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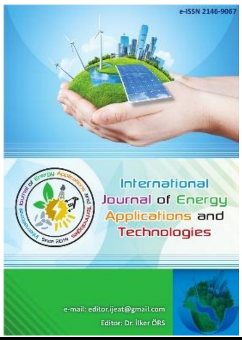

Original Research Article

Evaluation of combustibility and energy potential of municipal solid waste: The case of Esenler Municipality

Fatih Taşpınar[1,*], M. Akif Uslu[2]

[1] *Environmental Engineering Department, Düzce University, Düzce, TURKEY*
[2] *İstanbul Metropolitan Municipality, İstanbul, TURKEY*

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* Corresponding author
fatihtaspinar@duzce.edu.tr

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ABSTRACT

Waste management legislation has been amended and a policy has been set up to reduce the amount of waste sent to landfills within the framework of the EU regulations adoptions in Turkey. In this respect, the disposal of biodegradable wastes on landfills have been introduced and restricted with The Regulation on Landfilling of Wastes. For this purpose, the use of mechanical, biological and thermal processes to reduce waste amounts is envisaged. In this study, solid wastes produced in Esenler Municipality is characterized. Representative municipal solid waste (MSW) samples were collected and calorific values of MSW obtained from different socio-economic regions within the study area were examined.

Keywords: Municipal Solid Waste, Incineration, Calorific value, Energy gain

1. Introduction

Solid matters such as junks, domestic wastes and water treatment sludge, which is to be thrown by its manufacturer as solid wastes, need to be disposed of on a regular basis to the protection of environment [1-2]. Solid waste management is a way to collect and to dispose of solid wastes at points where they are produced, by some process including collecting, transmitting, processing, recovering and final removal. A human produces 0.7-1 kg waste/day for satisfying biological requirements. It may raise to 20 kg if requirements like dressing daily, shelter, road, car etc. are taken into account according to the development level of the country [3-4].

Municipal solid wastes generally consist of a heterogeneous character that can vary by waste type and local attributes they were produces. The amount of solid waste produced in a region is not only a function of the living standard, but also the lifestyle and socioeconomic status of the residents living there. Municipal solid waste management has emerged as one of the biggest challenges faced by environmental protection agencies in developing countries. As the world turns to the urban areas, solid waste management in these areas becomes more important than before. Ten years ago, while 2.9 billion people were living in cities, we were seeing an increase of about 0.64 kg per capita per day, which is the reason for this increase. The number of people producing waste was 3 billion and the average amount of waste produced per capita will predicted to be 1.2 kg up to 2025, which shows rates tend to increase by years. An estimated count of 4.3 billion residents will produce 1.42 kg per capita-day waste in near future. So, regulatory arrangements should be made in order not to grow in this regard [3-5, 17-18].

The incineration process can be used as a treatment for wastes in a wide range of wastes. The purpose of waste incineration is to treat (and intensify) or destroy the potentially harmful substances while reducing the volume and damage of the waste by treating the waste as in most of the waste treatment processes. The incineration process can also provide a method for recovering energy, mineral and/or chemical content from the waste. Municipal waste incineration in Europe as solid waste disposal method is used for over 50 years. The main benefit of preferred thermal methods is the mass and volume reduction of wastes by incineration in some countries where landfilling opportunities for landfills are limited. Nearly 400 solid waste incineration plants in the European Union countries are disposing 59 million tons of domestic solid waste per year. In the United States, there are 87 waste incineration plants where household wastes are disposed by incineration. Instead of storing and disposing of solid wastes in the framework of EU harmonization process, it is necessary for Turkey to find new solutions in order to minimize the damages to the environment and to give an economic sense to waste disposal [4, 15-16, 19].

Within the scope of this study, the general situation of waste incineration technology which is widely used as domestic solid waste disposal method especially in developed countries and its applicability to Istanbul is evaluated. Solid waste characterization in the environment and sustainable development process; efficient and speedy implementation of municipal services on waste management has great importance in monitoring environmental policies. In this study, the solid waste characterization study and the Esenler Municipality solid waste components were determined and an evaluation was made in terms of the compatibility of the waste with the burning ability by calorific value analysis.

2. Materials and Methods

The Municipality of Esenler, which is considered in this study, is a city that can be considered as the center of the city in the province of Istanbul which is composed of 16 districts and has a total area of 5.227 hectares. It is the 11th smallest district of Istanbul in terms of surface area. As of 2016, the population of Esenler district is 457.231. In this study, the Solid Waste Characterization Method was used as the standard method for the determination of the compositions of untreated urban wastes, which was established in many internationally recognized and accepted American standard technical methods (ASTM-American Society for Testing Materials, 2003).

2.1. Municipal solid waste characterization study

In the district where the solid waste characterization is to be carried out, samples are taken on Monday and Tuesday with separate waste collection vehicles from different points of the county (low, medium, high according to the market and income level). The reason for bringing the wastes generated on Mondays and Tuesdays is that a sample can be obtained that represents both the weekend and the week. The quantities of these wastes to be made for characterization should be the same as the quantities received and should be taken under expert supervision [5, 9, 14].

It is appropriate that the area where the waste characterization is to be made has a smooth slope and that a durable plastic covering of at least 5x10 m dimensions is laid on the floor during the process. The weighbridge must be calibrated before weighing. Waste collection vehicles from different regions empty the wastes so that each will form a separate batch. The discharged stacks are flattened separately. The waste shall be placed in equal amounts in each part of the pile, so that it will completely fill the inside of the fixed volume vessel (1x1x1 m or 0.5x0.5x0.5 m) from any of the stacks to be sampled. On the containers to be distinguished, the labels of the groups of substances (plastic, metal, glass, etc.) are affixed to avoid confusion. Sixteen components were identified for solid waste characterization with a separate container for each component in the separation process. These components are given in Table 1.

Table 1. Solid waste categories

Municipal Solid Waste Components	
Components	**Sources**
Organic	Food scraps, yard (leaves, grass) waste, wood, process residues
Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes
Carton	Milk cans, fruit juices cans, etc.
Volumed Carton	Carton boxes, etc.
Plastic	All plastic materials
Glass	Glass bottles, cups, etc.
Metal	Metal boxes, forks, knives, etc.
Volumed Metal	Metal cages, desks, etc.
Waste electric and electronic equipments	Telephone, radio, etc.
Hazardous waste	Battery, paint bins, detergent bins, drug bins, etc.
Park and garden waste	Branches, tree limbs, grass, etc.
Other incombustibles	Stones, sand, ceramic, etc.
Other combustibles	Textile wastes, napkins, shoes, slippers, pillows, carpets, bags, etc.
Other volumed incombustibles	Undefined volumed incombustibles
Other volumed combustibles	Furniture and wooden materials, etc.
Others	Unclassified materials

In the characterization, the empty weights (tare) of the containers record before proceeding to item group analysis. Then all the wastes are put into the appropriate ones from this pile spread on the plastic cover so as to leave food residues to the end. Mass loss may occur during grouping due to water evaporation. So the collected wastes should be separated as quickly as possible [9]. Fig. 1 shows the waste containers when separating wastes. If there are bags connected during the sorting process, they must be opened and the wastes from them must be placed in appropriate containers. The full container (gross) is weighed and noted. In winter, wastes should be passed through a screen having a diameter of 1 cm. The rest on the top is placed in the same container and weighed, weighing is noted. The difference between weighing made before and after the sifting of the wolf gives the weight of the pheasant. The amount of ash is thus separately found for each component. After all the groups have finished weighing, these weights are collected and the amount of ash in the total sample is obtained. The elimination of all the sample causes the cloud to be trapped in the waste, not to go under the screen

Figure 1. Waste separating using different containers

3. Results and Discussion

3.1. MSW characterization results

A variety of studies were carried out to collect the samples that would represent well the wastes produced in the vicinity of Esenler in İstanbul and gives the idea about the high income and low income levels. So, two different region Mimar Sinan and Nene Hatun areas in Esenler district with a population of 5000 were determined by interviewing. The next stage where the neighborhoods were identified was the selection of the areas to be sampled, which were interviewed by the authorities of the municipality's clean-up work, and appropriate sampling points were determined. Generally, nearly 1 ton (about 3-4 containers) waste samples from each income group were collected by cleaning and separating the MSW for analysis. It has also been found that the sieving phase during the winter season, the amount of ash that is contaminated or adhered to other wastes is negligible in the preliminary work, although it is stated in the proposed method that each waste category should be reweighed with the ash first, then through the sieve. For this reason, after each category is identified, it is preferable to weigh the remaining and measure the amount. So, wastes were shredded while separating the easily separable groups (paper, cardboard, metal, glass, etc.) into categories and an attention has been paid to removing it from residues. Residual ash mixed wastes were passed through the sieve with a pore size of 1 cm2, and the waste from the sieve was re-separated while the waste from the sieve was evaluated as ash and the amount of ash was determined. In the preliminary work, the equivalent of about 250-300 kg of 1 m3 waste did not make it possible to elaborate the waste. The measurements were made over a volume of 0.5 m3, so the results were doubled [7-8, 17].

Winter period solid waste characterization studies started in February, 2017 and finalized in March, 2017. Due to the unfavorable weather conditions, the MSW were usually collected weekly, which led to a longer period of work. Summer season work started in June, 2017 and ended in July, 2017. The statistical data obtained as a result of the study of the local waste characterization are given in Table 2 for weekly analyzes and in Table 3 for weekend analyzes. Waste statistics for wastes collected from Mimar Sinan and Nene Hatun districts in Esenler are summarized in 17 separate waste categories in these tables. It is seen that especially the amounts of waste organic wastes (Mimar Sinan- 35.51% and Nene Hatun- 43.64%), textile wastes (22.98% and 15.77%) and paper-cardboard (10,96% and 5.90%) were more than the amount of the other category members.

As shown in Table 2 and Table 3 for weekdays and weekend samples respectively, some changes were occurred in average composition of the MSW. Fig. 2 shows a summarized pie chart of the percentages of weekdays and weekend MSW categories, respectively. On weekdays and weekends, the most obvious difference in waste character appears to be textile wastes. The reason for this large difference of 17% in the area was the textile firms closed on the weekend, which are the biggest source of weekday textile wastes. There is an increase in organic wastes at the weekend also. In this increase, people are more likely to go to the fast-food on the weekend, causing the increase of the organic waste. In addition to these fast foods, the intake of soft drinks generally makes a differentiable ratio in glass amount. The increase in the number of bags, people market, bazaar-market and clothing can usually be considered as increasing shopping habits at weekends. As can be seen from these tables, the characterizations of the wastes in the cities vary depending on the different parameters. Changes in the weekday and weekend waste groups provide us reliable data about of the district character.

Table 2. MSW characterization results for weekdays samples

		MİMAR SİNAN		NENE HATUN	
Group	**Material**	**NET (kg)**	**PERCENT (%)**	**NET (kg)**	**PERCENT (%)**
1	Paper - Carton	12.210	10.956	11.830	5.901
2	Glass	1.995	1.790	4.630	2.310
3	Pet	0.995	0.893	1.030	0.514
4	Bag	9.045	8.116	21.175	10.563
5	Plastic	2.710	2.432	2.410	1.202
6	Metal	0.370	0.332	0.650	0.324
9	Organic wastes	39.575	35.511	87.480	43.637
10	Waste electric and electronic equipments	0.780	0.700	0.065	0.032
11	Hazardous waste	0.265	0.238	0.755	0.377
12	Tetrapak	0.380	0.341	0.675	0.337
13	Textile	25.605	22.975	31.625	15.775
14	Diaper	5.530	4.962	19.580	9.767
15	Park and garden wastes	0.000	0.000	0.510	0.254
16	Other combustibles	10.800	9.691	16.045	8.004
17	Other incombustibles	1.185	1.063	2.010	1.003
	TOTAL	**111.45**	**100.00**	**200.47**	**100.00**

Table 3. MSW characterization results for samples taken from weekends

		MİMAR SİNAN		NENE HATUN	
Group	**Material**	**NET (kg)**	**PERCENT(%)**	**NET (kg)**	**PERCENT (%)**
1	Paper - Carton	17.045	10.097	17.060	7.904
2	Glass	5.835	3.457	4.980	2.307
3	Pet	2.280	1.351	0.920	0.426
4	Bag	17.025	10.085	25.030	11.596
5	Plastic	3.385	2.005	3.750	1.737
6	Metal	0.480	0.284	1.475	0.683
9	Organic wastes	84.185	49.870	112.390	52.070
10	Waste electric and electronic equipments	0.000	0.000	0.450	0.208
11	Hazardous waste	1.250	0.740	0.455	0.211
12	Tetrapak	1.080	0.640	1.165	0.540
13	Textile	10.030	5.942	20.535	9.514
14	Diaper	11.700	6.931	13.480	6.245
15	Park and garden wastes	0.835	0.495	0.000	0.000
16	Other combustibles	13.300	7.879	14.035	6.502
17	Other incombustibles	0.380	0.225	0.120	0.056
	TOTAL	**168.81**	**100.00**	**215.85**	**100.00**

In Table 4, as a different parameter, high income and low income groups were analyzed individually. As shown in Table 4 and Figure 3, there are also various differences between the high income group and the low income group. The paper and cardboard waste group is higher than the low income group.

This is due to the fact that the literacy rate in high income places is higher than that in low income places, so newspapers, magazines, etc. more use of the products. This tells us clearly in the character of our horse. The reason that plastics are high in the high income group is that they take their food in more packages than the low income group. The fact that the bag ratio is higher in low incomes is because the higher the market exchange, the different bags given to each product make up the difference there. The fact that the textile ratio is high in high income, economically, they are paying attention to the fact that low income group is more economical as costume clothes. In low-income group, the reason for the surplus of domestic waste was to make shopping in cheaper places, causing the amount of waste to be increased more consciously and more than necessary.

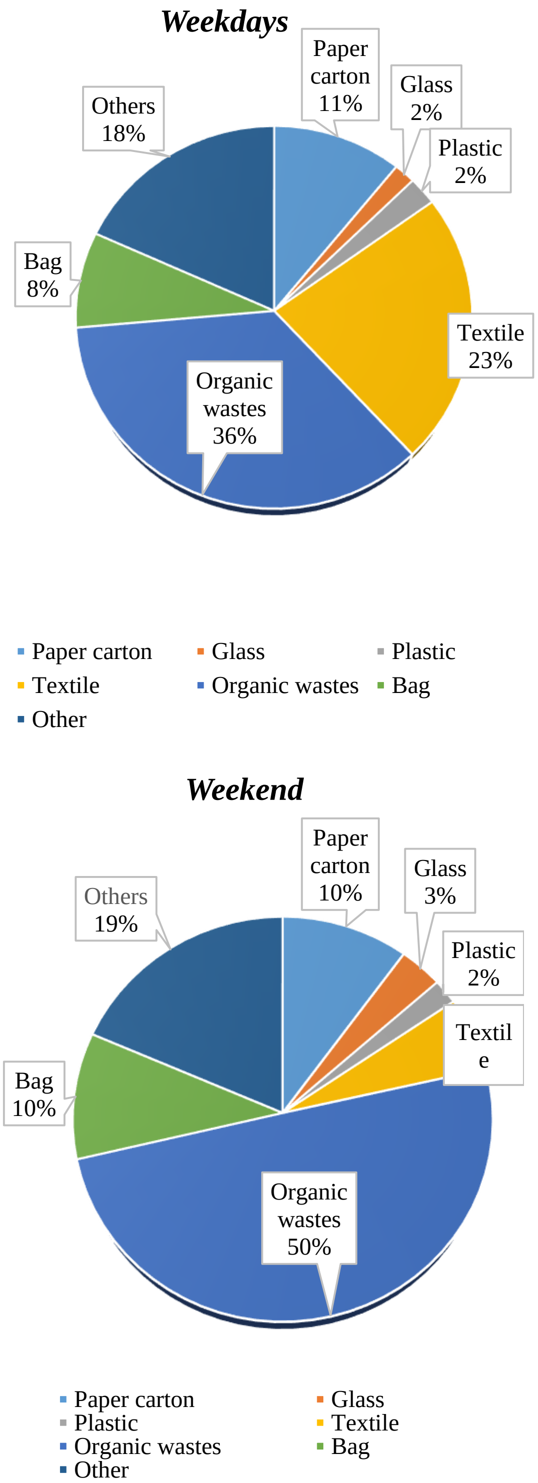

Figure 2. Waste fractions for the samples taken form weekdays and weekend

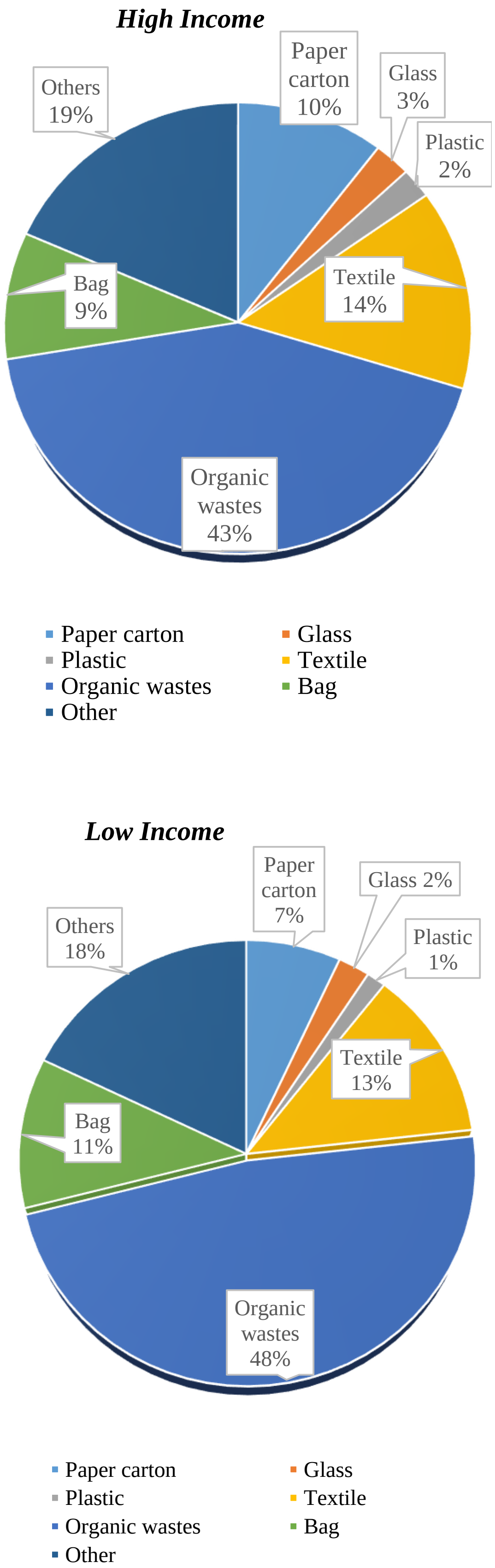

Figure 3. Chart of MSW statistics for the samples form high and low income areas

Table 4. The average MSW statistics with high and low income areas

Group	Material	High Income (%)	Low Income (%)	Weekdays (%)	Weekend (%)	General (%)
1	Paper - Carton	10.526	6.902	8.428	9	8.714
2	Glass	2.623	2.308	2.049	2.881	2.465
3	Pet	1.121	0.47	0.703	0.888	0.795
4	Bag	9.1	11.079	9.339	10.84	10.09
5	Plastic	2.218	1.469	1.816	1.871	1.844
6	Metal	0.308	0.503	0.328	0.483	0.405
9	Organic wastes	42.69	47.853	39.574	50.969	45.271
10	Waste electric and electronic equipments	0.349	0.12	0.366	0.104	0.235
11	Hazardous waste	0.489	0.293	0.307	0.475	0.391
12	Tetrapak	0.49	0.438	0.338	0.589	0.464
13	Textile	14.458	12.644	19.375	7.727	13.551
14	Diaper	5.946	8.006	7.364	6.588	6.976
15	Park and garden wastes	0.247	0.127	0.127	0.247	0.187
16	Other combustibles	8.784	7.253	8.847	7.19	8.018
17	Other incombustibles	0.644	0.529	1.032	0.14	0.586
	TOTAL	**100**	**100**	**100**	**100**	**100**

In general, the solid waste characterization data based on different regions provides very important information about the MSW character of the city by summarizing the socioeconomic situation of the region. In this study, the types and quantities of waste produced by working in Mimar Sinan and Nene Hatun districts in Istanbul Esenler Region were obtained and detailed. High income MSW statistics showed that paper and glass fractions were higher that the low income region whereas organic waste fraction of low income region were higher than high income part of Esenler district in İstanbul. It is an expected situation due to the different nutrition habits of these two socioeconomically different region. However, fractions of the other MSW groups were close to each other, indicating that generally organic fractions of MSW higher than the other factions.

3.2. Heat capacity of Esenler MSW

In order to determine, whether or not it is appropriate to include the incineration method in the waste management system, it is first necessary to determine the composition of the waste, that is characterization of the MSW, and the calorific value of MSW. As a result of detailed MSW characterization conducted in this study, average calorific value of MSW was analyzed by bomb-calorimeter and also was calculated.

Municipal waste is an inhomogeneous fuel that differs greatly from conventional fossil fuels. Calculating the calorific value of MSW is, therefore, complex and may lead to gross errors if done incorrectly. The representativeness of the samples analyzed is most critical, and variations must be accounted for.

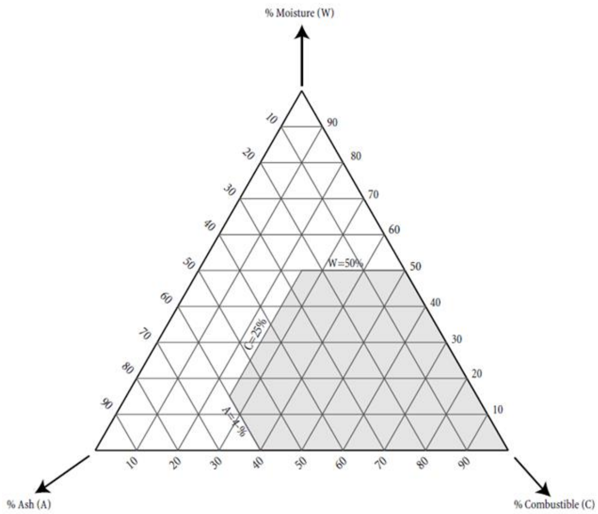

Figure 4. Tanner triangle for assessment of combustibility of MSW

The ability of waste to sustain a combustion process without supplementary fuel depends on a number of physical and chemical parameters, of which the lower (inferior) calorific value is the most important. The minimum required lower calorific value for a controlled incineration also depends on the furnace design. The combustibility of MSW is determined by analysis and heating value of MSW, which is the ash and water free calorific value (H_{awf}) expresses the lower calorific value of the combustible fraction (ignition loss of dry sample). Also Tanner triangle can be used to determine MSW combustibility as shown in Fig 4. The result may also be plotted in a Tanner triangle diagram to see where it falls within the shaded area indicating a combustible fuel. The waste is theoretically feasible for combustion without auxiliary fuel when: W < 50 percent, A < 60 percent, and C > 25 percent. A more accurate way to assess the fuel quality of a waste is to divide it into characteristic components (organic waste, plastics, cardboard, inerts, and the like), determine the water content (%W), the ash content (%A) and the combustible matter (%C) [8, 10-11].

Moisture determination was performed on the samples taken for the laboratory analysis, and the water content in the waste was determined. Then, the calorific values of the organic parts, which were dried and separately prepared, and the packaging wastes other than this, were determined. According to the results of calorific testing done in the laboratory, it is seen that the calorific value of waste is close to the wastes generated in the European countries where the incineration method is widely used. For direct incineration and energy recovery, the waste calorific value should be at least 2000-2500 kcal/kg, and 1500 1600 kcal/kg for the combustion without additional fuel (Istanbul Solid Waste Management Feasibility Report). If the heating value is below 1200 kcal/kg, it is understood that the solid waste cannot be economically burned. Solid wastes must be at a certain rate of moisture, organic matter and inorganic matter content in order for waste to be disposed of. Moisture content is expressed as a weight loss in a sample as a result of drying. When the moisture content of the waste is too high, it is necessary to use additional fuel to support the combustion. Moisture content of solid wastes in our country varies between 60-80%. The heat capacity of the wastes in Esenler should be determined in order to be able to reveal its calorific value. These values are given in Table 5. The analysis results shown here are suitable for the combustion process as a thermal value. The upper heat value and the lower heat value of the Esenler Municipality urban participation were determined as 3498 ± 262.8 and 1711 ± 401.6 kcal / kg respectively. Water content was 45.8 ± 6% and organic matter content was 81 ± 0.2%. The fact that the water content is less than 50% and the average calorific value is about 3200 kcal/kg as H_{awf} indicates that the Esenler Municipality solid wastes are suitable to be thermally disposed of such as MSW incineration method.

Table 5: Calorific analysis results of MSW of Esenler district

Municipality	**Water content, %**		**Upper Heating Value, kcal/kg**		**Lower Heating Value, kcal/kg**		**Organic matter, %**	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Esenler	45.8	6.0	3498.0	262.8	1711.1	401.6	81.1	0.2

4. Conclusion

In this study, the composition of the municipal solid wastes of the Municipality of Esenler was investigated and a detailed MSW composition was obtained. It was seen that kitchen wastes with organic residues constituted the biggest percentage of waste types. This is followed by paper and cartons, other burnables (cloth, nappy, shoes, slippers, pillows, carpets, rugs, bags, etc.), plastic waste and ash (dust, sand, stone). Kitchen wastes produce fruit and vegetable residues and food waste. Among these categories, packaging wastes and plastics, paper-cardboard, used diapers and different textile wastes have been found to account for most of the other flammable wastes. Especially low levels of ash amounts occupy an important place as most of the ashes collected during winter period. Plastic wastes have an important place among mixed waste contain 7 different recyclable plastics (HDPE, LDPE, PP, PE, PS, PET, other) and waste categories. Although each of these plastics have different chemical properties and economic values, they are mixed together because they are not considered for incineration as well as they are easily recyclable materials. Most of the hazardous wastes that are separated mostly constituted the packaging wastes of the cleaning products used in the houses. It has been found that the average moisture content of the wastes of 45% and the average calorific value of 3200 kcal/kg (H_{awf}) are suitable well to treat the wastes produced in the Esenler district in Istanbul by thermal methods and to use the resulting heat for energy production purposes.

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