Polish J. of Environ. Stud. Vol. 20, No. 2 (2011), 479-484

Original Research

Solid Waste Characterization of Kocaeli

Melek Keskin Yenice[1], Şenay Çetin Doğruparmak[2]*, Ertan Durmuşoğlu[2], Bilge Özbay[2], Hilmi Orkun Öz[2]

[1]Department of Environmental Protection, Kocaeli Metropolitan Municipality, 41100 Kocaeli, Turkey
[2]Department of Environmental Engineering, Kocaeli University, 41380 Kocaeli, Turkey

Received: 4 June 2010
Accepted: 29 October 2010

Abstract

This study investigated the solid waste characterization of the city of Kocaeli. With this aim solid waste groups were analyzed for sub-municipalities of the city. Representative sampling points were determined in municipalities with populations over 5,000. Four different socio-economic groups (the downtown district plus low, intermediate, and high income levels) were investigated in the study. Characterization studies were performed for a 2-year period. In this context, 16 and 13 different solid waste species were categorized for winter and summer seasons, respectively.

The results of the study showed that kitchen wastes constitute the highest proportion for all socio-economic groups despite dissimilarities in waste distribution of municipalities. It was followed by combustible wastes and plastic wastes. Reducing waste components into five groups as organic wastes, recycled wastes, hazardous wastes, combustible wastes and others, an increase was seen in amounts of recycled, hazardous, and combustible wastes in winter season, whereas the amount of organic wastes decreased. Investigating general waste distribution for different income levels without any seasonal distinction, it was observed that highest values of organic and recycled wastes were seen in the downtown district and high-income groups, whereas combustible, hazardous, and other wastes were higher in low-income groups. In general, as a result of the characterization study without any seasonal and/or economical distinctions, proportions of organic, recycled, combustible, hazardous wastes, and others were determined as 41.53%, 30.51%, 20.64%, 2.12%, and 5.20%, respectively.

Keywords: solid waste, characterization, analysis method, income groups, Kocaeli

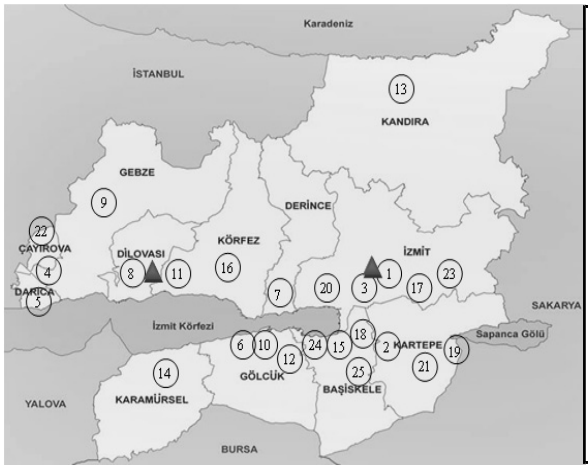
Introduction

Increasing populations generate large amounts of solid wastes all over the world. Municipal solid wastes coming from activities carried on in homes, places of public and private service, buildings, and commercial and service establishments form an important portion of the solid waste problem [1]. Management and treatment of these wastes is required in order to prevent serious environmental health risks [2].

*e-mail: senaycetin@hotmail.com

Knowledge of solid waste composition is necessary for adequate management of urban solid waste [3, 4]. Solid waste characterization supplies useful data for choosing appropriate disposal methods and developing collection and separation systems. Landfill life can be predicted and modifications can be made in present waste management by using characterization data.

In characterization of municipal solid wastes (MSW), amounts of the waste components vary with location, season, population density, economic conditions, and many other factors [5]. In literature, especially the effects of economic conditions have been investigated among these factors.



Municipilities with population >5000 (2008 year)		Joined municipilities (2009)	
1	Alikahya	1,3,20	İzmit
2	Aslanbey	2,17,19,21,23	Kartepe
3	Bekirpaşa	4,22	Çayırova
4	Çayırova	5	Darıca
5	Darıca	6,10,12	Gölcük
6	Değirmendere	7	Derince
7	Derince	8	Dilovası
8	Dilovası	9	Gebze
9	Gebze	11,16	Körfez
10	Gölcük	13	Kandıra
11	Hereke	14	Karamürsel
12	İhsaniye	15,18,24,25	Başiskele
13	Kandıra		
14	Karamürsel		
15	Karşıyaka		
16	Körfez		
17	Köseköy		
18	Kullar		
19	Maşukiye		
20	Saraybahçe		
21	Suadiye		
22	Şekerpınar		
23	Uzunçiftlik		
24	Yeniköy		
25	Yuvacık		

Fig. 1. Sampling points.

These studies have demonstrated that countries with lower incomes generate less waste and its components are more organic, although less recyclable [6, 7]. However, the relationship between population and environment is neither simple nor direct; it is influenced by social and economic organization. Society is more than population *per se* or its size, which interacts and transforms the base of natural resources and environment through the occupation of space that characterizes the developing process [8]. Gomez et al. investigated the effects of seasonal variations on groups with three different income levels in Chihuahua. Regarding the seasonal influence on waste generation, they observed a decrease from April to August and January [9]. It was concluded that values for January were 28% lower than in April. Furthermore, it was found that organic wastes that constitued 46% of municipal solid wastes (MSW) composition originated mostly from the group with an intermediate income level.

In this study, MSW characterization was carried out for Kocaeli, one of the most important cities of Turkey. Kocaeli is a highly industrialized city with sub-municipalities of different socio economic levels. Disposal of MSW is a serious environmental problem for Kocaeli, as the population shows a considerable increase every year. Population of the city was 1,522,408 in 2009 and the population growth rate has been determined as 5.9% for 2006-09 [11]. Results of this study will be useful in the decisions of appropriate solid waste disposal methods and modifying present methods.

Materials and Method

In our study, solid waste characterization was carried out according to the Standard Method for Determination of Raw Municipal Solid Waste Compositions [10]. In the first step of the study, representative sampling points were determined from eastern, western, southern, and northern parts of Kocaeli having populations more than 1.5 million [11]. In studies performed in 2008, 25 sub-municipalities with population more than 5,000 were chosen. In 2009 some municipalities were conjoined and the number of municipalities decreased to 12 from 44. This situation did not affect the study as characterization continued at 25 predetermined sampling points (Fig. 1).

As the next step of the study, contacts were made with cleaning works of municipalities in order to achieve regular sampling. With this aim, containers were located in districts exhibiting similar socio-economic levels. One ton of solid waste sample (approximately 3-4 containers) was collected from sampling points representing all predetermined socio-economic groups. Taking samples from the same points in equal amounts is essential in characterization studies.

In some municipalities (Karşıyaka, Kullar, Suadiye, İhsaniye ve Kandıra) sub-level groups could not be determined with the present information, so studies were carried on with samples taken from lower income levels.

Collected samples were stored separately in domestic solid waste landfill sites located in Izmit and Dilovası. Collected wastes were separated and weighed. Characterization process was achieved on flat ground coated with a tough 5 m × 10 m plastic cover. Steelyard was calibrated before weighing. Vehicles coming from different sampling regions removed their loads separately and then bulks were flattened.

Samples of equal amounts were taken from representative points of bulk homogeneously and placed into the two constant volume vessels (0.5 m × 1 m × 1 m) (Fig. 2). In previous studies it was seen that 1 m^3 of solid waste weighed 250-300 kg, so it is impossible to decompose the waste in detail. So measurements were made by using 0.5 m^3 waste and results were multiplied by two.

The names of material groups (plastic, metal, glass, etc.) were written on pots to avoid confusion. The 16 com-

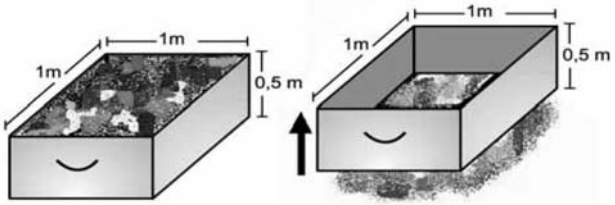


Fig. 2. Samples in constant volume vessels.

Table 1. Solid waste components.

Kitchen wastes	Food wastes, bread, vegetable, fruits, etc.
Paper	Newspapers, magazines, notebooks, etc.
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 wastes	Branches, tree limbs, grass, etc.
Other incombustibles	Stones, sand, ceramic, etc.
Other combustibles	Textile wastes, napkins, shoes, slippers, pillows, carpets, bags, etc.
Other volumed combustibles	Furniture and wooden materials, etc.
Other volumed incombustibles	Undefined volumed incombustibles
Others	Unclassified materials

ponents required for characterization are listed in Table 1 [10]. In addition to these components, ash was added to the list for winter season characterization.

Before analyzing material groups, tares of sampling vessels were weighed. Waste taken from bulks were separated into groups. Food waste was analyzed last due to its high water content. As mass loss can occur with evaporation of water, wastes were separated quickly. Bound sachets were opened during decomposition and wastes were put into predetermined vessels. Filled vessels were weighed and results were recorded.

Standard methods were applied mostly identically, but in some cases modifications were made due to the difficulties in practical applications. In the suggested method, it is advised that samples for characterization should be taken on Mondays (representing weekends) and Tuesdays (representing weekdays). In this study sampling was carried out on Sundays and Mondays for weekend and weekday characterization as some municipalities planned such a routine for collection. Furthermore in some municipalities samples were taken only on weekends or weekdays as a result of workload and/or lack of enough technical equipment and employees. This limiting situation is commonly seen in 2008 for municipalities with populations a little higher than 5,000.

Although the necessity of weighing each waste group with ash content and after sieving is emphasized for winter period studies, this was not applied as contaminated ash content was low and negligible. So after determination of all categories, remaining ash was weighed separetely. Firstly, bulk materials, such as paper, carton, metal, glass, etc. were separated from ash carefully in order to avoid any contamination. Remaining wastes involving ash were passed through a 1 cm sieve. Wastes on sieve were decomposed again, whereas materials passed from sieve were evaluated as ash.

Characterization studies of winter season were performed in periods between 26 February and 2 May in 2008; 2 November and 2 December in 2009. Summer season studies were carried out in periods from 26 May to 30 July in 2008 and from 8 June to 2 July in 2009.

Discussion of Results

In the study, averages of 156.89 and 143.54 kg of solid wastes were investigated for each municipility for winter and summer seasons, respectively. In this scope, it was aimed to categorize 17 waste species, including ash, but 16 and 13 species could be categorized for winter and summer seasons, respectively, as all species were not generated. Calculations were done for each socio-economic level by using general percentage values. Results are summarized in Table 2.

Despite obtaining different values for each municipality, kitchen wastes constituted the highest proportion for all income groups. This was followed by other combustibles (textile wastes, napkins, shoe, slippers, pillows, carpets, bags, etc.) and plastic wastes. Kitchen wastes were composed of fruit and vegetable remnants and food residues. It was seen that an important portion of other combustible wastes consisted of napkins and various textile surplus. Plastic wastes including 7 different recycled types (HDPE, LDPE, PP, PE, PS, PET and others) are another important group among waste categories. Although all these plastic types have different chemical properties and economic values, they were collected together as separation was not required in the applied method. Hazardous wastes were mostly composed of packaging wastes of detergents. As a result of battery collection campaigns of Kocaeli Metropolitan Municipality and IZAYDAS (Izmit Hazardous and Clinical Waste Incineration Plant), almost no batteries were found among the wastes.

In general, 17 waste compounds were regrouped into 5 groups during winter and summer periods. In these categories kitchen wastes and garden wastes were grouped as ‘organics’, and packaging wastes like paper, carton, plastic, metal, volumed metal, and glass wastes were grouped as ‘recycled wastes.’ Electronic and hazardous wastes were grouped in ‘hazardous wastes’, whereas other combustibles and other combustible volumed wastes were grouped in ‘combustible waste’ groups. Wastes not categorized in any of these groups were evaluated as ‘others.’ Seasonal variations of these five categories are given in Fig. 3.

As seen from Fig. 3, in summer an increase was seen in amounts of recycled, hazardous, and combustible wastes,

Table 2. Percentage distrubution of seasonal solid waste characterization in Kocaeli (2008-09).

Solid Waste Components (%)	Winter Season				Summer Season				Average
	Socio-economic levels				Socio-economic levels				
	Low	Intermediate	High	Downtown	Low	Intermediate	High	Downtown	
Kitchen wastes	36.98	36.32	38.14	40.25	36.82	36.96	41.83	42.20	38.69
Paper	3.22	4.15	7.38	3.70	3.93	8.96	6.17	6.12	5.45
Cartons	1.63	1.80	2.98	2.04	2.66	2.07	2.22	1.83	2.15
Volumed carton	2.49	3.19	3.14	6.01	3.56	4.73	4.58	6.03	4.22
Plastic	11.60	13.56	15.06	12.65	13.13	15.63	13.34	14.57	13.69
Glass	2.13	2.95	3.03	3.16	2.82	3.41	3.96	3.64	3.14
Metal	1.75	2.26	1.37	2.64	1.76	1.31	1.47	2.18	1.84
Volumed metal	0.02	0.02	0.03	0.05	0.00	0.00	0.00	0.00	0.01
Waste electric and electronic equipment	0.74	0.31	0.48	0.41	0.61	0.28	0.58	0.72	0.52
Hazardous waste	1.39	1.52	1.52	0.97	2.87	1.85	1.14	1.59	1.61
Park and garden waste	2.36	3.31	4.01	5.88	1.87	2.19	1.68	1.44	2.84
Other incombustibles	5.35	2.43	0.50	3.19	1.62	0.51	0.16	2.33	2.01
Other combustibles	21.41	19.45	17.44	15.15	28.37	22.10	22.86	17.35	20.52
Other volumed combustibles	0.00	0.57	0.23	0.17	0.00	0.00	0.00	0.00	0.12
Other volumed incombustibles	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ash	8.94	8.18	4.71	3.69	0.00	0.00	0.00	0.00	3.19
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

whereas organic wastes and wastes in the 'other' group decreased. The main reason for the increase in recycled materials like glass, plastic, and metal in the summer season can be explained with the increase in consumption of packaged drinks. Hazardous wastes, the minimal group, showed a tendency of increase but the rate of increase was not as much as that of a winter season. The amount of combustible wastes showed a tendency to increase in the summer. As the combustible wastes are commonly composed of napkins and textile wastes, this result is reliable since the consumption of these products increases in summers. Although the amount of organic wastes was determined to be higher in summer, the difference is not so much compared to winter. Wastes categorized in the 'others' group were considerably higher in winter months. Expansive combustion activities in winter months caused the formation of ash, an important component of the wastes in the 'other' group.

Fig. 4 shows general waste distribution for Kocaeli according to income levels without any seasonal distinction. Organic wastes reached the highest values for the

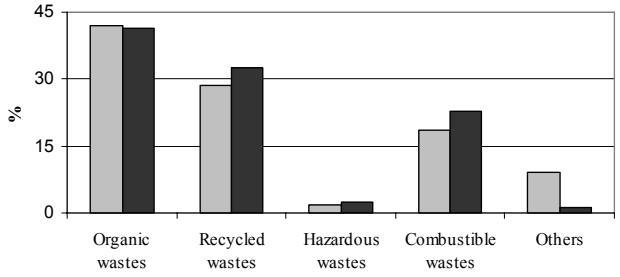


Fig. 3. Solid waste categorization of Kocaeli.

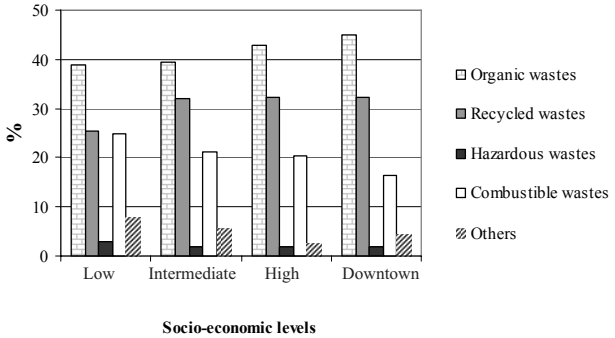


Fig. 4. General waste distrubution of different incoming groups in Kocaeli.

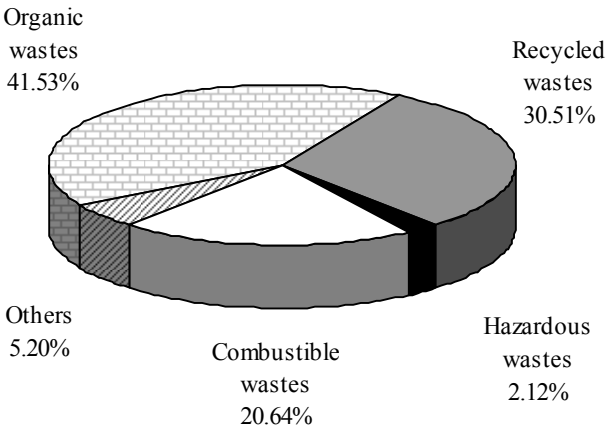


Fig. 5. Average composition of municipal solid waste in the city of Kocaeli.

downtown district group, whereas the lowest values were determined for the lowest incoming groups. As clearly seen from the figures, the improvement in socio-economic levels is directly reflected in consumption and purchasing habits. High and low income levels showed the highest and the lowest values for recycled wastes, respectively. Low income groups exhibited highest values for combustible and hazardous wastes. The highest and the lowest values of the 'others' group including ash, were seen in low and high income levels, respectively. In general, lower values of ash can be explained by the wide usage of natural gas in Kocaeli.

Results of general waste characterization ignoring seasonal and economic distinctions are presented in Fig. 5. The waste of the province was made up of 41.53% organic waste, 30.51% recycled waste, 20.64% combustible waste, 2.12% hazardous waste, and 5.20% other wastes not evaluated in previous groups.

It is an important result to have organic wastes with 41.53% proportion and direct landfilling should be prevented. With detailed investigations on organic wastes, it is possible to benefit from the composting process as an ideal disposal method.

Recycled wastes carrying economic importance have a ratio of 30.51% in waste composition. So, wastes should be separated in source and recycling procedures should be considered. The public should be made conscious of recycling through education.

Combustible wastes of 20.64% ratio could be incinerated as they are not suitable for recycling. However, if technological opportunities and criteria are not proper, sanitary landfilling might be preferred.

Although hazardous wastes were found in scarce amounts, collection and disposal of these wastes together with municipal wastes can cause serious environmental effects. So, inquired precautions should be taken for the separate collection and disposal of hazardous wastes.

Finally inorganic (inert) wastes categorized in 'others' include 5.20% of all wastes. A decrease is expected for this group, consisting of mostly ash, due to common usage of natural gas.

In order to obtain an international relevance, we have compared municipal solid waste composition of Kocaeli with that of other cities from different developing countries. In this regard, some dissimilarities are seen in solid waste compositions due to variations in socio-economical conditions. For example, ratios of recycled, organic and textile wastes were determined as 28%, 58.3% and 3.6% for Nablus district of Palestine, whereas the 'others' group constituted a ratio of 6.1% [12]. In this study wastes smaller than 10 mm size had a ratio of 3.9%. In another study, the composition of waste from Havana, the central city of Cuba, was found to be as follows: recycled (28.6%), organic (62.4%), textiles (2.9%), wood (3.5%), rubber (0.3%), and other (2.0%) [13]. Representative physical composition of Portuguese municipal solid waste in an urban region was determined as recycled (45.4%), organic (35.5%), textile (3.4%), others (2.25%), wood (0.75%), and fines (12.7%) [14].

Income levels and category of sources can be evaluated as the most important factors affecting variations occurring in waste composition. Variations can also occur based on the extent of source reduction and recycling opportunities. As opportunities exist to recycle wastes, the recycling facilities might have to grow at a similar pace to the generation of waste [15]. From this point of view, political and legal regulations of countries gain importance.

Conclusions

Solid waste characterization studies carry importance in the decision and the application of disposal methods. Since 2008, waste characterization could not be performed expansively for Kocaeli due to deficient knowledge, financial inadequacies, and lack of planning and organization in waste management applications. Now there is urgency to perform these studies as waste generation is continuously increasing due to financial developments in most cities. Two important prerequisites of characterization studies are: collection and separation of wastes with accurate methods. Reliability of characterization is directly affected by accuracy of collection and separation. For this reason the public should be made conscious of the topic and separation should be started in residences. Participation and awareness of the public would make it possible to achieve these aims.

References

1. BERNECHE-PEREZ G., SALVADRO S.C., MARIA G.A., ARTRURO D.V., ELENA S.S.M. Solid waste characterisation study in the Guadalajara metropolitan zone Mexico. Waste Management and Research. **19**, 413, **2001**.
2. WORLD RESOURCES INSTITUTE. United Nations Environmental Program, United Nations Development Program, The World Bank, Oxford University Press; Oxford, **1996**.
3. MC DOUGAL, WHITE P., FRANKE M., HINDLE P. Integrated Solid Waste Management: A Life Cycle Inventory. 2nd ed; Blackwell Science, Oxford, **2002**.

4. ZENG Y., TRAUTH K.M., PEYTON R.L., BANERJI S. Characterization of solid waste disposed at Columbia Sanitary Landfill in Missouri. Waste Management & Research. **23**, 62, **2005**.
5. TCHOBANOGLOUS G., THEİSEN H., VIGIL A. S. Integrated Solid Waste Management,. McGraw-Hill International Editions; Singapour, **1996**.
6. ACURIO G., ROSSIN A., TEIXEIRA P.F., ZEPEDA F. Situation of the municipal solid waste management in Latin America and the Caribbean. BID No. ENV. 97-107, Panamerican Organization, Washington, **1997**.
7. TINMAZ E., DEMIR I. Research on solid waste management system: to improve existing situation in Corlu Town of Turkey. Waste Management. **26**, 307, **2006**.
8. BRANES R. Manual de derecho ambiental mexicano (Manual of environmental Mexican right). Fondo de Cultura Económica (FCE) (Ed.), Mexico, D.F. **2004**.
9. GOMEZ G., MENESES M., BALLINAS L., CASTELLS F. Seasonal characterization of municipal solid waste (MSW) in the city of Chihuahua, Mexico. Waste Management. **29**, 2018, **2008**.
10. ASTM (American Society of Testing and Materials). Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste. Designation. 5231-5292, **2003**.
11. TÜİK (Statistical Department of Turkey), [online] http://tuikapp.tuik.gov.tr/adnksdagitapp/adnks.zul. Accessed **2010**.
12. A.AL-KHATIB I., MONOU M., F. ABU ZAHRA A. S., SHAHEEN H. Q., KASSINOS D. Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district – Paletsine. Journal of Environmental Management. **91**, 1131, **2010**.
13. JICA. Study on integrated management plan of municipal solid waste in Havana city. Progress Report. Cuba, **1**, **2004**.
14. MAGRINHO A., DIDELET F., VIRIATO S. Municipal solid waste disposal in Portugal. Waste Management. **26**, 1477, **2006**.
15. YOUSUF T. B., RAHMAN M. Monitoring quantity and characteristics of municipal solid waste in Dhaka City. Environmental Monitoring and Assessment. **135**, 3, **2007**.