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DEVELOPMENT OF PRIORITY MEASURES (SOLUTIONS) FOR THE ENVIRONMENTALLY SAFE MANAGEMENT OF MUNICIPAL WASTE AT THE COMMUNITY LEVEL

Екологічно безпечне управління відходами залишається однією з пріоритетних сфер діяльності громадянського суспільства. Незважаючи на запровадження низки нормативно правових актів, наприклад, Директива Європейського Парламенту та Ради 2008/98/ЄС від 19.11.2008, до теперішнього часу не вирішене питання ефективного управління у сфері поводження з відходами в кінцевій стадії. Тому в якості об'єкту дослідження розглянуто процес поводження з твердими побутовими відходами (ТПВ) на рівні територіальних громад. Серед основних недоліків цього процесу слід виділити відсутність дієвих механізмів та алгоритмів систем підтримки прийняття обгрунтованих рішень щодо поводження з відходами на їх специфічній території.

В роботі запропоновано науково-методичний підхід до комплексного експертно-аналітичного оцінювання процесів оперування побутовими відходами та обгрунтовано доцільність заходів управління екологічною безпекою. В ході дослідження проведено декомпозицію процесу оперування побутовими відходами. Це дозволило виявити джерела та характеристики виявлення небезпек, серед яких найбільший внесок складають об'єкти спалювання відходів без отримання енергії (47,41 %) та умови накопичення відходів із збільшенням небезпечності (54,95 %). Використання методу аналізу ієрархій дозволяє врахувати індивідуальні та колективні судження експертів, що не тільки підвищує якість дослідження, а й дозволяє визначити пріоритетність заходів управління екологічною безпекою процесу. За проведеними розрахунками найбільш важливим (44,01 % від загального внеску) визначено захід по запровадженню найкращих доступних технологій оперування ТПВ. Отримання таких результатів можливо завдяки тому, що метод аналізу ієрархій дозволяє в покроковому режимі визначати транзитивність і узгодженість експертних оцінок.

В порівнянні з аналогічними методами дослідження запропонований підхід, як досить простий та зрозумілий, зручний у використанні. Окрім викладеного підвищення ефективності прийняття прозорих рішень на рівні місцевих громад забезпечується за рахунок залучення в якості експертів висококваліфікованих фахівців в галузі екологічної безпеки та публічного управління.

Ключові слова: управління побутовими відходами, оперування відходами, екологічна безпека, експертна оцінка, метод аналізу ієрархій.

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1. Introduction

The operation study of the household waste (SHW) management process is the final stage of processing and is divided into the following components:

- recycling (i. e. elimination of dangerous waste properties for their further use);
- recovery (use of waste as material or energy resources);
- disposal (i. e. final destruction of waste).

Household waste is a valuable resource. On average, about 170 kg of biogas, 410 kg of compost, 50 kg of the first screening of rough elements and scrap metal, and 250 kg of the second screening (glass, fabric, wood, plastic) can be obtained from 1 ton of waste [1]. About 70 % of all screenings can be used for heat generation through combustion, pyrolysis, gasification, and specialty fuel production (RDF).

All these circumstances force the use of various intensive methods of using municipal solid waste (MSW): recycling with the removal of valuable components, combustion, pyrolysis, composting, etc. [2, 3].

The current state of waste management as a whole is characterized by significant shortcomings, in particular, the lack of constructive cooperation between local governments (executive authorities) and a clear (effective) system of regulation of waste recovery and disposal activities.

In order to implement an effective option for solid municipal waste management (MSW), regulatory support is not enough, such as Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. A mechanism is necessary to justify the choice (decision-support) or to find a common effective solution with the involvement of qualified

professionals. This is particularly relevant for local governments and united territorial communities in the context of decentralization of state power.

2. The object of research and its technological audit

The object of research is the process of solid waste management at the level of territorial communities.

In the context of decentralization of state power, local governments have many responsibilities for the management of controlled areas, including cleaning them from waste. At the same time, the management structures of such communities do not provide for any mechanisms to ensure environmental safety, which makes it impossible to make effective decisions. This leads to uncontrolled waste incineration, unauthorized disposal, low level of functioning the system of separate garbage collection, and so on. The process of solid waste management is reduced to inefficient means of dealing with them, without taking into account the factors of danger, social and economic aspects.

The feasibility of using one or other of the listed MSW management methods depends on many factors and indicators: the size of the city, the composition and properties of the MSW of a given city or region, the need for waste fractions, heat or fertilizer, climatic conditions, and so on.

The current state of MSW management is characterized by significant shortcomings:

- environmental acceptability in terms of reducing pollution of the atmosphere, water sources, land;
- low efficiency of technological and constructive decisions;
- lack of information, resources and mechanism in determining the best way to operate waste;
- mutually beneficial cooperation between municipalities;
- uncontrolled waste flow;
- lack of a system for regulating waste management activities in the final stage.

In addition to solving these problems, an additional advantage of the proposed method is the elimination of the influence of any third-party factors, including corruption, of decision-making.

3. The aim and objectives of research

The aim of research is to create and disclose a scientific and methodological approach to comprehensive expert and analytical evaluation of the MSW operation process.

In order to achieve the aim of the research, the following objectives are set:

1. To propose an approach to the formation and composition of the expert team to support decision-making in the field of MSW management.
2. To develop hierarchical structures of the process of MSW operation and environmental safety management.
3. To investigate the process of MSW operation using the developed procedures of expert analytical evaluation.
4. To summarize the results of the research in order to provide recommendations for improving environmental safety.

4. Research of existing solutions of the problem

Carrying out expert and analytical evaluation of the environmental safety of solid municipal waste management

processes using the analytic hierarchy process (AHP) [4], proves the possibility of making effective collective decisions in cases of complex structured tasks. In this publication the authors only partially cover the issues of formation and work of experts.

This publication will focus on this specific type of research, using the example of a municipal waste management process.

Expert-analytical evaluation involves the selection of experts to solve complex-structured problems and is always one of the keys to the general theory of system analysis and decision-making.

One of the tools for solving these problems is expertise, and the main source of information is specialists – experts [5, 6]. Increasing the reliability of expert assessments in the examination is achieved by involving the most competent experts in the group [7].

The selection of the expert group is considered [8, 9] as a multi-stage process. According to the authors of these studies, no general methodological approach to the target selection of the composition of any expert groups has been developed to date.

Studies [10, 11] have suggested approaches to creating a selection algorithm and forming expert groups. Among other things [12, 13], the number of specialists involved is justified, as well as the principles of forming expert groups with the highest level of trust at the minimum time and cost. One of the main problematic issues of expertise [14] is the consistency of experts' opinions, which, if highly divergent, may cast doubt on the results obtained.

The process of reaching consensus within the group, as well as numerous rounds of group analysis and discussion, were widely used to reach the decision that most experts accept [15]. The proposed consensus-building process is used to address the issue of security metrics but is not widely used due to the considerable time spent.

The most widely used method of choice in the decision-making system is AHP, which allows to rank disciplines, objects, factors of importance within the limits of certain competences [16, 17]. The group approach, based on AHP, among other advantages, addresses the problem of consensus of experts.

Another important component in solving multicriteria problems is to choose the best method of analysis when selecting the best alternative when making management decisions.

This research is devoted to the problem of choosing effective methods of decision-making by local authorities [18, 19]. The results of the in-depth analysis of scientific works have revealed the problems (limitations, disadvantages and contradictions) in the development of a method of making consistent management decisions [20, 21]. According to the conclusions [22, 23], traditional methods of examination do not practically work in the study of organizational and socio-economic systems.

AHP differs with the high structure and clarity from others, which allows it to be used in decision making at different levels of management [24]. The uniqueness of this method is that it is both qualitative and quantitative. AHP allows to determine in a step-by-step manner the transitivity and consistency of expert assessments [25].

The study of the directions of AHP development is performed [26]. A generalized approach for group decision-making is formalized, which allows to form the stages of the method depending on the initial data.

The particular value of the AHP method is the ability to take into account both individual and collective opinions of experts which is essential in conducting socially significant expert-analytical studies.

The use of the method is quite simple and accessible to meet the challenges of supporting managerial decision-making, in particular in the field of environmental security.

5. Methods of research

Choosing the most optimal way to operate MSW, taking into account the specific conditions of the local community is a difficult multifactorial task.

In the conditions of the extreme complexity of the problem, its novelty, impossibility of mathematical formalization of the process, it is necessary to use competent specialists – experts.

Summarizing the publications analyzed above regarding the formation and operation of expert groups, the following should be noted:

- there is no single universal approach to the selection of experts and the procedure of work of expert groups;
- there are many factors that influence the quality of expert research, the main one being the determination of the consistency of expert opinions;
- expert research with the involvement of up to 10 specialists – experts is the most appropriate;
- the more criteria are put to the selection of experts, the more difficult it is to form an effective group;
- the expert group should be headed by a specialist with experience in conducting expert-analytical studies.

The methodology of studies of increasing environmental safety using AHP was previously outlined by the authors in [27–29]. This allows to partially reduce the description of such procedures.

For a clear and simple way of conducting expert-analytical studies of MSW management processes, the pairwise comparison method is used, which is the easiest and most affordable to use.

In pairwise comparison it is not necessary, as in ranking, to order all objects, but only in each of the pairs it is necessary to find a more significant object or to establish their equality. Pairwise comparisons can be made for a large number of objects, and in cases where the difference between the objects is so small that it does not allow them to be ranked.

When participating in the survey of several experts, differences in individual estimates are inevitable, but the magnitudes of these differences are important in interpreting their content. A group assessment can only be considered reliable if there is a high degree of consistency in the responses of individual experts. Establishing the degree of consistency of expert opinions is a key indicator of the acceptability of such expertise.

5.1. Formation of the expert group. For the aim of this research, specialists were selected as experts in only two areas – specialization and work experience.

- The proposed composition of the expert group of ten people:
- chairman of the expert group – specialist with experience in conducting expert-analytical studies;
 - expert 1 – specialist in the field of environmental impact assessment;
 - expert 2 – specialist in the field of scientific and technical research;

- expert 3 – specialist in the field of environmental monitoring;
- expert 4 – specialist in the field of public waste management;
- expert 5 – specialist of environmental protection state institution;
- expert 6 – specialist in the field of waste disposal;
- expert 7 – specialist in the field of waste management;
- expert 8 – specialist in the field of ecological-analytical research;
- expert 9 – representative of the local self-government body (one or more, depending on the set goal).

All of the above specialists have higher education in the field of expertise and work experience of more than 10 years, which fully meets the requirements of the research outlined in Section 4.

5.2. Sequence of conducting expert-analytical research of MSW operation. Carrying out an expert-analytical research of MSW operation is based on seven main stages.

The first stage. Area of expertise and waste management analysis tasks structuring. At this stage, the chairman of the expert group, who has experience in conducting expert-analytical research using the AHP, is selected. This specialist provides methodological guidance for the process and communicative interaction between experts.

Identification and formalization of the necessary elements of the MSW operating system is carried out, the presence and content of the relationships between the elements is revealed.

The second stage. Setting the tasks of analysis of environmentally safe MSW operation. Initial information is collected and a description of the procedure for obtaining expert opinions is made (selection of evaluation methods, comparison scales, criteria, scenarios, list of tasks and questions to be considered by experts individually and collectively, etc.).

The third stage. Formation of an expert group and building a hierarchy. The formation of an expert group according to the specifics of the research (only specialization (specialty) and work experience is taken into account). Experts are provided with materials and documentation in accordance with paragraphs 1, 2 for preliminary study. During the hierarchical structuring of the problem, individual opinions are taken into account to create the completeness of the model for improving the environmental safety of the MSW operation process (in the proposed study – each levels of the hierarchy).

The fourth stage. Conducting an expert survey. The survey is conducted in any of the available ways: a separate survey (with the further agreement of experts), remote work, questionnaires, group work, etc. The purpose of the stage is to document expert judgments.

The fifth stage. Processing of the received expert assessments. The results are summarized. The main objective at this stage is to establish the coherence of the experts' opinions, which, according to the AHP methodology, should not exceed 10 %.

The sixth stage. Interpretation of results. The head of the expert group summarizes. The results obtained are interpreted in accordance with the content originally laid down by the chairman of the model under research. The answer to the questions of the expert-analytical research of the MSW operation process is given.

The seventh stage. Discussion of the results and forming a conclusion or specific expert opinion. The analysis results of the MSW operation process are discussed, with the conclusion of the examination in the form of a protocol. If necessary, a review of the analysis process is carried out. In the case of errors and inconsistencies, a re-analysis or form special expert opinion shall be conducted, as indicated in the protocol.

The expert analysis procedure is considered complete.

5.3. Formulation of questions for the research of SHW operation. The results of the environmental danger assessment of the MSW operation process and the priority of measures to reduce the negative impact on the environment depend substantially on the question posed.

The following questions are proposed to study the process of MSW operation:

Setting a task for the experts for pairwise comparison of level 1 elements: «Which type of MSW operation is most dangerous for the environment?»

Setting a task for the experts for pairwise comparison of level 2 elements: «Which of the environment components can have a more direct impact in the process of a particular type of MSW operation?»

Setting a task for the experts for pairwise comparison of level 3 elements: «Which of the comparable level 3 factors is likely to create a greater risk for the assessed level 2 component of the environment in the process of SHW operation?»

Setting a task for the experts for pairwise comparison of level 4 elements: «Which of the sources of MSW consumption may pose a greater threat to the environment if the level 3 factor in the MSW operation is available?»

Setting a task for the experts for pairwise comparison of level 5 elements: «Which of the level 5 activities will more significantly reduce the negative impact on the environment for a level 4 rated source in the process of SHW operation?»

The clearer and more accessible the issues are formulated, the better the coherence of the experts' opinions and, as a consequence, the calculation errors will be minimized.

6. Research results

The decomposition of MSW operation processes at levels consistent with the principles of AHP structuring is carried out in accordance with the content of Directive 2008/98/EC, the factors and sources of dangerous formation, and the possible (accessible) measures to improve environmental safety.

It is proposed to construct hierarchical structures in the general formalized form (Fig. 1):

- at the first level of the Ob hierarchy, the objective of the task is formed: to assess

the danger of the process of MSW operation to the environment;

- at the second level of SCr there are sub-criteria – processes of MSW operation, which create danger (recycling, recovery, disposal);

- at the third level C there are the criteria – components of the environment that are adversely affected or contaminated and evaluated from the standpoint of possible dangers;

- at the fourth level of ChF there is characterization of factors that create or contribute to the negative impact (quantitative, qualitative components of pollution, etc.);

- at the fifth level of SD there are sources of danger, the impact of which on the ability to manage the environmental safety of the MSW hierarchy will be evaluated in the synthesis process;

- at the sixth level of SM there are security measures, which ensure the reduction of negative impact and are aimed at achieving the normative level of environmental safety.

The overall assessment of the consensus of experts on the calculations of the AHP program was: 0.04643; the calculations were performed to the nearest 1e-05.

Relationships between elements of the hierarchy are established on the basis of the characteristics of the interaction of elements of adjacent levels of hierarchies. An example of the developed approach to formulating the characteristics of the content of relationships between elements of the upper and lower adjacent levels of the hierarchical structure is given in Table 1.

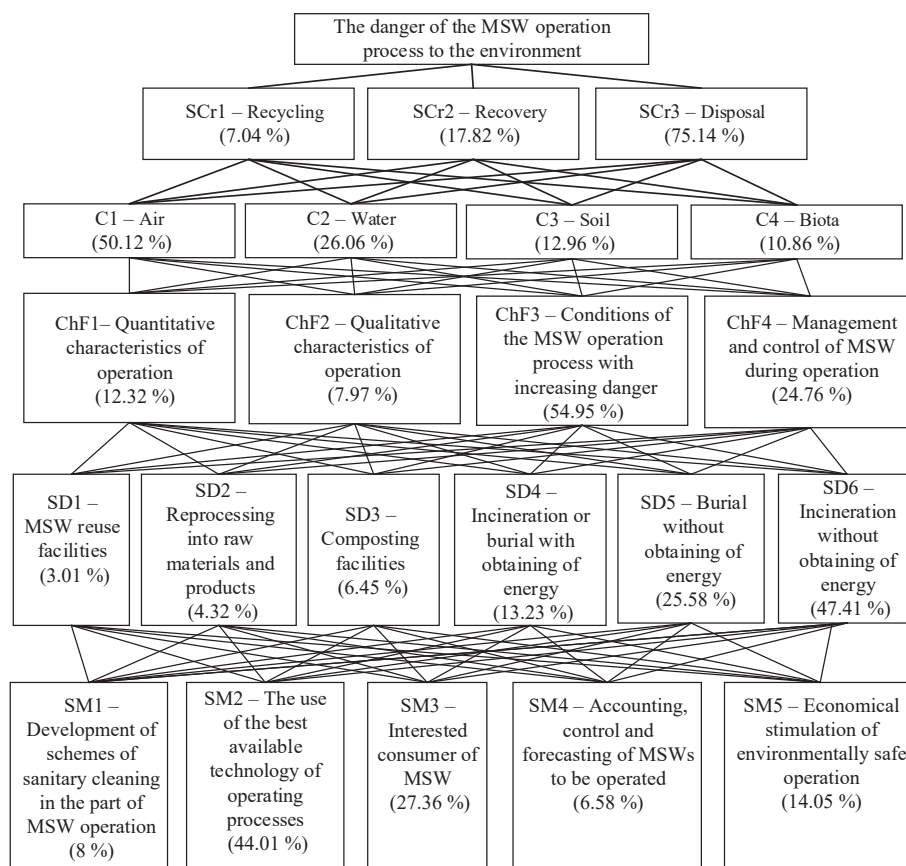


Fig. 1. Decomposition of the environmental safety management task of the municipal solid waste operation process

Table 1

Characteristics of the Relationships between the Elements of the municipal solid waste operation process

The name of the hierarchy level	The lower-level elements associated with the corresponding higher-level hierarchy element	Relationship characteristic that reveals the essence of interaction or influence between the elements of the assessed level from the position of the existing higher level and aspects of the overall purpose of the evaluation
1	2	3
Relationships between elements of level 1 (Objective) and elements of level 2 (Sub-criteria)		
Level 2. SCr (Sub-criteria) Dangerous MSW operation processes	SCr1 – Recycling	Contribution of the type of operation to the overall danger of the process. The term is defined as the reduction or elimination of dangerous waste by mechanical, physical, chemical or biological treatment
	SCr2 – Recovery	Contribution of the operation type to the overall danger of the process. The term is defined as any operation in which waste benefits by replacing other materials that would otherwise be used to perform a particular function, or waste prepared to perform that function, at a factory or for a larger economy
	SCr3 – Disposal	Contribution of the type of operation to the overall danger of the process. The term is defined as the implementation of operations with waste that does not lead to their disposal, such as burial, destruction
Relationships between elements of Level 2 (Sub-criteria) and elements of level 3 (Criteria)		
Level 3. C (Criteria) components of the environment that are adversely affected or contaminated and evaluated for potential dangers	C1 – Air	Possible dangerous impact of the MSW operation process on the air as a component of the environment is assessed
	C2 – Water	Possible dangerous impact of the MSW operation process on water resources as a component of the environment is assessed
	C3 – Soil	Possible dangerous impact of the MSW operation process on the soil as a component of the environment is assessed
	C4 – Biota	Possible dangerous impact of the MSW operation process on the biota as a component of the environment is assessed
Relationships between elements of level 3 (Criteria) and elements of level 4 ChF (Characterization of factors)		
Level 4. C (Criteria) Complex impact factors (waste impact characterization)	ChF1 – Quantitative characteristics of operation	Impact (dependence) of the amount of waste, expressed in weight, volume, etc., on the ecological safety component of the environment. As the amount of waste increases, their impact (danger) on the environment component increases
	ChF2 – Qualitative characteristics of operation	Impact (dependence) of the waste quality, which is expressed in the physical, chemical or biological properties of waste with increasing or occurrence of danger, etc., on the environmental safety of the environment component. With the deterioration of the waste quality (change in the physical, chemical or biological properties of the waste with the increase or occurrence of the danger), their impact on the environment component increases
	ChF3 – Conditions of the MSW operation process with increasing danger	Impact (dependence) of conditions of waste accumulation with increasing danger (technical characteristics of the place of accumulation, timely removal of waste, mixed or separately collected waste, etc.) on the environmental safety of the environment component. The long accumulation of waste is accompanied by decay and decomposition processes
	ChF4 – Management and control of MSW during operation	Management and control of the MSW operation process, which can affect the environmental safety of the environment component. The absence or poor functioning of the systems for management and control of the MSW operation process lead to an increase in the negative impact on the environment component
Relationships between elements of level 4 ChF (Characterization of factors) and elements of level 5 SD (Sources of danger)		
Level 5. SD (Sources of danger) Sources of MSW consumption (danger occurrence)	SD1 – MSW reuse facilities	Contribution of the source of MSW operation to the overall (complex) characteristic of the impact
	SD2 – Reprocessing into raw materials and products	Contribution of the source of MSW operation to the overall (complex) characteristic of the impact
	SD3 – Composting facilities	Contribution of the source of MSW operation to the overall (complex) characteristic of the impact
	SD4 – Incineration or burial with obtaining of energy	Contribution of the source of MSW operation to the overall (complex) characteristic of the impact
	SD5 – Burial without obtaining of energy	Contribution of the source of MSW operation to the overall (complex) characteristic of the impact
	SD6 – Incineration without obtaining of energy	Contribution of the source of MSW operation to the overall (complex) characteristic of the impact

Continuation of Table 1

1	2	3
Relationships between elements of level 5 SD (Sources of danger) and elements of level 6 SM (Security measures)		
Level 6. SM (Security measures) Measures to increase environmental dangers	SM1 – Development of schemes of sanitary cleaning in the part of MSW operation	Impact of the measure on the source of the danger. Development of a document containing the rationale, order and extent of implementation of measures and performance of works on sanitary cleaning. Systems and methods of MSW operation. The required number of technical means. The expediency of altering or constructing the facilities for MSW operation. Volumes and sources of financing. The sanitation scheme is the «road map» of the MSW treatment process
	SM2 – The use of the best available technology of operating processes	Impact of the measure on the source of the danger. Utilizing the best available technological solutions for the MSW operation process, from an environmental, social and economic point of view
	SM3 – Interested MSW consumer	Impact of the measure on the source of the danger. Presence of an enterprise, institution, organization for which the consumption of MSW is economically feasible (uses waste as raw material). Such a consumer is interested in maximizing the accumulation of waste in their economic use
	SM4 – Accounting, control and forecasting of operated MSWs	Impact of the measure on the source of the danger. Accounting, control and forecasting of MSW operation takes into account: – peculiarities of the territory in which operations are carried out; – type, quantity and source of waste produced in the territory; – organizational aspects related to waste management; – assessment of the utility and suitability of using economic and other tools in solving operational problems; – control of the operation process to prevent contamination of the environment, including compliance with established rules and norms by the operators, etc.
	SM5 – Economical stimulation of environmentally safe operation	Impact of the impact on the source of the danger. The best available technology is the MSW operation method, regardless of its economic feasibility (through grants, financing or other economic mechanisms)

The research made it possible to determine the contribution to the overall risk of operating each of its components, namely, disposal (SCr3) – 75.14 %; recovery (SCr2) – 17.82 %; recycling (SCr1) – 7.04 %.

The results obtained (Table 2) allow to compare the dangers for the environmental components of each type of MSW operation. The bottom row of the table by its values is not the arithmetic mean of all processes, which indicates the presence of system-wide emergent properties.

According to the calculations obtained, the significance of the components of the environment, which are dangerously affected in the process of MSW operation, was determined (Fig. 2): air (C1) – 59.83 %; soil (C3) – 16.79 %; biota (C4) – 14.39 %; water (C2) – 8.99 %.

Most significant in the danger formation of the MSW operation process are the increasingly dangerous conditions (ChF3) and the management and control of MSW operation (ChF4), accounting for 54.95 % and 24.76 % of the total contribution, respectively.

The results obtained (Table 3) allow to estimate the contributions of the factors of the formation of the dangers of the MSW operation process for each of the components of the environment. The analysis of information similarly (Table 2) established the presence of system-wide emergent properties.

Table 2

Contributions of municipal solid waste operation types to the overall danger for the environment components

The processes of MSW operation	Contributions of dangers for the environment components, %			
	C1 – Air	C2 – Water	C3 – Soil	C4 – Biota
SCr1 – Recycling	59.83	8.99	16.79	14.39
SCr2 – Recovery	59.17	6.51	16.19	18.13
SCr3 – Disposal	47.07	32.29	11.84	8.80
For operation in general	50.12	26.06	12.96	10.86

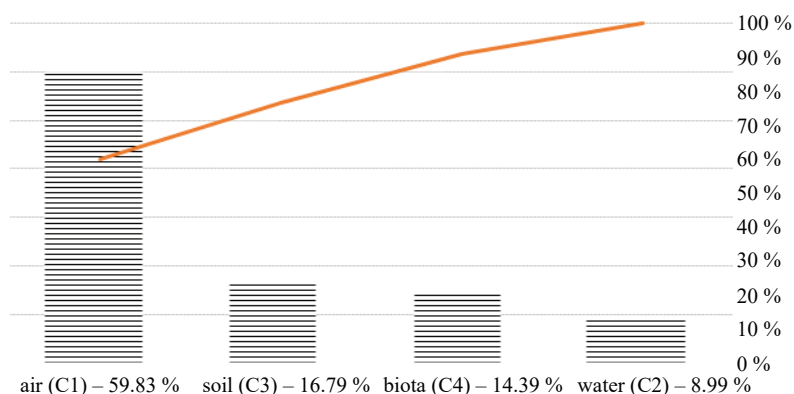


Fig. 2. Weight indicators of the environmental impact of the municipal solid waste operation process

Table 3

Contributions of danger formation factors for the environment

The processes of MSW operation	Contributions of dangers for the environment components, %			
	ChF1 – Quantitative characteristics of operation	ChF2 – Qualitative characteristics of operation	ChF3 – Conditions of the MSW operation process with increasing danger	ChF4 – Management and control of MSW during operation
C1 – Air	12.93	7.36	54.95	24.76
C2 – Water	12.93	7.36	54.95	24.76
C3 – Soil	12.93	7.36	54.95	24.76
C4 – Biota	7.36	12.93	54.95	24.76
For C in general	12.32	7.97	54.95	24.76

An important result of the environmental danger assessment study is the contribution of each of the MSW consumption objects (Fig. 3).

In addition to scientifically substantiating the choice of an appropriate method of MSW operation using the AHP, modified to solve environmental security tasks, it is also possible to solve an additional scientific and applied problem – improving the environmental safety of the MSW operation process.

This problem is solved by calculating the weighting factors for each of the environmental safety measures proposed by the expert group (Fig. 4).

7. SWOT analysis of research results

Strengths. By choosing the right way to form an expert group, it was possible to carry out an expert-analytical study of the MSW operation process, to create an appropriate hierarchical structure with the justification of the relationships of each element of such structure with each other and to reach an acceptable level of agreement of experts' opinions. The composition of the group is formed by levels and elements of the hierarchy, namely, selected specialists in such fields as, environmental security, public administration and control, environmental protection, local self-government, waste management.

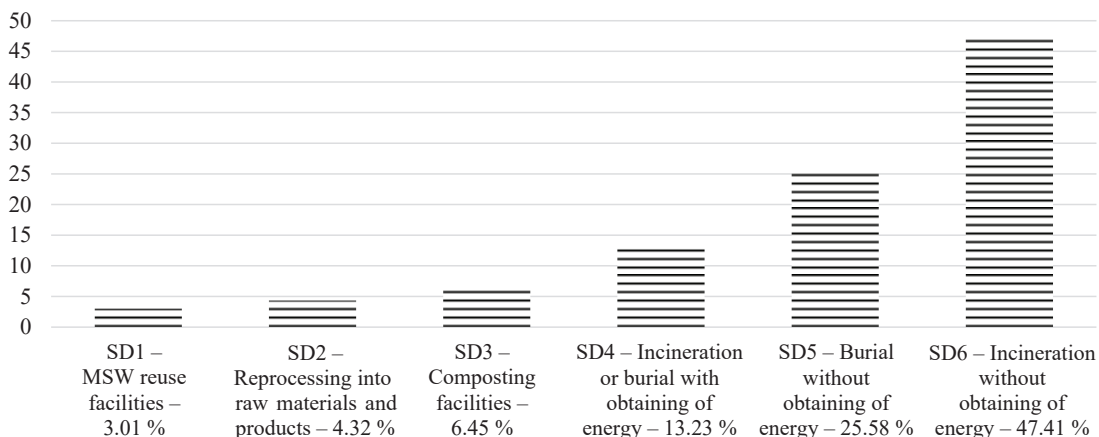


Fig. 3. Contribution of the municipal solid waste consumption objects as sources of danger to the environment during operation

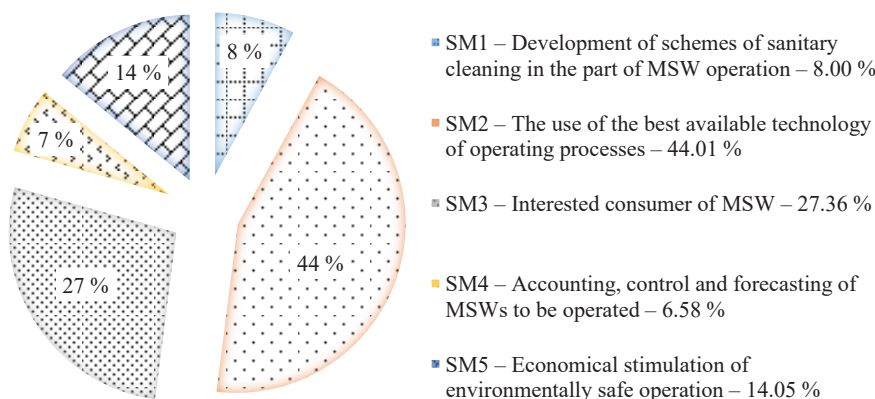


Fig. 4. Assessment of environmental security measures for the environmental impact of the municipal solid waste in the process of their operation

The proposed simplified way of forming expert groups is accessible to all territorial communities and their associations, which can effectively and transparently influence the compromise solution.

Weaknesses. The main difficulties in using the method include the selection of experts. The level of knowledge and experience, psychological characteristics, the ability to both individual and collective work are important in the study and affect the end result.

Opportunities. An additional advantage of the proposed method is the elimination of the influence on the decision-making of any third-party factors, including corruption. Prospects for the further development of this method depend on its practical implementation, purpose and specific objectives. Currently, the authors collect and analyze data obtained as a result of the practical application of the proposed methodological apparatus.

Threats. The main limitations of the application of expert-analytical procedures include the low competence of the specialists involved, the lack experience of using these methods, the complexity of the combination of individual and collective work, which significantly affects the adoption of agreed decisions.

In addition to the above, the proposed research requires additional costs for the operation of the expert group and the implementation of the proposed results.

8. Conclusions

1. The use of a simplified mechanism for the formation of a panel of experts on the choice of the best MSW operation process at the level of territorial communities makes it accessible to any local government. Involving a wide range of experts allows to analyze and calculate the maximum accuracy and specific features of the location of the research object. The overall assessment of the consistency of experts' opinions in this study is 0.04643, which corresponds to the conditions of AHP – up to 10 %.

2. Developed six-level hierarchical structures of the MSW operation processes allow to clearly understand the essence of the formation of hazards and the links between them. The use of a wide range of experts contributes to the maximum completeness of the built hierarchy and the proposed measures to improve environmental safety.

3. The decomposition of the environmental safety management process using a systematic multi-criteria integrated approach simplifies the process of evaluating (comparing) each of the elements of the hierarchy. The research made it possible to determine the contribution to the overall risk of operating each of its components, namely, disposal (SCr3) – 75.14 %; recovery (SCr2) – 17.82 %; recycling (SCr1) – 7.04 %. The obtained results allow comparing the dangers of each type of the MSW operation for the environmental components. The important result of the environmental risk assessment study is the establishment of the contribution of each of the solid waste consumption facilities, the largest of which is SD6 – incineration without obtaining of energy (47.41 %).

4. An additional advantage of using the method is the ability to evaluate (rank) measures to improve the environmental safety of the MSW operation process among proposed (generated) by experts. According to the calculations obtained, the most important (44.01 % of the total contribution measure) was identified for the implementation

use of the best available technology of operating processes (SM2). The use of AHP is a sufficient mechanism to support managerial decision-making on the choice of type of MSW operation at the level of territorial communities. The proposed methodology will also allow to solve the complex problem of MSW operation by several territorial communities at the same time.

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