Reducing economic costs through innovations in resource management

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Abstract. The article is aimed at introducing innovative technologies in the field of waste management, additional infrastructural development of the waste disposal and recycling network, increasing the interest of the population in improving the quality of life through direct participation in reducing the negative impact on the environment, increasing the comfort of the urban environment. Problems of solid waste management are at the epicenter of the state's attention and are interdisciplinary in nature. However existing methods for solving them are not enough to maintain the comfort and safety of the urban environment. Combining the efforts and resources of society through crowdfunding platforms in the search for more effective and safe ways of waste disposal opens up new opportunities for increasing the economic efficiency of waste disposal, developing the environmental responsibility of the population, and strengthening the potential for the utilization of recycled waste.

1 Introduction

Waste management, eliminating accumulated negative harm to the environment, building an effective system for the collection and disposal of solid household waste are becoming an increasingly pressing problem for states and affects every person in the world. The volume of waste produced by the population continues to grow every year, and its non-ecological disposal and storage make a detrimental effect on soil, ground and surface water, atmospheric air, and negatively affect people's health. The problem of waste management is most acute in large cities and adjacent areas, which significantly reduces the level of comfort of the urban environment. A poorly functioning solid waste management system requires urgent action at all levels of society.

Every year, the world generates about 2.01 billion tons of solid waste, of which approximately 33% is untreated. It is expected that by 2050 the volume of municipal solid waste generated will be 3.4 billion tons [1].

In current realities, the formation of a comfortable urban environment for their residents in all its aspects, including in the field of solid waste management, is becoming increasingly important for the "survival" of cities [2,3]. According to a number of experts [4], the resilience of a city is determined by its ability to take into account, withstand and overcome the consequences of economic, environmental, political and other crises, adapt to changes, formulate strategies to prepare for possible crises in the future, ensure sustainable

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development and well-being of the population - maintain competitiveness of the cities at all stages of global and local life cycles. The essence of the urban environment in the context of the requirements of sustainable development requires expanding the focus from “person” to “society”.

The creation and application of effective mechanisms for the direct participation of citizens in the formation of a comfortable urban environment, combining the capabilities of innovative and digital technologies, will direct the efforts of society towards creating more environmentally friendly living conditions.

This article proposes possible options for introducing local processing technology (hereinafter referred to as TLP) of the organic fraction of municipal solid waste. The option of introducing TLP by combining the efforts of society through crowdfunding platforms is considered in detail, the calculation and analysis of the result is given, options for the possible implementation of TLP are proposed when modeling territorial waste management schemes; the impact of reducing the volume of removal of municipal solid waste due to the processing of their organic part in the places of generation on the reduction of greenhouse gas emissions into the atmosphere was assessed.

2 Materials and methods

Russian legislation in the field of waste management has a multi-level system: it is based on the Constitution of the Russian Federation and international agreements, includes Federal Laws of the Russian Federation, Laws of the Russian Federation, Decrees of the President of the Russian Federation, Decrees of the Government of the Russian Federation, GOST R standards and inter-industry norms, regional laws and norms, industry-specific normative and methodological documents, municipal regulations, programs and requirements.

According to the Federal Law of June 24, 1998 No. 89-FZ “On Production and Consumption Waste,” waste is considered to be substances or objects generated during the production process, performance of work, provision of services or during consumption that are subject to disposal. Waste is classified according to the following criteria: state of aggregation (solid, liquid, gaseous), origin (industrial and domestic), composition (biological and man-made waste) and potential of recycling (recyclable and non-recyclable waste). Solid waste is divided into two groups: solid production waste and solid consumption waste. Consumption waste in turn divided into industrial and household.

Solid household waste (hereinafter referred to as SHW) includes municipal solid waste (hereinafter referred to as MSW), which is generated in residential premises during consumption by individuals, as well as goods that have lost their consumer properties during their use by individuals in residential premises for the purpose of satisfaction of personal and household needs. MSW includes organic waste, plastic, paper and cardboard, glass, textiles, wood, metal and others [5].

The State Program “Environmental Protection” has been approved in the Russian Federation. National project "Ecology", Federal projects “Clean Country” and “Integrated Municipal Solid Waste Management System” and others are being implemented. The Industry Development Strategy for the processing, recycling and disposal of production and consumption waste for the period until 2030 was approved.

Every year, a huge amount of organic waste is sent to landfills for direct disposal (without sorting). In 2023, 49.93 million tons of MSW were produced in Russia, of which organic waste makes up about 18 million tons. Due to the fact that Russia has not yet developed an effective system for separating MSW with the release of the organic fraction, it is not possible to estimate the amount of organic waste more accurately .

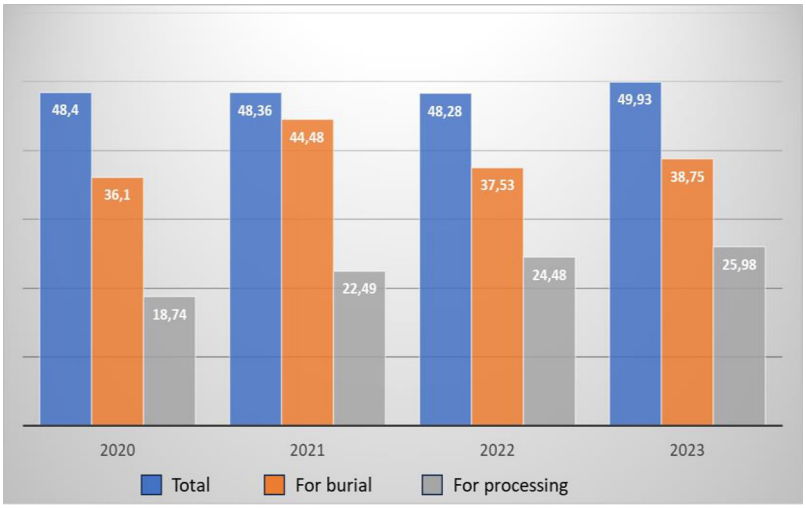

Fig. 1. The amount of generated municipal solid waste sent for disposal and processing (million tons per year)

According to Rosstat, in 2023, the share of waste allocated for disposal as a result of separate accumulation and processing (sorting) of MSW in the total mass of generated MSW was 13%.

In assessing the amount of MSW generated in different countries, the generally accepted approach is based on expert assessments, according to which the overall volume of MSW per capita in China is 0.43 kg/day, of which 53% is organic waste (0.23 kg/day); in Germany - 1.72 kg/day, of which 36% organic waste (0.61 kg/day), in Russia - 1.13 kg per day (412.5 kg/year), of which 36% organic waste (0.407 kg/day, 148.6 kg/year).

In accordance with the Methodological Recommendations for Conducting a Voluntary Inventory of Greenhouse Gas Emissions in the Subjects (constituent entities) of the Russian Federation, similar values are used in calculating greenhouse gas emissions when disposing of municipal solid waste in landfills and dumps during combustion and biological processing (including composting).

Sources of funding Federal projects “Clean Country” and “Integrated municipal solid waste management system" are federal budget funds, including interbudgetary transfers, consolidated budgets of constituent entities of the Russian Federation, extra-budgetary sources. Investments in fixed assets, in terms of waste collection, processing and disposal, are largely carried out at the expense of organizations' own funds. Funds from local budgets and environmental funds are not involved in this financing system. Therefore, they have resources to support environmental initiatives of citizens and improve the environmental situation in the cities.

3 Results

3.1 Models for financing the use of innovative technologies for local processing of solid waste

The term “crowdfunding” (from the English word - crowdfunding, crowd – “crowd”, funding – “financing”) first introduced by Jeff Howe in 2006 [6] and is a mechanism for voluntary financial participation of the public in solving problems of innovation, implementation of creative initiatives and new projects.

In order to make a decision on attracting a crowdfunding mechanism for the implementation of infrastructure, including environmental projects, an integrated approach is required, including the use of financial, information, innovative, digital technologies and legislative initiatives aimed at regulating the activities of crowdfunding platforms and the area of MSW management [7].

This article discusses an example of the use of crowdfunding investments in the implementation of an environmental project for local processing of the organic fraction of municipal solid waste generated in the urban environment.

The possibility of receiving reimbursable financing (monetization) from investments in a project with crowdfunding financing confirms its investment focus, but does not exclude its charitable role [8].

Together with crowdfunding, it is possible to use municipal private partnership mechanisms, such as a concession agreement, to solve environmental problems. In accordance with Article 4, paragraph 1, sub-paragraph 17 of the Federal Law of July 21, 2005 No. 115-FZ "On Concession Agreements", the objects of the concession agreement may also be: facilities where processing, accumulation, disposal, neutralization, and placement of solid municipal waste are carried out.

For the first time, with the release of Federal Law No. 259-FZ of August 2, 2019 "On attracting investments using investment platforms and on introducing amendments to certain legislative acts of the Russian Federation," the implementation of crowdfunding projects became possible in the Russian Federation. The activities of investment platforms to attract alternative financing to projects are possible only for legal entities or individual entrepreneurs to whom the operator of the investment platform provides services to attract investments, and other citizens who do not have the status of an individual entrepreneur can only be investors with an investment limit of up to 600 thousand rubles, but they cannot act as persons attracting investments. In 2023, according to information from the Russian Ministry of Economic Development, 11companies operating investment platforms were selected, with the help of which small and medium-sized businesses can attract investment in their projects and receive compensation for the platform's services.

According to the Bank of Russia, the volume of the domestic crowdfunding market in 2015 amounted to 1.5 billion rubles; in 2016 - 6.2 billion rubles; in 2017 - 11.2 billion rubles, in 2018 - 11 billion rubles; in 2019 - 7.1 billion rubles, in 2020 - 7 billion rubles.

To attract charitable funds for the implementation of private projects in various fields of activities, the most popular platforms in the world are: **«Kickstarter»** in the USA, «**Betterplace»** in Germany, «**Respect»** in Austria, «**dobro»** in Russia, «**Taobao Zhòngchóu»** in China. In these public areas, as a moral satisfaction, the sponsor can receive a non-financial reward, for example, a mention of his name on the site or points that increase his social rating. It should be noted that foreign private investors more often direct funds into the field of gaming and media technologies, design projects, while domestic ones are aimed at developing socially significant and charitable projects.

In 2022, for the first time in Russia, the Interregional Environmental Public Organization "ECA" implemented environmental projects involving crowdfunding investments. With the participation of the ECA movement, the following projects were developed and implemented: cleaning of forest areas; release of fry into rivers to restore the population of valuable fish species; construction of eco-trails; organization of yard environmental holidays with separate collection of recyclable materials; cleaning of coastal areas of Russian rivers and others [9].

Projects implemented within the framework of the above-mentioned ECA movement are aimed at increasing environmental awareness and public interest in solving environmental problems. However, they do not carry specific models capable

systematically influence the state of the environment and contribute to solving current environmental problems.

3.2 An example of the implementation of a crowdfunding project in the field of management of solid household waste

To calculate the TLP crowdfunding project, equipment produced by the South Korean company GAIA was used. GAIA equipment in Russia is included in the information and technical directory on the best available technologies - ITS 15-2021 “Waste disposal and utilization”. The equipment uses technology for drying organic waste in a closed circuit.

Various modifications of the equipment under consideration can process from 20 kg to 100 tons or more of organic waste in a cycle. The duration of a full cycle is 12 hours. The equipment operates autonomously without stopping, is connected to a public or private electrical network, and is installed indoors or in open areas with temperatures above 0ºC without exposure to weather conditions. During the processing process, organic matter is crushed, sterilized and dried to 80–90% [10]. The result of processing is a dry organic product that can be used as organic fertilizer, preparing pet food or as biofuel, etc. No foreign odors are emitted during operation of the equipment.

The following can be considered as possible options for financing the purchase and installation of innovative equipment with TLP for processing the organic fraction of MSW on the territory of residential complexes, residential settlements, micro districts, districts and individual households:

1. Purchase and installation of equipment at the initiative of citizens through crowdfunding investments using digital technologies of crowdfunding platforms. At the same time, residents can benefit from environmental waste disposal in the form of using the final product of processing or its monetization, and also increase their reputation for environmental behavior.

2. Purchase and installation of equipment at the expense of municipalities and management campaigns. In this case, municipalities and management companies save significant money by reducing the volume of MSW removal, and effectively organized sales of the finished product have the opportunity to recoup the costs incurred over time.

3. Purchase and installation of equipment with government support, using financial mechanisms of the municipal private partnership, such as concession agreements. In this case, state support may be an incentive to change approaches in the formation of new territorial schemes of the solid waste recycling and systematically influencing the ecology of the urban environment. It is also possible to make changes to the tariffs for garbage collection in houses using TLP.

4. The purchase and installation of equipment at the expense of a private investor gives the sponsor the opportunity to demonstrate his commitment to environmental behavior, become an example for his neighbors, as well as the opportunity to benefit from the sale of the finished product or its use.

One of the ways to motivate residents to install and use such equipment is to connect an electronic card system. For example, to receive a direct refund or identify residents to accrue points and convert them into reputation indicators.

For evaluation calculations, a multifunctional residential complex (MRC) with the number of households of 500, 1,000 and 2,000 units was taken. The volume of generated MSW was calculated based on the assumption that each household has 2 people.

Table 1. Amount of municipal solid waste produced by MSW kg/day

Number of households (units)	500	1 000	2,000
Number of residents (persons)	1 000	2,000	4,000
Average amount of MSW generated (kg/day)	1.13		
Total amount of MSW from households (with 2 people) in kg/day	1 150	2 260	4,520
Of which 36% organic waste (kg/day)	406	813.6	1 627

Having studied the technical parameters of GAIA's equipment, the most suitable installation for use in an Youth Residential Complexes – MZhK with (a population of 500 households is an installation with a waste processing volume of 100-200 kg/cycle. For MZhKs with a large number of residents, several such installations will be required, or an installation capable of processing a larger amount of organic waste.

With an installation cost of 18 million rubles. (in prices of the 1st quarter of 2023), the share of financial participation of each household in the MZhK amounted to 36,000 rubles. Consequently, with the feasible participation of MZhK residents, it is possible to carry out local processing of all generated organic waste. Of course, the solution to this problem depends on the degree of interest of residents and their desire to follow environmental principles of behavior in society.

The introduction of a system for recycling the organic fraction of MSW will significantly improve the sanitary and epidemiological situation in places where people live. The use of the final processed product is an additional bonus for residents, who can use it to enrich the soil under green spaces in their local areas, or, with the participation of the management company, receive income in the form of a financial reward for the sale of the final processed product.

The introduction of local organic waste processing technology into the solid waste disposal system will lead to: a reduction in the volume of solid waste removal, will reduce the processing time of other fractions of solid waste, will increase the efficiency of their disposal and processing processes, will reduce the volume of organics in landfills and dumps and will reduce greenhouse gas emissions into the atmosphere.

The author conducted a computational experiment to assess the impact of reducing the volume of MSW removal on reducing greenhouse gas emissions. Due to the fact that the decomposition of organic matter (composting) is a natural process, the release of greenhouse gases as a result of its decay is not taken into account in the emissions structure (except for landfills). It is possible to assess the reduction in greenhouse gas emissions indirectly by reducing the use of specialized vehicles (garbage trucks).

The calculation of greenhouse gas emissions was carried out in accordance with the Methodological Recommendations for Conducting a Voluntary Inventory of Greenhouse Gas Emissions in the Subjects of the Russian Federation.

Calculation of CO2, CH4, N2O emissions using the formula:

$$E_{CO2,CH4,N2O} = \sum_{a} A\,D_a * EF_a\text{right},$$

where:

$E_{CO2,CH4,N2O}$– CO2, CH4, N2O emissions (kg);

ADa – data on fuel consumption (TJ);

EFa – recommended emission factor for fuel (T/TJ).

An experimental calculation of emissions was carried out for Moscow, based on the number and analysis of the movement of ZIL garbage trucks running on gasoline (on the route 12 hours per shift, moving at an average speed of 17 km/h). Average fuel consumption, taking into account the cost of operating equipment, is on average 37 liters per 100 kilometers. The average density of gasoline is 0.735 g/cm3. The conversion factor

for natural units into energy units for gasoline is 43.67. The CO2 emission factor for gasoline is 69,300 kg/TJ. The estimated mileage of one garbage truck per day is 204 km. Under given initial conditions, the fuel consumption of one garbage truck per shift is 0.055 tons.

The number of garbage trucks in Moscow is 1615 units. (according to the main waste collection companies: MKM-Logistics LLC, Ecoline Group of Companies, Charter LLC, MSK-NT LLC and Spetstrans Group of Companies).

Gasoline quantity for all garbage trucks: $1615 * 0{,}055 \approx 0{,}088\ ht.t.$

Conversion of natural units into energy units: $43{,}67 * 0{,}088 \approx 3{,}84$ ht. jls

CO_2 emissions:

per day: $69300 * 3{,}84 = 266112\ kg. \approx 0, ht.t.$

per year: $0{,}266 * 365 \approx 97{,}1\ ht.t.$

CH_4 emissions:

CH_4 emission factor – 3.0 kg/TJ.

per day: $3{,}0 * 3{,}84 \approx 0{,}012\ t.$

per year: $0{,}012 * 365 \approx 4{,}38$ t.

N_2O emissions:

N_2O emission factor – 0.6 kg/TJ.

per day: $0{,}6 * 3{,}84 \approx 0{,}002\ t.$

per year: $0{,}002 * 365 \approx 0{,}73$ t.

Calculations have shown that it is possible to reduce greenhouse gas emissions from specialized vehicles by reducing the volume of solid waste removal, operating time and fuel consumption. Table 2 presents the calculation results. Currently, 100% of MSW is taken to landfills. By reducing the volume of MSW removal due to the introduction of local processing of the organic fraction by 36%, CO2 emissions will decrease by 35 thousand tons, CH4 by 1.57 tons, N2O by 0.26 tons; with a reduction in the volume of MSW removal by 60%, CO2 emissions will decrease by 58.26 thousand tons, CH4 by 2.62 tons, N2O by 0.44 tons per year.

Table 2. Reduction of greenhouse gas emissions from specialized vehicles by reducing the amount of exported MSW (tons/year)

Emission volume / Volume of MSW removal	100 %	with a decrease in export by 36%	with a decrease in export by 60%	Δwith a 36% reduction in exports	Δwith a 60% reduction in exports
	1	2	3	4=1-2	5=1-3
CO2 – thousand tons	97.1	62.1	38.84	35	58.26
CH4 – tons	4.38	2.81	1.76	1.57	2.62
N2O – tons	0.73	0.47	0.29	0.26	0.44

4 Discussion

A computational experiment on the introduction of local processing of organic waste in places of generation showed that it is possible to reduce greenhouse gas emissions by reducing the volume of MSW removal, which will also rid landfills and dumps of fetid, rotting organic matter. Therefore, greenhouse gas emissions at landfills will be reduced.

With the introduction of local processing plants for organic waste, the amount of exported MSW should be reduced by more than 30%, therefore, garbage trucks will only remove solid municipal waste that is not subject to decomposition and rotting. It will practically become easier to separate MSW into types of waste that are easier to remove, process and recycle. The weight of MSW will decrease due to the separation of the heaviest

fraction with a high moisture content. MSW can be collected once every two days in areas where a small population lives.

The introduction of equipment for local processing of the organic fraction of MSW into territorial waste management schemes is feasible, both in small MZhKs and in urban areas and entire cities. An example of this is the city of Shanghai (PRC). Local administrations that manage companies are working to introduce such innovative technologies into the urban environment. In China, municipal sanitation departments are responsible for the collection and disposal of household waste (including organic waste, food waste), and municipal trade bureaus are responsible for the collection and disposal of recyclable waste. Centralized collection of waste from households is carried out by management companies, which not only control waste containers, but also monitor the quality of waste sorting by residents. Also, it is the responsibility of management companies to inform residents about the rules for waste sorting [11].

The production of such domestic installations using technology for drying organic waste in a closed loop could reduce the cost of purchasing equipment and contribute to their wider use among the population.

To implement the technology for local processing of the organic fraction of MSW, an integrated approach is required using innovative, informational, stimulating, organizational technologies. The initiative must be supported by financial and digital technologies. The successful implementation of TLP depends on the quality of the applied waste separate collection system and the awareness of the population, to support which it is necessary to use control and supervisory technologies (monitoring, inspection, fines).

5 Conclusion

The introduction of a crowdfunding investment mechanism in projects aimed at improving the environmental situation in the field of collection, disposal and processing of solid municipal waste using innovative technologies for local processing of organic waste can help and attract the maximum range of investors and provide support for the project at an early stage of implementation. Crowdfunding investment can be a promising model for financing the development of new innovative domestic equipment for processing organic waste and its implementation in territorial recycling schemes.

The crowdfunding investment mechanism allows to combine voluntary donations and investments from citizens, legal entities, as well as local budget funds aimed at implementing environmental projects, including in order to improve the comfort of the urban environment. Crowdfunding is a universal and convenient way to comprehensively finance projects [12].

In this connection, there is a need to create convenient investment platforms that have the ability to combine the financial resources of all participants interested in the implementation of the project: charitable funds, investments of citizens and legal entities, budget funds. An integrated approach to financing environmental projects using the crowdfunding mechanism will unite and direct the efforts of society and the state to solve pressing environmental problems in the field of municipal solid waste management, will provide each person with the opportunity to influence the increase in the level of comfort of life, the state of health, and will also stimulate the development of citizen initiatives.

Crowdfunding has great potential in the implementation of environmental projects, and the creation of convenient crowdfunding platforms in the Russian Federation will help to involve a larger number of participants in the implementation of environmental initiatives. Performance indicators and effective implementation of the potential of crowdfunding will increase the qualitative and quantitative socio-economic indicators of the development of the state and individual cities.

The introduction of new technologies, stimulation of the development and use of domestic equipment for the processing of organic household waste, the use of crowdfunding investment methods for this, together with government participation, is a promising direction for the implementation of environmental projects that systematically affect the improvement of the environmental safety of the population and the improvement of the urban environment.

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