BIO Web of Conferences **130**, 03015 (2024)
BFT-2024
https://doi.org/10.1051/bioconf/202413003015

Selection of an optimal set of machines for sorting and crushing municipal solid waste

Azamat Zhikeyev[1], *Tavbay* Khankelov[2*], *Mavluda* Irisbekova[2], *Diloram* Sabirova[2], and *Nafisa* Muxamedova[2]

[1]Kostanay State University A. Baitursynov, Kostanay, Kazakhstan
[2]Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. The article is dedicated to the selection of the optimal set of machines for sorting and crushing municipal solid waste based on its properties and accumulation rates. Considering the properties of waste and technologies for its collection, a new technological scheme for processing municipal solid waste was developed and, based on this scheme, the optimal set of machines was selected. In addition, the research conducted to determine the fractional composition of the waste made it possible to substantiate the diameter of holes in the drum screen mesh. Based on the analysis of the morphological composition of the waste at the end of the technological chain, the type of crusher design was determined and the main parameters of the hammer crusher were substantiated in connection with the technological processing. The optimal set of machines will make it possible to process the components of municipal solid waste for use in the form of secondary raw materials with the least material and time costs.

1 Introduction

The composition, properties, and volume of municipal solid waste (MSW) generated in the process of human activity depend on the living standard of people, the method of waste collecting and transporting, climatic zones of residence, etc. An analysis of the waste composition shows that packaged materials have recently occupied a significant share in its structure. This is primarily due to the fact that if previously the packaging of goods was considered exclusively as a method of storage and delivery, now packaging is looked at as an additional source of profit [1].

On the one hand, solid waste is a source of environmental pollution, in particular, through microbes entering people's bodies in various ways, on the other hand, waste is a source of secondary raw materials. This becomes especially true when natural resources are being rapidly depleted. Consequently, the extraction of valuable components from solid waste becomes in demand due to various circumstances: firstly, sorted waste can be used as a product for the national economy; second, recycling waste will significantly reduce its volume, therefore, the costs of processing and transportation, and its disposal in landfills; third, the scale of environmental pollution will be significantly reduced.

* Corresponding author: xankelovt9@gmail.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

Numerous technological schemes were developed for the extraction of valuable components from the waste composition, and their processing and utilisation. However, it should be noted that the technological scheme for processing solid waste developed and created in one country might not be effective when implemented in another country. This is clearly seen in the example of the operation of an experimental solid waste processing plant built in Tashkent in 1976. The plant was closed down due to the high glass content in the compost produced by the plant [2]. Therefore, when creating and putting into operation complexes for sorting and crushing solid waste or waste treatment plants, it is necessary to consider local conditions and properties of waste, and the trends of their change in the next 10 years.

Many research works are devoted to the development of technological schemes and the selection of sets of machines for processing solid waste. For example, L.Ya. Shubov et al. [3, 4] considered issues related to the patterns of solid waste separation in technologies for its complex processing, and topical issues of resource saving. These publications also address the issues of waste enrichment. However, these articles do not cover the development of the scientific basis for the creation of crushing and screening machines of impact action in the system of complex processing of solid waste. G.K. Ubaydullaev [5] conducted a thorough analysis of existing technologies and machines at the decisive stages of the solid waste sorting process.

The study conducted by A.N. Mirny [6] not only covers issues related to the analysis of effective waste processing technologies but also considers the issues of choosing effective technologies based on local conditions.

Issues of choosing sorting technologies, calculating the basic parameters of sorting devices and their efficiency are considered in [7,8, 9]. However, these publications do not address the influence of a complex of factors on technology and equipment for waste treatment.

Studies by N.F. Abramov [10] are mainly devoted to issues of selective collection of solid waste and issues of sanitary cleaning of cities and populated areas from solid waste.

A.M. Gonopolsky et al. [11] investigated issues related to the disposal of food waste at the point of generation. In the course of research, the design of the crusher was developed and the main design and technological parameters were justified. A comprehensive evaluation of the crusher design was performed to meet the requirements.

Tasks related to justification and calculation of the key indicators of various designs of crushers for grinding solid waste are considered by B.V. Klushantsev, A.I. Kosarev, Yu.A. Muizemnek [12]. The results obtained for determining the force and energy parameters showed that the data from theoretical calculations and practical calculations differ greatly. The justification of main indicators of these crushers is based on three hypotheses, which are valid only when crushing elastic-brittle materials. B.S. Kirin, A.N. Klokova [13] in their research considered issues related to the separation of plastics from the waste composition.

In progress [14] considered the way of vibration separation of waste. The operation process was studied and the criteria for the effectiveness of sorting devices based on the vibration-pulsation effect were substantiated. However, these studies do not address the issues of determining the power and energy parameters of machines.

The studies of L.N. Reutovich, M.P. Arlievsky, N.A. Averyanova [15] and V.F. Reshitko, G.Yu. Zatsepina, A.A. Shashnin, V.S. Maslov, and E.B. Krelman [16] are devoted to the issues of cleaning compost from ballast inclusions and the complex of machines that could implement this technology. Based on thoroughly conducted patent searches, devices for the purpose of separating solid trash, as well as a complex for its application..

Studies conducted by V.B. Yushchenko [17] are devoted to the development of automated complexes for processing household waste and its further use. However, they do not address issues of equipment efficiency when working with mixed collected waste.

The works of I.Hussein, Abdel-Shafy, S.M.Mona [18] and Lu Hongmei [19] discuss certain issues of collection, transportation, and treatment of solid waste.

The article by G.K. Ubaydullaev [20] is devoted to the feasibility study of the construction of a waste treatment plant with a capacity of 150 thousand tons/year in Tashkent with the production of secondary raw materials. A rational technological scheme for processing solid waste, considering local conditions, is justified.

Issues of substantiating the rational parameters of machines for processing solid waste, and issues related to the development of technological schemes for waste processing were considered by T.K. Khankelov et al. [21,22]. In addition, the works of R.Kh. Khakimzyanov [23,24] devoted to determining the loads in the cabins of tractors operated in landfills for solid waste disposal should be also mentioned.

Despite the large number of studies conducted on the problem of collecting, transporting, and processing solid waste, the issues of selecting the optimal set of machines for sorting and crushing solid household waste remain relevant.

2 Materials and methods

To develop a new technological scheme for waste sorting and to select the optimal set of machines, it is necessary to acquire data on the morphological and fractional composition of waste.

Experiments were conducted in Tashkent city for 3 years. As the city consists of 12 districts, it was necessary to choose the appropriate number of districts; the requirement for the selection of objects was explained by the following reasons: selected districts should have objects of retail chains, organizations, blocks of multi-storey apartments, and blocks of private buildings.

The authors used 2-stage cluster sampling.

1. A cluster representation of the city's region is presented as the first stage.
2. The average value of organic components of solid waste by season was determined (experiments were conducted in 2022), X_{av}=33.3%
3. Variance was determined as:

$$\delta = \sum(X_i - X_{\text{cp}})^2 = 0{,}446$$

4. The standard deviation was determined by the following formula:

$$\sigma = \sqrt{\frac{\delta}{n-1}} = \sqrt{\frac{0{,}446}{10}} = 0{,}224\%$$

5. The sample size (number of districts needed for research) was calculated by the authors based on the assumption that, at a probability of 0.954, the sampling error would not be greater than 0.2% for a standard deviation. $\sigma = 0{,}224\%$:

$$n = \frac{t^2\sigma^2 N}{N\Delta_x^2 + t^2\sigma^2}, \tag{1}$$

where $t -$ is the confidence coefficient calculated from the Laplace table, chosen as t = 2; N − is the volume of the general population, $N = 11$ is the number of administrative districts; $\Delta_x -$ is the sampling error.

$$n = \frac{2^2 0{,}224^2 \cdot 12}{12 \cdot 0{,}2^2 + 2^2 \cdot 0{,}224^2} = \frac{2{,}4}{0{,}68} = 3{,}5,$$

i.e., to conduct research, it is sufficient to select 4 districts.

To study the morphological and fractional composition of solid waste, 16 points were selected in four districts of the city:

1. Mirabad district - (private houses located between G. Aliev Street and Sarakulskaya Street, buildings located near the central office of the Tashkent railway station ticket offices, residential buildings located near the Poytakht store, residential buildings near the “Aybek” metro station).

2. Chilanzar district (Farkhad market, 9th quarter, 5th quarter, Al-Kharezmi massif).
3. Mirzo-Ulugbek district (Center -2, area of the former Children's World store, residential buildings near the NPO "Uzyulmashservice", Feruza massif).
4. Yunusabad district (7, 13, and 19 quarters, "Bobodekhkan" Mahalla).

Ten samples, each weighing thirty kg, were chosen in order to assess the morphological and fractional content of MSW at garbage collecting locations. The morphological composition of the waste was determined by the quartering method, i.e. waste samples were evenly distributed on a tarpaulin measuring 2000 x 2000 mm, then three-quarters of the waste was discarded and one-fourth was taken for study.

The percentage of waste components by size (fractional composition) was estimated by waste components by name, i.e. morphological composition. In the composition of small fractions, the size of which is less than 50 mm, organic waste makes up approximately 90-95%. Consequently, the high content of fine fractions resulted in a high percentage of food waste in the screenings. To determine the percentage of waste constituents by size, a sieve was developed with mesh sizes of 250 x 250 mm, 150 x 150 mm, 100 x 100 mm, 50 x 50 mm, and 15 x 15 mm. The size composition of municipal solid waste was determined by gradually passing "average" waste samples onto sieves with mesh sizes of 250 x 250 mm, 150 x 150 mm, 100 x 100 mm, 50 x 50 mm, and 15 x 15 mm.

3 Results

A program and methodology for experimental research were developed to determine the optimal set of machines and justify their main parameters ensuring their effective operation.

Figure 1 shows the average value of the morphological composition of solid waste generated in Tashkent in 2022.

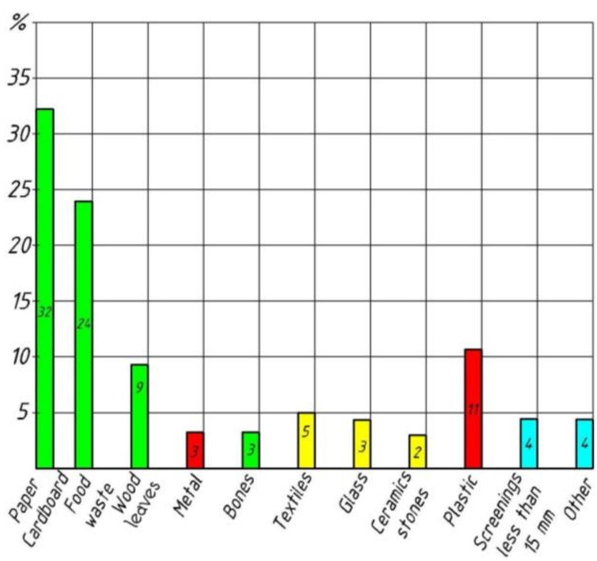

Fig.1. Morphological composition of municipal solid waste generated in Tashkent.

A system of devices for crushing and sorting waste can be made possible by the analysis of data on the morphological composition of solid waste. In addition, it should be noted that solid waste is collected at waste collection points in plastic bags. Therefore, it is necessary to equip the waste treatment line with bag breakers. A set of machines and a phased change in the morphological composition of solid waste as a result of processing is shown in Table 1.

 https://doi.org/10.1051/bioconf/202413003015

Table 1. Set of machines for crushing and sorting solid waste

№	Machines and mechanisms used in crushing and sorting solid waste	Morphological composition of solid waste after this operation (%)	Name of machine, device
1		Paper, cardboard-32; food waste-24; tree, leaves-9; metal-3; bones-3; textiles-5; glass-3; ceramics, stones-2; plastic-11; screening less than 15 mm-4; others-4	Bag breaker
2		Food waste-24; wood, leaves-9; metal-3; bones-3; textiles-5; glass-3; ceramics, stones-2; plastic-4; screening less than 15 mm-4; others-4	Sorting table
3		Food waste-24; wood, leaves-9; bones-3; textiles-5; glass-3; ceramics, stones-2; plastic-4; screening less than 15 mm-4; others-4	Magnetic separator
4		Food waste-24; bones-3; glass-3; ceramics, stones-2; plastic-4	Drum sieve
5		Food waste-24; bones-3; glass-3; plastic-4	Sorting device
6		Food waste-24;	Sorting machine equipped with artificial intelligence
7		Shredded food waste, raw materials that meet the requirements for compost production	Hammer crusher

Based on the analysis of the data obtained, it is possible to develop a technological scheme for processing solid waste. The technological scheme for waste processing was developed considering the properties of the waste. When choosing machines and devices, the factor of cost and quality of operation was taken into account. The developed technological scheme is presented in Fig. 2.

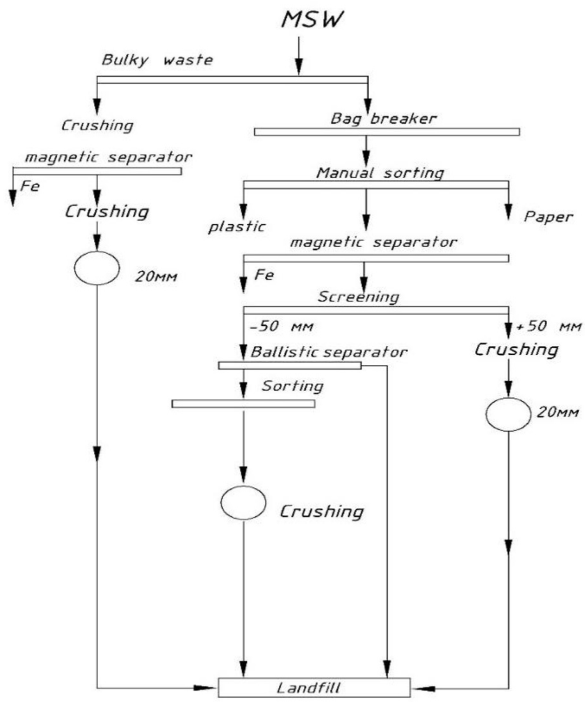

Fig. 2. New technological scheme proposed for sorting and crushing solid waste

The advantages of the proposed technological scheme for processing solid waste are as follows:
- the technological scheme is equipped with bag breakers since the bulk of waste is packaged in bags. The maximum dimensions of plastic bags determine the main parameters of the bag breaker;
- for crushing bulky waste, the technological scheme is equipped with disk crushers (shredders);
- for sorting food waste, the crushing and sorting complex presented in this technological scheme, is equipped with a robotic sorting device, in the working process of which elements of artificial intelligence are used.

Considering the morphological makeup of solid was produced in Tashkent, we have determined the set of machines for sorting and crushing waste, but to justify the main parameters of these machines, we need data on the fractional composition of waste. To determine the fractional composition, ten “average” samples were created. Samples were taken from containers where they had accumulated at different times of the day, weighing thirty kilograms each. The experimental results are shown in Table 2.

Table 2. Fractional composition of municipal solid waste generated in Tashkent

№	Residue on sieve mesh size, mm (%)					
	250x250	150x150	100x100	50x50	15x15	Screening less than 15 mm
1		3.4	20.0	24.2	44.2	5.4
2		3.0	24.0	24.3	42.5	6.2
3		5.8	18.4	21.5	46.1	7.2
4		3.6	17.5	29.7	43.6	5.4
5		3.2	21.7	26.1	43.0	6.0
6		2.4	21.4	25.6	43.7	6.9
7		2.8	23.3	25.2	42.5	6.4
8		3.7	20.4	25.6	44.3	6.4
9		3.3	20.6	23.8	46.8	5.5
10		2.8	19.4	24.2	47.8	5.8
Average value		3.4	20.7	25.0	44.3	6.1

An assessment of the results obtained (Table 2) shows that slightly less than half of the waste has a size ranging from 15 to 50 mm. The results of a series of experiments assessing the percentage of waste by name depending on the size values are presented in Table 3 (in % of the weight of the residue per separate sieve).

Table 3. Morphological composition of solid waste depending on the size of the fraction

Components	>250	150÷250	100÷150	50÷100	15÷50	<15
Paper	-	28	37	22	13	
Food waste	-	5	12	23	65	-
Textiles	-	12	17	4	2	-
Wood, leaves	-	20	-	6	4	-
Bones	-	-	12	6	4	-
Glass	-	-	-	4	3.5	-
Leather, rubber	-	12	11	7	2	-
Other	-	12	1	4	1	-
Metal	-	11	7	14	1.5	-
Stones	-	-	3	10	4	-
Screening (<15mm)	-	100	100	100	100	100

An assessment of the results of experiments to determine the percentage of waste components by name depending on the size of the components showed that the main part of organic components has a size from 15 to 50 mm: paper - 13%; food waste - 60%; textiles- 2%; wood - 4%; bones - 4%; glass - 3.5%; stones - 9%.

4 Discussion

In the course of studying the properties of waste, such as morphological and fractional compositions, the composition of the waste and the sizes of the fractions were determined, which in turn made it possible not only to determine and justify the set and design of machines but also to justify their main parameters, for example, by analyzing the size of waste fractions The diameter of the holes of the drum screen and the angle of inclination of the drum relative to the horizontal axis were determined. A restriction to the use of research data is that the data obtained cannot be transferred without adjustment since in other areas, living conditions, and incomes of the population, the properties of waste may differ significantly.

5 Conclusion

1. An optimal set of machines for crushing and sorting solid waste was developed, the use of which would allow effective sorting and crushing of waste with minimal time and material costs.
2. Determination of the fractional composition of the waste made it possible to justify the size of the holes in the drum screening cells.
3. The fractional composition of the waste obtained at the end of the technological chain made it possible to select the design of a hammer crusher with justified rational parameters.

References

1. Adylova M. The problem of primary waste sorting. Publishing house "Fan" of the Academy of Sciences of the Republic of Uzbekistan. - 2006. - No. 8. - P. 10-14.
2. Aslanov N.R., Mukhamedova N.B., Mirkhalikov S.M. Properties of municipal solid waste and their impact on processing technology // Science in Education. 2021. No. 9.- P.240-245.
3. Shubov L.Ya. Mechanical waste sorting schemes (technology analysis) // Municipal solid waste. 2012, No. 3, pp. 14-25.
4. Shubov L.Ya. Stavrovsky M.E., Oleinik A.V. Technology of solid waste: a textbook for students studying in specialty 100100 “Service” / Moscow, 2011. Ser. Technological service. - 159 p.
5. Ubaydullaev, G., Riskaliev, D., Ergashev, N., Rashidov, A., & Shadiev, S. (2021). Determination of installation bases of parts during their mechanical processing. In E3S Web of Conferences (Vol. 264). EDP Sciences. https://doi.org/10.1051/e3sconf/202126405046
6. Mirny A.N. Criteria for choosing a technology for the neutralization and processing of municipal solid waste. Clean city. M., 1998, No. 1, P.8-15.
7. Vetoshkina L.P. Separate collection and sorting of municipal solid waste // Solid household waste. 2014, No. 10, P.2-11
8. Tikhotskaya I.S. Japanese innovative concept of recycling resources and creating a society with a sustainable material cycle // Regional Studies. 2015. No. 2, pp. 117-127.
9. Murzina A.I., Fedorov G. Yu. Organization of a selective collection system // A.I. Murzina. KSPEU. Bulletin of magistracy. 2015. No. 1. Volume 1. P. 32-34.
10. Abramov N.F. Prospects for selective collection of solid waste in Moscow. Clean city. M., 1998, No. 1, P.32-39.
11. Gonopolsky A.M. et al. Technology of pulp processing and removal of food waste from places of their generation // Ecology and Industry of Russia, 2014 (12). P. 4-7.
12. Klushantsev B.V., Kosarev A.I., Muizemnek Yu.A. Crushers. Design. Calculation. Features of operation.-M.: Mechanical Engineering, 1990.-320 p.
13. Kirin B.S., Klokova A.N. Modern technologies for separating plastic waste. Advances in chemistry and chemical technology. Vol.XXVIII.2014.-No.3.-P.31-33.
14. Musaev A.M., Saifulin R.G. Method, device for vibration-pulsation sorting of solid household waste//Izvestia KazGASU: Ecology in construction.2011.-No.1.-P.141-145.

15. Method of cleaning compost from municipal solid waste from ballast fractions: patent application 2004104371/Russian Federation: MPKV9/00/L.N.Reutovich, M.P. Arlievsky, N.A. Averyanova; applicant and patent holder LLC GIPROCHIM-TECHNOLOGY.-No. 2004104371/03; application 10.02.2004.-11p.
16. Method of cleaning and processing solid household waste and a complex for its implementation: patent application 200013097/13/Russian Federation: MPKV09V3/13 V.F. Reshitko, G.Yu. Zatsepina, A.A. Shashnin. V.S. Maslov, E.B. Krelman; applicant and patent holder V.F. Reshitko, G.Yu. Zatsepina. -No. 2000130971/13; application 12/14/2000.-12s.
17. Yushchenko V.B. Automated complex for processing household waste and its further use in the social sphere / V.B. Yushchenko, L.S. Grabenko // Technical sciences: theory and practice: materials of the III International Scientific Conference (Chita, April 2016). - Chita: Young Scientist Publishing House, 2016. - P. 51-57.
18. Hussein I., Abdel-Shafy, Mona S.M. Mansour.Solid waste issue: sources,composition,disposal,recycling,and valorization. Egyptian journal of Petroleum 27(2018)-1275-1290.
19. Hongmei Lu, Roman Sidortsov. Sorting a problem: A co-production approach to household waste management in Shanghai, China. Waste Management 95(2019) pp.271-277.
20. Ubaydullaev, G., Riskaliev, D., Shadiev, S., & Rasulova, D. (2023, March). Informational model of the geometric image of parts. In AIP Conference Proceedings (Vol. 2612, No. 1). AIP Publishing. https://doi.org/10.1063/5.0134626
21. 21. Tavbay Khankelov. (2022). Results of experimental studies of the process of sorting elastic components of municipal solid waste. Academic Journal of Manufacturing Engineering, vol.19, 97-102, doi: https://ajme.ro/PDF_AJME_2021_4/L14.pdf
22. Batirbay Kosimbetov, Tavbay Khankelov. (2021).Usage advanced technological methods for the recovery of cone crusher equipment. E3S Web of Conferences 264(11): 02063. CONMECHYDRO-2021,1-6, doi: https://doi.org/10.1051/e3sconf/202126402063
23. Khakimzyanov R.R. Rashidov A. Definition of Bending Moment and Curvature in the Plastic Zone of Elastic-Plastic Calculation of the Carcass Construction. ICPPMS-2021. -https://doi.org/10.1063/5.0090298
24. Khakimzyanov R., Rashidov A., Togaev A. The stress-strain state of the universal chassis of the tractor trailer in T-Flex. CONMECHYDRO 2021, https://doi.org/10.1051/e3sconf/202126402008