



# Solid waste composition and the properties of biodegradable fractions in Izmir City, Turkey: an investigation on the influencing factors

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## Abstract

**Background** Waste composition and characteristics are determinative in selecting technological alternatives to develop waste management strategies that can meet legislative requirements. The aim of this study is to identify the major factors influencing the municipal solid waste (MSW) composition and the properties of its biodegradable fraction in İzmir city, Turkey.

**Methods** MSW composition was determined in samples collected from different income level areas of the city. Water and organic matter contents, calorific value, and the total chlorine levels in seven biodegradable waste (Bio-MSW) size fractions (between >120 mm and > 10 mm) and in the fine fraction (<10 mm) were analyzed. The data on waste components and Bio-MSW properties were statistically investigated.

**Results** The average shares of biodegradables and recyclables in MSW were found as 50.2 and 40.3%, respectively. The organic matter content of Bio-MSW increased with waste size ( $r=0.313$ ,  $p<0.05$ ) and its calorific value were in the range of 2310–3686 kcal/kg. A link between the plastics' share in MSW and the Bio-MSW chlorine levels was recognized ( $r: 0.666$ ,  $p<0.1$ ). PCA analysis identified the main factors degrading the Bio-MSW quality as the cross contamination due to the mixed collection (30.8%), compaction applied in waste trucks (27.5%), and the inert broken materials trapped in larger fractions (21.3%).

**Conclusion** Strong negative impact of mixed collection on Bio-MSW quality indicated that implementation of source separated collection of MSW is crucial for İzmir city in order to develop an integrated waste management system that meets the legal requirements by means of end product quality.

**Keywords** Biodegradable waste · Calorific value · Chlorine · Mixed collection · PCA · Waste composition

## Introduction

Municipal solid waste management has always been a major problem, especially for large cities [1–4]. The location of a city on earth, the geographical features of its land, and climate are the most important determinants of agricultural and industrial potential and trade opportunities of its terrain. All of these features have direct or indirect impacts on the city population and the socioeconomic and cultural structure, and therefore, effect the rate of waste generation, its composition and properties in the region [5–8]. Therefore, not only waste generation rates and flows, but also its composition and properties are

unique for the countries and the cities and differ in a wide range on the world. The ratio of biodegradables in municipal solid waste (MSW) was reported as 26% in Japan, 44.4% in Italy, and as high as 69% in Turkey, while the rate of major recyclables varies in a range of 8%–60% in world countries [9, 10].

Waste composition and characteristics are determinative in selecting technological alternatives to develop waste management strategies that can meet legislative requirements. However, assessment of possible technologies and scenarios within the framework of economic considerations is inevitable to obtain a sustainable waste management system. That is why solid waste management practices may vary in different countries having similar waste compositions and/or legislative considerations (Table 1).

For example, in European countries, Landfill Directive 1999/31/EC [18] and Waste Framework Directive [19] introduced strict technical requirements for waste and landfills for preventing and reducing the negative effects of waste landfilling on environment. However, waste management

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**Table 1** Solid waste management in some countries [11–17]

	Waste Generation kg/cap.day	Landfilling %	Incineration * %	Composting %	Recycling %	Reference
Austria <sup>a</sup>	1.55	4	38	32	26	[11]
Germany <sup>a</sup>	1.73	0	33	18	49	
Italy <sup>a</sup>	1.34	34	21	17	28	
Ireland <sup>b</sup>	1.61	42	17	6	34	
Czechia <sup>a</sup>	0.85	56	18	3	23	
UK <sup>a</sup>	1.34	28	27	17	28	
EU 28 <sup>a</sup>	1.31	28	27	16	29	
Canada <sup>b</sup>	–	71	4	7	18	[12]
USA <sup>a</sup>	2.01	53	13	9	26	
Japan <sup>a</sup>	0.96	1	78	0	21	
Greece	1.25 <sup>c</sup>	81 <sup>a</sup>		19 <sup>a***</sup>		[13]
Iran <sup>d</sup>	0.65	80		20 <sup>***</sup>		[14]
Iraq	0.97	~100	negligible			[15]
Morocco	1.46	96 <sup>**</sup>			4	[16]
Tunisia	0.81	95 <sup>**</sup>			5	
Turkey <sup>d</sup>	1.08	90.2 <sup>**</sup>		0.5	9.3	[17]

\* Incineration with and without energy recovery, \*\* Landfilling + open dumping, \*\*\* Composting and recycling, <sup>a</sup> Reported data for 2014, <sup>b</sup> Reported data for 2012, <sup>c</sup> Reported data for 2011, <sup>d</sup> Reported data for 2016

practices in the European Union countries within the Waste Framework Directive are different; as landfilling have been almost banned in Germany, while 56% of the solid waste in Czechia have still been landfilled (Table 2). Similarly, waste incineration rates in Europe vary in a large range (17% in Ireland and 38% in Austria) [11].

In Turkey, the total MSW generated in 2016 is 31.6 Mt., where 61.2% of that waste was sent to landfills and 29% of it was mainly disposed to open dumping areas [17]. The biodegradables consist of more than 40% of MSW, where the shares of recyclables vary in a large range because of the different climatic and socio-economical features of the cities (Table 1).

The legislations on waste management in Turkey are being developed to adapt solid waste management system to the EU directives about the waste [19], landfilling of waste [18], waste incineration [28], and the promotion of the use of energy from renewable sources [29].

Even though the legislations on source separation and recycling of MSW and diversion of biodegradables from landfill areas has been on force since 2004 [30, 31], the capacities of Mechanical and Biological Treatment (MBT), incineration, or source separated composting and/or anaerobic digestion plants are limited with 9.8% of the total waste generated [17].

Similar to the other Turkish cities, the MSW generated in Izmir Metropolitan City is mix collected and about 8000 tons of daily MSW is directly disposed of in landfill sites with limited future capacities. Therefore, selecting a new and integrated waste management strategy that aims to divert MSW from landfilling areas in order to meet legal requirements is crucial for the city. For this purpose, not only the waste

composition and the characteristics but also the factors influencing the waste properties should be well defined. By this way, it will be possible to develop efficient approaches to improve waste characteristics and to select competent technologies for an integrated waste management system in the city. However, the data on waste characteristics and composition of the city is limited [25, 26] and the factors influencing the waste characteristics was not studied previously.

Reported researches on the determination of MSW composition and characteristics are widespread in the literature [8, 9, 13, 16, 20–23, 32, 33]. On the other hand, the studies including the statistical evaluation of data are few in number. Al-Jarallah & Aleisa [34] used analysis of variance for identifying the influence of seasons and governorate on waste composition in the State of Kuwait. Miezah et al. [35] applied a regression analysis to the data on waste generation rates, household income level and household size in Ghana. Edjabou et al. [36] studied the links between the waste generation rate, Danish housing types, and waste composition variations, statistically, in order to obtain reliable data for a sound waste management and resource recovery. Aslani and Taghipour [37] investigated the seasonal characterization, generation rate, and chemical properties of MSW in Iran and evaluated the interrelations among waste components by using Spearman's correlation matrix.

The findings of above mentioned studies were generally used to develop possible waste management scenarios for the corresponding residential areas or countries. However, there is a gap in the literature on the reasons of the levels of measured data and the identification of the impacts resulted

**Table 2** Municipal solid waste composition in some countries and in Turkey, % [9, 13, 16, 20–27]

Countries	Biodegradable	Plastic	Paper	Metal	Glass	Textile, leather etc.	Ash	Inert and other	Reference
China <sup>b</sup>	35.8	3.8	3.7	0.3	2	–		47.5	[9]
Germany <sup>a</sup>	30	13	24	1	10	4		18	[20]
Italy <sup>b</sup>	31	11	24	4	8	5.5		16.5	[9]
Japan <sup>b</sup>	26	9	46	8	7	–		12	
Singapore <sup>b</sup>	44.4	11.8	28.3	4.8	4.1	–		6.6	
UK <sup>b</sup>	38	7	18	8	7	3		19	
USA <sup>c</sup>	28.2	12.9	26.5	9	4.4	9.5		9.5	[21]
Greece <sup>c</sup>	48	8	20	4	5			15	[13]
Iran <sup>d</sup>	72.59	5.01	9.46	2.57	1.86	1.7		6.81	[22]
Iraq <sup>e</sup>	55	25.2	7	3	2.9	4.5		2.4	[23]
Tunisia	68	11	9	4	2			6	[16]
India	35	2	3		1			59	
Turkish Cities									
Ankara	55	4	0.57	0.51	0.55	–	–	39.37	[24]
Antalya	64.79	11.45	7.83	2.56	3.73	3.2	–	7.52	
Bursa	43	19	7	1	4	–	–	26	
Eskişehir	56.4	12	8.9	1.5	9.97	–	3.33	7.9	
Erzurum	44.45	11.48	14.81	2.6	3.7	–	–	22.96	
Gaziantep	69	15.74	5.44	0.79	2.02	–	7.01	–	
İstanbul	53	17	13	1	6	4	3	3	
Kayseri	62.59	3.6	2.68	0.99	2.49	0.83	–	26.84	
Kocaeli	57.78	10.23	8.39	1.02	4.06	–	1.91	16.6	
Şanlıurfa	65	8	6	1	2	2	2	14	
Tekirdağ	34	2	16	1	6	–	–	41	
Trabzon	47.3	18.62	8.2	3.92	5.01	5.18	–	17.6	
Izmir Metropolitan City	46	12	12	3	4	–		23	[25]
	52	10	3.8	3.1	2.9	–		28.2	[26]
Turkey, range	40–80	3–21	6–18.4	0.6–2	2–15	1–19.6		0.3–64.5	[26]
	>40	5–14	7–18	1–6	2–6	–		7–24	[27]
	34–69	2–19	0.57–16	0.51–3.92	0.55–9.97	0.83–5.18	1.91–7.01	3–41	[24]

<sup>a</sup> Reported data for 2006, <sup>b</sup> Reported data for 2007, <sup>c</sup> Reported data for 2014, <sup>d</sup> Reported data for 2016 (Tehran city), <sup>e</sup> Reported data for 2012 (Basrah District)

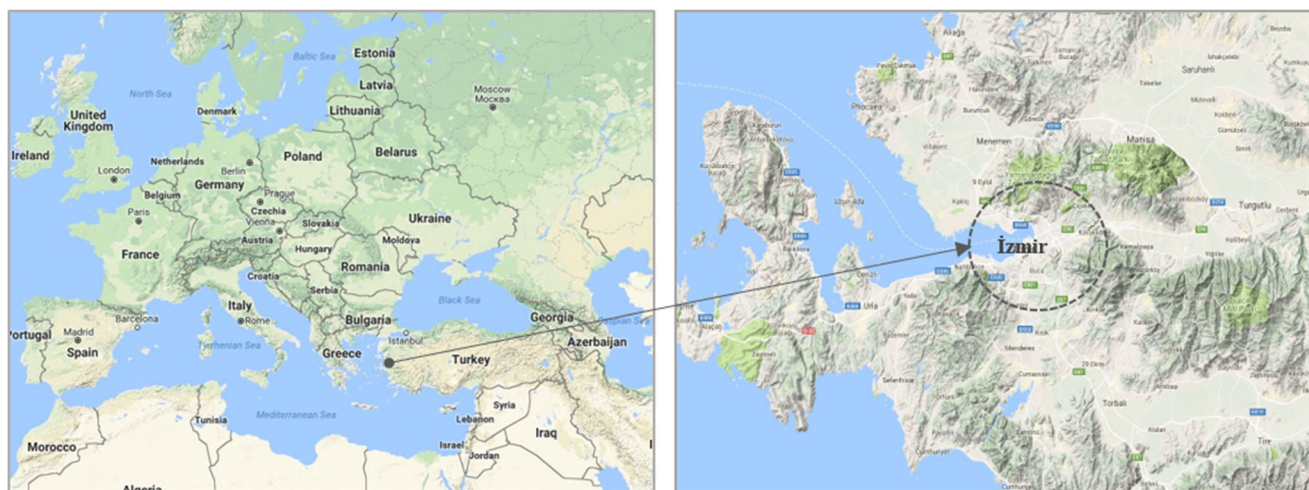
with a change in waste composition and characteristics. On the other hand, such information may provide a well understanding of the deficiencies, faults, benefits, or advantages of existing waste management practices in the cities and countries and can be used to improve and/or reorganize the MSW management systems and related legislations.

For this reason, here, the solid waste composition and the properties of biodegradable fraction of İzmir city were investigated and different from the previous studies, statistical analysis of data was performed to identify the major factors affecting the waste properties. According to our knowledge, the approach used in the study is new in this area and both the methodology and findings of the study can be well-considered by municipalities and ministries to improve MSW management practices, develop efficient waste management strategies, and recommend new legal controls on waste quality.

### Study area-Izmir

Izmir is a large metropolitan city (4.2 million inhabitants in 2016) located on the western Anatolia region in Turkey and has a coast to the Aegean Sea via the Gulf of Izmir [38] (Fig. 1). There are commercial, industrial, educational and touristic economic activities in the city; moreover, agricultural activities on four large planes surrounding the city are continued on the districts away from the city center.

The city has a Mediterranean climate; hence, it has long, hot, and dry summers and mild to cool, rainy winters. The annual average temperature is between 14 and 18 °C, while 50% of the annual precipitation (700 mm) falls in winter and 40–45% of it falls during spring and fall [39]. It was reported that, as most of the Turkish cities, the share of biodegradables in MSW is more than 50% in Izmir, where the percentage of



**Fig. 1** Study area

recyclables (plastics, paper and cardboard, metals and glass) is about 25% (Table 2) [26].

In Izmir, 1,960,000 tons of waste was generated in 2015 and 93% of this amount was disposed of in landfill areas after mixed collection, as the remaining part ended up in uncontrolled dumping sites [40]. In addition, annual population increase in the city was reported as 13.2% [38], daily personal MSW generating rate was 1.32 kg/ca in 2016, and the average annual increase in daily personal waste generation rate was 0.03 kg/ca between the years of 2008 and 2016 [41].

## Materials and methods

### Sampling and on-site composition studies

The sampling was conducted as described by the Turkish Ministry of Environment and Urbanization (formerly Turkish Ministry of Environment and Forestry) [42]. The MSW samples representing low (LIL), medium (MIL) and high (HIL) income level areas of the city were collected from street containers by municipal garbage trucks in the weekdays of April 2015. Three samplings for each income level were completed from different districts located in the urban parts of the city. The garbage trucks, loaded with more than 3 tons of mixed collected waste, were weighted after the each round prior to the processing. The total amount of processed waste for the study was 30.8 tons.

At the end of each round, the waste material was dumped on a floor covered with an impermeable liner and spread. The waste components (plastics, metals, glasses, paper and cardboards, composite items (recyclables made of multi material, mixed), textiles, porcelains and ceramics, WEEE, hazardous materials such as batteries, pills, etc., hygiene materials such as diapers, pads, etc., woods) were sorted and weighted. After sorting, the remaining material having a mass of between 1.3

and 1.9 tones, which is mainly biodegradables (Bio-MSW), was sieved to obtain fractions according to particle size. Six Bio-MSW fractions, namely;  $A > 120 \text{ mm}$ ,  $120 \text{ mm} > B > 100 \text{ mm}$ ,  $100 \text{ mm} > C > 80 \text{ mm}$ ,  $80 \text{ mm} > D > 50 \text{ mm}$ ,  $50 \text{ mm} > E > 30 \text{ mm}$ ,  $30 \text{ mm} > F > 10 \text{ mm}$  were obtained. The under screen part of 10 mm sieve representing the fine fraction of the bulk waste and the fractions from the screening of Bio-MSW were weighted. The Bio-MSW fractions and the fine fraction were deposited into plastic bags and stored at 4 °C for further analysis. The recorded weights of the sorted waste components, the Bio-MSW fractions, and the fine fraction were used to calculate the distribution (%ww) of each constituent in waste.

### Laboratory analyses

Each of the Bio-MSW fractions and fine fraction were separately homogenized first, and then quartered until obtaining about 2000 g of a laboratory sample to be used in analytical procedures. Water content and organic matter content were determined from the weight loss [43]. A bomb calorimeter (IKA, C200) was used to determine calorific value of the dry samples according to the method of ASTM D5468–02 [44]. Moreover, total chlorine amount was determined with respect to ASTM E776–16 based on oxygen bomb [45] by using the same bomb calorimeter. All analysis were in triplicate and the mean values are presented.

### Statistical analysis

The correlations among the income level and the shares of waste components were investigated in order to identify the impacts on waste composition by using SPSS 24.0 for Windows (IBM Inc., Chicago, Ill., USA). The input variables were income level, the shares of biodegradables and fine fraction in wet waste and the shares of recyclable components in

total recyclables. Distribution of annual household disposable incomes for Izmir City [46], minimum average wage, and the wage on poverty line in 2015 [47 & 48] were used to define different income levels. As a result, the household annual average disposable incomes of 5300 \$ USD, 9200 \$ USD, 21000 \$ USD were used to define LIL, MIL, and HIL respectively.

The correlations among the properties of biodegradable size fractions (waste size, income level, water content, organic matter content, calorific value, total chlorine, and the share of corresponding size fraction in Bio-MSW) were also investigated. Principal Component Analysis with Varimax rotation and Kaiser normalization was applied to this data set (n:54) to describe the main factors influencing the biodegradable waste characteristics. Sample size was tested by applying KMO and Bartlett’s Test to data set by using SPSS 24.0 for Windows (IBM Inc., Chicago, Ill., USA). Kaiser-Meyer-Olkin Measure of Sampling Adequacy was determined as 0.521 and the significance of Bartlett’s Test of Sphericity was 0.001; therefore the sample size was found suitable to be evaluated by using PCA. Only major principal components (PCs) were extracted with significant clusters defined by factor loading coefficients >0.5 and with Eigenvalues greater than 1.0.

The weighted average of the data on waste composition obtained for different income levels was presented and it was calculated according to the population distribution of annual household disposable incomes for Izmir city [46].

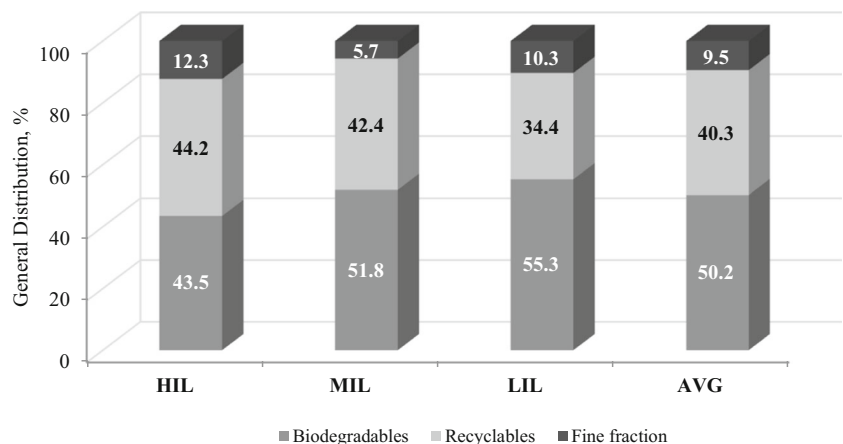
## Results and discussions

### The composition of solid waste

Here, the average shares of biodegradables, recyclables and fine fraction in MSW were determined as 50.2%, 40.3%, and 9.5%, respectively. The distribution of biodegradables (Bio-MSW), total recyclables, and fine fraction in MSW according to income levels is presented with Fig. 2. Compared to the

reported results obtained in 2011 [26], it was seen that, according to the average of data, the biodegradables in waste has the highest share both in 2011 (52.0%) and in this study (50.2%). The most remarkable differences were the increase in the average shares of recyclables from 25.5% (2011) to 40.3% and the decrease in the share of fine fraction from 22.5% (2011) to 9.5% in waste with time. It is known that the number of natural gas users in the city has increased in the ratio of 68% between the years of 2011 and 2015 [49]. That is why one of the reasons of this finding is the reduced amount of fossil fuel residues in MSW due to the increasing use of natural gas in residential areas for heating purpose. However, this fact can only explain the decrease in the production of fine fraction, and do not contributes to the increase in recyclables share. For better understanding the phenomenon well, the impact of fine fraction share can be eliminated. If the share of fine fraction in MSW is neglected, the shares of biodegradables and recyclables in 2011 could be calculated as 67.1 and 32.9%, respectively, while these values will be 55.5% for biodegradables and 44.5% for recyclables in 2015. Therefore, an actual increase in the production of recyclables can be considered since 2011, as the amount of biodegradable waste produced in the city has not shown significant changes in time [25, 26]. On the other hand, it should be noted that, due to the high values of materials in scrap market [50] hand picking of some of the recyclables (such as metals, paper, and cardboard) from the street containers before the waste trucks’ visit is very common in the city which leads lower shares of recyclables. Despite with this fact, the observed increase in the production of recyclables in the households is a result of the changes in the lifestyle in this large and cosmopolitan city [51]. Residents’ shopping habits has changed and packed foods were started to be preferred [52] since they have become attractive and affordable for any income level [53]. It is apparent from the results that, the share of biodegradables decreases with increasing income level, while vice versa is valid for recyclables. This finding is well matching with the

**Fig. 2** Distribution of biodegradables, recyclables and fine fraction in MSW according to income levels



results of previous studies completed in Istanbul and Eskisehir cities in Turkey [32, 54].

The distribution of plastics, paper and cardboard, glass, metals, textile, and composite wastes in total recyclables is presented with Fig. 3. According to the average values obtained for income levels, the plastics represented the largest share in the recyclable wastes, followed by glass, hygienic items, paper & cardboard, textile, and composite recyclables made of multi materials (mixed). Metals, that have high value in scarp market, showed a share as low as 1.33% due to their rigorous removal from street containers by waste pickers. Paper and cardboard, plastics, household hazardous components, and ceramics and porcelain items were detected in higher rates in the waste from LIL areas. Ceramics and porcelain, woods, WEEE, and household hazardous components represented a total share of 5.1% in waste.

The annual expected generation of waste constituents for the years of 2018, 2023, and 2028 were calculated according to the statistical data on population increase rate, personal waste generation rate and its increase for Izmir city (see “Study area-Izmir” section) and the waste composition obtained in this research (Table 3). According to the recent data shared by Izmir Metropolitan Municipality, in 2018, 4500–5000 tons of waste is generated in the city center, while about 3500 tons of waste is produced in adjacent residential areas [55, 56]. Hence, the total actual MSW amount produced in the city is around 8000 tons per day in 2018, which is compatible with the predicted amount (7537 tons/day) for 2018 in this study.

It was understood that the produced MSW amount will significantly increase in next 10 years with rapidly growing population and rising personal waste generation rate. Therefore, it is essential and urgent to develop and implement new and integrated municipal solid waste collection and management schemes for the city, which allow diverting waste

from the landfill sites, recycling the valuable components, recovering its energy content, and producing soil improvers.

### The properties of the biodegradable and fine waste fractions

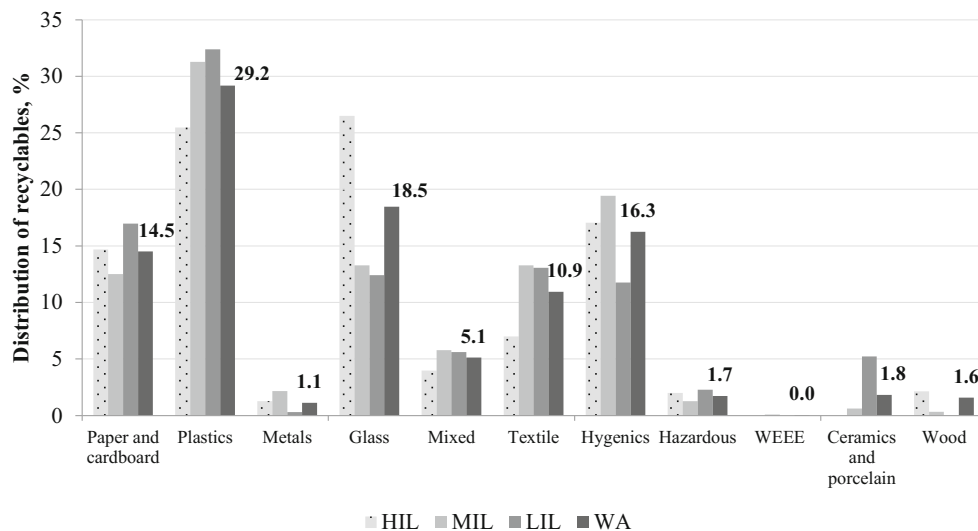
According to the wet weight based size distribution of biodegradable fraction (Table 4), it was understood that, more than 82% of the Bio-MSW was present in the fractions between 80 mm and 10 mm, for all income levels, and the average share of larger fractions in Bio-MSW was as low as 15.54%.

Figure 4 represents the water content of biodegradable fractions regarding the income levels and particle size. The material having a size between 50 and 100 mm (fractions C and D) showed lower water contents (62.1 and 50.7%) than the smaller and larger fractions. The average water content was found as 66.6%, which was lower than previously reported value of 78% [26].

The average organic matter content of biodegradable fractions found for HIL, MIL and LIL areas were 68.2%, 68.9 and 70.5%, respectively (Fig. 5) and lower than previously reported [26]. Lower organic matter contents were found for the fractions of E (50 mm–30 mm, 67.0%) and F (30 mm–10 mm, 59.5%), while the average organic matter of the fractions was calculated as 69.2%. Contrary to the situation in their water contents, fractions C (100 mm–80 mm, 74.6%) and D (80 mm–50 mm, 82.5%) have higher organic matter contents, along with fraction B (120 mm–100 mm, 75.0%).

The calorific value of the biodegradable waste size fraction was in the range of 2310–3686 kcal/kg on a dry weight basis (Fig. 6) and coherent with the previously reported data [26]. It is seen that the size fractions having lower organic content (between the size of 10 mm–50 mm) resulted with unexpectedly high calorific values. This contradiction indicates that some non-biodegradable items, that could not be sorted since

**Fig. 3** Distribution of recyclable components in the total recyclable wastes according to the income levels



**Table 3** Expected amount of a) major waste components, and b) recyclable components in years 2018, 2023, and 2028 in Izmir city (P + CB: Paper and Cardboard, PLA: Plastics, MET: Metals, GLS: Glass,

MXD: Recyclables made of multi materials, TXT: Textiles, HYG: Hygiene materials, HZD: Hazardous items, WEE: Waste Electrical and Electronic items, C + P: Ceramics and Porcelain, WO: Wood)

a)											
Year	Population	Waste generation rate, kg/ca.day	Total MSW		Major waste components, 10 <sup>3</sup> t/year						
			t/day	10 <sup>3</sup> t/year	Bio-MSW	Total Recyclables	Fine waste (<10 mm)				
2018	5,381,981	1.40	7537	2751	1381	1109	261				
2023	10,004,014	1.62	16,241	5928	2976	2389	563				
2028	18,595,438	1.88	34,997	12,774	6413	5148	1214				
b)											
Recyclable components, 10 <sup>3</sup> t/year											
Year	P + CB	PLA	MET	GLS	MXD	TXT	HYG	HZD	WEE	C + P	WO
2018	74.6	149.4	720.6	92.9	26.6	61.0	85.3	7.5	0.2	9.4	7.4
2023	160.8	322.0	15.5	200.2	57.3	131.4	183.7	16.3	0.5	20.3	16.0
2028	346.5	693.9	33.5	431.4	123.6	283.1	395.9	35.0	1.0	43.8	34.5

they adhered to wet waste, could be the source of a portion of the organic matter in these size fractions.

The average calorific value of Bio-MSW was found as 3234 kcal/kg, while the minimum allowable calorific value in refuse derived fuel (RDF) is given as 2500 kcal/kg in the national statement [57]. On the other hand, the European Association of Waste Thermal Treatment Companies for Specialized Waste (EURITS) determined the bottom limit of calorific value as 15 MJ/kg (~3583 kcal/kg) for waste co-incinerated in cement plants as substitute fuel [58]. It is understood that, average calorific value of Bio-MSW meets national requirement. However, the EU limit for the RDF calorific value could only be obtained by mechanically separating the fractions having high calorific content such as; fractions C and E in LIL waste, fractions B and D in MIL waste, and fraction F in LIL waste.

The typical chlorine level in the MSW is reported to be between 0.2 and 0.8% [59] and in our study, the average chlorine level of Bio-MSW from HIL areas was compatible with the typical values, while most of the samples from LIL and MIL areas exceeded the upper limit of the range (Fig. 7). It is known that, EURITS limits the Cl level in RDF with 0.5% dw. The average chlorine contents for income levels obtained

in our study also exceeds this value [58]. On the other hand, the Turkish national statement requests the chlorine content under 1% dw in RDF [57]. The waste chlorine levels obtained in this study are generally below this limit, excluding wastes from the MIL zone; nevertheless, the level of Cl could be adjusted by combining wastes from different income levels.

Using RDF as an alternative fuel in cement kilns is common in EU countries; about 30% of heat requirement have been met from the waste, while this rate is low as 3% in Turkey [60]. However, 35 of the total 50 cement plants in the country are using RDF produced from 250 different waste types other than MSW [61]. That is why, RDF production from Bio-MSW by bio-drying technology and wide spread use of Bio-MSW based RDF could be a viable option to reduce fossil fuel consumption in cement kilns in Izmir region and in Turkey. The same approach could be suitable for many countries having similar waste composition and properties.

The properties of fine fractions (< 10 mm) from different income level areas showed that, this material was poor in organic matter (45.3%–55.6%) and having lower water content (50.2–58.2%) than the biodegradable fractions. The ranges for calorific value and chlorine content in fine fractions were found as 569.1–3457.8 kcal/kg (2505.4 ± 885.7 kcal/kg in average) and 0.54–1.15% dw (0.74 ± 0.17% dw in average), respectively.

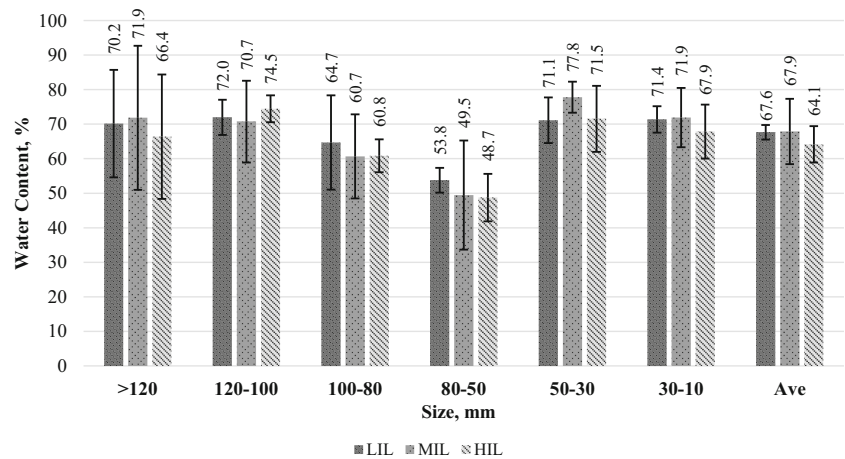
**Table 4** Size distribution of biodegradable fraction of MSW (% wet weight with standard deviations)

Fraction	Size (mm)	LIL	MIL	HIL
A	>120	3.58 ±0.88	5.49 ±3.51	6.35 ±2.80
B	120–100	5.11 ±3.66	4.18 ±3.52	3.71 ±0.86
C	100–80	4.81 ±2.90	6.19 ±1.88	7.22 ±3.27
D	80–50	18.62 ±1.59	22.78 ±4.14	22.94 ±5.55
E	50–30	26.28 ±1.29	28.19 ±3.99	27.23 ±5.36
F	30–10	41.59 ±7.72	33.18 ±4.81	32.56 ±5.19

**The statistical assessments**

The correlations among the income level and wet weight shares of biodegradables, fine fraction, and the recyclable components in waste are presented in Table 5. The only significant impact of income level has seen on the share of biodegradables; rate of Bio-MSW in total waste have been decreasing with elevating income level (r:–0.701, p < 0.05). The correlations of income level with the shares of recyclable components were poor and statistically insignificant. However,

**Fig. 4** Water content of biodegradable size fractions regarding the income levels



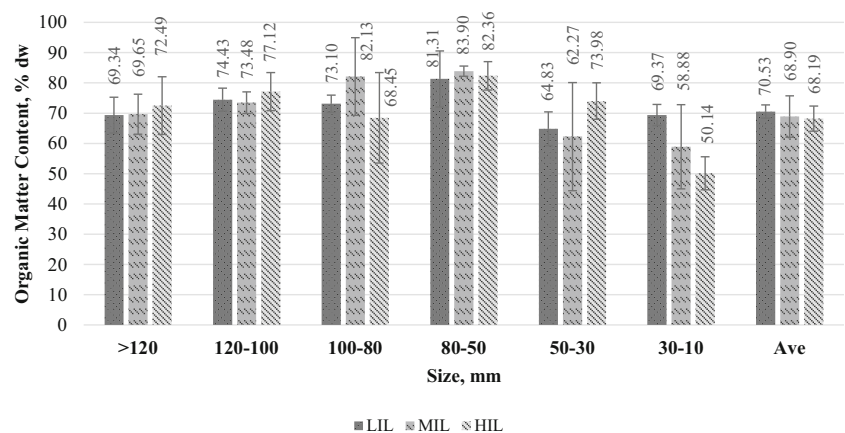
hazardous items ( $r=-0.644$ ,  $p < 0.1$ ) and glass ( $-0.811$ ,  $p < 0.01$ ) in waste were decreasing with increasing share of Bio-MSW; that is why these components have been suggested to be richer in waste from LIL areas. This finding indicated that, in the case of mixed collection, the waste from low income level districts should not be used neither in biochemical nor in thermal waste processing facilities to avoid the risks as low end-product quality, process destructions, excessive residual matter, and higher emissions. Not only the hazardous items and glass, but also the ceramics and porcelain items in the input material could be reduced by diverting the LIL waste from the waste stream that feeds biochemical and thermal conversion facilities.

The correlations between WEEE and plastics ( $r: 0.922$ ,  $p < 0.001$ ) and mixed waste and textiles ( $r: 0.937$ ,  $p < 0.001$ ) were very strong and statistically significant. Other statistically significant correlations were detected among plastics, metals, and hygienic waste components ( $r > 0.830$ ,  $p < 0.01$ ). The correlations of glass, ceramics and porcelain, wood, and fine waste with the other recyclable components were found insignificant. A study on the MSW components in Iran [37] resulted with different findings; statistically significant correlations between the shares of textiles and organics, plastics

and paper, glass and metals, and wood and textiles were detected. In our study, as the shares of recyclables in waste was found independent from income level, according to the significant correlations detected among many recyclable components (paper and cardboard, plastics, metals, multi material items, textiles, hygienic items, and WEEE) it can be suggested that source separated waste collection system is available to be implemented in all districts of the city. Street bins dedicated to glass items can be useful to collect this waste separately from the other recyclables.

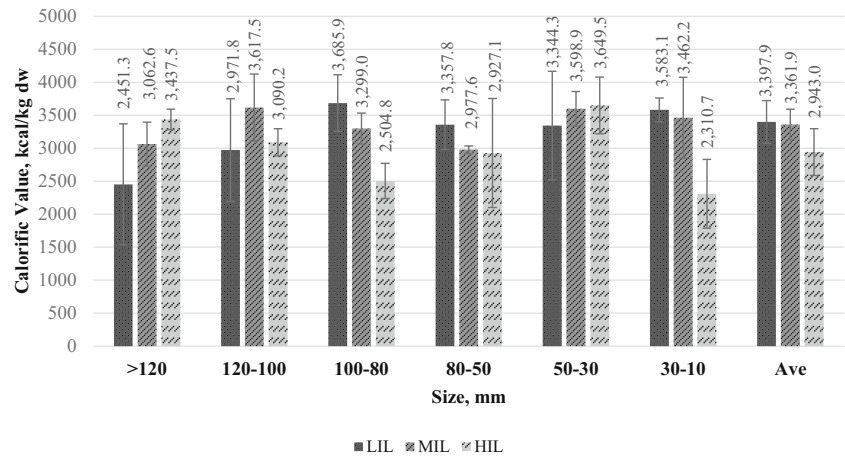
A correlation matrix was determined for the data on Bio-MSW size fractions' properties (Table 6). Income level has not shown any impact on Bio-MSW properties and amount of biodegradables in size fractions. Bio-MSW water content and the organic matter content were negatively correlated ( $r = -0.350$ ,  $p < 0.01$ ). A strong and statistically significant negative correlation between the waste size and percent Bio-MSW ( $r = -0.905$ ,  $p < 0.001$ ) indicated that larger fractions have been carrying more biodegradable material than smaller fractions. The positive correlation detected between the Bio-MSW size and the organic matter content was statistically significant ( $r = 0.313$ ,  $p < 0.05$ ). A positive correlation between size and total chlorine was also obtained ( $r = 0.255$ ,

**Fig. 5** Organic matter content of biodegradable size fractions regarding the income levels





**Fig. 6** Calorific value of the biodegradable size fractions regarding the income levels



$p < 0.1$ ). It was reported that the organic-bound chlorine is generally caused by high plastic content (mostly PVC) in refuse derived fuel (RDF) [62]. That's why the average chlorine content of the Bio-MSW was calculated by using the data obtained for size fractions and its correlation with the share of plastics in wet waste was determined separately. As a result, the link between the rate of plastics in waste composition and the chlorine value in Bio-MSW was approved with a correlation coefficient of 0.666 ( $p < 0.1$ ). The small plastic particles in the wastes can be mixed with the biodegradable part during collection and transport operations. In addition, the substances in plastic bottles containing the residues of saline beverages and the cleaning agents can easily mingle with other wastes in a mixed collection system. The positive correlation between the calorific value and the total chlorine ( $r = 0.253$ ,  $p < 0.1$ ) and the negative correlation between the organic matter content and the share of biodegradables ( $r = -0.271$ ,  $p < 0.05$ ) also support this hypothesis.

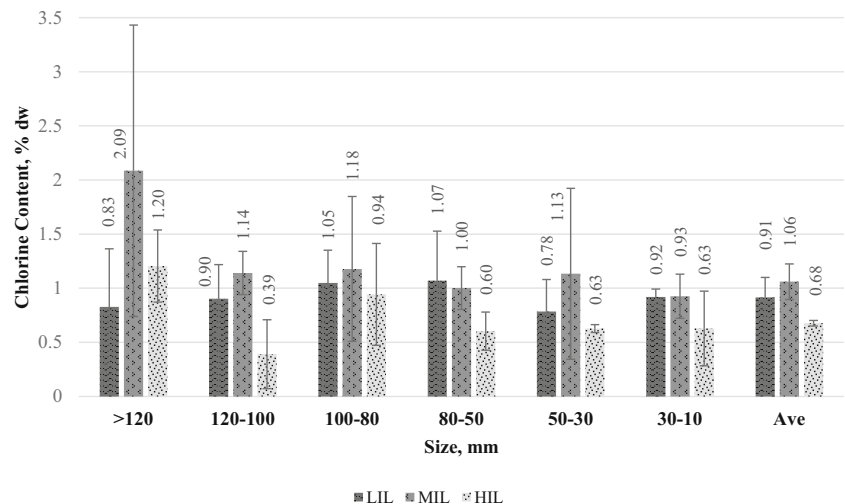
Principal Component Analysis (PCA) was carried out to identify the major factors having impact on the waste management. The data sets of the studied parameters in Bio-MSW

were evaluated by PCA and three principal components were extracted. The variances explained by principal components (PCs) were all high and accounted for 79.617% of the total variance in the analysis (Table 7).

In the component matrix (Table 8), high factor loading coefficients were obtained for the organic matter content (0.774), the Bio-MSW size (0.654), and the total chlorine (0.607) in the first principal component (PC1) that explains the 30.8% of the total variance. In other words, higher organic matter and total chlorine contents were present in larger B-MSW size fractions. As it was explained in above paragraphs, the link between the plastics and Bio-MSW chlorine content was expressed by the data obtained for mixed collected MSW in this study. Therefore, PC1 was considered as the mixed collection that influence the quality of the Bio-MSW due to blending of wet waste and recyclable components. This factor has a negative impact on the availability of Bio-MWS to be used as RDF.

PC2 explains the 27.5% of the total variance and a high factor loading of water content (0.807) was present in this component along with the loadings of calorific value and total

**Fig. 7** Chlorine content of the biodegradable size fractions regarding the income levels



**Table 5** Correlations among the waste components and the income level (IL: Income Level, BIO: Biodegradable fraction, P + CB: Paper and Cardboard, PLA: Plastics, MET: Metals, GLS: Glass, MXD: Multi

material recyclables, TXT: Textiles, HYG: Hygiene materials, HZD: Hazardous items, WEE: Waste Electrical and Electronic items, C + P: Ceramics and Porcelain, WO: Wood, FIN: Fine fraction)

		IL	BIO	P + CB	PLA	MET	GLS	MXD	TXT	HYG	HZD	WEE	C + P	WO	FIN
IL	r	1.000	-0.701 <sup>c</sup>	0.239	-0.043	0.211	0.383	-0.102	-0.209	0.313	0.002	0.000	-0.561	0.449	0.140
	p		0.035	0.535	0.913	0.587	0.309	0.794	0.590	0.412	0.995	1.000	0.116	0.225	0.720
BIO	r		1.000	-0.489	-0.078	-0.220	-0.811 <sup>b</sup>	-0.107	0.160	-0.490	-0.644 <sup>d</sup>	-0.055	0.310	-0.182	0.200
	p			0.182	0.843	0.570	0.008	0.784	0.680	0.181	0.061	0.889	0.417	0.639	0.605
P + CB	r			1.000	0.688 <sup>c</sup>	0.492	0.366	0.555	0.435	0.783 <sup>c</sup>	0.346	0.382	-0.303	0.393	-0.202
	p				0.040	0.178	0.333	0.121	0.242	0.013	0.362	0.310	0.428	0.296	0.602
PLA	r				1.000	0.855 <sup>b</sup>	0.132	0.782 <sup>c</sup>	0.748 <sup>c</sup>	0.830 <sup>b</sup>	0.233	0.761 <sup>c</sup>	-0.151	-0.150	-0.340
	p					0.003	0.735	0.013	0.020	0.006	0.547	0.017	0.699	0.701	0.370
MET	r					1.000	0.184	0.658 <sup>d</sup>	0.641 <sup>d</sup>	0.878 <sup>b</sup>	0.216	0.922 <sup>a</sup>	-0.325	-0.176	-0.480
	p						0.636	0.054	0.063	0.002	0.577	0.000	0.393	0.650	0.191
GLS	r						1.000	0.387	0.084	0.426	0.680 <sup>c</sup>	-0.034	-0.061	-0.204	-0.497
	p							0.304	0.831	0.253	0.044	0.931	0.876	0.598	0.174
MXD	r							1.000	0.937 <sup>a</sup>	0.775 <sup>c</sup>	0.352	0.472	0.106	-0.307	-0.449
	p								0.000	0.014	0.353	0.200	0.786	0.421	0.225
TXT	r								1.000	0.684 <sup>c</sup>	0.079	0.534	0.197	-0.202	-0.397
	p									0.042	0.840	0.138	0.611	0.601	0.290
HYG	r									1.000	0.431	0.739 <sup>c</sup>	-0.284	0.030	-0.442
	p										0.247	0.023	0.459	0.940	0.233
HZD	r										1.000	0.123	0.034	-0.433	-0.221
	p											0.752	0.931	0.245	0.568
WEE	r											1.000	-0.186	-0.537	
	p												0.633	0.767	0.136
C + P	r												1.000	-0.215	-0.165
	p													0.578	0.671
WO	r													1.000	0.240
	p														0.533
FIN	r														1.000
	p														

<sup>a</sup> Correlation is significant at the 0.001 level (2-tailed), <sup>b</sup> Correlation is significant at the 0.01 level (2-tailed), <sup>c</sup> Correlation is significant at the 0.05 level (2-tailed), <sup>d</sup> Correlation is significant at the 0.1 level (2-tailed), <sup>e</sup> *p* shows the statistical significance of the correlations among the studied parameters

chlorine. This cluster of parameters have emphasized that Bio-MSW water content was linked with materials having higher calorific values and total chlorine. The calorific value of Bio-MSW size fractions was correlated with neither the

distribution of size fractions in waste nor their organic content (Table 6). For this reason, the source of high calorific value cannot be related to Bio-MSW. It was understood that plastic containing packing materials carrying liquid remaining, such

**Table 6** Correlation matrix for Bio-MSW size fraction properties (IL: Income Level in USD, Size: The average size of the corresponding Bio-MSW fraction, WC: Water Content, OM: Organic Matter Content, CV:

Calorific Value, T-Cl: Total Chlorine, Bio-MSW: The share of the corresponding size fraction in total Bio-MSW)

		IL, \$	Size, mm	WC, %	OM <sub>dw</sub> , %	CV <sub>dw</sub> , kcal/kg	T-Cl, ppm	Bio-MSW, %
IL, \$	r	1.000	0.000	-0.074	-0.048	-0.171	-0.101	0.000
	p		1.000	0.592	0.729	0.218	0.466	1.000
Size, mm	r		1.000	0.015	0.313 <sup>c</sup>	-0.125	0.255 <sup>d</sup>	-0.905 <sup>a</sup>
	p			0.915	0.021	0.366	0.063	0.000
WC, %	r			1.000	-0.350 <sup>b</sup>	0.143	0.179	0.015
	p				0.010	0.302	0.194	0.913
OM <sub>dw</sub> , %	r				1.000	0.172	0.147	-0.271 <sup>c</sup>
	p					0.214	0.290	0.047
CV <sub>dw</sub> , kcal/kg	r					1.000	0.253 <sup>d</sup>	0.109
	p						0.065	0.433
T-Cl, ppm	r						1.000	-0.198
	p							0.151
Bio-MSW, %	r							1.000
	p							

<sup>a</sup> Correlation is significant at the 0.001 level (2-tailed), <sup>b</sup> Correlation is significant at the 0.01 level (2-tailed), <sup>c</sup> Correlation is significant at the 0.05 level (2-tailed), <sup>d</sup> Correlation is significant at the 0.1 level (2-tailed), <sup>e</sup> *p* shows the statistical significance of the correlations among the studied parameters

**Table 7** Total Variance Explained by PCA

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.540	30.804	30.804	1.540	30.804	30.804
2	1.374	27.483	58.287	1.374	27.483	58.287
3	1.067	21.330	79.617	1.067	21.330	79.617
4	0.610	12.209	91.826			
5	0.409	8.174	100.000			

as the rest of the beverage or the cleaning materials, are crushed and compacted in the waste truck so that both the water content (% ww) and the calorific value (kcal/kg dw) and total chlorine (% dw) levels of the Bio-MSW increase. Therefore, PC2 was evaluated as an influence of mixed waste collection, too; however, in this case the negative impact of waste compaction during collection was become prominent.

The high factor loading coefficients were found for size (0.634) and calorific value (−0.691) in PC3, which explained 21.3% of the total variance. Negative factor loading coefficient of calorific value shows that, this factor was related with the inert materials in larger Bio-MSW fractions. Inert materials such as broken glasses, ceramics and porcelain parts present in the larger fractions of Bio-MSW not only reduce the waste calorific value, but also create a handicap to produce high quality compost [63].

### Conclusion

In this research study, the composition of MSW samples from low, medium, and high-income level areas of Izmir city, Turkey and the analytical properties of biodegradable fractions were determined and the major factors influencing the waste characteristics were identified by using statistical analysis.

The shares of recyclable materials in mixed waste were found to be independent of the income level. The recyclable

components were found well correlated with each other, except glass. These findings indicate that it is possible to establish a source separated waste collection system in all income level districts of the city. The MSW from low income level districts should be diverted from biochemical and in thermal waste processing facilities to avoid process destructions, excessive residual matter, and higher emissions. A tangible link between the ratio of plastics in the waste composition and the chlorine value in the biodegradables has been determined. Since chlorine levels in biodegradables increase with increasing waste size, it is recommended to remove large fractions from waste streams directed to thermal processing plants. Principal Component Analysis (PCA) has established that the mixed collection has a great unfavorable impact on the quality of biodegradable waste via cross contamination during the collection, the compaction applied in waste collection trucks, and the broken inert materials trapped in large fractions.

Hence, the main conclusion of the study is that in the large cities a source-segregated waste collection system must inevitably be implemented before the integrated waste management system is established. By this way, not only the high quality biodegradables to be fed to the biochemical or thermal processing facilities but also the recyclable components can be recovered efficiently. The importance of statistical evaluation of reliable data sets in the area of waste management is also revealed here. Researchers, policy makers and municipalities should consider generating data on waste components and waste characteristics for their cities and countries in order to improve the waste management systems and legislation by identifying the factors affecting current practices.

**Table 8** Component Matrix

	Component		
	PC1	PC2	PC3
Size, mm	0.654		0.634
WC, %		0.807	
Om <sub>dw</sub> , %	0.774		
CV <sub>dm</sub> , kcal/kg		0.534	−0.691
T-Cl, ppm	0.607	0.542	

Extraction Method: Principal Component Analysis

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References

- Chatterjee R. Municipal solid waste management in Kohima City-India. *J Environ HealthSci Eng*. 2010;7(2):173–80.
- Huang W, Wang J, Dai X, Li M, Harder MK. More than financial investment is needed: food waste recycling pilots in Shanghai, China. *J Clean Prod* 2014;67:107–116.
- Moy P, Krishnan N, Ulloa P, Cohen S, Brandt-Rauf PW. Options for management of municipal solid waste in new York City: a preliminary comparison of health risks and policy implications. *J Environ Manag*. 2008;87:73–9. <https://doi.org/10.1016/j.jenvman.2007.01.032>.
- Zhen-Shan L, Lei Y, Xiao-Yan Q, Yu-Mei S. Municipal solid waste management in Beijing City. *Waste Manag*. 2009;29:2596–9. <https://doi.org/10.1016/j.wasman.2009.03.018>.
- Akinci G, Guven ED. Municipal solid waste: introduction sources, trends, quality and quantity. In: *Municipal solid waste: management strategies, challenges and future directions*, Nikolaos Tzortzakis, editor. Waste and Waste Management Series. New York: Nova Science Publishers; 2017. p. 447.
- Geerts B, Linacre E. Sunspots and climate. 1997. <http://www-das.uwo.edu/~geerts/cwx/notes/chap02/sunspots.html>. Accessed 9 Jun 2018.
- Issar AS, Zohar M. Climate change - environment and civilization in the Middle East. Germany: Springer Science & Business Media; 2004.
- Sewell WRD, Kates RW, Phillips LE. Human response to weather and climate geographical contributions. *Geogr Rev*. 1968;58:14025(2):262–80.
- Shekdar AV. Sustainable solid waste management: an integrated approach for Asian countries. *Waste Manag*. 2009;29:1438–48. <https://doi.org/10.1016/j.wasman.2008.08.025>.
- The Ministry of Environment and Urbanization. Ulusal Atık Yönetimi Ve Eylem Planı 2023. 2016. [http://www.csb.gov.tr/db/cygm/editordosya/Ulusal\\_Atik\\_Yonetimi\\_ve\\_Eylem\\_Plani.pdf](http://www.csb.gov.tr/db/cygm/editordosya/Ulusal_Atik_Yonetimi_ve_Eylem_Plani.pdf). Accessed 8 Jun 2018.
- EuroStat. Waste generation and treatment. 2018. <http://ec.europa.eu/eurostat/web/environment/waste/database>. Accessed 8 Jun 2018.
- OECD. Municipal waste, Generation and treatment. 2018. <http://stats.oecd.org/#>. Accessed 8 Jun 2018.
- Kalogirou, E., & Sakalis, A. Overview of the waste management situation and planning in Greece. 2016; Retrieved from [http://www.vivis.de/phocadownload/Download/2016\\_wm/2016\\_WM\\_107-116\\_Kalogirou.pdf](http://www.vivis.de/phocadownload/Download/2016_wm/2016_WM_107-116_Kalogirou.pdf)
- Khayamabshi, E. Current Status of Waste Management in Iran and Business Opportunities, Waste Management on Occasion of Smart Engineering Tokyo 2016, United nations industrial development organization. 2016; retrieved from <http://www.unido.or.jp/files/Iran-updated.pdf>
- Chabuk A, Al-Ansari N, Hussain HM, Knutsson S, Pusch R. Present status of solid waste Management at Babylon Governorate, Iraq. *Iraq Eng*. 2013;7(7):408–23. <https://doi.org/10.4236/eng.2015.77037>.
- Hoomweg D, Bhada-Tata P. What a Waste: A Global Review of Solid Waste Management. Urban Development Series; Knowledge Papers No.15, World Bank, vol. 116; 2012. <https://doi.org/10.1111/febs.13058>.
- Türkiye İstatistik Kurumu. Bertaraf/Geri Kazanım Yöntemleri ve Belediye Atık Miktarı. Retrieved August 14, 2018; from <http://www.tuik.gov.tr/UstMenu.do?metod=temelist>
- European Union. Directive 1999/31/EC on landfill of waste. 1999. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0031&from=en>. Accessed 18 Apr 2018.
- European Parliament and Council. Directive 2008/98/EC on waste and repealing certain directives. 2008. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN>. Accessed 18 Apr 2018.
- Mühle S, Balsam I, Cheeseman CR. Comparison of carbon emissions associated with municipal solid waste management in Germany and the UK. *Resour Conserv Recy*. 2009;54:793–801. <https://doi.org/10.1016/j.resconrec.2009.12.009>.
- Environmental Protection Agency. Materials generated in the municipal waste stream, 1960 to 2014. In: *advancing sustainable materials management: 2014 tables and figures, assessing trends in material generation, recycling, composting, combustion with energy recovery and landfilling in the United States*. 2016. [https://www.epa.gov/sites/production/files/2016-11/documents/2014\\_smm\\_tablesfigures\\_508.pdf](https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf). Accessed 17 Apr 2018.
- Rezaei M, Ghobadian B, Samadi SH, Karimi S. Electric power generation from municipal solid waste: a techno-economical assessment under different scenarios in Iran. *Energ*. 2018;15:46–56. <https://doi.org/10.1016/j.energy.2017.10.109>.
- Abbas AAK, Al-rekabi WS, Yousif YT. Integrated solid waste Management for Urban Area in Basrah District. *J Babylon Univ/Eng Sci*. 2016;24(3):666–75 Retrieved from <https://www.iasj.net/iasj?func=fulltext&aId=112756>.
- The Ministry of Environment and Urbanization. 2017 yılı il çevre durum raporları. 2017. <http://ced.csb.gov.tr/2017-yili-il-cevre-durum-raporlari-i-85928>. Accessed 9 Jun 2018.
- Metin E, Eröztürk A, Neyim C. Solid waste management practices and review of recovery and recycling operations in Turkey. *Waste Manag*. 2003;23:425–32. [https://doi.org/10.1016/S0956-053X\(03\)00070-9](https://doi.org/10.1016/S0956-053X(03)00070-9).
- Akinci G, Guven ED, Gok G. Evaluation of waste management options and resource conservation potentials according to the waste characteristics and household income: a case study in Aegean region. *Turkey Resour Conserv Recy*. 2012;58:114–24. <https://doi.org/10.1016/j.resconrec.2011.11.005>.
- Hasnine MDT, Bilgili MS, Bahauddin KM, Engin G, Alam M, Afrin T. exploring the. Challenge and scope of solid waste management: a comparative analysis of Bangladesh and Turkey. In: *Eurasia*, vol. 2016. Istanbul: Waste Management Symposium; 2016.
- European Parliament and Council. Directive 2000/76/EC on the incineration of waste. 2000. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0076&from=EN>. Accessed 18 Apr 2018.
- European Parliament. Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC. 2009. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN>. Accessed 18 Apr 2018.
- Resmi Gazete. Atıkların Düzenli Depolanmasına Dair Yönetmelik, Çevre ve Orman Bakanlığı. 2010. <http://www.resmigazete.gov.tr/eskiler/2010/03/20100326-13.htm>. Accessed 8 Jun 2018.
- Resmi Gazete. Ambalaj ve Ambalaj Atıklarının Kontrolü Yönetmeliği, Çevre ve Orman Bakanlığı. 2011. <http://www.resmigazete.gov.tr/eskiler/2011/08/20110824-6.htm>. Accessed 8 Jun 2018.
- Ozcan H, Guvenc S, Guvenc L, Demir G, Ozcan HK, Guvenc SY, et al. Municipal solid waste characterization according to different income levels: a case study. *Sustain*. 2016;8(10):1044. <https://doi.org/10.3390/su8101044>.
- Taşpınar F, Uslu MA. Evaluation of combustibility and energy potential of municipal solid waste: the case of Esenler municipality. *Int J Energy Appl and Technol*. 2018;5(1):1–8 Retrieved from [www.dergipark.gov.tr/ijeat](http://www.dergipark.gov.tr/ijeat).
- Al-Jarallah R, Aleisa E. A baseline study characterizing the municipal solid waste in the State of Kuwait. *Waste Manag*. 2014;34(5):952–60. <https://doi.org/10.1016/J.WASMAN.2014.02.015>.

35. Miezah K, Obiri-Danso K, Kádár Z, Fei-Baffoe B, Mensah MY. Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. *Waste Manag.* 2015;46:15–27. <https://doi.org/10.1016/J.WASMAN.2015.09.009>.
36. Edjabou ME, Jensen MB, Götze R, Pivnenko K, Petersen C, Scheutz C, et al. Municipal solid waste composition: sampling methodology, statistical analyses, and case study evaluation. *Waste Manag.* 2015;36:12–23. <https://doi.org/10.1016/j.wasman.2014.11.009>.
37. Aslani H, Taghipour H. Seasonal characterization and quantification of municipal solid waste: energy content and statistical analysis. *J Adv Environ Health Res.* 2018;6:34–43. <https://doi.org/10.22102/jaehr.2018.105728.1053>.
38. TurkStat. Population of provinces by years. 2018. <http://www.turkstat.gov.tr/UstMenu.do?metod=temelist>. Accessed 19 Jun 2018.
39. Meteoroloji Genel Müdürlüğü. İzmir- illere göre mevsim normalleri (1981–2010). 2018. <https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=IZMIR>. Accessed 16 Mar 2018.
40. TMMOB. İzmir çevre durum raporu. 2017. [http://www.cmo.org.tr/resimler/ekler/e12115662e1d4ad\\_ek.pdf?tipi=78&turu=H&sube=3](http://www.cmo.org.tr/resimler/ekler/e12115662e1d4ad_ek.pdf?tipi=78&turu=H&sube=3). Accessed 9 Jun 2018.
41. TurkStat. Solid waste statistics of municipalities. 2018. <https://biruni.tuik.gov.tr/medas/?kn=119&locale=tr>. Accessed 18 Jun 2018.
42. Çevre ve Orman Bakanlığı. Katı Atık Ana Planı. Katı Atık Oluşumu ve Karakterizasyonu Raporu. Prepared by MİMKO for Çevre Yönetimi Genel Müdürlüğü Atık Yönetimi Daire Başkanlığı, vol. 35; 2006.
43. APHA-AWWA-WPCF. Standard methods for the examination of water and wastewater. American Public Health Association. 18th ed. Washington, DC: American Water Works Association, Water Pollution Control Federation; 1992. p. 1–834.
44. ASTM International. Standard test method for determination of forms of chlorine in refuse-derived fuel; 2018. <https://doi.org/10.1520/E0776-16>.
45. ASTM International. Standard test method for gross calorific and ash value of waste materials; 2018. <https://doi.org/10.1520/D5468-02R07>.
46. TurkStat. Consumption expenditure statistics. 2018. [http://www.turkstat.gov.tr/PreTablo.do?alt\\_id=1012](http://www.turkstat.gov.tr/PreTablo.do?alt_id=1012). Accessed 9 Jun 2018.
47. CCPAS Chambers of Certified Public Accountants of Sakarya . 2015 yılı asgari ücret açıklandı. 2018. <http://www.sakaryasmmmo.org.tr/Yazi/2015-yili-Asgari-Ucret%2D%2Daciklandi-2536>. Accessed 9 Jun 2018.
48. TurkStat. Poverty statistics. 2018. [http://www.tuik.gov.tr/PreTablo.do?alt\\_id=1013](http://www.tuik.gov.tr/PreTablo.do?alt_id=1013). Accessed 9 Jun 2018.
49. Izmirgaz. Natural gas in Izmir. 2016. <http://www.izmirgaz.com.tr/tr/Izmir-Dogalgaz/Dogalgaz/Izmir-de-Dogalgaz.html>. Accessed 16 Mar 2018.
50. Wilson DC, Araba AO, Chinwah K, Cheeseman CR. Building recycling rates through the informal sector. *Waste Manag.* 2009;29(2):629–35. <https://doi.org/10.1016/j.wasman.2008.06.016>.
51. Günden C, Bilgic A, Miran B, Karli B. A censored system of demand analysis to unpacked and prepackaged milk consumption in Turkey. *Qual and Quant.* 2011;45(6):1273–90. <https://doi.org/10.1007/s11135-011-9501-6>.
52. Özsoy M. User preferences on transformations of shopping centers into private urban public spaces : the case of Izmir. *Turkey Afr J Bus Manag.* 2010;4(10):1990–2005 Retrieved from <http://www.academicjournals.org/AJBM>.
53. Troschinetz AM, Mihelcic JR. Sustainable recycling of municipal solid waste in developing countries. *Waste Manag.* 2009;29(2): 915–23. <https://doi.org/10.1016/j.wasman.2008.04.016>.
54. Banar M, Özkan A. Characterization of the municipal solid waste in Eskisehir City, Turkey. *Environ Eng Sci.* 2008;25(8):1213–20. <https://doi.org/10.1089/ees.2007.0164>.
55. İzmir Büyükşehir Belediyesi. Katı Atık Değerlendirme ve Bertaraf İşlemleri. Retrieved August 20, 2018a, from <http://www.izmir.bel.tr/tr/Projeler/kati-atik-degerlendirme-ve-bertaraf-islemleri/1312/4>
56. İzmir Büyükşehir Belediyesi. Yeni Katı Atık Değerlendirme ve Bertaraf Tesisleri Kuruluyor. Retrieved August 20, 2018b, from <http://www.izmir.bel.tr/tr/Projeler/yeni-kati-atik-degerlendirme-ve-bertaraf-tesisleri-kuruluyor/1317/4>
57. Resmi Gazete. Atıktan Türetilmiş Yakıt, Ek Yakıt ve Alternatif Hammadde Tebliği. 2014. <http://www.resmigazete.gov.tr/main.aspx?home=http://www.resmigazete.gov.tr/eskiler/2014/06/20140620.htm&main=http://www.resmigazete.gov.tr/eskiler/2014/06/20140620.htm>. Accessed 8 Jun 2018.
58. European Commission. Refuse derived fuel, current practice and perspectives. 2003; July:1–219.
59. Wang L-C, Lee W-J, Lee W-S, Chang-Chien G-P, Tsai P-J. Effect of chlorine content in feeding wastes of incineration on the emission of polychlorinated dibenzo-p-dioxins/dibenzofurans. *Sci Total Environ.* 2003;302(1–3):185–98. [https://doi.org/10.1016/S0048-9697\(02\)00306-6](https://doi.org/10.1016/S0048-9697(02)00306-6).
60. TÇMB. Türk çimento sektörünün alternatif yakıt ve alternatif hammadde kullanımı yaklaşımı. 2014. [http://www.tcma.org.tr/images/file/Turk\\_cimento\\_sektorunun\\_alternatif\\_yakit\\_hammadde\\_kullanim\\_yaklasimi\\_Kasim\\_2014.pdf](http://www.tcma.org.tr/images/file/Turk_cimento_sektorunun_alternatif_yakit_hammadde_kullanim_yaklasimi_Kasim_2014.pdf). Accessed 8 Jun 2018.
61. Ordu Ş, Öztürk E. Çimento fabrikalarında alternatif hammadde ve yakıt kullanımı: örnek çalışma alternative. *Doğal Afetler ve Çevre Dergisi, Artvin Çoruh Üniversitesi, Doğal Afetler Uygulama ve Araştırma Merkezi.* 2017; 10.21324/dacd.293309.
62. Beckmann M, Ncube S. Characterisation of refuse derived fuels (RDF) in reference to the fuel technical properties. 8th European Conference on industrial furnaces and boilers, INFUB-8, Vilamoura - Algarve, Portugal. 2008:1–15.
63. European Compost Network (ECN). The ECN concept for quality assurance of compost. In: ECN quality assurance system. 2010. [https://www.kompost.de/uploads/media/06\\_ECN\\_ECN\\_QAS.pdf](https://www.kompost.de/uploads/media/06_ECN_ECN_QAS.pdf). Accessed 17 Apr 2018.