The standard justification for the municipal solid waste accumulation

I V Stefanenko, A V Azarov, N V Menzelintseva, N Yu Karapuzova*, I M Statyukha
Volgograd State Technical University, 28, Lenin Avenue, Volgograd, 400064, Russia
E-mail: karapuzova_ny@mail.ru

Abstract. MSW accumulation dynamics depending on the category of the facility, time of year, is examined using the example of the Dagestan Republic. The average standards for MSW accumulation of for the considered categories of objects per day, as well as the average and annual average are established. The lists of objects’ categories having the minimum and maximum range of changes in the ratio to the average seasonal depending on the season change are identified. The solid waste export frequency should be performed taking into account these characteristics.

Introduction
The environmental safety of the urbanized territory is largely determined by the current policy compliance in the field of waste management with the normative requirements [1,2,6-16].

Modern legislation in the field of waste management regulates a number of concepts, including municipal solid waste (MSW), the standard for the MSW accumulation [1-3].

Solid municipal waste is the waste generated in residential premises in the process of consumption by individuals, as well as the goods that have lost their consumer properties in the process of their use by individuals in residential premises to satisfy personal and domestic needs. MSW also includes the waste generated in the course of legal entities’ activities, individual entrepreneurs and similar in composition waste generated in residential premises during consumption by individuals [2,3].

The waste accumulation refers to the waste storage for a period of not more than eleven months for the purpose of their further processing, disposal, scrap, detoxification [2,3].

The standard for the municipal solid waste accumulation is the average amount of municipal solid waste generated per unit time [2,3].

A number of factors affect the standard value for MSW accumulating, for example, natural and geographical conditions, the development characteristics, the improvement degree of the territory, time of year, day of the week, etc.

Based on the MSW accumulation standards, the required capacities of equipment and vehicles for the MSW collection and removal, the sizes of landfills for their placement, the plants’ productivity for their processing are determined.

Materials and methods
Field studies of the waste accumulation from various objects located in the Dagestan Republic territory were conducted.
In accordance with [5], the municipalities groups on the territory of which the field studies were carried out have been established: group “a” - where the predominant industry is agriculture, group “b” - where the predominant industries are chemical, manufacturing, mining and other industries, group “c” - the municipalities, where a large area is occupied by specially protected areas, recreational and forest zones. In total, the studies were conducted in 11 settlements.

For example, group “a” refers to the rural settlement of Bammatyurt, Khasavyurt municipal district (population 4,932 people), group “b” refers to the city of Derbent, population 123,182 people, group “c” refers to the village of Tlyarat, Tlyaratinsky municipal district, population 1200 people.

The field studies were carried out in the spring, summer, autumn and winter periods of the year.

Waste accumulation standards were determined for 43 categories of facilities, a selective list of which is given in Table 1.

Table 1. The selective list of the objects’ categories for establishing the MSW accumulation standards

| No. | Objects’ name                                      | Account unit                        |
|-----|---------------------------------------------------|-------------------------------------|
| 1   | Landscaped apartment buildings and individual     | Per 1 resident                      |
|     | residential buildings                             |                                     |
| 2   | Car gas stations                                  | 1 car place                         |
| 3   | Hotels                                            | For 1 bed                           |
| 4   | Food stores                                       | On 1 sq.m of the total area         |
| 5   | Stations, bus stations                            | On 1 sq.m of the total area         |
| 6   | Horticultural cooperatives                        | On 1 sq.m of the total area         |
| 7   | Tourist bases                                     | On 1 sq.m of the total area         |

The field studies were carried out according to the method [4]. The main indicators in determining the MSW accumulation standards are the mass, volume and density of the injected waste.

The accumulated waste volume in the event of waste removal and emptying the tank at the start of the calculated day \(V_{d0}\) is determined by the formula:

\[
V_{d0} = N \frac{V_T}{100}
\]  

(1)

where \(N\) – is the container fullness, \%; \(V_T\)– is the tank volume.

If there was no waste collection, then the formula was used:

\[
V_{d0} = N \frac{V_T}{100} - V_{0PD}
\]  

(2)

where \(V_{0PD}\) - the amount of waste accumulated over the previous day.

The accumulated waste mass in the event of waste removal and the tank emptying at the start of the calculated day \(M_{d0}\) is determined by the formula:

\[
M_{d0} = M_{WT} - M_T
\]  

(3)

where \(M_T\) – is the tank mass, kg.

In the absence of waste collection:

\[
M_{d0} = M_{WT} - M_{WT}^{PD}
\]  

(4)

where \(M_{WT}^{PD}\) – is the waste weight, taking into account the previous day capacity.

The density of accumulated waste in the event that the capacity is emptied and the waste is removed at the start of the day in question is calculated by the formula:
\[ D_{w} = \frac{M_{w}}{V_{w}} \]  \hspace{1cm} (5)

If the container is emptied and the waste is removed at another time, then when calculating according to the formula [5], an error of up to 20-30% arises, which is explained by the presence of voids between the components of the accumulated waste in the previous day. This process can be characterized by the coefficient of the waste uneven distribution in the tank \( K_{\text{une}} \), which can be considered an additional characteristic of the conditions for the studied objects’ MSW accumulation.

To find a more accurate value of the average density of the waste, you can use the dependence:

\[ D = \frac{M_{WT}}{V_{w}} \]  \hspace{1cm} (6)

where \( V_{w} \) – is the total amount of waste accumulated in the tank at the time of the experimental measurements’ start.

An additional value characterizing the conditions for the waste accumulation is the total density of accumulated waste for the entire measurement period based on the total volume and density

\[ D_{W} = \frac{\sum_{i=1}^{n} M_{W}^{d}}{\sum_{i=1}^{n} V_{W}^{d}} \]  \hspace{1cm} (7)

Table 2 shows the average density of accumulated waste calculated by the general indicators of mass and volume for the studied categories and seasons of the year, and the average density calculated by the accumulated values.

| Table 2. Study of the waste accumulation density for a sample list of objects |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Object Category                | Average density of accumulated waste in terms of total weight and volume, kg/m³ | Average density by accumulated values, kg/m³ |
|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Landscaped apartment buildings and individual residential buildings | 115.2 | 105.46 | 90.62 | 173.61 | 91.12 | 124.81 |
| Car gas stations               | 89.98 | 115.84 | 59.94 | 78.22 | 105.91 | 107.36 |
| Hotels                         | 89.19 | 90.44 | 70.61 | 99.86 | 95.85 | 103.31 |
| Food stores                    | 64.60 | 57.40-| 44.97 | 56.76 | 99.25 | 72.83 |
| Stations, bus stations         | 137.77 | 219.84 | 101.73 | 96.95 | 132.58 | 158.67 |
| Horticultural cooperatives     | 100.71 | 198.00 | 9.88 | 98.59 | 96.43 | 126.01 |
| Tourist bases                  | 127.14 | 145.95 | 110.83 | 123.64 | 128.13 | 141.97 |

Based on the data of Table 2 the coefficient values of waste uneven distribution in the studied containers have been received, which allows us to conclude the efficiency of the containers’ use in the studied objects’ categories (Table 3).

| Table 3. The coefficient values of waste uneven distribution for a sample list of objects |
|---------------------------------|-----------------|
| №                              | Category Name   | Value |
|--------------------------------|-----------------|-------|
| 1                              |                 |       |
Landscaped apartment buildings and individual residential buildings 1.08
Car gas stations 1.06
Hotels 1.16
Food stores 1.13
Stations, bus stations 1.15
Horticultural cooperatives 1.25
Tourist bases 1.12

The data analysis given in Tables 2, 3, made it possible to conclude that the capacities are most effectively used on the following categories of objects studied: warehouses for food products; wholesale bases, warehouses of industrial goods; universities, technical schools; boarding schools and orphanages; dormitories; garage cooperatives; department stores, horticultural cooperatives, car washes. car parks.

The obtained values of MSW accumulation standards for the year seasons are presented in Table 4.

| Object Category | Average standards for the solid waste accumulation per day, m³/day, kg/day, winter | Average standards for the solid waste accumulation per day, m³/day/kg/day, autumn | Average accumulation MSW rates per day, m³/day/kg/day, summer | Average accumulation MSW rates per day, m³/day/kg/day, spring |
|-----------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| 1               | 0.005152/0.488202                                                             | 0.005363/0.435757                                                               | 0.002296/0.321329                                           | 0.008287/0.607783                                           |
| 2               | 0.005741/0.795352                                                              | 0.005628/0.418981                                                               | 0.002252/0.239148                                           | 0.006717/0.465583                                           |
| 3               | 0.005011/0.715774                                                              | 0.005974/0.509637                                                               | 0.003199/0.350093                                           | 0.005924/0.450376                                           |
| 4               | 0.003243/0.156465                                                              | 0.003181/0.114756                                                               | 0.002910/0.160146                                           | 0.004374/0.418882                                           |
| 5               | 0.000477/0.078422                                                              | 0.000322/0.033278                                                               | 0.000405/0.037785                                           | 0.00060/0.038923                                            |
| 6               | 0.000000/0.000000                                                              | 0.000003/0.000283                                                               | 0.000025/0.002375                                           | 0.000313/0.029903                                           |
| 7               | 0.000023/0.002473                                                              | 0.000053/0.006093                                                               | 0.000057/0.005983                                           | 0.00060/0.006557                                           |

Based on the obtained values, the average seasonal and annual values of the standards have been determined (Table 5).

| Category | The average standard (per unit), m³/year Seasonal average / annual average | The average standard (per unit), kg / year Seasonal average / annual average |
|----------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 1        | 2                                                                             | 3                                                                             |
Based on the studies, the lists of objects’ categories with a minimum (Table 6.) and maximum (Table 7.) changes range in the average seasonal ratio to the ratio depending on the season change are established.

**Table 6.** The select list of the objects’ categories with the highest average ratio to seasonal (higher than average)

| №  | Object’s category name                              | Season   |
|----|----------------------------------------------------|----------|
| 1  | Horticultural cooperatives                         | Spring   |
| 2  | Landscaped multi-unit and individual residential buildings | Spring   |

**Table 7.** The selective list of objects’ categories having the lowest relation coefficient to the average seasonal (below the average seasonal)

| №  | Object category name                              | Season   |
|----|---------------------------------------------------|----------|
| 1  | Horticultural cooperatives                         | Winter   |
| 2  | Tourist bases                                     | Autumn   |
| 3  | Landscaped multi-unit and individual residential buildings | Spring   |

Based on a comparison of the MSW accumulation standards indicators for each study period with the average seasonal standards, the objects’ categories with the highest average ratio to the seasonal (higher than the average) and the objects’ categories with the lowest average ratio to the seasonal (lower than the average seasonal) were determined.

**Table 6.** The selective list of the objects’ categories with the highest average ratio to seasonal (higher than average)

| №  | Object’s category name                              | Season   |
|----|----------------------------------------------------|----------|
| 1  | Horticultural cooperatives                         | Spring   |
| 2  | Landscaped multi-unit and individual residential buildings | Spring   |

**Table 7.** The selective list of objects’ categories having the lowest relation coefficient to the average seasonal (below the average seasonal)

| №  | Object category name                              | Season   |
|----|---------------------------------------------------|----------|
| 1  | Horticultural cooperatives                         | Winter   |
| 2  | Tourist bases                                     | Autumn   |
| 3  | Landscaped multi-unit and individual residential buildings | Spring   |

Based on the studies, the lists of objects’ categories with a minimum (Table 6.) and maximum (Table 7.) changes range in the average seasonal ratio to the ratio depending on the season change are established.

**Table 8.** The list of objects’ categories having the maximum variation range of the coefficient values depending on the year period change

| №  | Object’s category name                              |
|----|----------------------------------------------------|
| 1  | Horticultural cooperatives                         |
| 2  | Concert Halls, Public Libraries                    |
| 3  | Garage cooperatives                                |
| 4  | Universities, technical schools                    |
| 5  | Schools                                            |
| 6  | Beaches                                            |
| 7  | Kindergartens and nurseries                        |
| 8  | Sports buildings and facilities                    |
| 9  | Baths, saunas                                      |
| 10 | Landscaped multi-unit and individual residential buildings |
Table 9. The list of objects’ categories with a minimum variation range of the coefficient values depending on the year period change

| №   | Object’s category name                                      |
|-----|----------------------------------------------------------|
| 1   | Repair of household appliances                           |
| 2   | Auto Workshops                                           |
| 3   | Repair of glasses, keys, photocopying services            |
| 4   | Hotels                                                   |
| 5   | Car parks                                                |
| 6   | Wholesale bases, warehouses of industrial goods          |
| 7   | Shoe repair shops                                        |
| 8   | Hairdressing salons                                     |
| 9   | Car gas stations                                         |
| 10  | Markets                                                  |

For the categories with a maximum changes range in values depending on the year change, the MSW export frequency during the year should be adjusted.

Discussion and Results
Based on the studies, it was found that it is necessary to clarify the housing facilities’ categories classification. Currently, two categories are accepted: comfortable multi-apartment and individual residential buildings; unfurnished, comfortable multi-unit and individual residential buildings. In the work course, the difficulties arose when classifying the housing facilities as comfortable or non-comfortable. Such a classification requires the collection of detailed information and cannot depend solely on the utilities’ availability at the facilities. It would be more appropriate to classify the housing stock as follows: apartment buildings, individual residential buildings.

In addition, it was found that there are no full-fledged household facilities - public services. The activities to serve the population are not carried out comprehensively, but mainly by the specialized organizations. To the household category can be referred: shopping areas and shopping complexes. Therefore, it is advisable to exclude from consideration the following objects of the household category: public services. The category of trade centers should be renamed to: the category of shopping complexes.

Summary
1. The dynamics of the MSW accumulation, depending on the facility category, time of year was studied using the example of the Dagestan Republic.
2. The average standards for the MSW accumulation for the considered objects’ categories per day, as well as the average and average annual.
3. The lists of objects’ categories having the minimum and maximum range of changes in the ratio of the average seasonal standards to the ratio depending on the season change are identified, taking into account the MSW removal frequency during the year should be adjusted.

References
[1] Federal Law of June 24, 1998 No. 89-FL “On Production and Consumption Wastes” [Electronic resource]. Information on www.consultant.ru/document.
[2] Federal Law of December 29, 2014 No. 458-FL (as amended on December 29, 2015) “On Amendments to the Federal Law “On Production and Consumption Wastes” [Electronic resource]. Information on www.base.garant.ru//7083116.
[3] Decree of the Government of the Russian Federation of April 4, 2016 No. 269 "On determining the standards for the accumulation of municipal solid waste" [Electronic resource]. Information on http3://legalae.ru/

[4] Guidelines on issues related to the determination of standards for the accumulation of municipal solid waste (order of the Ministry of Construction and Housing and Communal Services of the Russian Federation No. 524 dated July 28, 2016) [Electronic resource]. Information on www https:/doc plan.ru.

[5] Order of the Ministry of Natural Resources and Ecology of the Republic of Dagestan dated December 6, 2016 No. 469 “On the Approval of Temporary Standards for the Accumulation of Solid Municipal Waste” [Electronic resource]. Information on expert.poisk.ru.

[6] Gutenev V V 2014 Ecology of the city (Volgograd: Prien Terra –Design, Moscow) 436.

[7] Smetanin V I Krasovskaya S P, Schekudov E V, Vorobyov L A 2012 Dynamics of generation and accumulation of production and consumption waste in resort towns (on the example of the city of Sochi) Environmental Engineering 113.

[8] Korablev N A, Shishova O N 2013 Study of the rate of formation of municipal solid waste in the city of Sochi of Sochi, Leningrad Region Technical and technological problems of service 1 (23) 73.

[9] Lowe P, Whitman G 2009 Ecology and the social sciences Journal of Applied Ecology 46 297–305.

[10] Marques R C, da Cruz N F, Ferreira S, Cabral M, Simxes P 2014 Packaging waste recycling in Europe: Is the industry paying for it? Waste Management 34 298-308.

[11] Marquexd R C, da Cruz N F, Simxesa P, Ferreiraa S F, Pereiraa M C, De Jaeger S 2014 Economic viability of packaging waste recycling systems: A comparison between Belgium and Portugal Resources, Conservation and Recycling 85 22-33.

[12] Al-Fahide A A 2003 A strategy for waste management in Yemen (Yemen).

[13] Abd Al-Wahab 2008 A Technology to recycle waste (Yemen).

[14] Cope C, Fuller W, Willetts S 1983 The Scientific Management of Hazardous Wastes (Cambridge) 13.

[15] Thomanetz E, Parasaran O 1985 Rapid analysis methods for special wastes Chemical Waste Handling and Treatment (Berlin, Springer Veriaq) 69-88.

[16] Johnson L, R James 1988 Sampling and analyses of hazardous wastes Standard Handbook of Hazardous Waste Treatment and Disposal (N.Y.: Ete.) 13.3-13.43.