Study of the morphological composition of municipal solid waste in the Perm region

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Abstract. The article describes the research of the morphological composition of municipal solid waste (MSW) in the Perm Territory during the period of self-isolation associated with SARS-CoV-2. It has been substantiated that the indicator of the morphological composition of MSW is decisive in the field of MSW management and determines the choice of the most acceptable method of waste disposal. Despite the growing interest in technologies for sorting and processing MSW, the most common method in Russia is waste disposal by soil methods - waste disposal at MSW landfills, which can pose a threat to the environment, since At many MSW disposal facilities, anti-seepage screens were not initially provided, there are no insulating backfills, many facilities are used beyond the design period. Experimental studies of the complex (morphological) composition of MSW were carried out in two settlements of the Perm Territory with a population of over 500,000 and a population of less than 300,000. The research methodology and tools are presented. The percentage of utilized components in the studied samples in the spring and summer seasons was calculated and the classification of the components according to the degree of biodegradation at MSW landfills, as well as the percentage of MSW components after the extraction of waste suitable for recyclable materials transported to the MSW landfills according to the research results. The percentage of the reduction in the penetration of hard-to-decompose and conditionally non-degradable fractions of MSW at the MSW landfills of the Perm Territory was calculated. Therefore, the purpose of the research was to study the morphological composition of MSW in the Perm Territory during a pandemic and to determine the percentage of components suitable for recyclability in the studied MSW samples by seasons (spring and summer seasons of 2020).

1. Introduction
The problem of the formation and further utilization of MSW both in the world and in the Perm Territory in particular, has recently become more acute. The current situation can lead to serious environmental consequences in the next decade. These consequences, first of all, include long-term (up to 1000 years) soil pollution by the resulting wastewater (leachate and surface runoff from MSW landfills) and gaseous emissions into the atmosphere from MSW landfills [1]. One of the indicators of MSW affecting the biodegradation (decomposition) of waste is their morphological composition [2]. Waste decomposition at the disposal site and the quality of the resulting filtrate to be further purified [3–5] and gases depend on the nature of organic substances. In particular, the presence of substances that are toxic to the bacterial flora can slow down or stop the biodegradation of waste. Modern trends in the use of plastics and paper...
in trade are such that they are included in MSW, getting to landfills, will lead to the fact that, due to limitation in nitrogen and/or phosphorus, the time of biodegradation of waste will be lengthened [6].

2. Equipment and devices used in studies

The study of the component (morphological) composition of MSW was carried out in accordance with the approved method for studying the properties of solid waste (Moscow, Stroyizdat) for two seasons, a feature of which was the finding of the population on self-isolation associated with the SARS-CoV-2 virus. Research is carried out in two settlements with a population of less than 300,000 - conventionally designated as object 1, and over 500,000 people - conventionally designated as object 2. Delivered to a prepared closed site, an average waste sample from an average waste source for each group of settlements (including waste from the population and infrastructure), were weighed on electronic scales. We used an M-ER 333 AF/FARMER scale with a scale division of 0.01 kg. To determine the component composition of the waste, an MK-32.2-A20 balance with a scale division of 0.001 kg was used. The calculation of the component (morphological) composition of solid municipal waste \( x_i \) was determined in weight percent with respect to the total weight of the waste according to the formula:

\[
x_i = \frac{m_{\text{comp}}}{m_{\text{general}}} \times 100\% ,
\]

where: \( x_i \) - content of each waste component, % by weight; \( m_{\text{comp}} \) - mass of each component, kg; \( m_{\text{general}} \) is the total mass of waste.

In total, 42 components were identified during the execution of the work, which are combined into 12 categories: organic waste, waste paper, polymers, glass, metals, textiles, wood, combined materials, hazardous materials, inert materials, others and screenings.

The determination of the component composition of MSW was carried out simultaneously with the analysis of the fractional composition of MSW (the composition of individual fractions).

For this, a selected sample weighing 100 ± 20 kg was sieved through a set of three sieves with mesh sizes, respectively: 250x250 mm, 80x80 mm and 20x20 mm, arranged in series from a sieve with a large mesh size to a sieve with a small mesh size. The TCR sample was preliminarily weighed to a mass of 100 ± 20 kg and was loaded in portions onto the surface of a sieve with a mesh size of 250x250 mm and sieving was performed. When the fraction with a size of less than 20x20 mm was isolated, its further sieving was not performed and the component (morphological) composition was not determined.

3. The results of the study and their discussion

3.1. Primary data processing

The primary research protocols were processed and compiled into a single database, on the basis of which the percentage indicators of the component (morphological) composition of MSW were calculated for each waste sample for seven days with a frequency of twice a day for samples from object 1 and object 2 in the spring and summer seasons. The obtained results of the percentage component (morphological) composition of MSW were averaged over the number of sampling of this waste stream.

3.2. Analysis of taken samples (object 1 - more than 500,000 people)

When conducting experimental studies of object 1, 1347.8 kg were collected and sorted in the spring season, and 1183.6 kg of MSW in the summer. A pie chart of the summary data on the percentage of various fractions in MSW samples in the spring and summer seasons for object 1 is shown in Figure 1.
Figure 1. Pie charts summarizing the percentage of different fractions in MSW samples in the spring (a) and summer (b) seasons (object 1).

Studies have shown that when analyzing the coarse fraction, cardboard, textiles, leather (footwear) and food waste in the form of watermelons prevailed in the waste composition of object 1. The fine fraction from 20 to 80 mm contained small residues of food waste, waste paper and plastic. Minor quantities in the medium and fine fractions contained hazardous materials (batteries, hazardous household chemicals, medicines, medical waste, including medical gloves, syringes and medical masks). The most recyclable subsequently, suitable for recyclability, components were contained in the average fraction from 80 to 250 mm. These are waste paper (cardboard and paper), polymers (mainly PET bottles and plastic packaging), glass containers, metals (mainly aluminum and cans). A large amount was contained in the middle fraction of diapers (about 3.15% of the total MSW in the sample). An increase in food waste was a characteristic sign for the period of self-isolation of the population associated with SARS-CoV-2 [7]. In general, the mass of organic waste due to food waste in the studied MSW samples at facility 1 increased by 4.49% in the summer season compared to the spring season.

3.3. Analysis of taken samples (site 2 - less than 300,000 people)

During experimental studies at facility 2, 1302.58 kg of MSW in the spring season and 1188.78 kg of MSW in the summer season were collected and sorted. A pie chart of the summarized data on the percentage of various fractions in MSW samples in the spring and summer seasons is shown in figure 2.

Figure 2. Pie diagrams of summary data on the percentage of different fractions in MSW samples in the spring (a) and summer (b) seasons (object 2).

Studies have shown that in the MSW taken from object 2 (with a population of less than 300,000 people) in the summer season, the large fraction (more than 250 mm) was 32.4% (compared to the spring season, it increased 1.8 times), the average (80–250 mm) was 57.63% (compared to the spring season, it decreased by 1.17 times) and fine (20–80 mm) was 5.9% (compared to the spring season, it decreased by 1.6 times), while the percentage of dropouts in the averaged indicators of the component composition
The MSW of object 2 in the summer season is, on average, 0.26% less than the percentage of dropouts in the summer samples of facility 1. In general, in MSW samples for both facility 1 and facility 2, the average dropout weight was 1.25% less than average indicators of the mass of dropouts in the spring samples of MSW, which is associated with the processes of decay of fruits and vegetables and an increase in the adhesive properties of organic waste.

The main components in the coarse fraction were textiles and other inert materials: foam plastic, glass wool, polystyrene, etc. The coarse fraction also contained construction waste - 7.06% (summer season). At site 1, the content of organic waste in the summer season increased due to an increase in food waste in MSW samples by 4.5% (due to an increase in the weight of vegetables and fruits). Also, in the summer season, the indicator of textiles in the MSW sample of object 2 exceeded the corresponding indicator of object 1 by 2.243% (respectively, the indicators were 9.227% and 6.984% for object 2 and object 1). Comparative data on the fractional composition of MSW samples in the spring and summer seasons for object 1 and object 2 are presented in tables 1 and 2.

Table 1. Analysis of the fractional composition in the spring and summer seasons in MSW samples (object 1).

| Season  | Average fraction content, % |
|---------|-----------------------------|
|         | Over 250 mm | 80–250 mm | 20–80 mm | Dropout less than 20 mm |
| Spring  | 13.23       | 69.61     | 11.41    | 5.75 |
| Summer  | 14.56       | 74.27     | 6.71     | 4.46 |
| Average | 13.895      | 71.94     | 9.06     | 5.105 |

Table 2. Analysis of the fractional composition in the spring and summer seasons in MSW samples (object 2).

| Season  | Average fraction content, % |
|---------|-----------------------------|
|         | Over 250 mm | 80–250 mm | 20–80 mm | Dropout less than 20 mm |
| Spring  | 17.42       | 67.95     | 9.59     | 5.04 |
| Summer  | 32.4        | 57.63     | 5.9      | 4.07 |
| Average | 24.91       | 62.79     | 7.745    | 4.555 |

The histogram of the enlarged component (morphological) composition of MSW in settlements of the Perm Territory is shown in Figure 3. Analysis of the research protocols showed that the recyclable components that make up MSW that can be used for recyclability are waste paper not contaminated with food waste, polymer waste in the form of PET - bottles and polycarbonate bottles (containers), metal, including mainly aluminum and tin cans; textiles (mainly clothing) and glass containers.

Due to the fact that the bulk of MSW is disposed of in the future at MSW landfills, conventionally all waste was divided into 3 components according to the degree of their biodegradation [8]:

- Degradable - food and vegetable (at MSW landfills, complete biodegradation of waste takes place from one to three years with the formation of biogas and leachate, with the introduction of control technologies at landfills);
- Hardly degradable - waste paper, wood, textiles, combined materials, screening (the course of biodegradation processes at MSW landfills lasts up to 25–30 years);
- Conditionally non-degradable - polymers, glass, metals, inert materials, other materials (the natural process of waste biodegradation can last up to 100–1000 years).
Figure 3. Histogram of the enlarged component (morphological) composition of MSW in settlements of the Perm Territory.

The main components in the morphological composition of MSW traditionally processed as recyclable materials are the components presented in Table 3.

| Components of MSW for recyclable materials | Content of MSW components suitable for Recyclable materials, % by seasons |
|-------------------------------------------|--------------------------------------------------------------------------------|
|                                           | Spring                      | Summer                     |
| Waste paper                               | 10.42                       | 10.446                     |
| Polymers                                  | 21.32                       | 13.171                     |
| Glass                                     | 11.90                       | 14.675                     |
| Metals                                    | 2.25                        | 2.421                      |
| Textile                                   | 6.2                         | 8.106                      |
| Wood                                      | 1.82                        | 1.323                      |
| Total                                     | 53.91                       | 50.142                     |

The research results for the seasons of the year are presented in Table 4.

| Components of MSW by the degree of biodegradation | The percentage of MSW constituents according to the seasons of the year, % |
|--------------------------------------------------|---------------------------------------------------------------------------|
|                                                  | No sorting | Spring | Summer | After sorting | Spring | Summer |
| Degradable                                       | 27.76      | 28.746 |       | 27.76         | 28.746 |        |
| Difficult to decompose                           | 25.13      | 26.143 |       | 6.69          | 6.268  |        |
| Conditionally non-degradable                    | 47.06      | 45.074 |       | 11.59         | 14.807 |        |
| Dangerous                                        | 0.05       | 0.037  |       | 53.91         | 50.142 |        |

Studies have shown that hardly degradable and conditionally non-degradable components of MSW, which include: glass, metals, textiles, wood and which are to be disposed of as recyclable materials [9] and with the introduction of advanced technologies for the separate collection and / or sorting of MSW, the amount of these components, MSW transported to landfills will significantly decrease. Thus, the
extraction of MSW components during sorting for recycling will make it possible to reduce the hard-to-decompose and conditionally non-degradable MSW components in terms of the degree of their biodegradation, transported to MSW landfills in the spring season by 18.44% and 35.47%, respectively, and in the summer season by 19.87% and 30.27%, respectively.

4. Conclusions

1. It has been shown that the morphological composition of MSW in settlements of the Perm Territory in the spring and summer seasons of 2020 is represented mainly by organic waste (27.76% and 28.75%, respectively), polymers (21.32% and 13.18%, respectively), glass (11.90 and 14.68% respectively) and waste paper (10.42% and 10.45%, respectively).

2. Analysis of the composition of waste showed that in the spring and summer seasons, the fraction over 250 mm contained the most recyclable part of cardboard, textiles, rubber, etc., other components utilized as secondary raw materials are represented by the middle fraction, in which a significant part represents waste paper and textiles and almost 100% metal content (in the form of aluminum and tin cans), polymers (in the form of PET bottles) and glass (in the form of glass containers). The fraction 20–80 mm in size had an insignificant content and practically had no components suitable as secondary raw materials. Fraction of 0–20 mm (a mixture of food waste, pieces of soil, scraps of paper and film), practically did not lend itself to manual sorting.

3. The investigated waste contains hazardous waste, in particular, medical waste, batteries and chemicals, fluorescent lamps, medical, masks, syringes and gloves, which may pose a certain threat to personnel during waste processing and MSW disposal at landfills.

Calculations showed that the percentage of utilized components in the studied samples of the Perm Territory in the spring season was 53.91%, and in the summer season - 50.14%. Studies have shown that the extraction of MSW components during sorting for recycling will reduce the hard-to-decompose and conditionally non-degradable MSW components in terms of their degree of biodegradation transported to MSW landfills in the spring season by 18.44% and 35.47%, respectively, and in the summer season by 19.87% and 30.27% respectively.

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