Morphological composition of municipal solid waste in urban areas (on the Dagestan Republic example)

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Abstract. Experimental studies of the waste morphological composition from various objects (43 categories) in 11 settlements of the Dagestan Republic in spring, summer, autumn and winter periods of the year were carried out. The average seasonal content of waste components was determined for the studied objects’ categories. The objects, for which MSW has the maximum content of certain components have been established, which should be taken into account when organizing the MSW collection and transportation.

Introduction
One of the most acute global problems of the modern world is the existing waste management system. Our country is no exception. According to the official data of Federal Service for Supervision of Natural Resources, up to 5 billion tons of waste are generated in Russia annually, about 60 million tons of which are the municipal solid waste (MSW) [1,2]. On average, up to 500-800 kg of MSW are generated for each resident of large cities [3].

In our country, the most common approach to MSW disposal is landfill, no more than 2.5% of waste is directed to incinerator plants, 7% to the recycling facilities. To date, 243 waste recycling plants, 50 waste sorting complexes and 10 waste incineration plants operate in the country, which is clearly not enough to solve the MSW problem. More than 31 billion tons of unused waste has already accumulated in the country’s territory [4].

There are about 11,000 official landfills in the Russian Federation, where about 82 billion tons of waste are buried. Existing landfills are already loaded on two-thirds, and only 30% of them comply with regulatory requirements [3].

During the landfill of solid waste, 9 billion tons of waste paper, 1.5 million tons of ferrous and non-ferrous metals, 2 million tons of polymer materials, more than 0.5 million tons of glass are lost annually [1]. It is known that during a landfill, the waste decomposition time is as follows: newspapers - 1 month, wool - 1 year, paper disposable cup - 5 years, painted board - 13 years, tin can - 100 years, aluminum can - 500 years, disposable colds - 500 years, plastic bottle – 500 years; glass - practically is not decomposed [3].

In accordance with modern legislation, solid municipal waste is understood as waste generated in residential premises in the consumption process by individuals, as well as goods that lost their consumer properties in the process of their use by individuals in residential premises to satisfy the personal and domestic needs. MSW also includes waste generated in the course of activities of legal entities, individual entrepreneurs and similar in composition waste generated in residential premises in the consumption process by individuals [5-7]. 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 [6,7].

Economic forecasts show that every year waste disposal will be more expensive than its processing [8]. Consequently, the waste processing industry requires a significant increase in efficiency. One of the ways to solve this problem is to increase the composition forecasting of the waste, primarily MSW [8,9].

MSWs have a multicomponent heterogeneous composition, which is represented by both inorganic (metals, stones, etc.) and organic (food waste, polymers, etc.), which can differ significantly in both chemical and physical properties, size [1, 8, 9 - 11].

The totality of the components that make up the MSW, taking into account their content in the total waste volume, is usually called the morphological composition.

The MSW component composition in different countries, as well as in different cities of one country, is almost the same, but the content of individual components can vary widely and depends on a number of factors, including the culture of the population consumption, the waste collection and disposal characteristics, the secondary market raw materials development level, climatic conditions, seasonal and weekly fluctuations [1, 3, 8, 12, 15 - 21].

**Table 1.** Changes dynamics in the content of components in MSW in Moscow

| No. | Component                  | A period of time |
|-----|----------------------------|------------------|
|     |                            | 1926-1930        | 1930-1935        | 1960-1967        | 1970    | 1988    | 2001    | 2008    | 2015    |
| 1   | 2                          | 3                | 4                | 5                | 6       | 7       | 8       | 9       | 10      |
| 1   | Wood                       | 7.0-7.2          | 7                | 2                | 2.4     | 1.9     | 1.4     | 0.9     | 1.9     |
| 2   | Paper                      | 16.4-17.2        | 16.7             | 36.4             | 34      | 37.7    | 54.0    | 19.7    | 20.0    |
| 3   | Textile                    | 2.5-4.3          | 4.3              | 3.4              | 4.6     | 5.4     | 4.6     | 2.0     |
| 4   | Food waste                 | 16.5-28.2        | 22.2             | 36.8             | 33.1    | 30.6    | 26.3    | 18.0    | 24.2    |
| 5   | Coal Slag                  | 1.1-3.1          | -                | -                | -       | -       | -       | -       |
| 6   | Bones                      | 1.9-2.8          | 2.3              | 1.3              | 1.1     | -       | -       | -       |
| 7   | Other waste                | 0.4-0.7          | 0.1-0.2          | 3.4              | 1.4     | 11.4    | 12.1    | 2.1     |
| 8   | Metal                      | 1.1-1.6          | 1.3              | 3.4              | 3.3     | 4.5     | 0.6     | 0.6     |
| 9   | Stones                     | 3.6-8.3          | 5.1              | 0.9              | 2.9     | 0.8     |
| 10  | Glass                      | 1.6              | 1.6              | 3.7              | 4.8     | 3.7     | 4.4     | 4.4     | 12.5    |
| 11  | Fine screening (3 mm)      | 16.3-22.0        | 39               | 6.3              | 7.9     | 9.7     | -       | 11.4    | 11.2    |
| 12  | Large screenings (15 mm or more) | 19.6-24.5 | - | - | - | - | - | - | - |
| 13  | Leather, rubber            | -                | -                | 1.6              | 2.2     | 0.5     | 0.8     | 1.0     |
| 14  | Plastic, polymers          | -                | -                | 0.8              | 1.6     | 5.4     | 4.2     | 14.2    | 17.7    |
| 15  | Construction garbage       | -                | -                | -                | -       | -       | 4.9     | 0.9     | 0.3     |
| 16  | General humidity, %        | 47               | -                | -                | -       | -       | -       | -       |
| 17  | Total                      | -                | 99.5             | 100              | 100     | -       | -       | -       |

An analysis of the data in Table 1 shows a clear relationship between the waste composition and the ongoing socio-economic processes. So, for Moscow, the main trend is an increase in the share of
polymer waste, the dropout rate is also reduced and the “coal and slag” fraction completely disappears due to heating and gasification centralization. A decrease in the MSW metal content is noted, since they are selected at the stage of the container site, and there is a constant decrease in the metal consumption of products from the household items to the household appliances. The same trends are observed for other cities of our country [1, 3, 8, 12].

The analysis made it possible to conclude that the morphological composition study in certain regions of the country has been carried out for a long time, the composition of the waste over the past period has changed significantly [1, 3, 8, 12]. Therefore, to obtain the correct values when planning the MSW accumulation, the frequency of their removal, and also when designing the facilities for MSW processing, it is necessary to clarify the waste morphological composition.

Materials and methods
Experimental studies of the morphological composition of waste from various objects of settlements of the river Dagestan were carried out. In total, the studies were carried out in 11 settlements, including Derbent (population 123162 people), Makhachkala (population 722314 people), urban settlement Komsomolsky of urban district Kizlyar (population 2568 people), village Terekli-Mekteb Nogai Municipal District (population 6884 people), village Murego Sergokalinsky municipal district (population 4308 people), village Dzhinabi, Kaitagsky municipal district (population 727 people), village Tlyarata, Tlyaratinsky municipal region (population 1200 people), village Toh-Orda, Tlyaratinsky municipal district (population 192 people), village Kosob, Tlyaratinsky municipal district (population 244 people).

The field studies were carried out in the spring, summer, autumn and winter periods of the year. The morphological composition was determined for 43 categories of objects, a selective list of which is given in Tables 2 and 3. An average sample was taken at the studied objects, its composition was investigated, and the content of the considered components was determined using the manual sorting method. The average seasonal content of each waste component was calculated from the studied categories of objects using the obtained content values of the components in the MSW, $N_{j}^{CP}$

$$N_{j}^{CP} = \frac{\sum_{i=1}^{n} N_{j}^{i}}{m} \tag{1}$$

where $m$ – is the number of objects, $j$ – defines the categories in which the field measurements were taken and the component T was discovered, $N_{j}^{T}$ - is the component content T in MSW category object j.

Table 2. The average seasonal morphological composition of waste by the studied objects’ categories (part 1)

| Type of waste | Object Category |
|---------------|-----------------|
| kg /%         | Landscape multi-unit and individual residential buildings | Hospitals, motels, other health care facilities | Household, retail space | Kiosks, trade pavilions, trays | Unfurnished, individual and residential buildings |
| 1 | 2 | 3 | 4 | 5 | 6 |
| Food waste | 4.51/21.04 | 14.96/24.59 | 7.18/13.27 | 1.19/12.41 | 3.80/22.75 |
| Vegetable waste (landscape gardening) | 2.96/13.81 | 4.81/13.91 | 3.50/6.47 | 0.30/3.13 | 2.70/16.17 |
| Waste paper (including newsprint, office paper and cardboard) | 1.86/8.68 | 6.34/10.42 | 11.95/22.09 | 1.96/20.44 | 1.10/6.59 |
| Type of waste                                                                 | Object Category   | kg /%  |
|-----------------------------------------------------------------------------|-------------------|--------|
| Hazardous waste (batteries, accumulators, containers for solvents, paints, mercury lamps, thermometers, medicines) | 0.19/0.89         | 0.67/1.10 | 0.28/0.52 | 0.00/0.00 | 0.10/0.60 |
| Wood                                                                        | 0.45/2.10         | 0.92/1.51 | 1.52/2.81 | 0.00/0.00 | 0.10/0.60 |
| Black scrap including cans)                                                 | 0.73/3.40         | 1.20/1.97 | 1.29/2.38 | 0.28/2.92 | 0.30/1.80 |
| Non-ferrous scrap metal (including aluminum cans)                           | 0.50/2.33         | 0.77/1.27 | 1.53/2.83 | 0.13/1.36 | 0.20/1.20 |
| Textile                                                                     | 0.76/3.54         | 3.99/6.56 | 1.29/2.38 | 0.04/0.42 | 0.30/1.80 |
| Glass                                                                       | 2.14/9.98         | 5.71/9.39 | 5.74/10.61 | 1.56/16.27 | 1.60/9.58 |
| Polymers (including film, bottles, etc.)                                     | 0.54/2.52         | 2.91/4.78 | 6.94/12.83 | 1.16/12.10 | 1.20/7.19 |
| Estimates                                                                    | 3.30/15.39        | 7.45/12.18 | 5.35/9.89 | 0.97/10.11 | 2.90/17.37 |
| Other plastics                                                               | 0.54/2.52         | 2.13/3.50 | 1.59/2.94 | 0.30/3.13 | 0.10/0.60 |
| Leather, rubber                                                             | 0.23/1.07         | 1.16/1.91 | 0.83/1.53 | 0.00/0.00 | 0.2/1.2 |
| Tetrapak                                                                     | 0.84/3.92         | 1.49/2.45 | 0.79/1.46 | 0.26/2.71 | 0.6/3.59 |
| Polymer films (polyethylene)                                                | 0.29/1.35         | 1.34/2.20 | 0.72/1.33 | 0.31/3.23 | 0.3/1.8 |
| Polyethylene terephthalate (bottles, etc.)                                   | 0.71/3.31         | 160/2.63 | 2.13/3.94 | 0.74/7.72 | 1.00/5.99 |
| Polypropylene (without films)                                               | 0.06/0.28         | 0.46/0.76 | 0.16/0.30 | 0.20/2.09 | 0.00/0.00 |
| Polyvinyl chloride                                                           | 0.03/0.14         | 0.25/0.41 | 0.04/0.07 | 0.00/0.00 | 0.00/0.00 |
| Other                                                                        | 0.18/0.84         | 2.71/4.46 | 1.27/2.35 | 0.19/1.98 | 0.00/0.00 |
| Total weight                                                                 | 21.44/100         | 60.83/100.0 | 54.10/100.0 | 9.59/100.0 | 16.7/100.0 |

**Table 3.** The average seasonal morphological composition of waste by the studied objects’ categories (part 2)
**Polymers (including film, bottles, etc.)**

| Component | Content in MSW | Object Category |
|-----------|----------------|-----------------|
| Estimates | 21.57/13       | Dormitories     |
| Other plastics | 0.42/1.83    | Horticultural cooperatives |
| Leather, rubber | 0.26/1.13   | Wholesale bases, warehouses of industrial goods |
| Tetrapak | 1.02/4.45     | Laundries, dry cleaners |
| Polymer films (polyethylene) | 1.05/4.58 | Wholesale bases, warehouses of food products |
| Polyethylene terephthalate (bottles, etc.) | 1.46/6.37 | Auto Workshops |
| Polypropylene (without films) | 0.16/0.70 | Bath, saunas |
| Polyvinyl chloride | 0.02/0.09 | Chips, noodles |
| Other | 0.48/2.09 | Jewelry workshops |
| Total weight | 22.93/100.00 | 10.80/100 | 64.1/100 | 6.44/100 | 6.1/100 |

**Discussion and Results**

The analysis of the obtained results made it possible to establish the objects for which MSW that the content of certain components is maximum, which should be taken into account when organizing the MSW collection and transportation (Table 4).

**Table 4.** The list of objects with the maximum content of individual components in MSW

| No. | Component primarily contained in MSW | Component content in MSW | Object Category |
|-----|-------------------------------------|--------------------------|-----------------|
| 1   | Food waste                          | 38.72                    | Dormitories     |
| 2   | Vegetable waste (landscape gardening) | 24.65                    | Horticultural cooperatives |
| 3   | Waste paper (including newsprint, office paper and cardboard) | 31.03 | Wholesale bases, warehouses of industrial goods |
| 4   | Hazardous waste (batteries, accumulators, containers for solvents, paints, mercury lamps, thermometers, medicines) | 17.65 | Laundries, dry cleaners |
| 5   | Wood                                | 8.16                     | Wholesale bases, warehouses of industrial goods |
| 6   | Ferrous scrap metal (including tin cans) | 6.96 | Auto Workshops |
| 7   | Non-ferrous scrap metal (including aluminum cans) | 9.38 | Clubs, discos |
| 8   | Textile                             | 33.04                    | Studio          |
| 9   | Glass                               | 31.47                    | Car gas stations |
| 10  | Polymers (including film, bottles, etc.) | 20.52 | Jewelry workshops |
| 11  | Estimates                           | 33.33                    | Wholesale bases, warehouses of food products |
| 12  | Other plastics                      | 6.44                     | Shoe repair shops |
| 13  | Leather, rubber                     | 17.05                    | Jewelry workshops |
Tetrapak 8.29 Repair of household appliances
Polymer films (polyethylene) 8.37 Theaters, cinemas
Polyethylene terephthalate (bottles, etc.) 16.59 Car gas stations
Polypropylene (without films) 3.28 Car parks
Polyvinyl chloride 1.59 Garage cooperatives
Other 9.22 Shoe repair shops

Summary
1. The study of the MSW morphological composition in certain regions of the country has been carried out for a long time, the waste composition over the past period has changed significantly. To obtain the correct values when planning the MSW accumulation, the frequency of their removal, and also when designing the facilities for MSW processing, it is necessary to clarify the morphological composition of the waste.

2. The experimental studies of the waste morphological composition from various objects (43 categories) in 11 settlements of the Dagestan Republic in spring, summer, autumn and winter periods of the year were carried out. The average seasonal content of each component of the waste was determined for the studied objects’ categories.

3. The objects for which MSW has the maximum content of certain components have been established, which should be taken into account when organizing the MSW collection and transportation.

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