System-logistic Approach in the Field of Recycling of Municipal Solid Waste in the Chuvash Republic

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Keywords: Solid Municipal Waste, Separate Waste Collection, Processing of Solid Municipal Waste, Logistics Principles, Placement of Waste Processing Enterprises.

Abstract: Obsolete approach to solid municipal waste management (SMW) prevails in the regions of the Russian Federation, among others including the Chuvash Republic. The existing way of SMW disposal at landfills virtually with no preliminary waste classification and sorting results in a plethora of environmental and economic costs, thus demonstrating gross inefficiency. The goal of the article is the scientific substantiation for the ideal placement of waste recycling plants in the regions of the Chuvash Republic using the method of multi-criteria optimization. Fundamental and applied works of Russian and foreign experts in the field of arrangement of social and economic systems of solid municipal waste management, system-oriented analysis, empirical observation, description and generalization, ranking method made up the methodological basis of the study. To resolve the issue of ideal placement of waste recycling plants in the regions of the Chuvash Republic, multi-objective optimization problem was estimated. As a result of the estimate, five districts were identified for the placement of waste recycling plants - Cheboksary, Kanash, Alatyr, Yadrinsk, and Kozlovsk. The bottom line is that for purposes of optimization of transportation costs, it is advisable to place would-be waste recycling plants in the Cheboksary, Kanash, Alatyr, Yadrinsk and Kozlovsk Districts of the Chuvash Republic. The suggested method of multi-objective optimization to determine the placement of waste recycling plants can be used to plan the placement of waste recycling plants in other regions or Federal districts.

1 INTRODUCTION

In the regional economic activity, the solid municipal waste (SMW) disposal presents a serious problem, calling for urgent solutions.

The regional, municipal authorities and public service providers, as well as researchers, must ensure possible harmless emission processes and more complete use of all waste. The problems of SMW disposal are difficult to solve, as there is no a system for the rational separation of various types of waste into useful components and an insufficient amount of waste processing enterprises in the regions. The purpose of this article is to substantiate the optimal placement of (future) waste processing enterprises in the Chuvash Republic districts using the multi-objective optimization method, when the center of gravity between the population, the generated waste volume and the distance to neighboring large settlements is determined to locate the optimal centers for processing enterprises. At the same time, this method can be used to solve the problem of the optimal distance of waste removal from its generation site to its processing site. Waste processing enterprises will make it possible to provide permanent jobs for the population in the region. Recyclable materials contribute to resource saving, solutions to environmental and safety issues to a certain extent. This article can be of practical significance to entrepreneurs to provide a place and optimal location for an enterprise and its infrastructure.

The current situation in our country in the SMW collection and disposal management causes dangerous environmental pollution, irrational use of natural resources, and serious economic damage; it presents a real threat to the health of modern and

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future generations of Russians. Balanced ecological and economic regional development is analyzed in many works of Russian scientists.

O.P. Litovka and M.M. Fedorov emphasize the need to form environmental and economic relations in the region. This system of interrelations can act as the initial stage of a biosphere-compatible process within the framework of global regional development (Litovka and Fedorov, 2007).

Scientists register an increase in natural disasters from 2000 to the present, resulting in significant costs of material and human resources to eliminate the consequences of environmental disasters (Minakova and Kovarda, 2012).

One of the recognized indicators of sustainable development is ecologically adjusted GDP. Experts also propose to switch to ecologically adjusted GRP to demonstrate a decrease in the Human Development Index in depressed regions in terms of ecology (Ryumina, 2013).

Private investments of big companies contribute greatly to balanced ecological and economic regional development, especially in conditions of insufficient budget funds (Uskova and Razgulina, 2015; Malysheva, 2019, 2020).

Today the moment has come when from separate individuals it is possible to "assemble" a society capable of being post-industrial (Shishkin, 2012).

The regulation mechanisms in SMW management area were studied by S.N. Bobylev, A.M. Gonopolsky, A.V. Ivanov, A.M. Malinin et al.

In the modern world, economic growth results in the environmental pollution, depletion of resources, climate change and human health deterioration (Bobylev and Zakharov, 2011).

The ideology of SMW management shall imply the formation of a full cycle of its collection, transportation and processing within the network of logistics centers (Gonopolsky, 2011).

At the same time, SMW management was least affected by market relations: lack of competition, reasonable tax policy, residual financing and costly tariff formation (Ivanov, 2009).

In cities, construction waste often exceeds the volume of generated SMW, therefore it is necessary to provide for SMW joint disposal and construction waste using an interterritorial component (Malinin et al., 2010).

The issues of program development for the solid municipal waste management are studied in the works of A.K. Golubin, V.V. Devyatkin, L. Ya. Shubova et al.

Along with conventional SMW management measures, scientists recommend alternative methods: separate waste collection, reuse of garbage, reuse of household items (Golubin and Maksimovich, 2011).

The waste management economics in Russia is in a rather poor state, SMW operations are unprofitable, therefore it is necessary to strengthen the state policy in this area (Devyakin, 2009).

As the experience of different countries shows, there is no universal method of SMW processing. But the rational sorting of MSW serves as a unifying element in the process of complex waste processing (Shubov et al., 2011).

Foreign authors define SMW as waste, with its collection, transportation, and disposal performed by the municipality (R. Baudry).

Foreign studies also describe that the average rate of SMW generation in high-income countries is about six times higher than in low-income countries (Wilson, 2015).

The most effective method of SMW sorting by sorting percentage is a secondary collection in different containers (65%), sorting at waste sorting stations (30%), then a collection of components at SMW secondary collection points (10%). Separate collection of recyclable materials is one of the key measures in waste management; in some cases, the reception of recyclable materials from the population can be organized through collection points for recyclable materials. Foreign experience demonstrates that the proper organization of waste processing makes it possible to use up to 90% of SMW recycling products for the construction industry (Lowe and Whitman, 2009).

2 RESEARCH METHODOLOGY

In the Russian Federation regions, various approaches are applied to SMW integrated management. In regions and cities with a high population density and standard of living, waste incineration plants, waste sorting lines, and waste transfer stations are included in the waste management chain.

Since January 1, 2019, a new SMW management system has been introduced in our country, it provides for a change in the principles and mechanisms of waste collection, sorting, processing, and disposal. The Russian Federation regions received the right to appoint operators to deal with the complete chain of solid municipal waste collection and disposal from a garbage can to a special landfill.

In the Chuvash Republic, a territorial scheme for SMW management was also established by Order of the Ministry of Natural Resources and Ecology of the Chuvash Republic No. 1036 dated September 22,

2016. As part of the transition to a new system for solid municipal waste management, on April 27, 2018, in the Chuvash Republic, an agreement was signed on the organization of activities for solid municipal waste management between the Ministry of Construction, Architecture, Housing, and Communal Services of the Chuvash Republic and LLC MVK Ekotsentr.

Since on January 1, 2019, in the Chuvash Republic the regional operator represented by LLC MVK Ekotsentr was appointed, but it has not yet started operations due to the insufficient number of waste trucks and container fleet, the existing system of SMW collection and disposal operates according to the previous scheme. The SMW management chain in the Chuvash Republic can be described as follows (see Fig. 1):

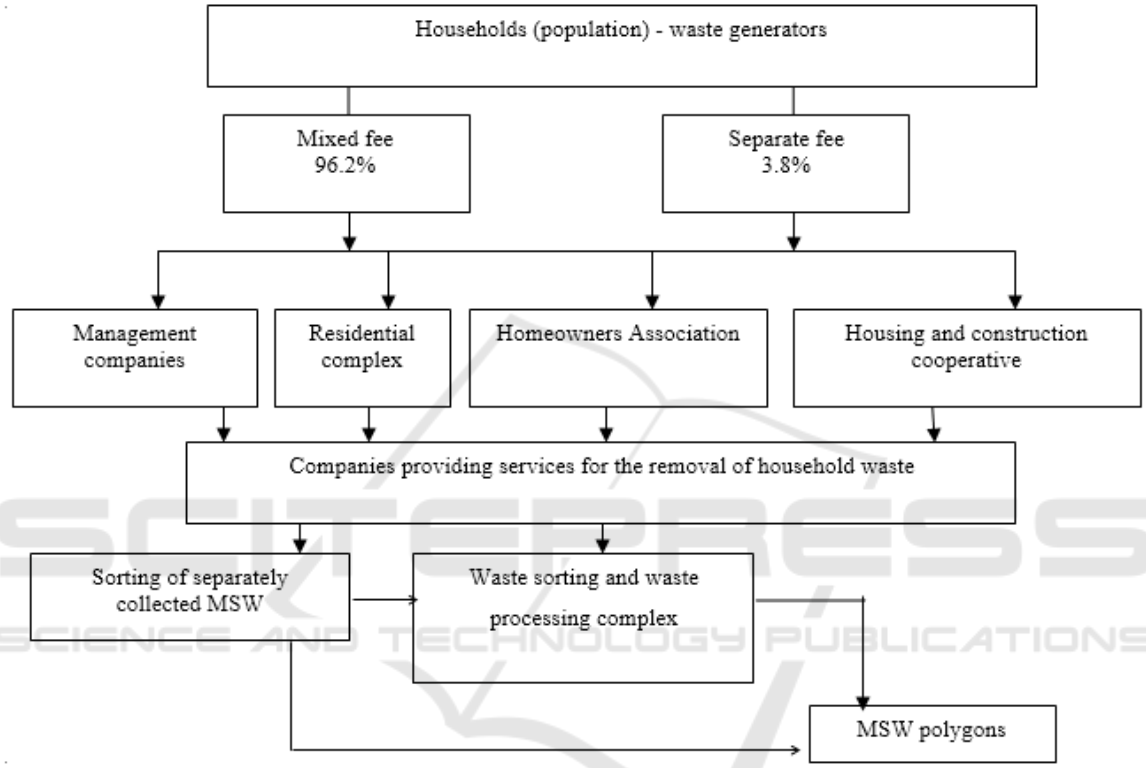

Figure 1: The existing system for the collection and disposal of MSW in the Chuvash Republic.

At present, all operations with waste in the republic are arranged according to the municipal principle, with low values of economic efficiency, environmental friendliness, and, in fact, in the absence of sorting. SMW sorting is performed only in Cheboksary and Novocheboksarsk. In the city of Cheboksary, the introduction of the separate waste collection began 10 years ago. Containers for paper, glass, plastic, and organic matter appeared in many courtyards. However, the waste separate collection came to nothing soon. Today you can see special waste containers in Guzovsky Grove, in the Shupashkar Park behind the Tractor Builders' Palace of Culture, in the “Lakreevsky Forest” recreation park, and in some school grounds. There are practically none of them left in courtyards. The situation seems to be even worse in comparison with other regions. In the Greenpeace ranking, where the situation in 106 Russian cities was analyzed, Cheboksary took the 80th place. According to environmentalists, only 3.8% of Cheboksary residents can use bins for separate waste collection near their homes (A. V. Boytsova).

In the Chuvash Republic municipalities, SMW is accumulated at the sites of specialized containers and bunkers. Moreover, bagged waste is stored either on established or arbitrary street sites, or near yard farms to be collected by a waste truck.

In municipal districts of the Chuvash Republic, container sites are not sufficient or absent at all. At the same time, in some settlements, containers for SMW accumulation were established. In these situations, the most effective way of organizing MSW accumulation sites in such settlements was to arrange

SMW accumulation sites in bags (other containers) in one designated place for the whole settlement. Using this method of accumulation, solid municipal waste shall be transported to their placement site by loading them in bulk, often by non-specialized transport.

An example of a container-free accumulation system for the whole administrative district of the republic is the Yalchevsky District; there are no container sites on its territory, the waste accumulation, and transportation from the population in all nine rural settlements is carried out according to the schedule and in bags. There is no container accumulation on the territory of Alikovsky District. Poretsky District can serve as an example of a poor organization of SMW accumulation system; on average, in each settlement out of eleven (i.e., with the exception of the Poretsky rural settlement, providing 35 0.75 m3 containers), there is currently one container. There is a selective system of waste containers in Kozlovsky District settlements. Thus, a number of settlements have neither installed containers nor arrange sites for the SMW accumulation. In general, both a containerized and bulk SMW accumulation system is used in the district. Also, the method of waste accumulation is applied individually in each farm with further transportation to waste disposal sites using tractor equipment.

These circumstances demonstrate the existing problem of the organized collection and accumulation of solid municipal waste, both in many rural settlements as a whole, or even throughout the entire municipal district of the republic.

In total, the region has 12 landfills for waste disposal. In the Chuvash Republic, there is one SMW processing and disposal SMW, built by the efforts of Waste Management JSC in 2015 under a concession agreement with the Cabinet of Ministers of the republic. The complex consists of a waste disposal landfill (at least 200 thousand tons per year), waste sorting and waste processing complexes with a capacity of at least 150 thousand tons per year. The amount of investment in the construction of these facilities amounted to 1.45 billion rubles. The waste sorting station is capable of separating waste into more than 20 types of recyclable materials. So far, this is the only such facility in the Chuvash Republic.

Thus, at present, on the Chuvash Republic, territory, there are not enough facilities for processing, recycling waste, as well as facilities that dispose of waste in accordance with the requirements of the legislation of the Russian Federation in the field of environmental protection. It can affect the environmental condition in the Chuvash Republic and the formation of unauthorized dumps. Also, due to the insufficient number of waste disposal facilities included in the SRWDS (the State Register of Waste Disposal Sites), waste from some municipal areas is transported to other areas of the Chuvash Republic, resulting in a rapid overflow of existing waste disposal facilities.

Commercial fractions of production and consumption waste (paper, cardboard, metal, plastic, etc.), as recyclable materials, are mainly exported from the Chuvash Republic territory. It is related to the absence of enterprises that process or dispose recyclable materials in the republic.

The development of waste processing production in the republic will significantly reduce the export of recyclable materials outside the republic, increase the employment of population and improve the environmental situation in the Chuvash Republic.

In these conditions, it seems relevant to study the issue of building new waste processing enterprises in the Chuvash Republic. The author considers it necessary to radically revise the territorial scheme of SMW circulation in the Chuvash Republic in favor of waste processing companies. The separate waste collection at their generation sites will make it possible to reduce tariffs for residents of the Chuvash Republic.

Waste processing enterprises shall be located closer to the settlements with the highest population and, accordingly, where more waste is generated. It is possible to solve similar problems using multi-objective optimization methods. In this case, the so-called “ideal point” method should be used (G.L. Brodetsky, 2010).

The following optimization criteria were initially defined:

- average distance to neighboring district centers, from where waste is removed (km);
- population of nearby settlements (thousand people);
- mass of waste, generated in the settlement (tons/year).

The distances were determined based on the Autodispatcher automobile portal of cargo transportation, the population size and the mass of generated waste were taken according to statistical data. To calculate the “ideal point”, the best distance value is the minimum - 34.5 km, and in terms of population and waste size - the maximum values, 273 479 thousand people. and 145,383 tons/year, respectively.

Then, for each parameter, the sum of deviation squares (Li) was determined:

$$Li = \Sigma(Ni - Nip)^2 \quad (1)$$

where Li is the sum of deviation squares of parameter indicators;

Ni is the individual parameter indicator;

Nip is the indicator value at the “ideal point”.

Then the distances of each individual indicator to the "ideal point" were identified:

$$Ri = \sqrt{Li} \quad (2)$$

where PiPiRi is the distance of each individual indicator to the "ideal point".

The final stage of calculations was the ranking of indicators in ascending order of values. It is preferable to locate future waste processing plants in areas with the shortest distance to the “ideal point”.

3 RESEARCH RESULTS

The calculation results for the Chuvash Republic districts are presented in Table 1. The cities of Cheboksary and Novocheboksarsk, as well as the Cheboksary district, are excluded from the list of Table 1 since a waste sorting and processing complex already operates in this area.

Table 1: Ranking of district centers of the Chuvash Republic for the arrangement of waste processing enterprises.

Urban district, district center (district)	Distance to IP	Rank
Kanashsky	68.5	1
Alatyrsky	60,888.13	2
Yadrinsky	103,773.28	3
Kozlovsky	104,147.06	4
Yantikovsky	112,108.47	5
Tsivilsky	124,419.14	6
Krasnochetaysky	124,539.87	7
Batyrevsky	125,027.72	8
Krasnoarmeysky	125,096.34	9
Morgaushsky	125,959.55	10
Shemurshinsky	129,138.66	11
Vurnarsky	130,305.11	12
Komsomolsky	130,606.21	13
Ibresinsky	131,675.32	14
Poretsky	133,248.49	15
Urmarsky	134,627.37	16
Mariinsko-Posadsky	135,468.14	17
Alikovsky	136,507.61	18
Yalchiksky	136,874.84	19
Shumerlinsky	141,144.73	20

The final zoning results of the location of waste processing enterprises in the Chuvash Republic regions are presented in Table 2.

Table 2: The zoning results of the location of waste processing enterprises in the Chuvash Republic regions.

Zone name	Municipalities
Cheboksary	Cheboksary urban district Novocheboksary urban district Cheboksary district Mariinsko-Posadsky district
Kanash	Kanashsky district Vurnarsky district Ibresinsky district Yantikovsky district Komsomolsky district
Alatyr	Alatyrsky district Poretsky district Shemurshinsky district Batyrevsky district Yalchiksky district
Yadrinsky	Yadrinsky district Alikovsky district Krasnochetaysky district Shumerlinsky district
Kozlovsky	Kozlovsky district Tsivilsky district Morgaushsky district Krasnoarmeysky district Urmarsky district

4 DISCUSSION OF RESULTS

Thus, to solve the problem of optimal arrangement of waste processing enterprises in the Chuvash Republic regions, the calculations of the problem of multi-objective optimization were developed. As a result of calculations, five zones for the arrangement of waste processing enterprises were identified - Cheboksary, Kanash, Alatyr, Yadrin, and Kozlovka. In terms of transport costs optimization, it is recommended to locate future waste processing enterprises in these specified zones.

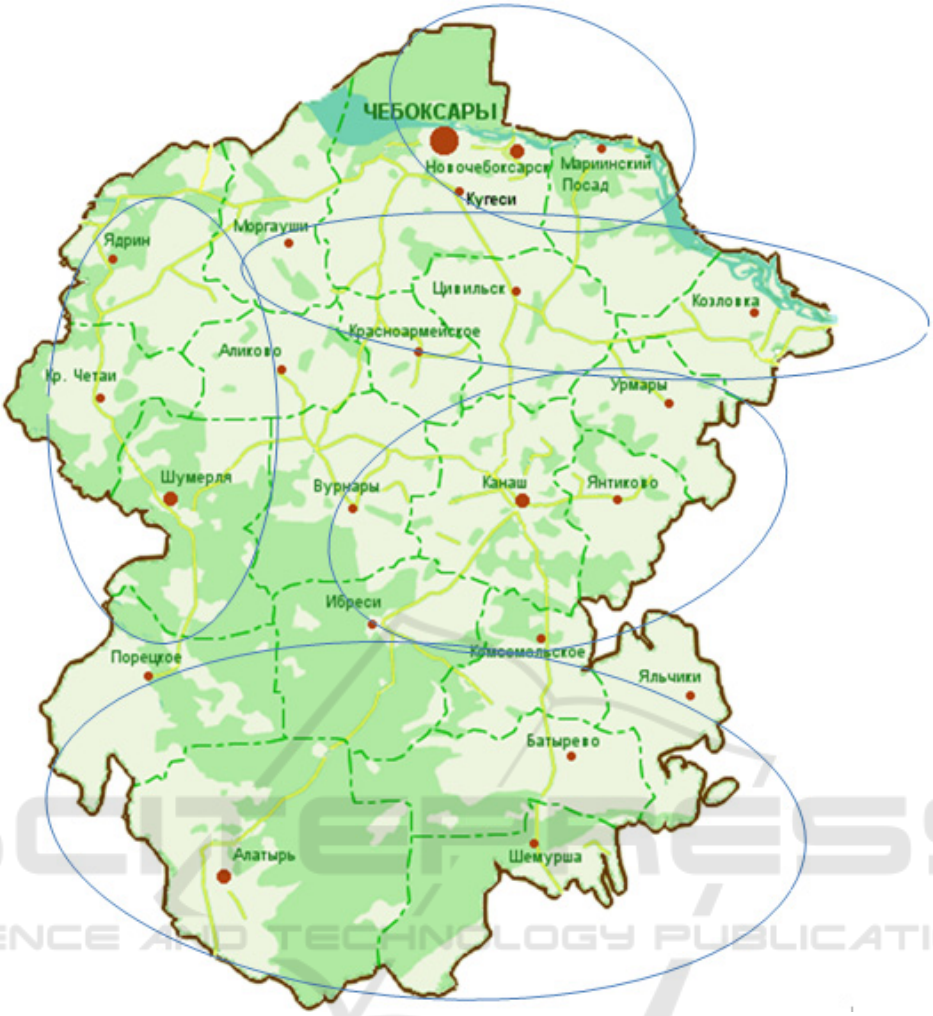

Figure 2: Zones of optimal arrangement of waste processing enterprises on the map of the Chuvash Republic relative to the distance between regional centers, population, and mass of the generated waste.

5 CONCLUSIONS

Thus, to solve the problem of optimal arrangement of waste processing enterprises in the Chuvash Republic regions, the calculations of the problem of multi-objective optimization were developed. It is concluded that in terms of transport costs optimization, it is advisable it is recommended to locate future waste processing enterprises in addition to Cheboksary, in the Kanash, Alatyr, Yadrin, and Kozlovka zones of the Chuvash Republic. The proposed method of multi-objective optimization for arrangement of waste processing enterprises can be used to plan the location of waste processing enterprises in other regions or federal districts.

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