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Zhumadilova, Anar
Department of Ecology, M.Kh. Dulaty Taraz Regional University

Zhigitova, Saule
Department of Ecology, M.Kh. Dulaty Taraz Regional University

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Features of Modern Areas of Solid Waste Disposal

Anar Zhumadilova[1,*], Saule Zhigitova[1]
[1]Department of Ecology, M.Kh. Dulaty Taraz Regional University, Taraz, Republic of Kazakhstan

*Author to whom correspondence should be addressed:
E-mail: azhumadilova3@gmail.com

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Abstract: The problem of waste, from the environmental factor, is increasingly becoming a social and economic factor. The purpose of this study is to examine the international experience of waste management. The main research method was induction. In addition, the imperial method, the method of literature review, data collection and structuring were used; quantitative and qualitative research methods are described, as well as recommendations for further research. In the course of the study, the most accessible and effective waste management practices were searched. Special attention is paid to the experience of Sweden as the country with the most developed waste management system, and the most advanced experience in Sweden of the city of Malmö, which is comparable in population with Taraz. The result of the study was the selection of managerial and social practices of waste management, technical solutions for their disposal, and some samples of equipment during the analysis. The subsequent adaptation of the study results can be applied to the organization of waste collection and disposal management in the Jambyl region of the Republic of Kazakhstan, to the development and decision-making on waste management at the city, region level, and after testing, to make proposals for the development of legal regulations of the Republic of Kazakhstan, which sets tasks on a scale and time comparable with the countries of the European Union, guided by the Sustainable Development Goals until 2030.

Keywords: household waste structure; hierarchy of household waste management; waste management practices; product movement infrastructure; the role of municipalities; product reuse

1. Introduction

Conceptual foundations of sustainable development set out in the United Nations (UN) policy document "Agenda 21"[1)] are the basis of all strategic documents of the countries of the world. Sustainable development implies the possibility of meeting the needs of people through the development of the economy while causing minimal damage to the environment. For production, this means reducing non-renewable resources extracted from nature and minimizing the return of waste to nature, that is, the use of low-waste or non-waste technologies, which is not always possible to achieve in the production cycle of one enterprise. Whole technological chains and cooperation are required. This matter is disclosed in the terms "circular economy" or "closed-loop economy". Increasing attention is being paid to the development of a circular economy in the documents of the UN and the European Union (EU). The circular economy is a kind of economic system in which the cost of resources, materials and products is kept in the process as far as possible, and waste reduction is an important contribution of the EU efforts, which implies the development of low-carbon technologies of a sustainable type, the resources of an efficient and competitive economy. Previously, environmental sustainability was considered closely related to economic damage, but in the circular economy model, waste minimization and cost preservation are considered as a course towards economic, social and environmental sustainability[2)-4)].

The existing economic models focused on quantitative indicators are not sufficiently focused on achieving a global transition to waste-free technologies. The process develops gradually and inconsistently. Therefore, it is advisable to focus on the study of waste disposal generated under existing economic conditions, having studied the experience of other countries that, through consistent long-term work with waste, have achieved environmental purification, making the countries safe and comfortable for the health of the population. The problem of household waste is especially relevant to people due to its direct influence on daily life. Waste management systems are most developed in European countries, in particular in Sweden[5)]. The objectives of the study are to examine the experience of waste management in European countries, to select the most effective management and technical solutions for waste disposal; some examples of equipment for recycling can be adapted and applied to build an effective waste management

system in the Jambyl region of the Republic of Kazakhstan. So far, the main way to dispose of waste is to take it to a landfill. Landfills occupy large areas and are dangerous objects for human health and the environment. A step forward is the separate collection of certain types of waste. In the absence of a systematic consistent approach, obvious economic and social advantages, actions for separate waste collection will be fragmented and inefficient.

In the EU countries, the level of waste recycling is different. Most of the waste, which ranges from 30% to 50% or more, is recycled in countries such as Germany, Switzerland, Denmark, Sweden, the Netherlands, and others. With regards to countries such as Greece, Iceland, the United Kingdom (UK) and Portugal, it is worth noting that they process the least, namely up to 15%. About 2% of waste is recycled in Russia[6), 7)]. Local self-government bodies (municipalities) play a key role in the issue of waste management. This is specified by H. Jouhara et al.[8)], M. Bissmont[2)], B. Onn[9)], P.C. Slorach et al.[10), 11)]. The state at the legislative level creates favorable conditions for the activities of municipalities, which are engaged in daily activities to cleanse the living space of people from waste. This is not a secondary, but a strategic area of planning their activities. To understand the level at which a city or region is located in the field of waste management, it is important to briefly describe the hierarchy of waste management[11)]. These are waste prevention, reuse, material recycling, biological treatment, and other types of recycling – for example, incineration for energy production and landfill disposal. Moreover, a modern sanitary landfill is considered a specialized system for the recovery of landfill gas (the recovery efficiency is 68%) and collecting filtrate for wastewater treatment in compliance with safety requirements.

Sweden, the world's leading waste management country, which sends less than 1% of household waste to landfills and accepts waste from Norway and the UK, is only approaching the task of preventing waste generation and creating a reuse infrastructure. Its experience is being studied and adapted in many countries. In Sweden, the most developed waste management system is in the city of Malmö with a population of 324 thousand people (comparable in population with the city of Taraz of Jambyl region).

The experience of handling household waste exists mainly at the level of municipalities, which are located in different geographical and climatic conditions, have different conventions and waste structures. It is hardly generalized and is unique. Therefore, the description and primary analysis of existing waste management practices and technologies for disposal dominate the scientific literature, which was used in this study. Thus, the experience of waste management is described in the studies in the Sweden by L. Milios and C. Dalhammar[12)] in the UK – P.C. Slorach et al.[13)], in China – Q. Ma[14)], in Germany – R. Herzberg et al.[15)]. The experience of waste management in different countries is considered by I.N. Rykova et al.[16)], A.E. Kalinina and L. Van Geffen et al.[17)].

Studies by B.A. Khan et al.[18)], A. Konti et al.[19)], F. Meng and J. McKechnie[20)], M.K. Murodov and K. Pitchai[21)], S.A. Opatokun et al.[22)], V.R. Sankar Cheela and B. Dubey[23)] are dedicated to reviews of waste disposal technologies, their comparative characteristics in terms of the cost of processing, social and economic efficiency, their impact on the environment, emissions of greenhouse gases in the process of waste disposal.

This study is aimed at contributing to the creation of a waste management system in the Jambyl region, studying the experience of Sweden, accelerating the transfer from the disposal of waste in landfills to the prevention of waste generation.

2. Materials and Methods

The materials and methods used in the study involved a collection of information about waste management organizations in different countries, methods of waste disposal, ways to prolong the life of products before they turn into waste, areas of educational work of municipalities, environmentalists, other specialists, ways of cooperation of various business structures, municipalities, and the population. The methodological basis of the research on the disposal of household waste is the UN Program "Agenda 21"[1)]. The study is empirical, and involves collecting information about waste management in different countries, methods of waste disposal, ways to prolong the life of products before they turn into waste, and areas of educational work of municipalities, environmentalists, and other specialists. The study also examines the ways of cooperation between various business structures, municipalities, and the population.

The main research method was induction. This method was based on the study of theory, international legal doctrine and provided an opportunity to explore the primary analysis of individual problems of waste management and its disposal, identified the key characteristics through the analytical method, allowed presenting waste management as an integral system, showing connections with the environment in which it exists, forming a comprehensive approach to the problem.

Thanks to the method of the literature review on soil research, the authors of this article managed to compile the main Features of modern areas of solid waste disposal. These included both journal articles and articles on various statistical websites.

The data collected from the literature review and the method of induction were analyzed to identify the key features of modern areas of solid waste disposal. The data analysis included both qualitative and quantitative methods to provide a comprehensive understanding of the topic. For example, case studies – is a qualitative method which useful for understanding the practical implications of waste management practices and identifying successful

approaches that can be applied in other contexts.

The quantitative method consisted of the statistical analysis that involves using mathematical and statistical techniques to analyze data collected through surveys or other quantitative research methods. This method can be useful for identifying trends, patterns, and relationships between variables related to solid waste disposal.

The study of existing effective waste management practices and technological solutions allows choosing the most appropriate ones for adaptation and application in the Jambyl region of the Republic of Kazakhstan and Taraz. Particular attention is paid to the positive social and environmental effects of the cooperation of residents with municipalities and businesses, of the cooperation of municipalities that combine efforts to dispose of waste (for example, the construction of plants to produce energy from waste). Notably, each of the issues considered may also be the subject of numerous separate studies.

Also, the authors of this article have made recommendations that are based on the key characteristics of modern solid waste disposal areas identified in the study. These recommendations can be used to guide future research and policy development.

3. Results and Discussion

In modern conditions in Kazakhstan, there is a problem associated with the processing of municipal solid waste and its direct disposal. To control and plan work to resolve this problem, state authorities monitor unauthorized waste, of which 89% have been eliminated; in particular, they are eliminated in the cities of Almaty and Shymkent, as well as in Atyrau and Kyzylorda regions[24]. Also, in order to resolve a range of problems, work is underway to process waste, which is characterized by an increase in indicators (Figure 1).

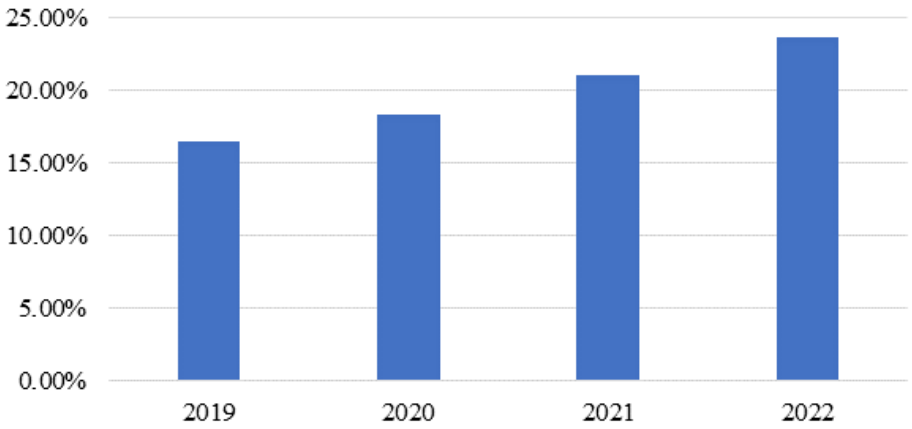

Fig. 1: Share of municipal solid waste recycling in Kazakhstan 2019-2021.

Source: compiled by the authors based on[24].

The data provided allows for drawing a conclusion that the state policy is taking all possible measures, in accordance with which the indicators are increasing. For a more detailed assessment of the effectiveness, it is worth considering the level of solid waste processing by region (Figure 2).

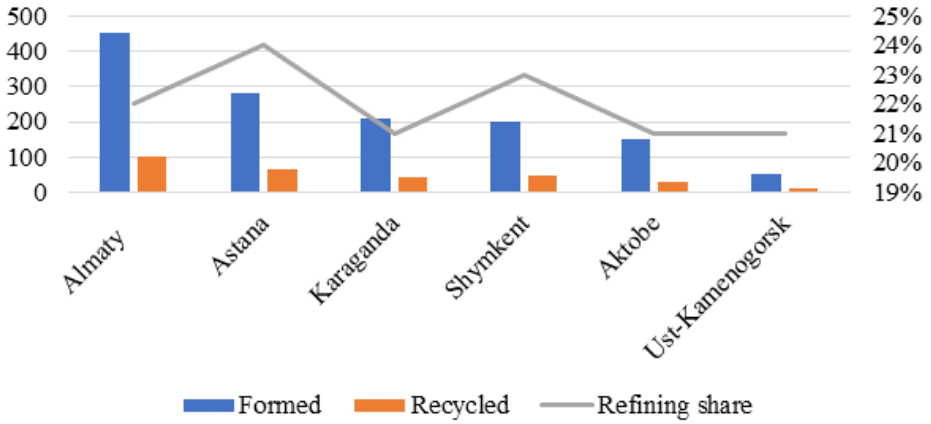

Fig. 2: Production and processing of solid waste in the cities of the Republic of Kazakhstan, thousand tons/year, 2022.

Source: compiled by the authors based on [25].

As can be seen from the statistics provided, at the moment, only 1/5 of the incoming solid domestic waste is recycled. This shows that the level of waste processing is very low, which especially affects the state of the state's ecology. To resolve the range of problems that are currently present in the state, the authorities must ensure the openness of information and public participation in recycling, organize waste sorting, prohibit the circulation of disposable plastic products, etc. But in order to develop recommendations that will be distinguished by a high level of efficiency, it is worth studying the theoretical component of the issue of municipal solid waste and considering the international experience of state policy in the area under study. This will provide an opportunity to bring the ecology of Kazakhstan to a new level, improve the welfare of the population, ameliorate the environmental situation in the country, and ensure the introduction of new technologies.

Table 1. Types of household waste

Waste type	Examples	Management method
Organic waste	Food waste, wood biomass, paper, garden waste	Can be disposed of with different levels of centralization (in a household, restaurant, supermarket, at the level of a territorial community)
Non-decomposable waste	Plastic, textiles, rubber, other materials	Subject to recycling or disposal at special enterprises
Inorganic waste	Glass, metals	Subject to recycling or disposal at special enterprises

Source: compiled by the authors.

The most vulnerable point of centralized waste management systems is their transportation to landfills and large processing plants. Therewith, collection and transportation costs account for 40 to 60% of the total municipal expenses for solid waste management[7]. Municipality focuses on possible decentralized methods of food waste disposal – composting, anaerobic digestion, pyrolysis and gasification, sterilization of mixed household waste by autoclaving. Composting is possible in containers of various capacities and through small, automated composting plants, an example of which is the automatic composting machine from Red-Donatura™. This is the smallest part of the possible options with a productivity of 25 kg/day. These are suitable for restaurants, offices and households. To collect food waste for subsequent composting, bags made of natural materials, such as starch, should be used, which decompose during the composting process. For example, Bio-Bag offers affordable biodegradable bags.

Another area of food waste disposal is anaerobic digestion to obtain biogas, which contains 50-80% of methane concentration and can also be used as an energy source for turbines, boilers, and internal combustion engines, both individually and in a mixture, the total solids content is estimated at 80-97%. Due to the fact that anaerobic digestion contains a large amount of moisture, it is more suitable than thermochemical processing technologies. Particular attention is paid to the sterilization of waste by autoclaving, especially in those areas where waste is not sorted (Sterilization is a process aimed at the destruction of pathogenic microorganisms. Autoclaving of solid household waste is a form of mechanical heat treatment). Due to sterilization, the volume of waste is reduced by approximately 60%, while humidity is considerably reduced as well. Sterilization of waste can extend the period of its harmless storage before transportation to the disposal site and reduce the need for transport. An example of primary processing of raw unsorted household waste is the installation of Marine Assets Corporation (MAC) for the production of secondary fuel (RDF – refuse-derived fuel). The MAC Waste Converter can reduce volume by more than 70% while reducing weight by about 50%. It is worth noting that further reduction is possible due to RDF granulation. They can be used as a fuel to be burned in an industrially safe manner for the production of heat or electricity since they usually have a high level of calorific value.

A. Konti et al.[19] provide an expanded list of processes by which food waste can be converted into biofuels or energy: interesterification of oils and fats to produce biodiesel; anaerobic digestion to produce biogas; pyrolysis and gasification; fermentation of carbohydrates to produce bioethanol or biobutanol; dark fermentation to produce hydrogen; hydrothermal carbonization; combustion. Food waste is a necessary raw material for the production of bioethanol, which will have distinctive environmental benefits. It is worth noting that it is a source of clean bioenergy, has renewable and environmentally friendly characteristics, as well as its potential to replace gasoline in the transport sector. Research by F. Meng and J. McKechnie[20] is dedicated to the production of butanol and ethanol from mixed municipal solid waste, various approaches to evaluating its life cycle in the EU and the USA, which may hinder the development of its production in EU countries. S.A. Opatokun et al.[22] propose a combined method for the disposal of food waste by anaerobic digestion and pyrolysis, comparing its environmental characteristics with anaerobic digestion, and pyrolysis, used separately.

When developing circulation systems in a smart city, system planning and implementation of solutions must

include environmental, social and economic sustainability indicators. A complex handling system based on the integration of modern technologies and system engineering into the preparation of management decisions is proposed in the study by V.R. Sankar Cheela and B. Dubey[23]. B.A. Khan et al.[18] describe the technology of obtaining biogas from the waste of small clinics, disinfecting and disposing of potentially hazardous waste. The advantages of a power plant that would combine the energy of the sun and the energy released during the disposal of household waste are substantiated by M.K. Murodov and K. Pitchai[21]. All technical solutions, as a rule, are aimed at recycling and disposal of already generated waste. However, its amount is growing every year.

Waste prevention and reduction is part of Goal 12 of the UN, Sustainable Development Goals until 2030[26], aimed at ensuring responsible consumption and a "Production model". The problem of waste is considered there in close connection with the sustainable management of natural resources, production, consumption, and lifestyle. Within the framework of the EU Framework Directive on Waste, waste prevention is the measures that are taken to ensure that certain aspects that will become waste provide the opportunity to reduce: the amount of waste; adverse effects on the environment and public health; the content of hazardous substances in materials and products. In Sweden, where the waste recycling system is the most developed, researchers pay attention to a number of considerable problems related to the prevention of waste generation. Thus, municipalities, as the main link in waste management, have sufficient authority to act at the final stage of the product life cycle, that is when it turns into waste that needs to be collected, recycled, or dumped. In the issue of waste prevention, the function of municipalities is mainly to inform consumers about the need to minimize waste, but currently, the functions of municipalities have expanded due to the organization of the development of the product reuse infrastructure. To prevent the generation of waste, it is also essential to have a retail infrastructure near the consumer's place of residence, so as not to provoke them to buy an excessive amount of food with a limited shelf life.

Recognizing the importance of informing consumers and changing their consumer behavior, researchers state that the overproduction of consumer goods, and the stimulation of irrational consumer behavior by producers, which is dictated by the conditions of existing economic models are the main reason for the current situation[27]. The problem of modern discourse is that overproduction in the context of excessive consumption is not considered. By using the waste hierarchy as the basis for food waste prevention and prevention decisions along with the other stages of the hierarchy, the focus shifts from prevention to food surplus management. This is a fight against the consequences, but it in no way affects the root causes of the huge amount of food waste (according to the Food and Agriculture Organization of the United Nations[28], a third of the food produced in the world ends up in waste). The need to change production models entails a change in consumption patterns. A study by L. van Geffen et al.[17] is devoted to factors influencing consumer behavior patterns and the possibilities to change approaches to food handling.

Local governments (municipalities) play an important role in changing consumption patterns. As an example, the activities of the municipality of Malmö (Sweden) are recognized as the best in waste management. It made waste management one of the main areas of urban planning and worked to achieve its sustainability in collaboration with businesses and academia. The general plan of the city of Malmö states that, firstly, waste generation should be prevented, and this requires managing changes in consumption patterns. The municipality manages the allocation of places for reuse and exchange, for recycling and other waste. Exchange spaces in residential areas are also required. Reuse spaces have the potential to become common places and create jobs. Providing visible spaces in the city is also a way to show daily waste production and the importance of recycling activities[29)-31]. Management in Sweden is focused on “soft measures” and “free will management”, which is noted by all researchers. For comparison, in China, management is regulated, assumes mandatory compliance and entails sanctions for non-compliance[14), 32].

Many municipalities, to ensure reuse as one of the ways to prevent waste, create reuse centers or recycling centers with adjacent reuse centers where, for example, clothes, building materials, etc. can be deposited. These centers cooperate with humanitarian organizations and businesses that repair products. At some centers, there are shops where one can buy things for reuse. Municipal revenues from waste management are used for the development of this area. In cooperation with businesses, municipalities adhere to the principle of free competition. For example, in Sweden, groups of goods were identified that are most suitable for reuse. These include furniture, building materials, and electrical equipment since other types of materials are largely used by charitable organizations (for example, textiles)[33), 34]. Repair, restoration, and alteration of products are considered to be reuse operations.

The costs of preparing products for reuse can be covered by regulating tariffs for household waste. This is possible due to the fact that the preparation for reuse maybe recycling. It is also important to note that waste that is collected for reuse has a conditional environmental value. The reuse of products also has an important social effect. 74% of people engaged in the business of reusing products, through internships or industrial training (subsidized by state unemployment assistance bureaus), experienced their increased importance, stress relief, and more active participation in society[35), 36].

There is a positive experience of product reuse centers in other countries, for example, the Federation of

Environmental Entrepreneurs in the Social Economy (KOMOSIE) chain of reuse centers in Flanders (Belgium). KOMOSIE stands for the action entrepreneurs in the social economy. It is an umbrella non-profit organization that includes all recycling centers in Flanders accredited by the Public Waste Agency of Flanders (OVAM). It is worth mentioning the main elements of an efficient reuse chain in Flanders. It is important to note the integration of reuse into regional employment policy; formation of inter-municipal partnerships; quality control monitoring; carefully planned marketing policy with the support of the umbrella organization KOMOSIE.

Reuse centers have responded to the opportunities identified by the solid waste policy, quickly profiling themselves as indispensable participants in the removal of household waste and thus gaining an additional role in municipal waste management policy[37)-39)]. Therefore, reuse centers can enter into individual agreements with OVAM to receive an annual subsidy for 4 consecutive years in accordance with the duration of the Waste Management Plan. To be eligible, reuse centers must participate in supporting the Flemish Policy, provide an annual report, and integrate their activities with OVAM. Reuse centers have also been included in the legal obligation to take back waste electrical and electronic equipment in accordance with the decree of the Flemish government of December 17, 1997, on the introduction of the Flemish regulations regarding the prevention and treatment of waste. It is worth noting that the professionalization of reuse centers was a significant step to consolidate the positions achieved within the framework of the waste management policy. The KOMOSIE chain has introduced its own quality mark for reusable goods called “Revisie”, mainly in relation to electrical equipment. The turnover of reuse centers in Flanders accounts for two main sources, namely in-store sales, and subsidies[11)].

The prevention of waste generation by minimizing it consists of the rejection of single-use products (dishes, containers, bags, etc.) and the purchase of products with a longer usage period that can be repaired, which requires a change in consumer behavior. The possibility of wholesale purchase of a number of long shelf-life products not only in special stores could reduce packaging waste. A revision of the policy of companies manufacturing electronic equipment on its frequent updates according to contracts is also required[40),41)]. In Sweden, the trend towards a “circular wardrobe” for adults is becoming increasingly popular, as is the case with the flow of children's clothing. More and more clothes are bought in second-hand stores and in 2016, the purchase of clothes in these stores exceeded the purchase of new clothes[42)].

To minimize food waste, as available measures at the level of municipalities, local businesses, and residents themselves, the provision of infrastructure for the sale of food is considered, which would allow the consumer to buy the right number of perishable products without creating stocks, optimizing portions of food in restaurants and cafes[43)]. Informing the population about various ways of cooking, and making maximum use of raw materials, can also play a considerable role. Thus, the entire list of actions aimed at preventing the generation of waste and other actions related to it can have a positive impact on achieving the sustainability of society in all important aspects.

4. Conclusions

Up to the present, dumping in landfills is the main way to dispose of used waste. The rapid development of production, demographic growth, the growth and accumulation of waste, and environmental pollution have brought the conditions of daily human life into a dangerous state and have led to global climate change. Accordingly, production and consumption models, and management models, including household waste management, are currently subject to revision. The sphere of household waste management includes its processing to obtain new materials and useful products (for example, compost), along with disposal by physical, chemical, and biological methods to obtain fuel and energy. Some countries, such as Sweden, have been successful in this, sending less than 1% of household waste to landfills.

Currently on the agenda is not only the efficient disposal of household waste but also the prevention of its generation by minimizing excessive consumption and reusing a number of products (furniture, building materials, clothing, electrical goods). Opportunities to act can be promoted through legislation aimed at creating a circular economy and reducing waste. It is possible to provide for the facilitation of rental, repair of used goods by reducing taxes, standardization of the secondary market and exchange, and strengthening consumer rights in relation to complaints about substandard products.

The problems identified in the study and the positive experience of other countries can contribute to the adoption of the most appropriate solutions for household waste management. In addition, the issues raised may become the subject of further research. Global problems are increasingly reflected in the strategic documents of the UN, the European Union, and individual countries, gradually changing people's approaches to production and consumption standards, and attitudes to the environment, normalizing all spheres of life. The methodological basis of all these documents and changes is the Program adopted by the UN “Agenda 21”.

The main purpose – to review the world experience of waste management – has been achieved, however, there are a number of topics that would help to expand this study. Further research can focus on conducting a comparative analysis of waste management practices in different countries, with a specific focus on identifying successful approaches and factors contributing to their success; exploring the effectiveness of specific legislative

measures, such as tax reduction on the repair of used goods, in promoting sustainable waste management practices; developing and evaluation of innovative waste management technologies, such as waste-to-energy and waste-to-fuel technologies, for the efficient and sustainable management of solid waste.

The study of the features of modern areas of solid waste disposal is of significant importance due to the increasing social and economic impact of waste on the environment. The study's significance lies in its potential to contribute to the development of sustainable waste management practices, which are crucial for promoting a healthy environment and supporting sustainable development. The study's findings can be used by waste management companies, local authorities, and residents to make informed decisions and take necessary actions toward the effective and sustainable management of solid waste.

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