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Relevance of Environmental Surveys on the Design of a New Municipal Waste Management System on the City of Kokshetau (Kazakhstan)

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Abstract: The increasing amount of municipal solid waste is one of the most urgent problems for many countries in the world, including Kazakhstan. In 2021, a new environmental code was adopted in the country. In accordance with this code, some types of garbage (such as plastic, paper, cardboard or glass) are not accepted at sanitary landfills. Besides this, a separate collection system of municipal solid waste in Kokshetau is practically absent, and only a few points for the collection of secondary raw materials are currently available. The state bodies are faced with the task of introducing dual waste collection technology. This work shows the results obtained by a sociological online survey performed among the residents of the city in order to identify their attitudes with respect to the separation and classification of waste. This survey allowed us to study the level of environmental awareness and interest in solving waste-related issues in the population of Kokshetau. The results show that the majority of the population is concerned about the problem of municipal waste management and is ready to cooperate on the classification of waste at the original source. Additionally, it was revealed that the survey participants have weak environmental knowledge, so it is necessary to conduct environmental education activities for the population. The existence of a statistically significant relationship between the variables under consideration in terms of the Pearson Chi-squared criterion was observed.

Keywords: municipal solid waste; environmental survey; food waste; separate collection; waste sorting; dual system; recycling

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1. Introduction

One of the most relevant environmental issues in modern cities is municipal solid waste (MSW) management. Recent studies have been made in China [1], Russia [2], Hong Kong [3], Turkey [4], Italy [5], Colombia [6] and Spain [7]. Recent reviews about the sustainable management of municipal solid waste are also available in the scientific literature [8] and specific studies on food packaging management [9] and the environmental impacts induced by food waste in America [10] and in Europe [11] have also been done. Environmental impacts are mainly identified as a consequence of landfilling [12], and some numerical models for the optimal management of recyclable waste have been recently developed [13,14]. The increasing annual consumption volumes together with the increasing population lead to higher environmental pressures, and waste production is expected to increase from today's 2.01 billion tons to 3.40 billion tons by 2050 [15].

According to the World Bank, Kazakhstan belongs to the group of countries with an above-average gross national income (USD 7958.7 per person) [16], and the level of waste generation is expected to range from 0.69 kg in 2016 to 0.99 kg in 2050, i.e., an increase

in the amount of waste is projected of almost 44%. In terms of the total amount of waste generated, Central Asia (including Kazakhstan) and Europe are in second place in the world (annual production = 392 Mt/y), after East Asia and the Pacific region.

Data about the dynamics of solid household and municipal waste generation in Kazakhstan (Table 1) are provided by the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan and the Bureau of National Statistics [17]. According to these data, the amount of solid waste generation in the country decreased by 17% from 2015 to 2020. At the same time, the volume of recycled solid waste increased by almost 9 times. The amount of municipal waste generation in the country increased slightly over the same period of time (6%), while the intensity of municipal waste generation per capita ranged from 158 kg to 202 kg. There was a sharp increase in the level of recycling and disposal of municipal waste in 2020 by almost 2 times, compared with 2019. In Medan, Indonesia, urban residents produce about 108 kg of waste per year per person, which is almost half the production observed in Kazakhstan (202 kg) [18]. In countries with a high level of national income, the amount of the per capita waste production reaches 578–759 kg. MSW in many countries has become an environmental problem that poses a threat to the environment [19].

Table 1. Dynamics of solid household and municipal waste generation in the Republic of Kazakhstan from 2015 to 2020.

	Unit	2015	2016	2017	2018	2019	2020
Municipal Solid Waste (MSW)							
MSW production	10^3 t/year	5467.3	5400.9	4864.3	4319.2	4736.6	4551.7
MSW recycling	10^3 t/year	99.7	140.3	440.0	497.1	705.2	868.9
MSW per capita production	kg/(person year)	311.7	303.5	269.7	236.3	255.8	242.7
Household Waste (HW)							
HW production	10^3 t/year	3235.5	2813.6	3415.0	3692.0	3674.0	3441.6
HW recycling	10^3 t/year	372.5	346.1	442.7	427.1	418.3	760.0
HW per capita production	kg/(person year)	184	158	189	202	198	183

According to the Ministry of Ecology, Geology and Natural Resources, in Kazakhstan, 4.6 million tons of solid waste were collected in 2020. Two thirds of this amount is household waste, while the rest is industrial waste, equated to household waste, street garbage and market waste. Almost 70% of the collected waste goes to landfilling and only 30% is classified. By the end of 2020, about 46 million tons of waste has accumulated in landfills across the country [20]. Some important problems related with the MSW management activities arise not only in Kazakhstan [21], but also in many countries around the world such as the USA [22], Saudi Arabia [23], Dominican Republic [24] and Thailand [25]. Some of these problems are: (i) lack of licensed landfills, (ii) increasing number of unauthorized landfills, (iii) increasing production of solid household waste, (iv) lack of waste recycling facilities, (v) lack of funding and (vi) poor conditions for business and entrepreneurship development. Many experts have noted that surveying the opinions of the population and their attitude to the environmental problems associated with waste management is important to guarantee a sustainable management system and make the right environmental decisions [26–31]. The current research is devoted to identifying the value bases prevailing in ecological consciousness and the prevailing types of ecological behavior of the population of small towns in the field of solid waste management [32], the assessment of solid waste management in households [33], the attitude of the population to waste disposal [34], studies of the readiness of the urban population to introduce separate collections of solid waste [35] and the study of factors and conditions for the transition of the population to a system of separate waste collection [36]. One of the most economically sound solutions for

reducing municipal waste is the introduction of a dual system of separate collection, which does not involve large economic costs [37–40]. The selective waste collection implemented in many cities has failed due to insufficient support from the population and the incorrect planning of separate collection. The results of studies performed in St. Petersburg (Russia) show that from 25% to 75% of citizens are ready to participate in waste sorting, but only after carrying out an environmental education program [41] and are paid for waste separation by producers. This is a very essential part of the whole chain. Despite the present work that focuses mainly on the issue of waste separation by producers, increasing waste recyclability should be the final goal of the MSW management system. Separation in itself does not guarantee high ratios of recyclability and low ratios of landfill disposal. These facts have been clearly identified, especially with plastic waste [42].

In 2021, a new environmental code was adopted in the Republic of Kazakhstan [43], which introduced a new waste classification system that meets European standards. This system aims to achieve a sustainable waste management system by minimizing waste generation, encouraging reuse and recycling, and minimizing waste disposal in sanitary landfills. Waste collection organizations and companies are obliged to provide separate collection in two fractions: (i) inorganic waste (dry) and (ii) organic waste (wet). According to the new code, it is prohibited to accept such waste as plastic, glass, cardboard, wastepaper or food in sanitary landfills. The process of separate waste collection has just begun in the largest Kazakh cities, such as Almaty, Nur-Sultan and Karaganda. However, the efficiency of the system is still low as it has not been introduced in society for a sufficient time. The scarce scientific studies performed so far on solid waste management have been focused on this set of the largest cities of Kazakhstan [44–49].

2. Materials and Methods

The city of Kokshetau is the capital of Akmola province in northern Kazakhstan. It has a population of 125,225 inhabitants (2007). Figure 1 shows the location of Kokshetau city, within the Akmola region.



Figure 1. Location of the city of Kokshetau inside the Akmola Region (Kazakhstan).

The metropolitan area of Kokshetau is divided in 18 microdistricts. The spatial distribution of the city borders and the internal structure of its microdistricts are shown in Figure 2.

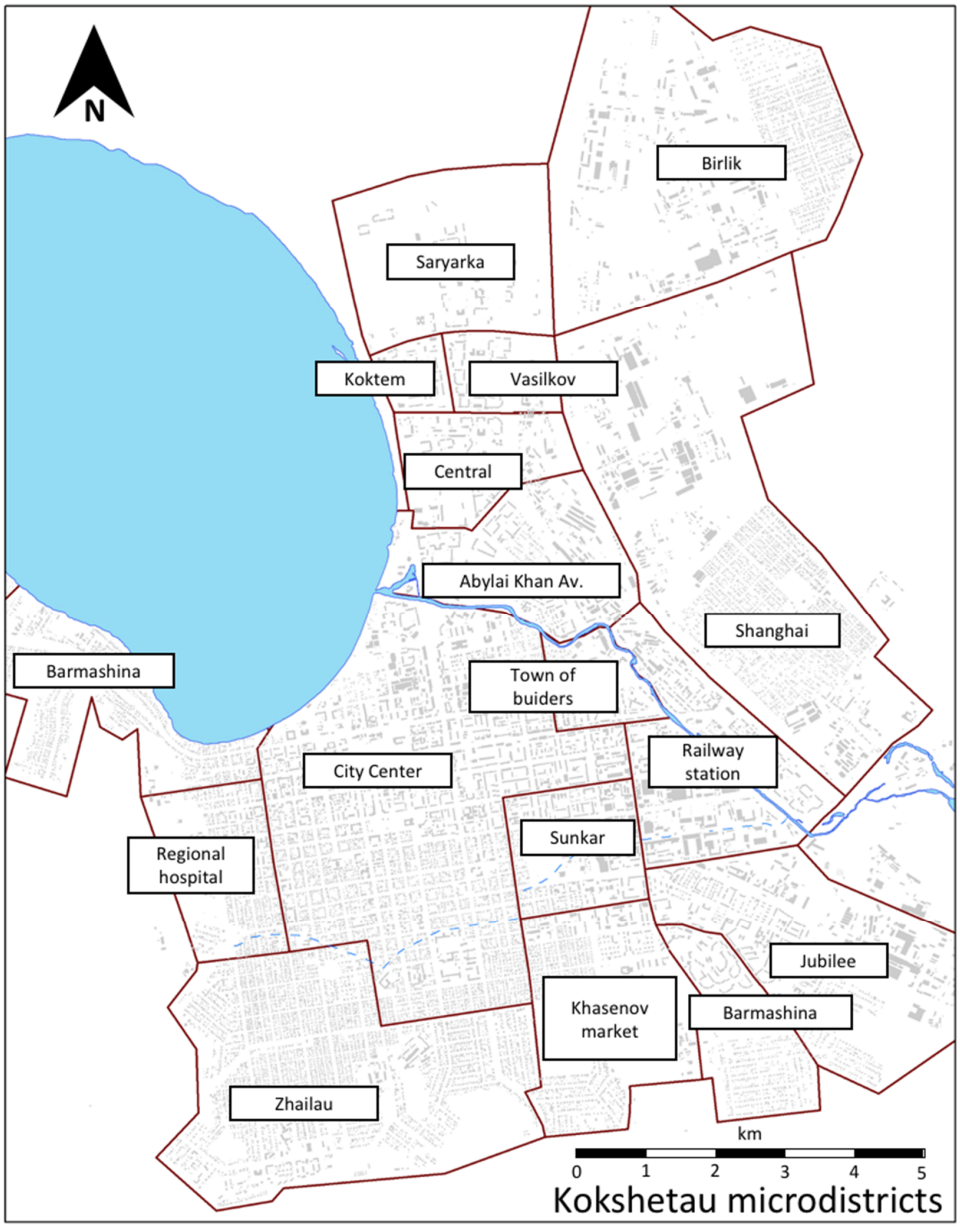


Figure 2. Internal structure of Kokshetau microdistricts.

In Kokshetau, the current system of municipal waste collection includes the simple collection of unsorted waste at container sites, transportation to a processing site and storage at sanitary landfills [50,51]. The local administration plans to introduce a separate collection system in the near future. In order to implement this new management system properly, this work analyzes the results of the survey conducted with Kokshetau city residents regarding their knowledge, attitudes and opinions about waste sorting and separate waste collection, allowing us to better understand the level of environmental awareness and public interest in solving waste-related issues. This is the first ever survey study of these characteristics performed in Kokshetau. Though further studies are still required, the results obtained are considered to be the first step towards the modernization of the municipal solid waste management system of the capital city of the Akmola Region.

In order to determine the readiness of the population for separate waste collection in Kokshetau city and to identify a microdistrict for piloting dual the waste sorting system, a three-part questionnaire was developed. The following 20 questions were included in the survey:

1. Age
2. Education degree
3. Marital status
4. Microdistrict in which respondent live
5. Social status (working, part-time job, unemployed)
6. Area of work (agriculture, industry, . . .)
7. Degree of concern about waste management (high, low)
8. Knowledge about waste sorting systems (yes/no)
9. Is respondent ready to sort waste?
10. Degree of knowledge of the concept of "Dual Waste Sorting System"?
11. From different types of garbage, mark those that are organic waste
12. From different types of waste, mark those that are inorganic waste
13. Are you ready to take waste to a collection point (waste paper, glass, plastic, etc.) for recycling?
14. Of different types of waste, mark those that you could sort at home
15. Of different types of waste, mark the ones that prevail in the trash can in your home
16. Do you know where waste goes after it has been taken away by a garbage truck?
17. Do you know how some types of waste can be reused?
18. Do you know where the collection point for glass, paper or plastic is located?
19. Do you want separate waste collection containers to appear in your microdistrict?
20. Are you ready to take part in the garbage collection and cleaning system of the municipality?

In the first part of the questionnaire, general questions about the respondents were included: age, education, marital status, place of residence, social status and fields of activity.

The second set of questions allowed us to identify the level of environmental awareness of respondents so as to study their environmental education and knowledge about specific waste management terms, such as waste sorting, dual system, waste classification, organic and inorganic waste, etc. In this second set of questions, a group of open-answer questions was designed so respondents could note the best possible answer, in their opinion. These questions referred to nine types of solid waste: plastic packaging, bottles, bags, children's toys, disposable tableware, glass, food waste, vegetables, fruits, garden waste, metal, paper and cardboard, textiles, rubber, and animal skin and bones.

The third set of questions concerned the social activity of respondents and their interests in solving the problem of waste sorting. Answers were evaluated using a 3-point scale (yes, no, I find it difficult to answer).

Open answers and a 3-point scale were chosen due to the simplicity and convenience for respondents, as this study aimed to study the opinions of different social population segments, including those who are actively working. Respondents spent no more than 10 min of their time filling out the questionnaire. This made it possible to reach a wider range of residents of the city. The survey was conducted in Kokshetau city from 1 June to 30 July 2021. A total number of 364 people participated in the survey. To conduct the survey, an online "Questionnaire Survey" method was used using the Google Forms platform. The questionnaires were distributed only online through social networks (Facebook, Vacap and Instagram), due to the fact that COVID-19 quarantine restrictions were applied in Kazakhstan. Residents of 18 residential districts of Kokshetau took part in the survey. A short version of the full set of answers to the survey is provided as Supplementary Materials.

3. Results and Discussion

3.1. Characteristics of Respondents

Figure 3 shows the frequency distribution of the respondents' locations inside the city of Kokshetau. A total number of 364 answers to the survey were received. The most active part of the population in terms of participating in the survey lived in the City Center. While 21.7% of respondents lived in the City Center, 11.5% lived in the Central District. However, a high participation from microdistricts in the southeastern part of the city (Yubileyny

and Borovskoi—14.8%) and the northern part of the city (Vasilkovsky, Koktem—13%) was observed. As expected, the smallest number of respondents was located in the outskirts of the city, where private houses are mostly located.

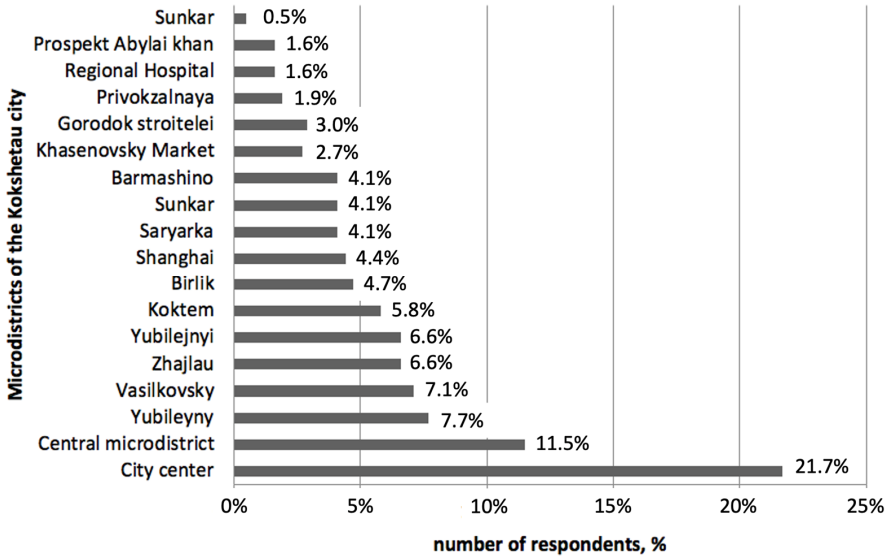


Figure 3. Percentage of answers to the survey according to each microdistrict.

Figure 4 shows the age distribution of the survey respondents. Respondents aged 12 to 79 years took part in the survey. The majority of participants (41.2%) were included in the age range from 24 to 40 years, the average age of respondents being 37.8 years. Thus, the survey participants represented the youngest and most active working group of the population.

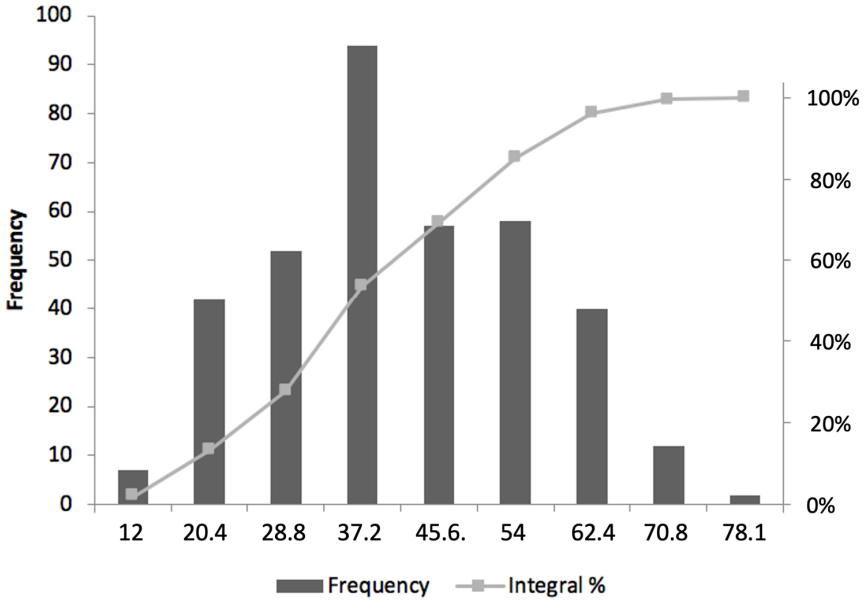


Figure 4. Age distribution of respondents.

Figure 5 shows the characteristics of respondents by marital status, educational level and social status. According to the research results, most of the respondents (59.9%) are in a legal or civil marriage. More than half of the survey participants (69.2%) have a permanent job, and unemployed respondents (or those who have a non-permanent place of work) represent only 4.4%. The education level of the respondents was high as more than 70%

of the participants have a higher education degree. Besides this, it should be noted that a fairly significant share was made up of students (14.8%). Only 3.1% of respondents did not have an education degree, including children or older people who, for certain reasons, did not receive an education. Concerning the education level of the participants in the survey, these results are coherent with those found in research when conducting a similar survey among Hong Kong residents [52].

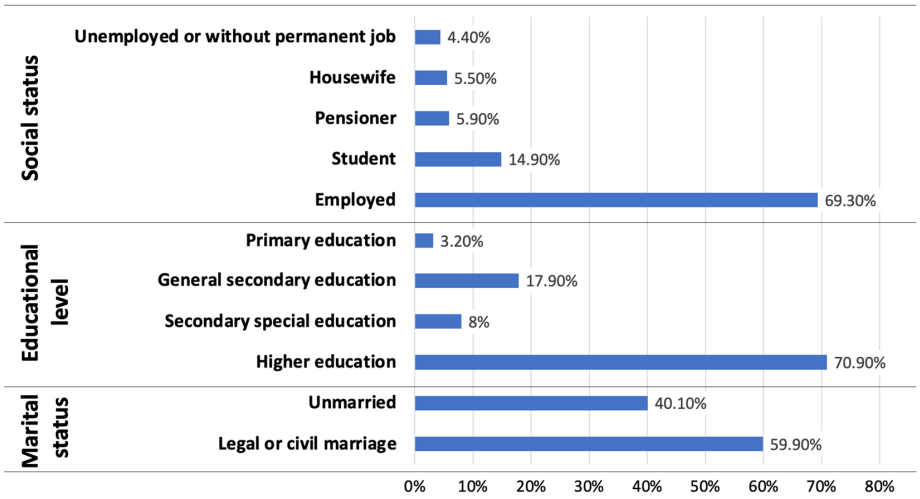


Figure 5. Characteristics of respondents by marital status, educational level and social status.

Figure 6 shows the working field of activity distribution of the survey respondents. Representatives of various fields of activity took part in the survey, including education, medicine, public service, trade, production workers, financiers, etc. The vast majority of respondents (60%) work in medicine or education; 14% of respondents work in public services, such as executive authorities and administration. To a lesser extent, workers in the service sector (8.1%) and trading (4.2%) were represented. The results show that the most economically active part of the population expressed its opinion by participating in the survey. Despite the specific results of each category being available (see Supplementary Materials), the limited number of answers to the survey (364) makes it unnecessary to perform a statistical analysis of the survey results of each category. The representativeness of the results must be understood by taking this fact into account.

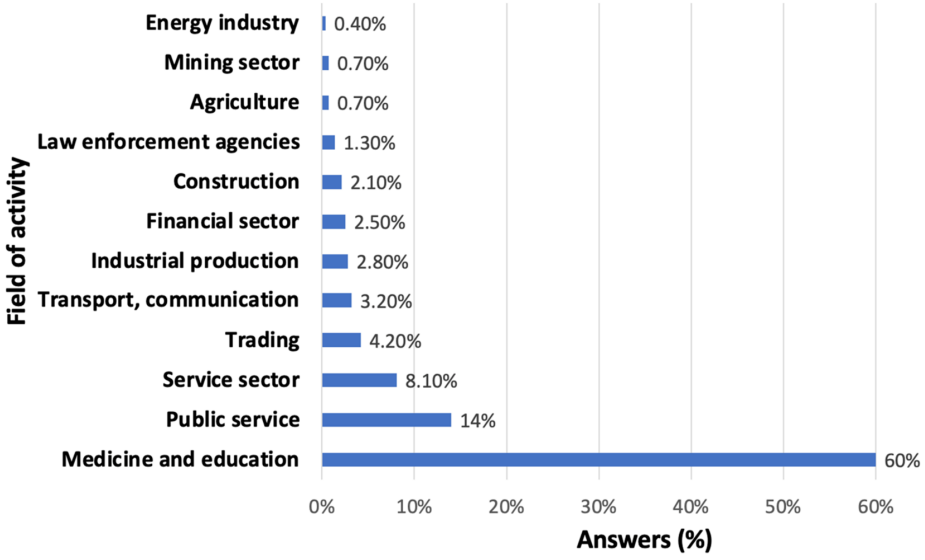


Figure 6. Working field of activity distribution of the survey respondents.

3.2. Respondents' Willingness to Implement Separate Waste Collection

Table 2 shows the summary of the survey results about waste sorting. Currently, the problem with waste management in the city of Kokshetau is extremely relevant. The survey results show that 92.9% of respondents are concerned about this situation. Residents of the city also showed a willingness to sort waste (84.1%) and are positive about the possibility of installing containers that allow for separate waste collection (93.1%).

Table 2. Respondents' attitudes to waste sorting.

Questions	Answers	Frequency	%
Are you concerned about the problem of garbage in your city?	Yes	338	92.9%
	No	18	4.9%
	Difficult to answer	8	2.2%
Are you ready to sort household waste?	Yes	306	84.1%
	No	25	6.9%
	Difficult to answer	33	9.1%
Are you ready to take the waste to the recyclables collection point (wastepaper, glass, plastic, etc.)	Yes	290	79.7%
	No	27	7.4%
	Difficult to answer	47	12.9%
Do you want containers for separate garbage collection to appear in your neighborhood?	Yes	339	93.1%
	No	9	2.5%
	Difficult to answer	16	4.4%
Are you ready to take part in the program?	Yes	247	67.9%
	No	56	15.4%
	Difficult to answer	61	16.8%

On the other hand, some respondents are not satisfied with the need to take waste to special collection points for secondary raw materials, and they prefer containers for separate waste collection near their homes. The percentage of those who want to take part in free voluntary cleaning campaigns is not as high as expected (67.9%).

The results of the survey show that most of the surveyed residents of the city of Kokshetau showed a willingness to classify waste into groups in their own home. Most of the respondents (84.1%) agreed to carry out pre-sorting, while only 9% of respondents believe that it is not very convenient or is unacceptable for them.

Besides this, the results show that the majority of household waste produced contains food waste (75.3% of respondents) and plastic materials (71.7% of respondents). More than half of the waste includes the remains of vegetables, fruits and paper products. The remaining components of garbage are represented in much smaller amounts (3–8%). These results are coherent with previous studies that consider the problem of food waste management to be one of the most urgent, as food waste is included at the highest proportion in household garbage [53].

Residents of the city believe that they could sort plastic waste (86.5% of respondents), paper (62.4% of respondents) and food waste (58.5% of respondents) at home. To a lesser extent, they showed a desire to sort the remains of rubber products and leather, animal bones, as well as scrap metal (22–25% of respondents).

Figure 7 shows the analysis of respondent's answers to questions about organic and inorganic waste. It should also be noted that most of the survey participants do not quite understand how organic waste differs from inorganic waste, as all types of waste appeared in the responses as organic.

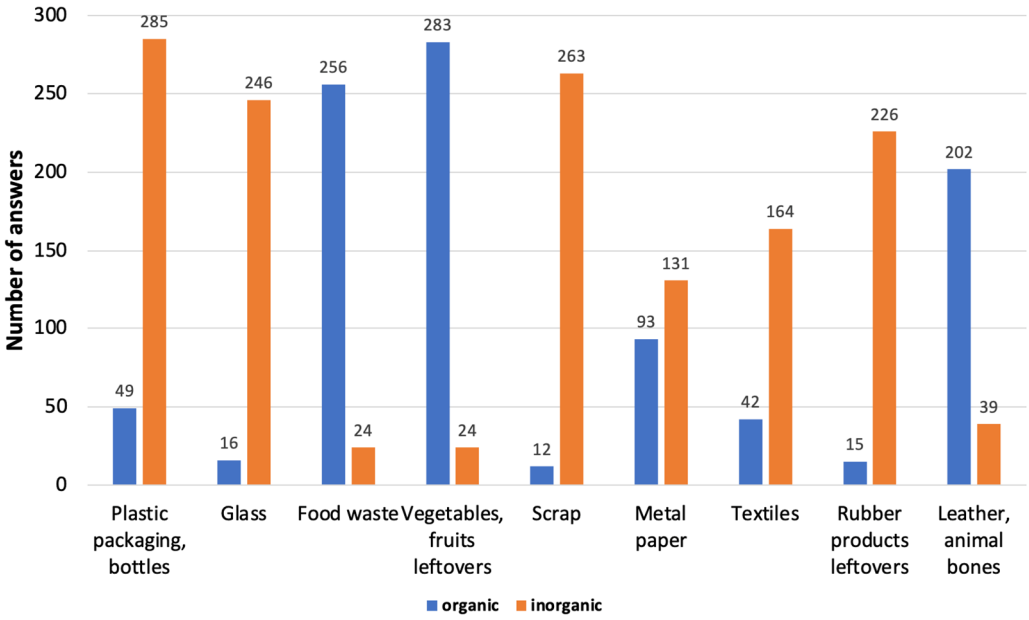


Figure 7. Analysis of respondents' answers to questions about organic and inorganic waste.

Despite the fact that food waste (70.3%), plant residues (77.7%), and animal skin and bones (55.5%) were found most frequently in the answers to the survey, only 103 respondents (28.3%) chose all three correct answers; 59 respondents (16.2%) chose two correct answers and 72 respondents (19.78%) named only one type of organic waste.

The rest of the survey participants also referred to organic waste as other types of waste that are not such. The most common organic waste was paper (25.5%) and plastic materials (13.5%).

Some common mistakes were found in the answers to the survey. While 25% of respondents believe that paper belongs to organic waste, 36% consider it as an element of inorganic waste.

Waste containing plastic is considered as organic waste only by 13% of the respondents. These results indicate that it is necessary to work with the population in terms of raising awareness and environmental education. The effectiveness of dual waste sorting measures will depend on this.

At the same time, respondents have rather vague ideas about how waste is collected, where it is transported and where are the points that receive some types of garbage separately.

Table 3 summarizes the awareness of respondents about separate waste collection. While 12.1% of respondents do not know that garbage can be sorted at all, almost 40% of respondents have a poor idea of what happens to waste after it is collected.

Table 3. Awareness of respondents about separate waste collection.

Questions	Answers	Frequency	%
Did you know that garbage is sorted?	Yes	320	87.9%
	No	35	9.6%
	Difficult to answer	9	2.5%
Are you familiar with the concept of "Dual garbage sorting system"?	Yes	108	29.7%
	No	231	63.5%
	I don't know. I am not interested	25	6.9%
Do you know where the garbage goes after it has been taken away by a garbage truck?	Yes	226	62.1%
	No	97	26.6%
	Difficult to answer	41	11.3%

Table 3. *Cont.*

Questions	Answers	Frequency	%
Do you know how some types of waste can be reused?	Yes, I know, but I don't use these methods	200	54.9%
	No, I don't know, but I would like to know	121	33.2%
	No, I don't know, I'm not interested	43	11.8%
Do you know where the collection point for glass, paper or plastic is located?	Yes	144	39.6%
	No	183	50.3%
	Difficult to answer	37	10.2%

Less than half of the respondents (39.6%) are aware of where the collection points of some types of household waste are located, and most of the survey participants (63.5%) have no idea about the dual waste sorting system.

3.3. Statistical Dependencies between Waste Variables

Following the results obtained by the survey, the statistical relationships between different waste variables were analyzed. Considering that all variables are qualitative, cross-tabulation was used to study the relationship between them.

The analysis of conjugacy tables reveals the presence or absence of not causal, but statistical dependencies. In this research, in order to verify the statistical significance of the relationships between qualitative variables, the Pearson Chi-squared criterion was applied.

The cross-tabulation results of the relationship between respondents' knowledge of the concept of the dual waste sorting systems and their awareness of its further use are shown in Table 4.

Table 4. Relationship between respondents' knowledge of the concept of dual waste sorting system and their awareness of its further use.

Chi-Square Test			
Indicators	**Value**	**Number of Degrees of Freedom**	**Asymptotic Significance (Two-Way)**
Pearson's Chi-square test	21.391 [a]	4	0.000
Likelihood ratio	21.670	4	0.000
Linear-linear connection	15.361	1	0.000
Number of acceptable cases	364		

[a] cell a.1 (11.1%) has an expected value < 5. Minimum expected value = 2.82.

The Pearson Chi-squared criterion allows for assessing the statistical significance of differences between two or more relative indicators (frequencies, fractions). The relationship analysis between the following variables was conducted:

- Respondents' knowledge of the concept of dual waste sorting system and their awareness of the further use of garbage, the possible reuse of certain types of waste, and the locations of recycling collection points;
- Respondents' knowledge of what happens to garbage after it is taken out of the city and people's willingness to hand over waste to recycling collection points.

The Chi-squared test results demonstrate a statistically significant relationship between the above variables, with a Chi-squared value of 21.391 and an asymptotic significance (two-sided) equal to 0.000. Asymptotic significance is the probability of randomness of the connection. The smaller this value, the higher the statistical significance (reliability) of the relationship.

Table 5 shows the cross-tabulation results of the relationship between respondents' knowledge of the concept of dual waste sorting systems and the possible reuse of certain types of waste.

Table 5. Relationship between the degree of awareness of respondents about the concept of dual waste sorting systems and the possible reuse of certain types of waste.

Chi-Square Test			
Indicators	**Value**	**Number of Degrees of Freedom**	**Asymptotic Significance (Two-Way)**
Pearson's Chi-square test	39.915 [a]	4	0.000
Likelihood ratio	43.284	4	0.000
Linear-linear connection	27.225	1	0.000
Number of acceptable cases	364		

[a] cell a.1 (11.1%) has an expected value < 5. Minimum expected value = 2.95.

The results show that 79.6% of the total number of respondents are familiar with the concept of dual waste treatment system, and they know how some types of waste can be reused. The Chi-squared test results demonstrate a statistically significant relationship between the above variables, with a Chi-squared value equal to 39.915 and an asymptotic significance (two-sided) equal to 0.000.

The cross-tabulation results of the relationship between respondents' knowledge of the concept of dual waste sorting system and their knowledge of the location of glass, paper or plastic collection points are shown in Table 6.

Table 6. Relationship between the respondents' knowledge of the concept of dual waste sorting system and the locations of glass, paper or plastic collection points.

Chi-Square Test			
Indicators	**Value**	**Number of Degrees of Freedom**	**Asymptotic Significance (Two-Way)**
Pearson's Chi-square test	11.711 [a]	4	0.020
Likelihood ratio	11.620	4	0.020
Linear-linear connection	9.407	1	0.002
Number of acceptable cases	364		

[a] cell a.1 (11.1%) has an expected value < 5. Minimum expected value = 2.54.

Based on the results shown in Table 6, it can be concluded that 62.4% of respondents are familiar with the concept of a dual waste sorting system and are aware of the location of recycling collection points. The Chi-squared test results demonstrate a statistically significant relationship between the above variables, with a Chi-squared value of 11.711 and an asymptotic significance (two-sided) equal to 0.020.

Table 7 shows the results of cross-tabulation of the relationship between respondents' knowledge of what happens to waste after it is taken out of the city and people's willingness to hand over waste to recycling collection points.

Of the total number of respondents who know about what happens to waste after it is removed from the city, only 40.7% are ready to hand over waste to a recycling point, and 55.8% of respondents answered this question negatively. The chi-squared test results demonstrate a statistically significant relationship between the above variables, with a chi-squared value of 14.603 and an asymptotic significance (two-sided) equal to 0.006.

The results regarding the statistical significance of the relationship between the qualitative variables obtained during the research show the presence of a statistically significant relationship between the variables under consideration.

Table 7. Relationship between respondents' knowledge of what happens to garbage after it is taken out of the city and people's willingness to hand over waste to recycling collection points.

Chi-Square Test			
Indicators	**Value**	**Number of Degrees of Freedom**	**Asymptotic Significance (Two-Way)**
Pearson's Chi-square test	14.603 [a]	4	0.006
Likelihood ratio	13.253	4	0.010
Linear-linear connection	5.357	1	0.021
Number of acceptable cases	364		

[a] cell a.1 (11.1%) has an expected value < 5. Minimum expected value = 3.04.

4. Conclusions

This paper contributes to the scarce literature in the field by presenting new data from a rapidly developing Central Asian city, the capital of Akmola region in Kazakhstan, Kokshetau.

The results of the survey described in this work performed with residents of Kokshetau reveal that the population of the city is ready for a dual waste sorting system. This is a very important fact to the primary assessment of the potential of deriving secondary material resources from city waste. Besides this, the survey results show that the residents of the central part of the city are ready to pilot a dual waste sorting system. However, it is first necessary to design and conduct an intense environmental education program.

The main problems identified during this research are: (i) the lack of containers, (ii) the remoteness of waste collection points and (iii) the deficiencies of the current waste management system. Similar results have been observed by researchers in other countries as well [54,55].

The survey results demonstrate that most residents of Kokshetau city are ready and interested in selective waste collection. However, in order to effectively implement a full new system of separate waste collection, it is necessary to conduct awareness-raising work, as respondents showed a lack of environmental knowledge in this matter.

This work is an example of how the method of data collection influences the results of environmental surveys. For these types of surveys related to waste management (as well as in other areas), it is essential to perform stratification and statistical analyses of the data correctly [42].

Besides this, when respondents express themselves voluntarily on the internet, they are usually inclined toward the problem being addressed. This in itself may have a significant effect on the results. In this work, it was not possible for the authors to influence the nature of the data, so it is necessary to take this into account to fill this gap when performing future work that complement those already in progress.

The results found are a first step towards designing an optimal solid waste management system in the city, and may be applicable to other cities in Central Asia in which a large fraction of organic waste is found inside MSW. To reduce landfilled waste and to minimize environmental impacts, composting is recommended.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142114368/s1, Survey.

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