Forecast of solid waste generation in Atyrau region

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Abstract. The article calculates the formation of solid household waste in the city of Atyrau and 7 districts of Atyrau region. The calculation was carried out taking into account the number of people in the previous four years, based on the characteristics of the average population growth. According to calculations for the next 5 years (2020-2024), the amount of waste in Atyrau will increase every year, which is associated with an increase in the population. Among the districts can be identified such areas as Zhyloy district, Inder district and Makat district, where there is a significant increase in waste, as the population growth in these areas is positive (0.1% in Inder district, 0.34% in Makat district and 1.3% in Zhyloy district). In the Issatay district, an increase is also predicted, but only slightly, since the population growth is 0.09%. In the remaining three districts, such as Kurmangazy district, Kyzylkuginsk district and Makhambet district, the amount of waste will decrease annually, which is associated with a decrease in population growth, while the maximum decrease is typical for Makhambet region (-4.18%). In the Kurmangazy and Kyzylkoginsk areas, the population growth rate of -0.41% and -0.72%, respectively.

1. Introduction
The problem of solid household waste (MSW) is very relevant, since its solution is associated with the need to ensure the normal life of the population, sanitary cleaning of cities, environmental protection and resource conservation. The volume of formation and accumulation of solid household waste on the territory of any locality largely depends on the standard of living of the population. With the increase in the level of welfare of the population of the republic, there is also an increase in the volume of municipal waste generation. At the same time, as a result of labor migration, a significant part of the rural population has moved to the cities in search of work, while the generation of household waste per capita in cities is significantly higher than in rural areas. This is due not only to higher income levels in cities, but also to differences in waste management: for example, in rural areas, food waste is usually fed to pets. Along with the increase in mass, the density of solid household waste decreases due to the increase in the content of paper and plastic in them due to packaging materials [1].

In Atyrau, as in many cities of Kazakhstan, the predominant method of disposal of municipal waste is its disposal in landfills. In Atyrau region, there are 9 enterprises engaged in the placement of solid waste, such as "Spetsavtobaza" LLP, "Zhylyoy Tazalyk" LLP, "Inder Tek" LLP, "Isataygazstroyservice" LLP, "Ar-Tri" LLP, "Zhana Arna" LLP, "Tazalyk kyzmet" LLP, "Tazalyk Kogal" LLP, "Aslim" LLP [2].

Existing landfills of solid waste in the settlements of the region do not meet modern requirements and issues of placement, processing of solid waste require early decision-making. The main specialized
enterprise engaged in the collection and removal of solid waste from most of the city is: “Spetsavtobaza” LLP, which has been operating in Atyrau since 1956. According to the information of "Spetsavtobaza" LLP, 802793 m$^3$ (111589 tons) of waste was taken to the landfill daily in 2016 [3].

In Atyrau and 7 districts (population of the region as of May 1, 2016). It amounted to 598.8 thousand people, including urban-305.8 thousand people (47.8%), rural – 312.6 thousand people (52.2%), as of July 1, 2019, only 645.28 thousand people, including urban - 355.117 thousand people (55.03%), rural - 290.163 thousand people (44.97%). Compared to May 1, 2016, the population increased by 49,317 thousand people or by 13.9%) [4].

2. Research methods

The calculation of the volume of waste generation is carried out by registering vehicles that deliver waste to the landfill, as well as calculations based on the normative indicators of waste generation in 2, 5m$^3$/person/year [5].

At the entrance to the landfill, garbage trucks are weighed on a platform scale. If the platform scales do not work, the waste is calculated by calculation, based on the practice of weighing the load of each garbage truck (in tons) [6].

3. Results and discussion

The main sources of solid household waste (MSW) are private households, multi-storey buildings, office buildings, commercial business enterprises, industrial enterprises and public organizations, kindergartens, schools, hospitals, small enterprises, agriculture, markets and bazaars and other waste generation sites covered by the municipal waste collection system.

The volume or mass of solid waste formation can be determined by analytical means, i.e. using the accumulation rate of different categories of waste set according to one accounting unit [7].

The accumulation rate is calculated as the average amount of waste generated per Accounting Unit (1 person for residential buildings) set over a certain period of time – a year or a day.

In accordance with the LRD (leading regulatory documentation) 03.1.0.3.01-96 "Procedure for dosing the volume of production waste and waste disposal", the norms for the formation of household waste are as follows [8]:

- in the private sector-2.27 m$^3$/year per 1 person.

In this paper, the volume of solid waste formation was calculated according to the following approach [9]:

The annual volume of solid household waste accumulation is expressed by the following formula:

$$M_{ann} = \sum_{i=1}^{n} p_i \times m_i - Q_{rec} - Q_{inc}$$

where: $M_{ann}$-annual residual amount, t/year;
$p_i$ - waste accumulation rate, t/year, person;
$m_i$ - population, people;
$Q_{rec}$-annual amount of recycled waste, m$^3$/year;
$Q_{inc}$-annual amount of incinerated waste, m$^3$/year.

The entire population of Atyrau city lives in urban areas. The population is growing rapidly, from 198.500 in 2005 y. to 247.286 in 2010y. (average annual growth-4.5%), 275.896 people in 2015 y. (average annual growth of 2.3%) and 355.117 people in 2019 y. (average annual growth - 5.6%) [10-13]. The average population growth rate is typical for the city of Atyrau (table 1).
Table 1. Population growth of the city of Atyrau for 2016-2019 (in %).

| Years | 2016 | 2017 | 2018 | 2019 | Average |
|-------|------|------|------|------|---------|
| The percentage | 3.95 | 4.35 | 3.35 | 4.8  | 4.1     |

Thus, the average population growth characteristic of the city of Atyrau is 4.1%. Using the average percentage of population growth, it is possible to estimate the population forecast of the city of Atyrau for 2020-2024 (table 2).

Table 2. Population forecast of the city of Atyrau for 2019-2024.

| Years | 2019  | 2020  | 2021  | 2022  | 2023  | 2024  |
|-------|-------|-------|-------|-------|-------|-------|
| Total | 355117| 369676| 385454| 401257| 417708| 434834|

We calculate the volume of household waste generation:

For the city of Atyrau:

\[ M_{\text{ann}}^{2019} = 355117 \times 2.27 \times 0.3 - 0.0 = 241834.677 \text{ t/ year} \]

\[ M_{\text{ann}}^{2020} = 369676 \times 2.27 \times 0.3 - 0.0 = 251749.356 \text{ t/ year} \]

\[ M_{\text{ann}}^{2021} = 385454 \times 2.27 \times 0.3 - 0.0 = 262494.174 \text{ t/ year} \]

\[ M_{\text{ann}}^{2022} = 401257 \times 2.27 \times 0.3 - 0.0 = 273256.017 \text{ t/ year} \]

\[ M_{\text{ann}}^{2023} = 417708 \times 2.27 \times 0.3 - 0.0 = 284459.148 \text{ t/ year} \]

\[ M_{\text{ann}}^{2024} = 434834 \times 2.27 \times 0.3 - 0.0 = 296121.954 \text{ t/ year} \]

Table 3. Population growth of Zhylyoy district for 2016-2019 (in %).

| Years | 2016 | 2017 | 2018 | 2019 | Average |
|-------|------|------|------|------|---------|
| The percentage | 1.73 | 1.33 | 1.49 | 0.67 | 1.3     |

Thus, the average population growth characteristic of Zhylyoy district is 1.3%. Using the average percentage of population growth, it is possible to determine the forecast of the population of Zhylyoy district for 2019-2024 by localities (table 4).

Table 4. Population forecast of Zhylyoy district for 2019-2024.

| Years | 2019  | 2020  | 2021  | 2022  | 2023  | 2024  |
|-------|-------|-------|-------|-------|-------|-------|
| Total | 83521 | 84606 | 85705 | 86819 | 87947 | 89090 |

We calculate the volume of household waste generation:

For Zhylyoy district:

\[ M_{\text{ann}}^{2019} = 83521 \times 2.27 \times 0.3 - 0.0 = 56.877.801 \text{ t/ year} \]

\[ M_{\text{ann}}^{2020} = 84606 \times 2.27 \times 0.3 - 0.0 = 57616.686 \text{ t/ year} \]

\[ M_{\text{ann}}^{2021} = 85705 \times 2.27 \times 0.3 - 0.0 = 58365.105 \text{ t/ year} \]

\[ M_{\text{ann}}^{2022} = 86819 \times 2.27 \times 0.3 - 0.0 = 59123.739 \text{ t/ year} \]

\[ M_{\text{ann}}^{2023} = 87947 \times 2.27 \times 0.3 - 0.0 = 59891.907 \text{ t/ year} \]
The Inder district, which covers an area of 10.9 thousand square kilometers, was established in 1933. The administrative center is the village of Inder.

To determine the volume of household waste generation by year and for the future (2020, 2021, 2022, 2023, 2024), an analysis of the dynamics of population growth in the Inder district over the past years by localities was performed (table 5).

### Table 5. Population growth of Inder district for 2016-2019 (in %).

| Years | 2016 | 2017 | 2018 | 2019 | Average |
|-------|------|------|------|------|---------|
| The percentage | -0.33 | -0.64 | 0.81 | -0.27 | 0.1 |

Thus, the average population growth characteristic of Inder district is 0.1%.

Using the average percentage of population growth, it is possible to determine the forecast of the population of Inder district for 2019-2024 by localities (table 6).

### Table 6. Population forecast of Inder district for 2019-2024.

| Years | Total |
|-------|-------|
| 2019 | 32089 |
| 2020 | 32121 |
| 2021 | 32153 |
| 2022 | 32185 |
| 2023 | 32217 |
| 2024 | 32249 |

We calculate the volume of household waste generation:

For Inder district:

- \( M_{\text{ann}} \text{2019}= 32089 \times 2.27 \times 0.3-0-0 = 56877.801 \text{t/year} \)
- \( M_{\text{ann}} \text{2020}= 32121 \times 2.27 \times 0.3-0-0 = 57616.686 \text{t/year} \)
- \( M_{\text{ann}} \text{2021}= 32153 \times 2.27 \times 0.3-0-0 = 58365.105 \text{t/year} \)
- \( M_{\text{ann}} \text{2022}= 32185 \times 2.27 \times 0.3-0-0 = 59123.739 \text{t/year} \)
- \( M_{\text{ann}} \text{2023}= 32217 \times 2.27 \times 0.3-0-0 = 59891.907 \text{t/year} \)
- \( M_{\text{ann}} \text{2024}= 32249 \times 2.27 \times 0.3-0-0 = 60670.29 \text{t/year} \)

Issatay district was established in 1928, its area is 14.7 thousand square kilometers. The administrative center is located in the village of Akkistau.

To determine the volume of household waste generation by year and for the future (2020, 2021, 2022, 2023, 2024), an analysis of the dynamics of population growth in the Issatay district over the past years by localities was performed (table 7).

### Table 7. Population growth of Issatay district for 2016-2019 (in %).

| Years | 2016 | 2017 | 2018 | 2019 |
|-------|------|------|------|------|
| The percentage | -0.13 | -0.18 | 0.14 | 0.08 |

Thus, the average population growth characteristic of Issatay district is 0.09%.

Using the average percentage of population growth, it is possible to determine the forecast of the population of Issatay district for 2019-2024 by localities (table 8).

### Table 8. Population forecast of Issatay district for 2019-2024.

| Years | Total |
|-------|-------|
| 2019 | 26749 |
| 2020 | 26773 |
| 2021 | 26797 |
| 2022 | 26821 |
| 2023 | 26845 |
| 2024 | 26869 |

We calculate the volume of household waste generation:
For Issatay district:

- For 2019:
  \[ M_{ann} 2019 = 26749 \times 2.27 \times 0.3 - 0.0 = 18216.069 \text{ t/year} \]
- For 2020:
  \[ M_{ann} 2020 = 26773 \times 2.27 \times 0.3 - 0.0 = 18232.413 \text{ t/year} \]
- For 2021:
  \[ M_{ann} 2021 = 26797 \times 2.27 \times 0.3 - 0.0 = 18248.757 \text{ t/year} \]
- For 2022:
  \[ M_{ann} 2022 = 26821 \times 2.27 \times 0.3 - 0.0 = 18265.101 \text{ t/year} \]
- For 2023:
  \[ M_{ann} 2023 = 26845 \times 2.27 \times 0.3 - 0.0 = 18281.445 \text{ t/year} \]
- For 2024:
  \[ M_{ann} 2024 = 26869 \times 2.27 \times 0.3 - 0.0 = 18297.789 \text{ t/year} \]

Kurmangazy district, which covers an area of 20.8 thousand square kilometers, was established in 1928 and is located in the west of the Atyrau region of Kazakhstan. The administrative center is the village of Ganyushkino.

To determine the volume of household waste generation by year and for the future (2020, 2021, 2022, 2023, 2024), an analysis of the dynamics of population growth in the Kurmangazy district over the past years by localities was performed (table 9).

| Table 9. Population growth of Kurmangazy district for 2016-2019 (in %). |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Years | Population growth compared to the previous year | Average |  |
| 2016 | -0.36 |  |
| 2017 | -1.2 |  |
| 2018 | -0.1 |  |
| 2019 | 0.03 |  |
| The percentage | -0.41 |  |

Thus, the average population growth characteristic of Kurmangazy district is -0.41%.

Using the average percentage of population growth, it is possible to determine the forecast of the population of Kurmangazy district for 2019-2024 by localities (table 10).

| Table 10. Population forecast of Kurmangazy district for 2019-2024. |
|---------------------------------------------------------------|
| Population forecast of the city of Kurmangazy district, (pers.) | |
| Years       | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| Total       | 57357 | 57122 | 56888 | 56655 | 56423 | 56192 |

Kzylkoginsky district was established in 1944 and is located in the north-east of Atyrau region of Kazakhstan. Its area is 24.9 thousand square kilometers. The administrative center is the village of Miyaly.

To determine the volume of household waste generation by year and for the future (2020, 2021, 2022, 2023, 2024), an analysis of the dynamics of population growth in the Kzylkoginsky district over the past years by localities was performed (table 11).

| Table 11. Population growth of Kzylkoginsky district for 2016-2019 (in %). |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Years | Population growth compared to the previous year | Average |  |
| 2016 | -0.61 |  |
| 2017 | -2.1 |  |
| 2018 | -0.37 |  |
| 2019 | 0.19 |  |
| The percentage | -0.72 |  |

Thus, the average population growth characteristic of Kzylkoginsky district is -0.72%.

Using the average percentage of population growth, it is possible to determine the forecast of the population of Kzylkoginsky district for 2019-2024 by localities (table 12).
Table 12. Population forecast of Kzylkoginsky district for 2019-2024.

| Years | 2019   | 2020   | 2021   | 2022   | 2023   | 2024   |
|-------|--------|--------|--------|--------|--------|--------|
| Total | 30649  | 30429  | 30210  | 29993  | 29777  | 29563  |

We calculate the volume of household waste generation:

For Kzylkoginsky district:

\[ M_{\text{ann}}^{2019} = 30649 \times 2.27 \times 0.3 - 0 = 20871.969 \text{ t/year} \]
\[ M_{\text{ann}}^{2020} = 30429 \times 2.27 \times 0.3 - 0 = 20722.149 \text{ t/year} \]
\[ M_{\text{ann}}^{2021} = 30210 \times 2.27 \times 0.3 - 0 = 20573.010 \text{ t/year} \]
\[ M_{\text{ann}}^{2022} = 29993 \times 2.27 \times 0.3 - 0 = 20425.233 \text{ t/year} \]
\[ M_{\text{ann}}^{2023} = 29777 \times 2.27 \times 0.3 - 0 = 20278.137 \text{ t/year} \]
\[ M_{\text{ann}}^{2024} = 29563 \times 2.27 \times 0.3 - 0 = 20132.403 \text{ t/year} \]

Table 13. Population growth of Makhambet district for 2016-2019 (in %).

| Years | 2016 | 2017 | 2018 | 2019 |
|-------|------|------|------|------|
| The percentage | 0.55 | 0.01 | 1.65 | -18.94 |

Thus, the average population growth characteristic of Makhambet district is -4.18%.

Using the average percentage of population growth, it is possible to determine the forecast of the population of Makhambet district for 2019-2024 by localities (table 14).

Table 14. Population forecast of Makhambet district for 2019-2024.

| Years | 2019   | 2020   | 2021   | 2022   | 2023   | 2024   |
|-------|--------|--------|--------|--------|--------|--------|
| Total | 29267  | 28044  | 26872  | 25749  | 24673  | 23642  |

We calculate the volume of household waste generation:

For Makhambet district:

\[ M_{\text{ann}}^{2019} = 29267 \times 2.27 \times 0.3 - 0 = 19930.827 \text{ t/year} \]
\[ M_{\text{ann}}^{2020} = 28044 \times 2.27 \times 0.3 - 0 = 19097.964 \text{ t/year} \]
\[ M_{\text{ann}}^{2021} = 26872 \times 2.27 \times 0.3 - 0 = 18299.832 \text{ t/year} \]
\[ M_{\text{ann}}^{2022} = 25749 \times 2.27 \times 0.3 - 0 = 17535.069 \text{ t/year} \]
\[ M_{\text{ann}}^{2023} = 24673 \times 2.27 \times 0.3 - 0 = 16802.313 \text{ t/year} \]
\[ M_{\text{ann}}^{2024} = 23642 \times 2.27 \times 0.3 - 0 = 16100.202 \text{ t/year} \]

Makat district, with an area of 4.9 thousand square kilometers, was formed in 1924. The administrative center is the village of Makat.

To determine the volume of household waste generation by year and for the future (2020, 2021, 2022, 2023, 2024), an analysis of the dynamics of population growth in the Makat district over the past years by localities was performed (table 15).
Table 15. Population growth of Makat district for 2016-2019 (in %).

| Years | 2016 | 2017 | 2018 | 2019 | Average |
|-------|------|------|------|------|---------|
| The percentage | 0.13 | -0.06 | 0.66 | 0.61 | 0.34 |

Thus, the average population growth characteristic of Makat district is 0.34%.

Using the average percentage of population growth, it is possible to determine the forecast of the population of Makat district for 2019-2024 by localities (table 16).

Table 16. Population forecast of Makat district for 2019-2024.

| Years | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|-------|------|------|------|------|------|------|
| Total | 30563 | 30667 | 30771 | 30875 | 30980 | 31085 |

We calculate the volume of household waste generation:

For Makat district:

\[ M_{\text{ann}} = \text{Volume} \times \text{Percentage} \]

- \[ M_{\text{ann}} \text{2019}= 30563 \times 2.27 \times 0.3 \times 0 = 20813.403 \text{ t/year} \]
- \[ M_{\text{ann}} \text{2020}= 30667 \times 2.27 \times 0.3 \times 0 = 20884.227 \text{ t/year} \]
- \[ M_{\text{ann}} \text{2021}= 30771 \times 2.27 \times 0.3 \times 0 = 20955.051 \text{ t/year} \]
- \[ M_{\text{ann}} \text{2022}= 30875 \times 2.27 \times 0.3 \times 0 = 21025.875 \text{ t/year} \]
- \[ M_{\text{ann}} \text{2023}= 30980 \times 2.27 \times 0.3 \times 0 = 21097.38 \text{ t/year} \]
- \[ M_{\text{ann}} \text{2024}= 31085 \times 2.27 \times 0.3 \times 0 = 21168.885 \text{ t/year} \]

4. Conclusion

The growth of welfare of the population and scientific and technical progress, in Atyrau and in the district centers of the region, and also in major towns of the districts there is growth of education MSW, followed by an increase in the volume of the waste mass [10]. This is especially true of Atyrau and such areas as Zhylyoy, Inder, Issatay. The performed forecast calculations indicate the prospect of further increase in the volume of waste generation both in the regional center and in the districts of the region [10].

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