# Astana city Municipal Solid Waste Characterization

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**Abstract**

This study presents the characterization results of MSW, obtained by sampling and analysis over the period from September to November 2017. The objective of the sampling campaigns was to identify the MSW energy potential as Refused Derived Fuel (RDF) for future development of combustion technology for Astana city. This paper reports tendency on seasonal change of MSW constituent in Astana city as well as comparison with the case studies of previous years. The RDF fraction of collected domestic waste is analyzed for thermal properties such as proximate and ultimate analyses, gross calorific value (GCV), and trace metal constituents. It was revealed that average recyclable fraction is about 32%, whereas energy potential of Astana's MSW is roughly 9%. Moreover, the highest constituents in MSW of Astana are organics (47.8%), plastic (16.0%) and paper (11.9%). The GCV of RDF fraction on average for two seasons yielded roughly 23MJ/kg and 20MJ/kg.

**Keywords**: *classification, moisture, combustible fraction, RDF, GCV.*

## 1. Introduction

Landfilling remains the most widely applied technologies for the disposal of municipal solid waste (MSW) practiced worldwide due to its proven economic advantage and simplicity over other alternatives [17]. Nevertheless, its adverse environmental impact and the necessity for large land areas are provoking research on other technologies, such as combustion in combination to energy recovery and production of electricity. This necessitates collection of reliable information regarding MSW generation and characterization for developing apposite waste management system for each city or region which varies from place to place and from season to season.

Kazakhstan has growing economy, increased rate of urbanization and population growth, which leads to increase in goods consumption and thus waste generation. It is reported that less than 5% of all MSW is being processed, whilst remaining 95% is landfilled [7]. In capital city Astana, domestic waste generated from houses is being collected by collection trucks and delivered directly to landfilling facility *Ecopolygon Astana*. It is stated that city has MSW production of 1.39 kg capita$^{-1}$ day$^{-1}$ [9]. This number is projected to increase because of aforementioned reasons, which raises the waste management problem for implementing combustion or other alternative technologies to resolve the issue of side-effects associated with traditional landfilling. It is also reported that the real data for characterization of MSW is limited for Astana city (Ibid.), which has a great importance and thus its scarcity creates a hurdle in creating and implementing these technologies.

This paper presents the analysis of MSW composition, the amount of combustible fraction as well as its chemical, physical and thermal properties in the capital city of Astana city. In addition, the results presented in this work include summer and autumn periods of 2017. The objective of the sampling campaigns was to investigate the seasonal change of MSW fraction as well as potential for Refused Derived Fuel (RDF) for future development of combustion technology for Astana city.

## 2. Methodology

### *2.1 Sampling plan and methodology*

The methodology applied in this paper was similar to the one employed in Inglezakis et al. [10], in their study of MSW composition in Bulgaria and Romania, which considered careful determination of sampling plan in order to meet objective as well as to ensure reliable and representative testing results. Therefore, our sampling process consisted of the following steps:

(1) Determination of Sampling Plan
(2) On site: sampling, testing, and preparing the laboratory samples
(3) Laboratory analysis
(4) Evaluating test results and reporting

EN standards and Technical reports utilized as the basis for establishing in testing program are:

- EN 14899:2006; Characterization of waste- Sampling of waste materials – Framework for the preparation and application of a Sampling Plan
- EN 15002:2006; Characterization of waste – Preparation of test portions from the laboratory sample
- CEN/TR 15310-1:2007; Characterization of waste – Sampling of waste materials – Part 1: Guidance on selection and application of criteria for sampling under various conditions
- CEN/TR 15310-2:2007; Characterization of waste - Sampling of waste materials - Part 2: Guidance on sampling techniques
- TP CEN/TR 15310-3:2007; Characterization of waste - Sampling of waste materials - Part 3: Guidance on procedures for sub-sampling in the field
- CEN/TR 15310-4:2007; Characterization of waste - Sampling of waste materials - Part 4: Guidance on procedures for sample packaging, storage, preservation, transport and delivery
- CEN/TR 15310-5:2007; Characterization of waste - Sampling of waste materials - Part 5: Guidance on the process of defining the sampling plan

Sampling was carried out at the area of MSW landfill that belongs to Astana Ecopolygon. Astana city has approximately estimated population of 1.029.556 inhabitants and average daily waste production of 800 tons per day. [12, 9]. The identification of mean MSW composition was based upon collection and manual sorting over waste samples for one week period for both seasons and all three districts of Astana city. These districts are: Almaty, Saryarka and Yesil, also shown in Figure 1. Summer sampling was conducted on the last week of September, whereas autumn sampling was performed on the first week of October. The samples were taken from residential areas of aforementioned districts which were collected by refuse vehicles. These vehicles were picked up in a random order, each time and from different regions of each district in order to ensure representative composition of waste stream.


**Figure 1.** Astana city map

In order to further enhance representatives of the data, MSW samples of 200 to 300 kg were taken at each sorting campaign from the whole waste discharged by the vehicle. Thereafter, initial collection portions were extracted from collected waste by manual division by coning and quartering. The procedure was as follows: spread the sample on a flat surface in a circular shape; mixed with shovel and made a cone. Afterwards, sample was divided in a four slices with the shovel, of the same size. Two opposite sites were then discharged, and the remaining parts of the sample were mixed.

### *2.2 Sorting plan*

Once sample was chosen, the sorting was carried out in two steps as depicted in the Figure 2. During the first sorting step, larger pieces of waste were separated and weighted into following categories: paper (Cardboard, Paper, Tetrapack), plastic (HDPE LDPE, PET, other plastic), metals (FE and non FE), glass, wood, textile & leather, Waste Electrical and Electronic Equipment (WEEE), Construction and Demolition (C&D) and others. It is presumed that for the first step, recycling is feasible from technical and economical point of view (ibid.). At this stage *1$^{st}$ laboratory sample* was taken, which composed mainly organics, soil and traces of inorganic material.

Second sorting presumed classifying the remained waste into combustible fraction: mixed paper, mixed plastic, textile & leather and wood. In addition, other smaller items as metals (FE and non FE), glass, Waste Electrical and Electronic Equipment (WEEE), Construction and Demolition (C&D), diapers, organics (food waste, green waste, and rest), and fine fraction (<12mm) were also classified. At the end of each sorting step, the weight of each fraction was recorded on a digital scale (BEKA 600kg), with the standard error of 50g. By the completion of this, the *2$^{nd}$ laboratory sample* was taken, which composed of combustible fraction, potentially suitable for waste-to-energy utilization. All samples were taken to laboratory for further analysis and preserved in way that volatiles are not lost.

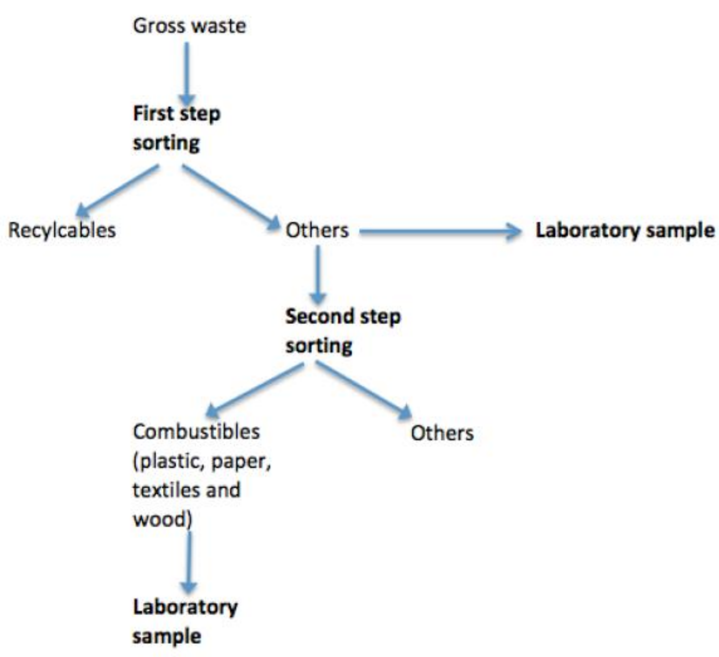


**Figure 2.** Sorting plan

### *2.3 Analysis of samples*

The laboratory analysis of sampled MSW included:

- Proximate analysis: identifying moisture, volatile matter, ash content and calculation of fixed carbon by difference. It was performed using ASTM D1762-84 standard, on a laboratory chamber furnace *Carbolite Gero ELF*.
- Ultimate analysis: identifying carbon, hydrogen, nitrogen and oxygen content in dry samples. It was performed using ASTM E777 standard, on a *vario MICRO cube* elemental analyzer. The amount of oxygen was determined by difference, knowing mineral content.
- Heave metal content determination: was performed on *ICP-MS iCAP RQ.*
- Gross calorific value determination: was performed on *Etalon colorimeter B-08MA K* bomb calorimeter.

The laboratory sample characterized in this paper consisted of combustible fraction for two seasons. For primary size reduction of samples, a garden chopper (PATRIOT SB 100E) was used. In order to further enhance homogeneity following procedure applied: crushed MSW was pelletized using manual hydraulic pellet press (911 Metallurgist TP2); then, was immersed to liquid nitrogen to complete solidification; ultimately, was grinded in a kitchen blender. Moisture was determined in as-is-state at 105°C at 24h in an oven (Carbolite RX 60).

## 3. Results and Discussion

### *3.1 Morphology of Municipal Solid Waste*

The average amount of MSW sampled for summer and autumn campaigns were 246.8kg and 253kg respectively. Figure 4 and 5 present the results of mean waste composition (%w/w) for each sampled fraction during 1$^{st}$ and 2$^{nd}$ campaign. It can be seen that paper (cardboard, paper tetrapack) and plastic (PET, LDPE, HDPE, other plastic) fraction has increased from summer to autumn period in the first step sorting campaigns. This could be explained by the fluctuation of Astana city population due to tourism in the summer and return from vacation of pupils and students towards autumn, which thereby contributes to the settlement of consumption pattern between these seasons. Similar tendency of an increase in disposal of recyclables from summer to autumn period was noticed in Greece, Lithuania, and Ukraine [8, 5]. Considerable increase in glass fraction from 5.1% to 7.2%, is due to change of inhabitants' consumption habits in colder times. Similar tendency of the highest glass disposal was observed in the period from September-November in St. Petersburg, Russia [5]. On average, 31.8% of MSW is suitable for material recycling in Astana city.

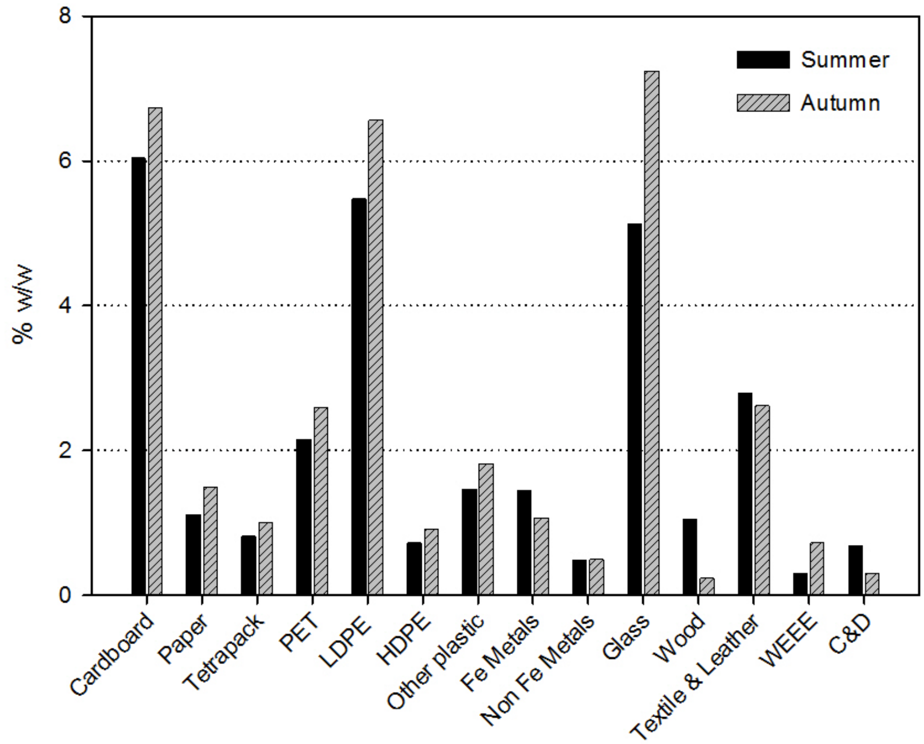


**Figure 4.** 1st sorting MSW characterization results.

From the second step sorting, the highest fraction in both seasons correspond to organic fraction approximately 50%. Since the fractions of WEEE, C&D, wood and metals is very low, log scale was applied. Generation of diapers is 6%, which infers dynamics of population growth in Astana city. According to the statistics, in the period of January-October 2017, the number of newborns has reached 23.668 [3], which accounts for 2% natural growth of population. The combustible fraction such as mixed paper, plastic, wood and textile & leather or Refused Derived Fuel fraction has also increased slightly from 8.8% to 9.4%.

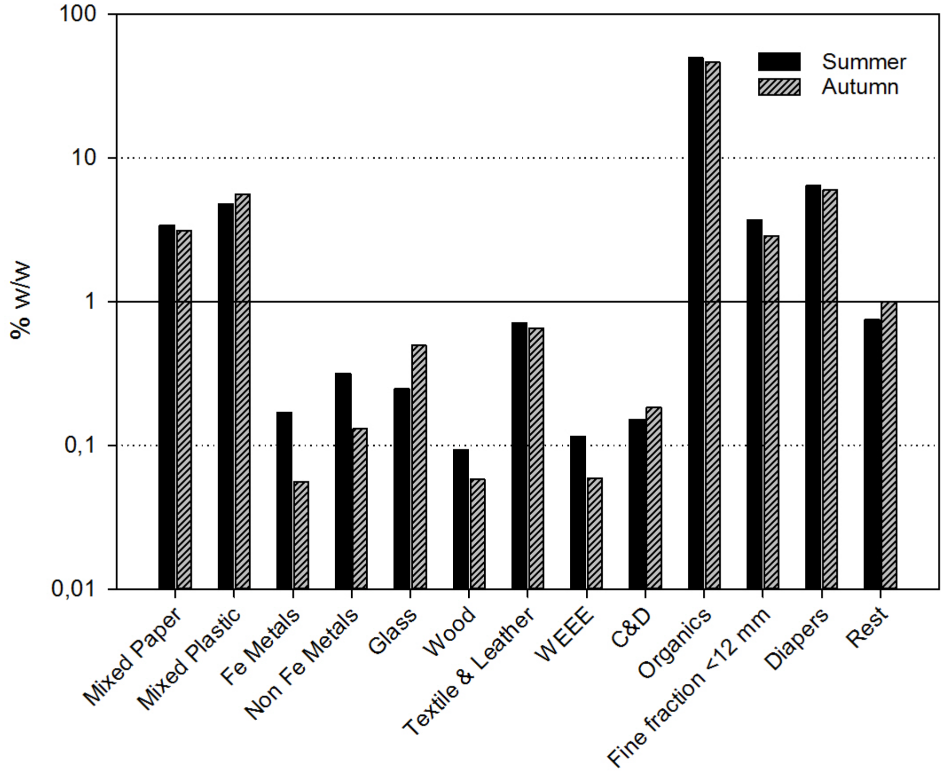


**Figure 5.** 2nd sorting MSW characterization results.

Table 1 summarizes average MSW composition for 2017 classified into 7 main parts: paper (cardboard, paper, tetrapack, mixed paper), plastic (LDPE, HDPE, PET, other plastic, mixed plastic), metals (Fe and non-Fe), textile, organics, glass and rest (diapers, WEEE, C&D, fine fraction<12mm, and rest). It also provides results of waste compositions studies conducted in Astana in 2006 and 2012. In addition, the dynamics of population growth was also provided. The paper fraction has decreased almost two times since 2006. The reason for that could be due to the introduction of scrap paper collecting system development. Plastic and metal disposal is almost uniform throughout, whereas glass and organic fraction variation is significant. It is explained by the fact that these studies were not conducted using the same sampling method or applying similar systematic approach. For instance, in 2012 it is reported that *Rest* fraction contained bones, whereas in our sampling campaign bones were classified as organic fraction. Another major reason is the population boost recorded in Astana city, which has almost doubled in the last decade. This infers expansion of a new city, with an inconsistent composition of municipal solid waste.

**Table 1.** MSW characterization in different years in Astana city.

| **MSW classification** | **2006 [6]** | **2012 [14]** | **2017*** |
|---|---|---|---|
| *Paper* | 25.9 | 13.0 | 11.9 |
| *Plastic* | 14.8 | 18.5 | 16.0 |

| | | | |
|---|---|---|---|
| *Textile* | 3.85 | 9.80 | 3.39 |
| *Organics* | 28.9 | 28.0 | 47.8 |
| *Glass* | 3.30 | 14.5 | 6.56 |
| *Metal* | 4.35 | 0.9 | 2.08 |
| *Rest* | 18.9 | 15.3 | 10.3** |
| *Astana city population* | 550,438 [12] | 742,918 [12] | 1,029,556 [13] |

*****only two seasons estimated; **diapers, rest and fine fraction<12mm.

*3.2 Laboratory analysis of RDF fraction of MSW*

Table 2 summarizes the average results of proximate and ultimate analyses of RDF fractions for two seasons. It also provides the comparison with other countries such as UK, Turkey and Greece. Moisture content of RDF for Astana city is considerable small than corresponding values, since dried sample was used. RDF consists mainly of volatile matter 60.1% and 74.6%, though, higher in autumn sampling, which infers that summer campaign contained more inorganic than organic constituent. Gross calorific values (GCV) for two seasons are 23.3 and 19.8MJ/kg: difference explained by lesser amount of inert material in summer campaign. GCV values and elemental analysis results for RDF in Astana city are in consistency with other reported values in different countries, which make it compatible for incineration.

**Table 2**. Properties of RDF and GCV.

| | **RDF – Astana September 2017** | **RDF - Astana November 2017** | **RDF – UK [11]** | **RDF –Turkey [15]** | **RDF- Greece [8]** |
|---|---|---|---|---|---|
| **%Moisture** | 1.53 | 1.60 | 5.9 | 14.8 | 11.7 |
| **%Ash** | 14.2 | 6.98 | 12.9 | 12.9 | 5.31 |
| **%Volatile matter** | 60.1 | 74.6 | 70 | 68.5 | 88.6 |
| **%Fixed Carbon** | 24.2 | 16.8 | 11.2 | 16.6 | 6.07 |
| **C(%)** | 47.6 | 48.2 | 58.65 | 56.47 | 59.2 |
| **H(%)** | 5.84 | 5.90 | 8.35 | 8.96 | 8.22 |
| **O(%)[a]** | 43.7 | 43.7 | 16.03 | 17.7 | na |
| **N(%)** | 2.58 | 2.11 | 1.0 | 1.50 | 0.52 |
| **S(%)** | 0.26 | 0.12 | 0.40 | 0.45 | na |

| | | | | | |
|---|---|---|---|---|---|
| **GCV ds (MJ/kg)** | 23.32 | 19.79 | 26.85 | 19.23 | 24.4 |

[a] Calculated by difference

Table 3 presents data for trace heavy metal analysis of RDF fractions of Astana city and two of UK and Romania. It can be noted that obtained results are similar to the ones provided as well as they are below compliance limits according to Reference Document on the Best Available Techniques for Waste Incineration (BREF, 2006).

**Table 3**. Trace metal analysis results (ppm).

| | **RDF – Astana Summer 2017** | **RDF - Astana Autumn 2017** | **RDF – UK [11]** | **RDF – Romania [10]** |
|---|---|---|---|---|
| **Cr** | **10.3** | **12.0** | **10.5** | **23** |
| **Fe** | **1738.3** | **1536.9** | **3928.5** | **1492** |
| **Co** | **1.1** | **1.4** | **1.8** | **<20** |
| **Ni** | **6.6** | **7.8** | **10.3** | **<30** |
| **Cu** | **22.7** | **22.1** | **31.8** | **37** |
| **Zn** | **128.2** | **127.9** | **132.1** | **127** |
| **As** | **0.6** | **0.5** | **1.4** | **<12** |
| **Cd** | **0.1** | **0.1** | **0.2** | **<20** |
| **Pb** | **5.1** | **4.4** | **29.5** | **147** |

## 4. Conclusion

MSW generated in three regions of Astana city: Almaty, Saryarka and Yessil at two different times of the year (September and November, 2017), was characterized for composition, physicochemical components and trace metal constituents.

MSW was classified in two steps sorting and it was revealed that recyclable fraction on average is 31.8%, whereas energy potential as RDF fraction is 9.1%. It was then allocated into major 7 fractions, with the highest being an organic fraction (47.8%), plastic (16.0%) and paper (11.9%). Proximate, ultimate, GCV and trace heavy metal analyses on RDF fraction did not show significant variation between seasons; however, obtained results had slight difference with other cities.

Understanding composition of MSW would greatly assist in resolving the landfilling issue and developing co-gasification incineration technology. It is projected to conduct a whole year seasonal sampling of MSW in order to have more reliable data for the characterization of MSW in Astana city.

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