E. 2018. Analysis of ecosystem services as a tool in the development of local environmental protection programs. Ecological Engineering, 19(5), 83–90. https://doi.org/10.12912/23920629/96220
9. Safranov, T.A., Shanina, T.P., Prykhodko, V.Y. 2021. Prerequisites for formation and implementation of a municipal solid waste management plan in Odesa Region. Ukrainian Hydrometeorological Journal, 27, 86–96. https://doi.org/10.31481/uhmj.27.2021.09
10. Khrutba, V., Lukianova, V., Anpilova, Y., Kotsiuba, I., Spasichenko, O., Kriukovska L. 2021a. Evaluation of the Impact on the Environment at Building and Reconstruction of Motorways Using the System Analysis Method. Environmental Research, Engineering and Management, 77(1), 85–95. https://doi.org/10.5755/j01.erem.77.1.27887
11. Khrutba, V., Morozova, T., Kotsiuba, I., Shamrai, V. 2021b. Simulation Modeling for Predicting the Formation of Municipal Waste. In: Shkarlet S., Morozov A., Palagin A. (eds) Mathematical Modeling and Simulation of Systems (MODS'2020). MODS 2020. Advances in Intelligent Systems and Computing, 1265, 24–35.
12. Kolodiichuk, I., Dubnevych, Y., Kolodiichuk, V., Dmytriv, V. 2021. Prospects for the Balanced Development of the Waste Management System in Ukraine. Global Business Review. https://doi.org/10.1177/09721509211034747
13. Kotsiuba, I., Lyko, S., Lukianova, V., Anpilova, Y. 2018. Computational dynamics of municipal wastes generation in Zhytomyr city. Environmental safety and natural resources, 25(1), 33–43. https://doi.org/10.32347/2411-4049.2018.1.33-43
14. Kotsiuba, I., Lyko, S., Lukianova, V., Anpilova, Y. 2020. Scientific and theoretical justification of solid household waste accumulation in Zhytomyr region. (Naukovo-teoretychne obgruntuvannia nakopychennia tverdykh pobutovykh vidkhodiv Zhytomyrshchyny). Environmental safety and natural resources, 36(4), 56–65. (in Ukrainian) https://doi.org/10.32347/2411-4049.2020.4.56-65
15. Kotsiuba, I.G., Skyba, G.V., Skuratovskaya, I.A., Lyko, S.M. 2019. Ecological Monitoring of Small Water Systems: Algorithm, Software Package, the Results of Application to the Uzh River Basin (Ukraine). Methods and objects of chemical analysis, 14(4), 200–207.
16. Morozova, T., Lukianova, V., Anpilova, Y. 2019. Conceptualization of latent ecosystem services. Environmental safety and natural resources, 29, 54–64. https://doi.org/10.32347/2411-4049.2019.1.54-64
17. National Waste Management Strategy in Ukraine until 2030. 2017. (Natsionalʹna stratehiya upravlinnya vidkhodamy v Ukrayini do 2030 roku. [Electronic resource]: https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80#Text (in Ukrainian).
18. Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A., Owolabi, H.A., Kadiri, K.O. 2015. Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements, Resources, Conservation and Recycling, 102, 101–112. https://doi.org/10.1016/j.resconrec.2015.06.001
19. Suryawan, I.W.K., Fauziah, E.N., Septiariva, I.Y., Ramadan, B.S., Sari, M.M., Ummatin, K.K., Lim, J. 2022. Pelletizing of Various Municipal Solid Waste: Effect of Hardness and Density into Caloric Value. Ecological Engineering & Environmental Technology, 23(2), 122–128. https://doi.org/10.12912/27197050/145825

20. Ojha, A., Reuben, A.C., Sharma, D. 2012. Solid Waste Management in Developing Countries through Plasma Arc Gasification- An Alternative Approach, APCBEE Procedia, 1, 193–198. https://doi.org/10.1016/j.apcbee.2012.03.031
21. Podchashinskiy, Y., Kotsiuba I., Yelnikova, T. 2017. Math modeling and analysis of the impact of municipal solid waste landfill leachate on the environment. Eastern-European Journal of Enterprise Technologies, 1, 10(85), 4–10. https://doi.org/10.15587/1729-4061.2017.91033
22. Shamrai, V., Korobiichuk, V., Sobolevskyi, R. 2017. Management of waste of stone processing in the framework of Euro integration of Ukraine. The Journal of Zhytomyr State Technological University. Series: Engineering, 1, 234–239. https://doi.org/10.26642/tn-2017-2(80)-234-239
23. Suryawan, I.W.K., Fauziah, E.N., Septiariva, I.Y., Ramadan, B.S., Sari, M.M., Ummatin, K.K., Lim, J. 2022. Pelletizing of Various Municipal Solid Waste: Effect of Hardness and Density into Caloric Value. Ecological Engineering & Environmental Technology, 23(2), 122–128. https://doi.org/10.12912/27197050/145825
24. Terrones-Saeta, J., Suárez-Macías, J., Corpas-Iglesias, F., Korobiichuk, V., Shamrai, V. 2020. Development of Ceramic Materials for the Manufacture of Bricks with Stone Cutting Sludge From Granite. Minerals. https://doi.org/10.621.10.3390/min10070621
25. Trofymchuk, O., Myrontsov, M., Okhariev, V., Anpilova, Y., Trysnyuk, V. 2021. A Transdisciplinary Analytical System for Supporting the Environmental Researches. Systems, Decision and Control in Energy II. Studies in Systems, Decision and Control, 346, 319–331. https://doi.org/10.1007/978-3-030-69189-9_19