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Environmental Assessment of Solid Waste Pollution of Urban Areas (on the example of Shymkent, Republic of Kazakhstan)

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Abstract: The environmental assessment of solid waste pollution in urban areas is relevant due to its impacts on the environment, public health concerns, alignment with sustainable development goals, informing policy decisions, and promoting resource recovery and circular economy practices. The purpose of this article is to assess the current state of municipal solid waste management in Shymkent and compare it with practices in other countries. The methods of this research included the method of induction, analytical methods, as well as methods of statistical analysis. In the course of the research, primary international documents and legislative acts of the Republic of Kazakhstan, theoretical publications, and research materials containing an analysis of certain aspects of municipal solid waste management were studied. This article assesses the state of municipal solid waste management in Shymkent, comparing it with international practices. It highlights the challenges faced by the city and presents recommendations for improvement. By implementing these recommendations, Shymkent can enhance its waste management systems and move towards a cleaner and more sustainable environment.

Keywords: structure of municipal solid waste; waste management hierarchy; waste collection and recycling; life cycle assessment; sustainable urban development

1. Introduction

To achieve sustainable development, as preservation and reproduction for future generations in a healthy state of society and economy in a favorable environment, the United Nations Conference on Environment and Development (UNCED) policy document "Agenda XXI"[1)] contains sections on the problems of waste and sustainable development of settlements as a habitat and human economic activity. Moreover, waste is considered not only as a factor in environmental pollution but also as a source of resources for further development. The Sustainable Development Goals[2)] also identifies these problems as the primary ones to address. All countries of the world are gradually bringing their legislation in line with these documents, reforming management institutions, and drawing up strategic plans. Thus, in the Republic of Kazakhstan, the Environmental Code of the Republic of Kazakhstan[3)] and the Law of the Republic of Kazakhstan No. 496 "On concept for the transition of the Republic of Kazakhstan to a "green" economy"[4)] were adopted, according to which up to 40% of waste should undergo recycling by 2030, and up to 50% by 2050.

The process of implementing these programs requires a lot of work and systemic attention as well as encounters resistance on the way of their implementation from functionally outdated management structures that seek to conserve their status quo. Such processes, occurring in many countries to a greater or lesser extent, result in the accelerating accumulation of waste within the context of population growth and urbanization, among which municipal solid waste (MSW) is the closest to everyday human life. The accumulation of MSW, especially toxic or potentially toxic, poses a threat to the health and life of people. A special report by S. Kaza et al.[5)] called "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050" was devoted to the forecast of doubling the amount of MSW by 2050.

However, the problems of MSW pollution exist in all countries of the world. Countries like Sweden have demonstrated the success of purposeful approaches to MSW management. Through efficient recycling and reuse practices, as well as environmentally friendly combustion, they have achieved high levels of MSW management, reduced waste accumulation, and generate income from waste materials and energy. Other countries of the European Union that have become involved in the process of conscious MSW management to reduce environmental pollution have also achieved good results, although

somewhat worse compared to Sweden, which is a leader in this area. Countries with developing economies, which include the Republic of Kazakhstan that is just starting to resolve the issue of reducing MSW pollution, have the same problems – the burial of MSW in open landfills, the lack of modern waste dumps, as well as the low level of waste sorting and recycling. This is evidenced by the studies of N. Ferronato and V. Torretta[6] who, during the study of MSW management in more than ten developing countries, identified these common characteristic features of the problem, which were mentioned above.

The same problems of MSW management, common to developing countries, are defined as a characteristic of them at the current level of MSW management in the report by R. Goodwin[7] made for the United Nations (UN) on the example of Rwanda, Burundi, and Tanzania, in the paper by J. Li et al.[8] on the example of Vietnam, in the paper by L. C. Malav et al.[9] on the example of India. Even in China, the priority at this stage is to equip modern sanitary landfills, as evidenced by the study carried out by H. Hu et al.[10]. The research conducted by I.O. Honcharenko et al.[11] shows that the effectiveness of measures to ensure regulatory environmental safety is provided at 60.22% at the local level, at 22.55% at the regional level and 17.23% at the state level. In other words, the local level is the most significant.

Before delving into more complex environmental assessment methods like Life Cycle Assessment (LCA) for MSW pollution in Shymkent, this research aims to achieve several preliminary objectives. These include determining the stages of MSW management present in the city, assessing the infrastructure's level of development, identifying priorities, understanding the composition of MSW as a crucial factor in management, and identifying the underlying causes of problems related to MSW management. The authors consider this research as the first step towards a systematic understanding of the problems of MSW management in Shymkent, as a basis for future scientific research and for practical steps in making decisions in the field of urban management. The application of scientific methods to assess MSW management in a specific city serves as a crucial step in testing the results of theoretical studies. While researchers generally agree on the theoretical level, practical application and local conditions may lead to debates on specific details. Scientific assessments form the basis for developing systematic MSW management practices in the city. These practices aim to reduce pollution and prioritize prevention measures to ensure the maximum effectiveness of waste management efforts.

The purpose of this article is to highlight the environmental assessment of municipal solid waste (MSW) pollution and its importance in guiding decision-making by authorities. The study aims to assess the current state of municipal solid waste (MSW) management in Shymkent, identify challenges and shortcomings, evaluate the effectiveness of existing practices, and provide a basis for future decision-making and research in MSW management in the city.

2. Materials and Methods

The methodological basis of the research on the assessment of environmental pollution by municipal solid waste is the UNCED "Agenda XXI"[1]. The purpose of this article was to give an environmental assessment of MSW pollution for the city as a whole, rather than for any individual object. This implies an integrated approach to the consideration of the issue. In other words, the city was considered a holistic complex object. Accordingly, this article can be largely attributed to the stage of the primary system analysis of MSW management in Shymkent. The analysis of the legislative base of the Republic of Kazakhstan became the starting point in the study of the state of regulation regarding the MSW management in the republic as well as the determination of the powers of local authorities in this area. Key issues of the current state of MSW management in Shymkent were identified and highlighted in the process of analyzing issues related to the MSW flows in the city. Various analytical methods, the method of comparison, and the methods of deduction and induction were applied for this purpose.

The analysis of the infrastructure for the MSW recycling and disposal in the city enabled identifying the main problems associated with its functioning, and based on this, as well as the criteria for the MSW disposal safety, determining the level of the MSW management system in Shymkent within the MSW management hierarchy. The level of management was also determined, by the decisions of which most rulings regarding MSW flows depend. The method of comparing the MSW management in Shymkent and that of the countries with developing economies was applied to determine the similarities and differences in the problems they face in reducing MSW pollution, as well as to study and compare the experience of their solution. Moreover, for comparison, the research included both countries with a less developed economy (for example, Rwanda, Tanzania) and countries with a more developed economy, in particular, industry (for example, China, India, and Vietnam). In addition, statistical analysis methods were applied. Thus, the analysis of time series was applied to analyze the dynamics of waste removal to controlled landfills for the MSW disposal for the period of 2019-2021.

Structural analysis of MSW in Shymkent according to a limited range of indicators for the period of 2019-2021 was applied to analyze changes in the structure of municipal waste after the city received the status of a city of republican subordination and administrative separation from the Turkestan region. The analysis of scientific publications enabled determining the criteria for assessing the level of MSW practices in the MSW hierarchy, identifying the method for assessing the life cycle of waste as the most comprehensive and allowing to assess of the possible damage to environmental sustainability at all

stages of its movement until complete disposal. The information base of this research includes documents and reports of international organizations and business associations of the Republic of Kazakhstan, legislative acts of the Republic of Kazakhstan, scientific publications, statistical materials of the Bureau of National Statistics of the Agency for Strategic Planning and reforms of the Republic of Kazakhstan[12]. The study of existing effective waste management practices, and technological solutions for the processing of plastic and mixed waste, including by pyrolysis, allows for choosing the most appropriate of them for adaptation and use in Shymkent.

3. Results

The Environmental Code of the Republic of Kazakhstan[3] refers to MSW as the waste accumulated in residential and public buildings, trade, entertainment, sports, and other enterprises (including waste from the minor repair of apartments), heating system waste, fallen leaves collected from yard areas, as well as bulky waste. This definition corresponds to the term "Municipal Solid Waste". Municipal waste can be divided into two large groups – organic and inorganic. Organic includes food, wood and garden waste, paper, plastic, textiles, rubber, leather, and other materials. Inorganic materials are mainly glass and metals. Organic waste is divided into degradable, which includes food waste, wood biomass, and paper, and non-degradable (poorly decomposable) waste, which includes plastic, textiles, rubber, and other materials. Degradable waste can be disposed of at various levels of centralization (household, restaurant, supermarket, community, or large enterprise), while non-degradable (poorly decomposable) waste can be recycled or disposed of at special facilities. To conduct an environmental assessment of MSW pollution, a large amount of information is required on various types of pollution sources to determine the correlation between their flows and the damage they cause to the environment and public health. One example of a set of indicators used is the research by I.O. Honcharenko et al.[11] In this regard, the determining factor, both for the environmental assessment of MSW pollution and for developing an adequate system for MSW management, is their structure.

It is also necessary to assess the level of the city of Shymkent in the hierarchy of MSW management. The highest and most environmentally friendly level is waste prevention. The next levels in descending order are reuse, recycling, and biological treatment of materials, as other types of processing, for example, incineration for energy production. The lowest level is the disposal of waste in landfills. Moreover, a modern sanitary landfill is a specialized system for capturing landfill gas (capture rate amounts to 68%) and collecting filtrate for wastewater treatment in compliance with safety requirements[13]. These two aspects are explored in this article. Since 2018, Shymkent has been a city of republican significance. The city is an industrialized center. From the point of view of the possibility of participating in the processing of non-ferrous metal waste, the most promising existing enterprise is the joint-stock company "Yuzhpolimetall" (Figure 1). In 2018, the LLP "Green Technology Industries" constructed a plant for processing polyethylene terephthalate waste (PET (polyethylene terephthalate) waste) in Shymkent. The capacity of the enterprise is 100 thousand tons of PET waste per year. In 2018, a plant for the processing of used oils by the regeneration method began operation with the production of motor oils and lubricants by the LLP "HillCorparation". The capacity amounts to 28 thousand tons of waste per year[14].

Fig. 1: Production of plastic pellets
Source: compiled by the authors.

Municipal solid waste is partially sorted and mainly disposed of at open landfills (Figure 2). Moreover, neither in the city of Shymkent nor in the Turkestan region (previously, until 2018, South Kazakhstan, the center of which was the city of Shymkent) there is not a single modern landfill equipped in compliance with environmental standards. These landfills mostly receive mixed waste. Even the ban on taking certain types of waste to landfills, provided for by the Environmental Code of the Republic of Kazakhstan[3], was delayed until the end of 2018 for electronic and electrical equipment, and until the end of 2020 for construction materials and food waste. Postponement of the ban is quite understandable since the cities and other settlements have no well-established infrastructure for the collection and processing of this waste, in countries with developing economies, only the last two items mentioned, collectively amount from 35 to 55% of the total volume of MSW.

Fig. 2: Aktas MSW landfill. Measuring the air quality composition using a gas analyzer
Source: compiled by the authors.

The city of Shymkent removes its MSW to the following landfills and open dumps, the vast majority of which do not meet environmental and sanitary standards:

1. Agricultural production cooperative (SPK) Sayajay-Bastaw (Temirlan Village).
2. Ecolife Astana (Shymkent).
3. Eco Shyna (Shymkent).
4. Waste disposal plant (Shymkent).
5. Polygon 118 (Shymkent).
6. Utilservis (Shymkent).
7. Glassware collection point (Shymkent).
8. Kyzyl-Temir (Shymkent).
9. Kazakh scrap metal company (Shymkent).

The unfavorable ecological situation is exacerbated by the fact that the waste landfill located in the city of Tashkent in neighboring Uzbekistan is close to the borders of the region and the Republic of Kazakhstan. According to the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, as of September 2021, there are not enough landfills in the Turkestan region as a whole – there are only 30 of them for 900 villages. For this reason, unauthorized dumps arise, 298 of which were discovered in the summer of 2021. Thanks to space monitoring, 217 of them were eliminated. However, this did not resolve the issue of removal and disposal of MSW. The pendulum migration of the inhabitants of the agglomeration between their settlements and the city of Shymkent in the conditions of a poorly organized system of MSW removal is a way of independent transportation of MSW to the city of Shymkent. Equipped sites for the collection of MSW to intercept these flows outside the city or its residential quarters have become points for the emergence of unauthorized dumps. According to the same Ministry, in 2019 alone, damage was caused to the environment of the Turkestan Region in the amount of USD 5.78 million[15]. Having correctly named the lack of organized landfills and the unsatisfactory system of MSW removal as the reason for the formation of unauthorized dumps, the Ministry limits itself to recommendations regarding community outreach, prevention of offenses, and punishment for violations.

The given data show that Shymkent, being a major economic and scientific center, has a good potential for moving towards sustainable development of the city, one of the conditions for which is the development of a system for managing MSW, which would help prevent its accumulation. Having set a course for transformations to achieve sustainable development, the Republic of Kazakhstan, along with other countries, monitors these changes according to a certain international nomenclature of indicators. Thus, since 2019, the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan[12] has been issuing these indicators not only for the country as a whole but also within the context of regions and cities of republican subordination. Indicators for the city of Shymkent can be found in Table 1, which indicates a positive trend in the share of collection and disposal of solid waste at controlled facilities from 77.3% in 2019 to 100.0% in 2020 and 99.0% in 2021. In other words, practically all MSW, according to the report on the achievement of the sustainable development goals, was removed to controlled landfills, respectively, minimizing the harm to the population and the environment by the products of its decomposition. Empirical data indicate the presence of unauthorized dumps, some of which have owners and are located, according to the Ministry of Ecology, in the “gray” business zone[15]. Accordingly, the flows of MSW to them, as well as the flows of MSW processing products, remain unaccounted for.

Table 1. The constituents of CNG[16]

	2019	2020	2021
Share of municipal solid waste that is collected and disposed of at controlled facilities of the total volume of municipal solid waste by city:			
Republic of Kazakhstan	85.1	81.4	82.0
Shymkent	77.3	100.0	99.0
Share of recycling and disposal of municipal solid waste of the total accumulated volume:			
Republic of Kazakhstan	14.9	18.3	21.1
Shymkent	22.7	25.0	27.2
Share of landfills that meet the ecological requirements and sanitary norms:			
Republic of Kazakhstan	20.1	18.8	20.0
Shymkent	0	0	0

Table 1 also shows an increase in the share of recycling and disposal of MSW in Shymkent from 22.7% in 2019 to 27.2% in 2021 (Figure 3), which makes it quite achievable

to bring this indicator to 40% by 2030, as provided by Law of the Republic of Kazakhstan No. 496 "On concept for the transition of the Republic of Kazakhstan to a "green" economy"[4]. However, if we move from these international indicators to the indicators of national statistics provided by the same Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan[12], then another picture of the gap with international indicators in achieving the "Sustainable Development Goals"[2] will be revealed.

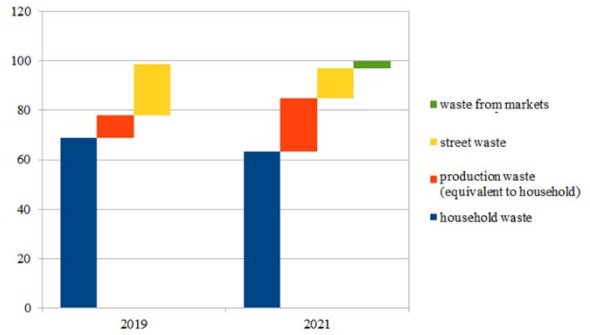

Fig. 3: Structure of collected municipal waste in Shymkent in 2019 and 2021 (in % of total volume)
Source: compiled by the authors.

2019 and 2021 were selected for analysis to see the dynamics of changes in the structure of municipal waste. 2019 was chosen because this is the first year of existence of the city of Shymkent in the status of a city of republican subordination, separate from Turkestan (formerly South Kazakhstan region). Unfortunately, the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan[12] provides the structure of collected municipal waste (according to the characteristics, they correspond to MSW) in Shymkent only in the summary table of bulletins for four items: household waste, production waste (equivalent to household waste), street waste and waste from markets. There are no data for Shymkent for items such as park waste, construction waste, etc. Most likely, they are hiding in the positions of "household waste" or production waste (equivalent to household waste) due to the postponement of the ban on their acceptance to landfills. The reduction in the share of household waste and street waste may be due to extended lockdowns in 2020 and 2021 in connection with the COVID-19 pandemic, and an increase in the share of construction waste hidden in production and household waste may be a consequence of the intensification of construction in the city after obtaining a new status.

The absence or fragmentation of information about the structure of MSW, at least for the main groups of large pollution sources, does not allow a correct assessment of the environmental situation in the city and leads to the adoption of chaotic management decisions. The practice, inherited from Soviet times, of simply removing waste to a landfill can no longer cope with the growing flow of waste. The removal of MSW to open landfills, as the main method of disposal of MSW, indicates that the city of Shymkent is still at the lowest level in the waste management hierarchy. The problems of MSW accumulation in Shymkent are not unique. They exist in all countries. However, those countries that have long and purposefully begun to address the issues of recycling and reuse of waste have turned waste into income for the country and its citizens. Sweden is the leader in this area. According to various estimates, from 1 to 3% of MSW is removed to landfills. In countries with developing or depressed economies, about 90%, and often more, of mixed MSW are disposed of by removal to open landfills, where a reduction in the volume of waste is often achieved by open burning, dumped into water bodies and other natural objects.

Taking into account the growth of the city's population, its industrial potential, and location, the priorities could include establishing systems for the separate collection and processing of especially toxic waste, food waste, tires, and construction waste due to their danger and large volumes, which could reduce the flow of MSW to landfills by more than half. If the share of food waste in the total volume of MSW in the EU countries amounts up to 25%, then in countries with developing economies, to which the Republic of Kazakhstan belongs, the share of food waste is 35-50%[5]. For example, the production of compost from food waste on equipment of various capacities could become not only a way to dispose of them, but also to produce a new product (compost) for agriculture. Recycling construction waste in the presence of enterprises for the production of construction materials in the city could give them raw materials for new products. In the meantime, in the Republic of Kazakhstan, the most promising way to dispose of waste is its incineration to generate energy (construction of waste incineration plants). Although the study of international experience could give many other ways of processing waste, organizing the management of its collection and processing. Cooperation between the city authorities, scientific organizations of the city, environmental organizations, and enterprises could become a mechanism for preparing decisions in the development of a new system for safe MSW management in Shymkent.

4. Discussion

The authors used the research and conclusions of scientists, mainly from Asian countries, which have problems with MSW management, similar to those of the Republic of Kazakhstan. Studies in this area are not conceptually contradictory. They complement or detail certain aspects of MSW management and offer various ways to process it. To a large extent, the problems of MSW management exist as a result of inefficient management of MSW flows. Evaluating the effectiveness of integrated MSW management using the Integrated Sustainable

Waste Management scorecard (ISWM), a team of Vietnamese authors F.M. Tsai et al.[17] comes to the conclusion that the lack of a holistic understanding of ISWM makes it impossible to assess waste volumes, which does not allow measuring the level of waste hierarchy for ISWM modeling. The current MSW management system in Vietnam is ineffective due to a lack of necessary administrative oversight, infrastructure as well as proper use of resources. As one can see, the development of an effective MSW management system in Vietnam faces the same problems of lack of the necessary infrastructure and administration of MSW flows that exist in Shymkent. The impossibility, therefore, of assessing the volume and structure of waste are the main obstacles to overcoming the problem of MSW pollution[18),19)]. Studying the experience of Vietnam could be useful for developing an MSW management system in modern conditions in a country with a rapidly developing economy.

Another group of researchers, N. Ferronato and V. Torretta[6)], makes a similar opinion regarding the importance of control for MSW management, based on measurements of the environmental impact of MSW in a number of countries in Asia and Africa. They state that mismanagement or improper waste management has an impact on the environment at three levels: municipal or local impacts, such as soil and groundwater pollution, the spread of diseases caused by animal vectors (mosquitoes, rodents), as well as air pollution; regional impacts such as pollution of water bodies used for agricultural and household purposes; global impacts such as global warming and marine waste. They also draw attention to the fact that the removal to open landfills remains the main method of waste disposal in Asia and Africa. Moreover, the lack of controlled dumps leads to the formation of unauthorized dumps. The opening of new open landfills that do not meet modern sanitary requirements regarding the impact on the air and groundwater only leads to even greater pollution, including the land under these landfills[20)-22)].

At the same time, B. Shahriari et al.[23)] draw attention to the fact that MSW management in some cases can lead to loss of resources and limited approaches to waste management, as there are barriers associated with maintaining sustainable MSW management practices. They especially pay attention to the fact that the low social status of MSW management leads to apathy, manifested in uncollected waste in residential areas, and deterioration of the aesthetic and environmental situation in unauthorized dumps. The absence of a national MSW management policy can also lead to negative environmental impacts, despite the existence of various programs. Moreover, under the policy in this area, the researchers mean the development, according to the goals outlined in these programs, of an MSW management system and, accordingly, a system for monitoring their implementation, as well as targeted actions to implement these programs. Not all countries set the task of developing an integrated MSW management system themselves. Even in a country like China, MSW management largely consists of removing it from a landfill. Currently, the development of sanitary landfills, as well as environmental impact assessment under the LCA program, are top priorities for the Chinese government[10)].

Researchers A. Allesch and P. Brunner[24)] devoted their paper to assessing the impact of MSW on the environment. Thus, pointing out the importance of a comprehensive assessment, they talk about the need to work on the identification of environmental impact targets, which include energy, air quality, biodiversity, flora, fauna and landscapes, water and water quality, soil quality and land use resources, renewable and non-renewable resources, environmental impacts on enterprises and consumers, the likelihood or magnitude of environmental risks, animal welfare. It is possible that when developing a comprehensive MSW management policy, the local authorities of Shymkent will be able to include these facilities for assessing the impact of MSW, not limited to air and water quality. Most researchers consider the method of life cycle assessment to be the most comprehensive method that meets environmental sustainability requirements. Thus, A. Constantinou et al.[25)] and M. Bissmont[26)] propose LCA to be carried out by comparing the waste flow at the stage of its formation and the products of its decomposition or processing, assessing its potential consequences for the environment and interpreting the results according to the assessment objectives.

P. Yadav and S. R. Samadder[27)] analyze the application of the life cycle assessment method to assess the environmental performance of various MSW management technologies. Thus, countries with high per capita income and high Gross Domestic Product (GDP) produce more packaging waste (plastic and paper), while countries with low GDP produce more biodegradable waste. The LCA is a tool to compare the environmental impact of different MSW technologies in order to determine the most environmentally, economically, and socially acceptable management option[28)]. Open dumping is the main method of MSW management in developing Asian countries, where only 4-16% of municipal budgets are used for MSW management, of which 80-90% is spent on waste collection. The developed countries of Asia (Japan, Singapore, Turkey, and South Korea) mainly use incineration, allocating more funds for disposal.

Since separate waste collection systems have not been properly developed, and sorting does not cover the entire volume of waste, there is a problem with mixed municipal solid waste management. Strategies for managing such waste using the life cycle assessment methodology were described by G. Fiorentino et al.[29)] J. Li et al.[8)] believe that in order to develop an effective MSW management model, it is not enough to assess the environmental impact of each type of waste. It is also important to assess the life cycle

cost of the waste. This will enable comparing possible options for management decisions and choosing the most optimal one. In addition, this will become the basis for developing a system of incentives for the processing and safe disposal of MSW. In addition, a lot of research is devoted to specific methods of waste management and disposal, for example, converting waste into energy, methods of efficient collection, sorting, and safe disposal of waste[9], pyrolysis as a method of thermal decomposition of organic materials in the absence of oxygen into coal, oil and gas[30)-32)].

According to A. Kerimray et al.[33)] and A. Nazhmetdinova et al.[34)], the disposal of mixed waste by pyrolysis can become a universal method of waste disposal in landfills, especially in old landfills, where their sorting is practically impossible, while long-term natural decomposition continues to pose a danger to air space, groundwater, and soil[35)]. At the same time, they focus on the need to equip modern landfills, sort waste and use other methods of processing besides pyrolysis. It is possible that the establishment of an enterprise for the disposal of mixed MSW (constituting the vast majority of Shymkent MSW today) would be one of the ways for the city authorities to unload existing and closed landfills in order to improve the environmental situation in the city and improve its aesthetic appearance and sanitary well-being. The improvement of methods for assessing the impact of MSW on the environment contributes to the adoption of more qualified management decisions, and the improvement of methods for managing MSW flows.

The proposed study aims to fill the gap in the existing literature on MSW management in Shymkent by providing a comprehensive assessment of the current state of MSW management practices in the city. Existing literature may lack specific information on the infrastructure, challenges, and shortcomings of MSW management in Shymkent. The study will address this gap by analyzing the city's capacity, identifying key factors influencing MSW management, and evaluating the effectiveness of existing practices. Also, the study contributes to solving the problems of solid waste management in Shymkent by providing a comprehensive assessment of the current state of waste management practices in the city. By analyzing the existing infrastructure, identifying challenges and shortcomings, and evaluating the effectiveness of current practices, the study offers insights into the specific issues that need to be addressed. This knowledge serves as a foundation for developing targeted recommendations and strategies to improve waste management in Shymkent and other cities.

5. Conclusions

Environmental assessment of municipal solid waste pollution is carried out for the adoption and adjustment of decisions by the authorities. The determining factor for such an assessment is the availability of information on the structure of MSW. Unfortunately, such information for the city of Shymkent is available only for certain very large groups of waste. The foundation for further research is the assessment of the city's capacity to manage MSW and its level in the hierarchy of MSW management. The analysis shows that Shymkent is at the bottom of the hierarchical ladder of MSW management, as waste is removed to open landfills and dumps, where disposal occurs mainly through the natural decomposition of waste, sometimes with open burning to reduce volumes, as well as possibly a minor process of sorting them. There is no landfill in the city that would meet sanitary and environmental requirements since the outdated landfills do not have systems for trapping leachate from falling into groundwater and trapping particles of waste decomposition into the air. MSW in the city is taken to landfills in a mixed form, i.e., degradable food waste and non-degradable other waste. In part, it can be said that metal waste and glass containers are largely collected separately.

The arrangement of containers for the separate collection of plastic waste and mercury-containing lamps is a positive step, but without being interconnected with other participants in the waste management process, this will not significantly affect the waste problem in the city. This is evidenced by the presence of unauthorized dumps not only outside the city limits but also in the city itself, jeopardizing even the rivers flowing in the city. At the same time, there is a big gap between the high human and economic potential of the city and the state of affairs with the management of MSW flows. Only by combining the efforts of the authorities, scientists, environmentalists, and enterprises, it is possible to create an MSW management system focused on minimizing waste and turning its maximum volume into raw materials for various types of economic activities, which meets the conditions and specifics of the city.

The scientific value of this study lies in its contribution to the understanding of municipal solid waste (MSW) management in Shymkent. By assessing the current state of MSW management, identifying challenges, and evaluating existing practices, the study provides valuable insights into the specific context of waste management in the city. Promising prospects for further research on municipal solid waste (MSW) management in Shymkent include in-depth waste composition analysis, applying life cycle assessment (LCA), exploring technological innovations, analyzing policy and governance, assessing socio-economic impacts, and investigating stakeholder engagement and public awareness. These research avenues can enhance the understanding and implementation of sustainable waste management practices in the city.

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