Study of solid municipal waste accumulation rates in penitentiary facilities in Perm Krai during the pandemic of 2020

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Abstract. Preventing the release of hazardous substances from waste into the environment is the most important environmental safety objective of municipal waste management. Uncontrolled dumping in landfills has a negative impact on the environment, being a source of harmful chemical and biological substances in the ground and surface waters, atmospheric air and soil, creating a certain threat to the health and life of the population. At present, the environmental problem associated with the collection and disposal of solid municipal waste (MSW) and is relevant not only for civil organisations, but also for institutions of the penitentiary system. The volume of MSW flows needs to be constantly updated, and therefore an average annual waste generation rate needs to be determined. The research described in the article was carried out during four seasons of 2020 at the facilities of the penal and correctional system of Perm Krai, on the example of remand prisons. The methodology for performing calculations based on the current regulatory documents is presented: methodological recommendations on issues related to the determination of MSW accumulation standards, approved by Order No. 524 of the Ministry of Construction and Housing and Communal Services of the Russian Federation dated July 28, 2016 and the Russian Government Decree No. 269 dated April 4, 2016 "On determining the accumulation standards for solid municipal waste". As a result of the work, the average daily and average annual volumes and masses of waste generated per person were determined. Fluctuations in waste generation during the four seasons were insignificant.

1. Introduction
In many countries of the world [1, 2] and, in particular, in the subjects of the Russian Federation, much attention has recently been paid to the analysis of solid municipal waste accumulation standards [3]. The dynamics of MSW accumulation depending on the category of the object, time of the year by the example of the Republic of Dagestan is shown in the works [4, 5]. This article presents a study of solid municipal waste (MSW) accumulation rates from correctional institutions of Perm Krai. Historically, the territory of Perm Krai is home to many correctional colonies. As of the end of 2021, the Perm Krai had 18 correctional colonies with 13529 inmates; 3 settlement colonies with 1588 convicts; 6 remand...
centres with 2590 inmates; 1 juvenile correctional facility with 112 teenagers serving their sentence. There is also Correctional Centre No. 1 (Solikamsk) and an area serving as a correctional centre (Gremyachinsk), as well as two hospitals under the jurisdiction of the Russian Federal Penitentiary Service for Perm Krai. The experiment on waste accumulation rates was carried out at two sites: remand prison number 1 and number 5 in Perm. Perm. Russia is currently undergoing a "rubbish reform" related to the introduction of selective waste collection and clarification of MSW flows. The morphological composition of waste on the example of Perm Krai has been studied earlier from two: small and large groups of settlements of Perm Krai, which is important for the development of technologies for waste sorting [6,7]. In Perm Krai the regional operator for MSW management is "Teploenergo" organization. Payments for MSW are now placed in separate accounts, which makes the MSW management system understandable. At the same time, there is a constant need to update the standards for MSW generation due to changes in the economic and environmental situation in the country.

2. Methods and equipment

Studies of waste accumulation rates were carried out in accordance with the Methodological Recommendations on issues related to the determination of MSW accumulation rates, approved by Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation from July 28, 2016 №524/pr and Decree of the Russian Government from 04.04.2016 №269 "On determination of solid municipal waste accumulation rates" during the four seasons of 2020 [8, 9]. The research was conducted at two sites: Detention facility 1 and Detention facility 5 of the Main Department of the Federal Penitentiary Service of Russia for Perm Krai. Crane scales, models: KV 3000A(K) up to 3 tons and VSK-1000A up to 1 ton were used to weigh the containers. The volume of waste was measured by filling the container (container, hopper), for which the height of the container was measured. The volume of accumulated waste was measured by measuring the geometric dimensions. The mass of the waste was calculated as the difference between the mass of the waste in the container (container, bunker) and the mass of the container (bunker).

The average daily rate for the season Gc.o was determined by dividing the waste mass by the number of calculated units multiplied by the duration of measurement (7 days)

\[ G_{c.o} = \frac{G_o}{n} \]  

where \( G_o \) - mass of waste of the \( i \)-th category, accumulated during the period of waste measurement, kg; \( n \) - number of calculation units of the \( i \)-th category; 7 - duration of waste measurement, days.

Average daily norm for the season, expressed in terms of quantity of mass per settlement unit per day Gc.k, for the facilities of \( j \)-th category is defined by the formula

\[ G_{c.k} = \frac{\sum_{i}^{m} G_{c.o}}{m} \]  

where \( G_{c.o} \) - average daily norm per season expressed in terms of quantity of mass per one unit per day, for the \( i \)-th object of the \( j \)-th category, kg/day; \( m \) - number of objects of the \( j \)-th category where waste was measured.

Average daily norm for the season, expressed in quantitative indicators of the volume per one settlement unit per day Vc.o, for the \( i \)-th object of the \( j \)-th category is defined by the formula

\[ V_{c.o} = \frac{V_o}{n} \]  

where \( V_o \) - volume of waste of the \( j \)-th category object accumulated within the period of waste measurement, m³; \( n \) - number of calculation units of the \( j \)-th category object; 7 - duration of waste measurement, days.
Average daily norm for the season, expressed in quantitative indicators of the volume per one settlement unit per day $V_{c,k}$, for the $j$-th category volumes is defined by the formula

$$V_{c,k} = \frac{\sum_{i=1}^{m} V_{c,o}}{m}, \quad (4)$$

where $V_{c,o}$ is the average daily norm for the season expressed in quantitative indicators of the volume per one settlement unit per day, for the $i$-th object of the $j$-th category, $\text{m}^3$/day; $m$ - the number of objects of the $j$-th category where the waste was measured.

The seasonal average daily norm expressed in terms of mass and volume per settlement unit per day was determined as an arithmetic average for four seasons.

The annual standard expressed in terms of weight and volume per settlement unit per year $G_g$ was determined by multiplying the seasonal average daily standard by 365 (where 365 is the number of days in a year).

3. The results of the study and their discussion

3.1. Processing of primary data

In the first stage, the volume and weight of the seasonal averages were determined for the facilities of the correctional facility category: detention centre no. 1 and detention centre no. 5. At the second stage, based on the data for the study period of 2020, the average daily norms of MSW generation by volume and weight for four seasons were calculated. Seasonal waste accumulation rates were calculated: quantitative index of mass and quantitative index of volume by category: correctional facilities (penal colonies, prisons) (Table 1).

| Detention centre number | Units of account | Daily averages | Average daily norm |
|-------------------------|------------------|----------------|-------------------|
|                         | Number of people | V, $\text{m}^3$ | m, kg             | V, $\text{m}^3$ | m, kg |
|                         |                  |                |                   |                   |
|                         |                  | 1.143          | 393.571           | 0.00075           | 0.25665 |
|                         | 1                | 1534           |                   |                   |
|                         | 5                | 524            | 0.709             | 93.579            | 0.00135 | 0.17859 |
| Standard by category   |                  |                |                   | 0.00105           | 0.21762 |
|                         |                  |                |                   |                   |
|                         |                  | 1.143          | 325.714           | 0.0007            | 0.2123  |
|                         | 1                | 1534           |                   |                   |
|                         | 5                | 524            | 0.644             | 68.386            | 0.0012  | 0.1305  |
| Standard by category   |                  |                |                   | 0.001             | 0.171   |
|                         |                  |                |                   |                   |
|                         |                  | 1.143          | 360.000           | 0.0007            | 0.2347  |
|                         | 1                | 1534           |                   |                   |
|                         | 5                | 524            | 0.629             | 67.357            | 0.0012  | 0.1285  |
| Standard by category   |                  |                |                   | 0.001             | 0.182   |
|                         |                  |                |                   |                   |
|                         |                  | 1.143          | 416.857           | 0.0007            | 0.2717  |
|                         | 1                | 1534           |                   |                   |
|                         | 5                | 524            | 0.660             | 75.786            | 0.0013  | 0.1446  |
| Standard by category   |                  |                |                   | 0.001             | 0.182   |
### 3.2. Determination of MSW accumulation rates

The calculated data on average daily and average annual rates of MSW accumulation by the category: penal institutions (penal colonies, prisons), as arithmetic averages, are given in Table 2.

**Table 2.** Collection rates of solid municipal solid waste by category: correctional facilities (penal colonies, prisons) in Perm Krai by seasons in 2020.

| The season                 | Norm per 1 person |
|----------------------------|-------------------|
|                            | V, m³             | m, kg          |
| Daily average in spring    | 0.00105           | 0.21762        |
| Daily average in summer    | 0.001             | 0.171          |
| Daily average in autumn    | 0.001             | 0.182          |
| Daily average in winter    | 0.001             | 0.2082         |
| Daily average over 4 seasons | 0.0010           | 0.1947         |
| Average annual             | 0.370             | 71.067         |

The dispersion of waste accumulation volumes by seasons of the year was small - 5E-10, by mass it was 0.00036. Compared to the source [10], accumulation rates of MSW from penitentiary facilities are much lower than those from sanatoriums and medical and preventive treatment institutions.

### 4. Conclusion

Solid municipal waste accumulation rates from penal facilities in Perm Krai during the pandemic year 2020 have been determined. The average annual value was about 71 kg by mass per person and 0.37 m³ by volume per person.

### References

[1] Liu J, Li Y, Xiao B and Jiao J 2021 Coupling fuzzy multi-criteria decision-making and clustering algorithm for msw landfill site selection (Case study: Lanzhou, China) *ISPRS International Journal of Geo-Information* **10**(6) 403

[2] Kurniawan, at el 2021 A societal transition of MSW management in Xiamen (China) toward a circular economy through integrated waste recycling and technological digitization *Environmental Pollution* **277** 116741

[3] Krivosheeva M M 2021 Analysis of MSW accumulation standards *Upravlenie tekhnosferoi* **4**(2) (In Russ.)

[4] Stefanenko I V, at el 2020, The standard justification for the municipal solid waste accumulation *IOP Conference Series: Materials Science and Engineering* **913**(5) 052060

[5] Azarov V N, Azarov A V, Menzelintseva N V and Statyukha I M 2020 Research of the process of storage of solid communal waste and setting of the standards for their storage on the example of the Republic of Dagestan *Bulletin of Volgograd State University of Architecture and Civil Engineering. Series: Civil Engineering and Architecture* **2** 138–144 (In Russ.)

[6] Sereda T G 2021 Study of the morphological composition of municipal solid waste in the Perm region *IOP Conf. Ser.: Earth Environ. Sci.* **677** 042080

[7] Sereda T G and Kostarev S N 2019 Development of automated control system for waste sorting *IOP Conference Series: Materials Science and Engineering* **537**(6) 062012

[8] 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 http://www.consultant.ru/
[9] 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 http://www.consultant.ru/

[10] Azarov V N, Azarov A V, Menzelintseva N V, Statyukha I M The research of standards for accumulation of municipal solid waste of urbanized territories SOCIOLOGY OF THE CITY 2020. № 1. 48-57 144 (In Russ.)