

**LEASECON 2020****International Conference «Land Economy and Rural Studies Essentials»****KRUTINSKY DISTRICT SOLID MUNICIPAL WASTE  
MANAGEMENT SYSTEM: INDICATORS OF SUSTAINABLE  
DEVELOPMENT**

Vera A. Khomich (a)\*, Svetlana A. Emralieva (b), Olga V. Pleshakova (c)

\*Corresponding author

- (a) Federal State Budget Educational Institution of Higher Education «The Siberian State Automobile and Highway University (SibADI)», 5 Mira Avenue, Omsk, Russia, vera\_khomich@mail.ru,  
(b) Federal State Budget Educational Institution of Higher Education «The Siberian State Automobile and Highway University (SibADI)», 5 Mira Avenue, Omsk, Russia, emralieva\_sveta@mail.ru  
(c) Federal State Budget Educational Institution of Higher Education «The Siberian State Automobile and Highway University (SibADI)», 5 Mira Avenue, Omsk, Russia, o.v.pleshakova@yandex.ru

**Abstract**

The management of municipal solid waste (MSW) is one of the central problematic issues in the development of rural areas. The system of MSW management of the Krutinsky municipal district of the Omsk region of Russia is considered, the volumes of waste in which are comparable to the volumes of other nineteen regions of the region. The problems in the functioning of the system are identified, associated with the need for containers and container sites, with the organization of waste disposal, with the formation of unauthorized dumps, with the organization of the collection of secondary raw materials. The system improvements are proposed. Estimated indicators of the development of the system are developed, based on solving problems and proposals for improving the system for the stages of collection, transportation and extraction of secondary resources. The development of the system is assessed using indicators of the performance of indicators on a 100-point scale, which is divided into numerical intervals corresponding to the levels of development of the system from low, through medium and high, to the highest. As of today, the MSW management system of the Krutinsky municipal district is at an average level of development. The sustainable development of the system will correspond to the dynamics of a constant increase in the amount of points for the performance of indicators with the transition of the system to higher levels.

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## **1. Introduction**

One of the areas of the current stage of sustainable development of rural areas is to improve the quality of life of the rural population (Boncinelli et al., 2015; Molchanenko & Shuvaev, 2014). The indicators describing the quality of life, according to their content, are divided into the quality of the environment and the standard of living. The quality of the living environment of rural residents depends on the degree of improvement of residential areas, the development of engineering and transport infrastructures, the development of a system for handling solid municipal waste (MSW) and other factors. In terms of importance among the types of work related to the improvement, sanitary cleaning of the territory from solid municipal waste takes the first place. The process of forming the living environment requires certain investments and takes years.

MSW management is one of the central problematic issues of rural development. Much attention is paid to solving these issues in cities (Esmailian et al., 2018). From modern scientific and political positions, the life support systems that determine the living conditions of a citizen should be approximately the same and not depend on the place of residence, the proximity of the territory to urban centers, the availability of resources, etc. Creation, functioning and development of modern systems for the districts will help improve the quality of the living environment of the rural population.

## **2. Problem Statement**

Municipal solid waste from rural municipalities is usually disposed of in landfills located far from residential areas, often in forested areas. In landfills, waste is incinerated, polluting all components of the environment. Rehabilitation of rural areas is an environmental problem, the solution of which includes measures for the elimination of existing landfills, the formation and development of systems for the management of MSW. The issues of monitoring and evaluating the development of MSW management systems in rural areas are poorly studied.

## **3. Research Questions**

The subject of the research is the formation and functioning of a system for handling solid municipal waste generated by municipal areas, and the assessment of the development of such systems.

## **4. Purpose of the Study**

To develop estimated indicators of sustainable development of the municipal solid waste management system of the municipal entity “Krutinsky District” of the Omsk Region of Russia, taking into account the solution of existing problems and further improving the functioning of the system for the stages of collection, transportation of waste and the extraction of secondary resources.

## 5. Research Methods

The study was carried out on the basis of the use of general scientific methods of comparative and logical analysis, data grouping.

## 6. Findings

On the basis of modern world experience, the basic principles of sustainable development of the municipal solid waste management system have been developed:

- extraction of secondary resources from waste by selective waste collection, collection of secondary raw materials and extraction of useful components from unsorted waste;
- extraction of hazardous components from waste;
- processing of waste to obtain products used in economic activities;
- reducing the amount of waste (Ferronato et al., 2018; Khan et al., 2019; Li et al., 2019; Noya et al., 2018; Starostina et al., 2018).

Based on these principles, a standard system for the management of municipal solid waste (MSW) is being created, which consists of organizational and technical, organizational-managerial and spatial-temporal components.

The functioning of the MSW management systems is presented in the schemes of sanitary cleaning of the territory of settlements (Abramov, 2007). The territorial scheme for MSW management in municipal areas contains a brief description of the area, regulatory and legal framework for MSW management, finding sources of waste generation in the district, the amount of waste generated, places of waste accumulation, facilities for processing, recycling and disposal of waste, waste transportation scheme and other information.

The organizational and technical component of a typical MSW management system includes:

1. Collection of municipal solid waste.
2. Transportation of municipal solid waste.
3. Sorting of solid municipal waste.
4. Recycling of solid municipal waste.
5. Landfill for solid municipal waste.

The development of the MSW management system is focused on reducing the amount of generated waste, as well as on recycling it instead of burying it (Pikalov, 2020; Song & Zeng, 2015; Sharp & Luckin, 2006; Subramanian, 2000; Weisman et al., 2011). When recycling, waste can be turned into fertilizers, building materials, heat energy. Waste processing is carried out at incineration plants and installations, as well as at waste processing plants.

The use of engineering structures or installations in the MSW management system (waste sorting stations, incineration plants or installations, waste processing plants or installations) is economically expedient, if they are operating at full capacity. The amount of waste supplied to the construction or installation from the territories of the municipal district must correspond to the performance of the

equipment. In this regard, the composition of the technical means of the MSW management system in the municipal district will depend on the volume of waste generated.

In the future, municipal areas with insignificant amounts of MSW will supply waste to processing plants that serve several municipal areas at once. For this, inter-municipal waste management centers should be created and inter-municipal transport schemes should function.

Forecasting changes in the volume of MSW for the future allows determining the needs for collection, transportation, storage, waste processing; that is, to ensure the planning of all indicators of the development of the municipal solid waste management system (Voronin et al., 2015).

The Omsk Region includes 32 municipal districts and the city of Omsk. The municipal formation “Krutinsky District” is located in the west of the Omsk region of the Russian Federation, it occupies 5.8 thousand km<sup>2</sup>. The Municipal Formation (MF) includes nine rural and one urban settlement—Krutinskoye—which includes the working settlement of Krutinka, which is the administrative center of the district. The names of settlements, data on the population size and the number of households in these settlements are presented in Table 1.

**Table 1.** Population and number of households in the Krutinsky municipal district

Settlement name	Population as on January 13, 2016	* Population as on January 1, 2019	No. of households as on January 1, 2019	No. of settlements
Krutinskoe	8057	7927	3069	4
Ziminskoe	1569	1495	463	5
Kiterminskoe	714	645	337	6
Novokarasukskoe	1356	1623	670	8
Oglukhinskoe	1720	1166	458	4
Panovskoe	992	1102	403	4
Ryzhkovskoe	409	542	225	4
Tolokontsevskoe	400	366	142	4
Shipunovskoe	880	1070	342	4
Yamanskoe	909	813	351	4
Total	17,006	16,749	6460	47

Note: \* population census data are provided by the administration of the Krutinsky municipal district.

MF "Krutinsky District" has a developed agro-industrial complex; the share of the food industry occupies 98% of the entire industry of the region.

The amount of solid municipal waste generated in the Omsk region in 2016 is equal to 1,158 thousand tons. The share of waste in the city of Omsk in the total volume of waste in the region was 51.74%, while in nineteen municipal districts out of thirty-two, the share of waste is less than 1%. Among them is the Krutinsky municipal district, the amount of waste of which is 4459.82 tons, which is 0.39% of the volume of all municipal waste in the region. The projected amount of solid municipal waste in 2021 will be 4572.44 tons, and 4687.9 tons in 2026. These data contradict the trend of a decrease in the population of the Krutinsky district by 1701 people by 2026 (Omsk Gubernia, n.d.).

Collection of solid municipal waste (MSW) in rural settlements of the district is carried out in bulk (individual collection using bags), and in the Krutinsky urban settlement in metal containers with a capacity of 0.75 m<sup>3</sup>. The total number of containers is 26, they are located on container sites, but not all

sites meet sanitary requirements: that is, they do not have concrete or asphalt pavement and are not fenced with curbs.

Until January 2017, the removal of solid municipal waste from the territories of settlements of the Krutinsky district was carried out by a specialized enterprise Zhilkomservis LLC on a contractual basis. Residents of the private sector refused the services of the enterprise and themselves disposed of waste on the outskirts of settlements. Thus, unauthorized dumps were formed, which were not only sources of air, soil and groundwater pollution, but also sources of infectious diseases, breeding grounds for mice, insects, and rats (Mataloni, 2016; Sliusar et al., 2015; Sliusar et al., 2016). Officially, there are 18 unauthorized landfills in the Krutinsky municipal district, which have already been closed, and their territories are subject to mandatory reclamation.

Currently, on the behalf of the regional operator Magnit LLC, which has a license to collect, transport, process, utilize, decontaminate, and dispose of waste of 1–4 hazard classes, MSW is removed by the operator MUP Vodokanal. From the territory of the urban settlement Krutinskoye, the waste is removed daily. Waste removal from the territories of rural settlements is carried out once or twice a month, which causes a large accumulation of waste at the places of their collection and turns these places into unauthorized dumps. According to sanitary rules and regulations, the period of temporary accumulation of unsorted MSW on the territory of municipalities should be from one to three days, depending on the air temperature (Tretyakov, 2020a).

Solid municipal waste is disposed of at landfills, authorized facilities with appropriate licenses. The main part of the waste is taken to the landfill located in the Krutinsky district, south of the working village of Krutinka, on the seventh kilometer of the Krutinka-Nazyvaevsk road. The landfill has been officially operating since September 2012 and has an area of 3.6 hectares. Large heaps of waste are generated in the landfill. To reduce the volume, they are set on fire. With the constant burning and smoldering of waste, a large amount of pollutants is formed, which are released into the atmospheric air, get into the soil, surface and ground waters. This landfill should also be closed, and the land on its territory should be reclaimed.

The landfill for waste disposal—LLC UK "Nazyvaevsk"—is located in the city of Nazyvaevsk, Omsk region, five kilometers from the highway "Nazyvaevsk-Gagarinka". The area of the site is about 154 thousand hectares. The polygon has been operating since the end of May 2012 and is currently almost completely loaded.

In the working village of Krutinka, there are stationary points for the collection of secondary raw materials: waste paper, scrap of non-ferrous and ferrous metals. The waste paper reception center accepts raw materials up to 30 tons per year. Three points for the reception of non-ferrous scrap and one point for the reception of ferrous metals are each capable of receiving 100 tons of raw materials per year.

In this work, numerical indicators are calculated that correspond to the stable functioning of the solid municipal waste management system in the Krutinsky municipal district for the current situation (calculations based on the population census for January 2019):

- the amount of waste generated from comfortable apartment buildings, comfortable and uncomfortable residential buildings;
- the required number of containers for waste disposal;

- the required number of container sites.

Also, a logistic scheme of routes for garbage trucks has been developed in nine rural settlements and in the Krutinsky urban settlement. The development of a system for the collection and utilization of secondary resources, which are components of MSW, is proposed.

The calculation of the annual amount of generated waste (calculation of their volume and weight) was carried out taking into account the structure of the building, and is based on the traditional regulatory approach, taking into account the number of inhabitants and the norms of accumulation of MSW, which are valid for a certain period of time and meet specific local conditions. The development structure of the Krutinsky municipal district is presented in Table 2.

**Table 2.** Structure of housing and the number of residents of the Krutinsky municipal district

Settlement name	Comfortable apartment and residential buildings		Uncomfortable apartment and residential buildings		Public buildings [pcs.]
	buildings [pcs.]	inhabitants [pers.]	buildings [pcs.]	inhabitants [pers.]	
Krutinskoe	16	934	3053	6993	84
Ziminskoe	-	-	463	1495	5
Kiterminskoe	-	-	337	645	5
Novokarasukskoe	-	-	670	1623	6
Oglukhinskoe	-	-	458	1166	6
Panovskoe	-	-	403	1102	6
Ryzhkovskoe	-	-	225	542	5
Tolokontsevskoe	-	-	142	366	6
Shipunovskoe	-	-	342	1070	6
Yamanskoe	-	-	351	813	9
Total	16	934	6444	15,815	138

MSW accumulation rates established by the regional operator Magnit LLC are: 1.44 m<sup>3</sup>/person from comfortable apartment buildings and residential buildings; 1.27 m<sup>3</sup>/person from uncomfortable apartment buildings and residential buildings; 40% of the amount of waste accumulation rates from comfortable and uncomfortable apartment buildings and from comfortable and uncomfortable residential buildings from public buildings.

The number of containers and container sites depends on the daily amount of waste generated in a particular settlement. The results of calculating the amount of waste, containers and sites are presented in Table 3.

**Table 3.** Estimated annual amount of MSW in the Krutinsky municipal district

Settlement name	MSW amount [m <sup>3</sup> ]	MSW mass [t]	Number of containers [pcs.]	Number of container sites [pcs.]
Krutinskoe	13,396.87	2143.43	73	19
Ziminskoe	2496.65	399.48	15	4
Kiterminskoe	1077.15	172,38	7	3
Novokarasukskoe	2710.41	413.07	15	4
Oglukhinskoe	1947.22	311.53	11	3
Panovskoe	1840.34	294.43	11	3

Ryzhkovskoe	905.14	144.89	6	2
Tolokontsevskoe	611.22	97.83	4	2
Shipunovskoe	1786.90	285.98	11	3
Yamanskoe	1357.71	217.24	8	3
Total	28,129.61	4480.26	161	46

According to the calculated data, the volume of waste from comfortable, uncomfortable apartment buildings and residential buildings and from public buildings formed in 2019 is 28,129.61 m<sup>3</sup>, their weight is 4480.26 tons. For waste disposal, 161 containers and 46 sites are required.

Based on the data on the required number of containers, the number of special equipment for transporting waste was calculated, the brand of garbage trucks was determined, a logistic scheme of routes indicating the duration of collection and removal of waste at each section of the route and the frequency of drives per shift was built.

The development of the MSW management system presupposes daily waste removal to the Krutinsky municipal district. In the process of developing a logistic scheme of routes for the removal of MSW, it was established that two garbage trucks of MUE Vodokanal are sufficient for transporting waste.

Garbage truck MK-20-01 (the useful body volume is 24 m<sup>3</sup>, the mass of removed waste is 4.5 tons) will collect MSW in rural settlements of the Krutinsky district, in two directions:

1) Tolokontsevo-Panovo-Zimino-Ryzhkovskoe-Yaman (the route length is 160 km, the volume of MSW removed is 19.76 m<sup>3</sup>, the weight is 3.16 tons);

2) Novokarasuk-Shipunovo-Kitherma-Oglukhino (the route length 92 km, the volume of MSW removed is 20.61 m<sup>3</sup>, the weight is 3.24 tons).

Garbage truck brand KO-440-2 (the useful body volume is 7.5 m<sup>3</sup>, the mass of removed waste is 3.12 tons) will collect and transport MSW in the Krutinsky urban settlement along 6 routes:

The development and implementation of logistic schemes for waste disposal routes will be a prerequisite for the development of MSW management systems, as they will reduce the time and financial costs for the operation of such systems.

According to the Russian policy in the field of MSW management, it is necessary to extract secondary raw materials and valuable useful components from waste. In world practice, the following methods of extracting secondary resources are known (Alyamovskaya & Nechiporenko, 2019; Lektorova et al., 2020; Molchanova, 2020; Tretyakov, 2020b).

1) The most common is the selective collection of individual components and fractions of waste in separate containers with appropriate labeling. Collected: waste paper (paper and cardboard), plastic and polymers, glass, scrap of non-ferrous and ferrous metals, textiles, leather, rubber, food waste, etc.

2) Reception and collection of secondary raw materials from the population in mobile and stationary points, transfer and accumulation of raw materials in receiving and procurement bases.

3) Extraction of recyclable components from unsorted waste at waste sorting stations.

The morphological composition of the municipal solid waste of the Krutinsky municipal district is as follows: 47.63% is waste paper; 23.69% is food waste; 3.16% is scrap metal; 3.15% is rubber; 3.67% is textiles; 1.32% is glass; 17.38% are polymeric materials.

When introducing a system for separate (selective) collection of MSW, the costs of purchasing and operating complex separation technologies are reduced; incentives are created to reduce waste. The advantages include:

- selection of valuable or hazardous MSW components;
- improving the quality of secondary raw materials;
- use of the organic component of MSW.

Waste components hazardous to the environment and human health include: unused agricultural fertilizers and pesticides, batteries, accumulators, electrical appliances, varnishes, paints, solvents, medical waste, lamps.

The drawbacks of the separate collection of MSW are:

- complication of logistics, as a result of an increase in the cost of transporting waste;
- increasing the number of containers used by installing special containers (or colored bags) at container sites for selective waste collection.

For certain types of waste, it is required to create special collection points (waste paper, glass, plastics, textiles, scrap metal). But the separation of all MSW components at the places of their formation in communal conditions is impossible or very laborious, therefore, the separation of individual fractions and components from unsorted waste is carried out at waste sorting stations.

The design of the waste sorting station includes lines with a feeding, sorting, outgoing conveyor, sorting booth, a press for recyclable materials and various separators. The materials are classified as follows: useful (for processing at enterprises); organic (for fertilizers); materials with calorific value (for fuel production); unsuitable (for burial at landfills).

The most suitable for the Krutinsky municipal district is a modern waste sorting complex with a capacity of 5 thousand tons/year. It is supposed to be located on the site of an authorized landfill after its closure and land reclamation on its territory. The creation of an intermunicipal waste management center in the future will make it possible to organize the reception of additional volumes of waste at the waste sorting station from the nearby Nazyvaevsky municipal district.

It is proposed to assess the development of the municipal solid waste management system of the Krutinsky municipal district in the near future using indicators (Merenkova, 2010; Molchanenko & Shuvaev, 2014). The performance indicators are developed based on the results of the analysis of existing problems and the proposed solutions:

1. Percentage of elimination of unauthorized landfills: the ratio of the number of eliminated landfills (waste removed, reclamation carried out) to the total number of unauthorized landfills;
2. Percentage of elimination of authorized landfills: the ratio of the number of eliminated landfills to the total number of authorized landfills;
3. Coefficient equal to the ratio of the number of containers used to their number corresponding to the volume of waste generated;
4. The level of development and implementation of a scheme for handling MSW (spatial layout of container sites, the required number of vehicles, a logistic scheme for transporting waste to the place of burial, sorting or processing, schedules for removal of MSW);



5. Coefficient showing the ratio of the number of container sites equipped with containers for separate collection of individual waste components to the total number of required container sites;
6. The level of development and implementation of a scheme for collecting secondary material resources (availability and work schedule of mobile collection points for recyclable materials, availability of receiving and storage facilities, logistic scheme for transporting compacted waste to the place of their processing, availability of facilities for processing recycled components);
7. Implementation (availability) of a waste sorting station.
8. The development of the MSW management system connects all spheres of social, environmental, economic and institutional development of rural areas at once. The proposed system of assessment indicators corresponds to the social and environmental sphere.
9. For a quantitative assessment of the development of the MSW management system, it is proposed to use a 100-point scale. Each indicator corresponds to a certain maximum number of points. The ratio between the scores and the percentage (shares) of reaching the maximum value of the indicator or part of the implementation of activities for the indicator is established using the corresponding indicators. The assessment of the development of the MSW management system in the Krutinsky district according to the system of indicators on a point scale using indicators is given in Table 4.

**Table 4.** Evaluation of the development of the MSW management system in the Krutinsky district according to the system of indicators in a point scale using indicators

Estimated indicators	Indicator	Performance scores	Maximum points per indicator
1. Percentage of elimination of unauthorized landfills	Elimination of one unauthorized dump in the municipal district out of 18	2.75 % or 1 point	9
	Elimination of rats	25 % or 4 points	
2. Percentage of elimination of authorized landfills	Extinguishing fire	50 % or 8 points	16
	Technical stage of reclamation	75 % or 12 points	
	Technical and biological stages of reclamation	100 % or 16 points	
3. Coefficient equal to the ratio of the number of containers used to their number corresponding to the volume of waste generated	Installation of 8 containers of 161 pcs.	0.05 or 1 point	20
	Availability of a spatial layout of container sites	6 points	
4. The level of development and implementation of the MSW management scheme	Availability of the required number of vehicles	6 points	24
	Availability of a logistic scheme for transporting waste to the place of their burial, sorting or processing	6 points	

	Availability of a schedule for the removal of MSW	6 points	
5. Coefficient showing the ratio of the number of container sites equipped with containers for separate collection of individual waste components to the total number of required container sites	Organization of 9 container sites of 46 pcs.	0.2 or 1 point	5
	Availability and working hours of mobile waste collection points	2 points	
6. The level of development and implementation of a scheme for collecting secondary material resources	Availability of receiving and procurement complexes	2 points	
	Availability of a logistic scheme for transportation of compacted waste to the place of their processing	2 points	8
	Availability of facilities for processing recyclable components	2 points	
7. Implementation of a waste sorting station	Waste sorting station	18 points	18
	TOTAL		100

The MSW management system in its development goes through certain levels from low, through medium and high, to the highest, by solving problematic issues and taking measures to improve the system. The system of the highest level meets the basic principles of sustainable development in the field of solid municipal waste management at the given stages of its functioning. We propose to monitor the dynamics of the development of the system by the amount of points in the system of indicators, which corresponds to one level or another:

the highest level (80 ... 100 points);

high level (55 ... 79 points);

average level (17 ... 54 points);

low level (0... 16 points).

The numerical intervals of the levels were established by means of expertly specified characteristics of measures for the implementation of indicators. As of the current state, the municipal solid waste management system of the Krutinsky municipal district is at an average level of development—the score is 25.

The sustainable development of rural areas is understood as a dynamic process of positive changes in indicators characterizing the social, economic and environmental state of rural areas (Shumakova & Rabkanova, 2014). From the standpoint of this concept, the sustainable development of the municipal solid waste management system will be responsible for the dynamics of constant growth in the value of the sum of points for the fulfillment of estimated indicators and the transition of the system to higher levels.

## 7. Conclusion

For most of the municipal districts of the Omsk region of Russia, the annual amount of solid municipal waste is less than 11 thousand tons, that is, less than 1% of all waste in the region. Such municipal districts include the Krutinsky district. Consideration and analysis of the functioning of the municipal solid waste management system of the Krutinsky municipal district allowed identifying a number of problems that negatively affect the quality of the environment and the improvement of rural residents:

- The need for containers and container sites in rural settlements;
- Removal 1–2 times a month instead of daily removal of MSW from rural settlements;
- Formation of 18 unauthorized municipal waste dumps, which are no longer operational, but the waste has not been removed from them, and their territories have not been rehabilitated;
- Waste is burnt at the only valid authorized landfill; the dump heap must be liquidated;
- Stationary points for the collection of secondary raw materials are located only in the urban settlement—the working village of Krutinka; There are no mobile points for collecting secondary raw materials in rural settlements.

For the Krutinsky district, based on the population (2019), building structure and waste generation rates, the required number of containers and container sites was calculated, a logistic scheme of routes for daily MSW removal was drawn up, proposals were made for the collection of secondary raw materials.

To assess the development of the MSW management system in the Krutinsky district, a system of assessment indicators has been developed. The content of the indicators answers: solving the existing problems of the functioning of the MSW management system and implementing the developed proposals for improving the system. Periodic analysis of the functioning of the MSW management system using the proposed system of assessment indicators, based on the results of the implementation of indicators on a 100-point scale, will allow assessing positive changes in the system and determine the sustainability of its development, as well as identifying shortcomings and lags in the actions of municipal authorities. The developed system of indicators meets the stages of collection, transportation and extraction of secondary resources from MSW.

The next stage in the development of the MSW management system—the waste processing stage—refers to the period of changes in the organizational and managerial component of the MSW management system, the creation of inter-municipal waste management centers, so it will be characterized by a different set of estimated indicators.

Conclusions:

1. The problems of the municipal solid waste management system of the Krutinsky municipal district, connected with the need for containers and container sites, with the organization of waste disposal, with the formation of unauthorized dumps, with the organization of the collection of secondary raw materials were identified.

2. Proposals have been developed for the development of a municipal solid waste management system for the Krutinsky district: arrangement of containers and construction of container sites, introduction of logistic schemes for waste transportation routes, separate waste collection, purchase of

mobile points for collecting recyclable materials in rural settlements, construction of a waste sorting station.

3. A system of estimated indicators of sustainable development of the municipal solid waste management system of the Krutinsky municipal district has been developed for the stages of collection, transportation and extraction of secondary resources. The assessment is carried out on a 100-point basis using indicators of performance indicators.

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