RESEARCH ARTICLE

Waste characterization in Istanbul and a proposal for biodegradable solid waste management

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ABSTRACT

The concept of integrated solid waste management is based on the strategies of waste prevention, waste reduction, reuse, recycling (including composting), incineration and disposal at existing landfills. Solid waste characterization is the basis for integrated solid waste management. It is important to identify the solid waste composition for the determination, planning and implementation of any solid waste management system. In order to ensure a cleaner environment and lower greenhouse gas emissions; Turkey requires more robust and coherent strategies regarding the solid waste management system. In order to plan an efficient integrated solid waste management system and ensure a circular economy, it is necessary to include all the materials and production resources in the solid waste stream. The first step in waste management studies is to determine the waste characteristics. The characterization study performed by ISTAC includes the determination of the timing and the selection of neighborhoods of the waste to be collected, collection of representative samples of unprocessed waste, manual sorting of the waste into individual waste components, data collection, laboratory analysis and reporting of the results. The characterization results have been analyzed and suggestions on the sustainable management of biodegradable waste have been introduced. This paper focuses primarily on Biodegradable Municipal Waste (BMW), which is produced largely by households and commerce.

The National Strategy on Biodegradable Waste has to set out and enforce a range of measures to meet EU's ambitious diversion targets. The key to success is for all involved– local authorities, waste operators, businesses and householders – to play their part in the successful implementation of the full range of integrated waste management options. Even though there are legislations, broad support in their implementation should be provided by the Government.

Keywords: Biodegradable waste, Istanbul, municipal solid waste

1. INTRODUCTION

The first step in waste management studies is to determine waste characteristics. According to the waste characterization, the facilities to be included in the solid waste management system and the capacities of these facilities are decided. It is also important to monitor the variation of solid waste characterization over certain periods. Solid waste characterization varies according to season, region and socio-economic situation.

Sufficient and representative samples are required for solid waste characterization analysis and testing. Solid wastes to be analyzed are in different environments and physical conditions. However, each sample taken should be consistent with these physical conditions and the waste to be characterized. Solid wastes are usually inhomogeneous mixtures and are in different forms. Thus, taking representative samples requires careful and well-planned work [1].

The municipal solid waste (MSW) characterization studies of Istanbul are performed by Istac. This study introduces the results of the 2017 summer and winter MSW characterization studies of Istanbul. The characterization results have been analyzed and suggestions on the sustainable management of biodegradable waste have been proposed.

2.　MATERIALS AND METHODS

In the characterization study, the standard named "ASTM D5231 Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste" and the methodology named "European Commission-Methodology for the Analysis of Solid Waste (SWA-Tool)" were taken as the basis [2]. The Ministry of Environment and Urbanization's "Solid waste characterization and solid waste disposal facilities information update" circular (dated 15.10.2007) and "Solid waste characterization analysis method (analysis of material groups)" booklet has also been taken into account. This method describes procedures for measuring the composition of unprocessed MSW by employing manual sorting. This test method applies to the determination of the mean composition of MSW based on the collection and manual sorting of a number of samples of waste over a selected time period. This method includes procedures for the collection of a representative sorting sample of unprocessed waste, manual sorting of the waste into individual waste components, data collection, laboratory analysis and reporting of the results. The samples were manually sorted into waste components. The weight fraction of each component in the sorting sample was calculated from the weights of the components. The mean waste composition was calculated using the results of the composition of each of the sorting samples.

In a characterization study, a zoning study should be performed before taking samples. Parameters like socio-economic effect, collection system, urban structure etc. are effective in zoning studies (SWA-Tool). In order to determine the solid waste content in Istanbul, waste characterization studies were carried out in different times, during summer and winter time from 2005 to 2017. The study conducted for the 39 district municipalities of Istanbul has considered three main socio-economic conditions: low income, high income and the commercial region. For the low and high level zones to be taken from the districts during the planning phase, the samples for the neighborhoods are determined by coordinating with the district municipalities on which days and from which vehicles the samples will be taken. It should be noted that the samples for the characterization study were collected from the trucks at the transfer stations, hence the possible minimizing effect of scavengers could not have been taken into consideration.

Prior to the study, the regions of the samples to be collected were identified and samples were sent to the site according to the specified work schedule. Routine collection procedures were carried out in the identified areas. The information about the area and the amount of waste collected for each vehicle was recorded accordingly. Waste loaded vehicles were weighed before sending to the region where the characterization study was performed.

All of the waste in the vehicles were emptied for sampling and mixed with the work machine (scoop). The waste piles were then laid out with a work machine and made suitable for sampling. It is important to note that the surface of the area of sampling should be impermeable. A sample specimen

of 0.5 m³, resistant to infiltration and flow, and recommended in the ASTM standard was used for the characterization sample as it complies with the criteria for working in 91-136 kg specimens. During sampling the specimen was filled with waste without any compression so that there is no space left. 2 kg of samples were sent for laboratory analysis per each vehicle.

To obtain representative min. 91 kg samples, ASTM recommends quartering and coning. Quartering is the separation of a truckload of waste into successive quarters after thoroughly mixing the contents with a front-end loader. The samples are then coned again and quartered again until they are about 91 kg [3]. After the quartering, the samples are mixed diagonally, ie. 1 and 3 or 2 and 4. Fig 1 depicts an example of quartering.
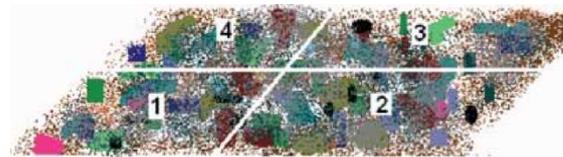
Fig 1. Quartering

It is important to determine how many categorical (group) batches are to be included in the sampling programs, in order to decide what to measure. The SWA-Tool, contains 13 compulsory primary categories and 35 recommended secondary waste categories and it encourages adjustments according to every country's local waste information requirements. For Istanbul, in the separation process, wastes are classified into 14 categories with reference to "Methodology for the Analysis of Solid Waste" (SWA-Tool) prepared by the European Commission for urban wastes and waste disposal technologies. The waste components for the Istanbul municipal solid waste characterization study are given in Table 1.

After the classification, the samples are taken to the laboratory. In the laboratory, followed by weighing and air drying; analysis of moisture content, ignition loss, calorific value, total nitrogen, total carbon, carbon nitrogen ratio, ash analysis were conducted.

2.1.　Analysis of municipal solid waste in Istanbul

The municipal solid waste characterization of Istanbul was carried out in all 39 districts of the city. Istanbul is a 1900 km² city which spreads over two continents, Europe and Asia. Within the scope of the study, samples were collected and characterized from solid waste collection vehicles from 25 districts on the European side and 14 on the Asian side for winter and summer seasons. In order to make the planning better, 39 districts were separated as Asian Side and European Side and studies were carried out accordingly. The names of the 14 districts on the Asian side are; Adalar, Ataşehir, Beykoz, Çekmeköy, Kadıköy, Kartal, Maltepe, Pendik, Sancaktepe, Sultanbeyli, Şile, Tuzla, Ümraniye and Üsküdar. And the names of the 25 districts on the European side are; Arnavutköy, Avcılar, Bağcılar, Bahçelievler,

Bakırköy, Başakşehir, Bayrampaşa, Beşiktaş, Beylikdüzü, Beyoğlu, Büyükçekmece, Çatalca, Esenler, Esenyurt, Eyüp, Fatih, Gaziosmanpaşa, Güngören, Kağıthane, Küçükçekmece, Sarıyer, Silivri, Sultangazi, Şişli, Zeytinburnu.

The municipal solid waste characterization results for Istanbul of 2017 are summarized in Fig 2. It can be clearly seen that almost 2/3 of the waste is biodegradable. Considering the daily amount of municipal solid waste is over 18000 tons in Istanbul, the amount of biodegradable municipal waste (BMW) is very high and actions should be taken immediately. It should be noted that the contamination over any waste composition was negligible.

Table 1. Waste Composition

No	Waste Composition	Content
1	Paper-Cardboard	All kinds of paper, corrugated cardboard
2	Glass	All kinds of color-colorless bottles, jars
3	Pet	Water and beverage bottles
4	Nylon bags	Any kind of grocery bags
5	Plastics	Any kind of plastics waste except PET
6	Textile	All kinds of textile materials
7	Composite	Fruit juice boxes, milk boxes
8	Diapers	All kinds of diapers
9	Metals	All kinds of metal materials
10	Electronics	Computer, telephone, radio, etc.
11	Hazardous waste	Battery, detergent boxes, medicine boxes, paint boxes
12	Biodegradable waste	Food waste, vegetables, fruit, park-garden wastes
13	Other Combustible	Shoe, carpet, bag, foam, food packaging, board
14	Noncombustible	Ash, stone, rubble, ceramic, dust
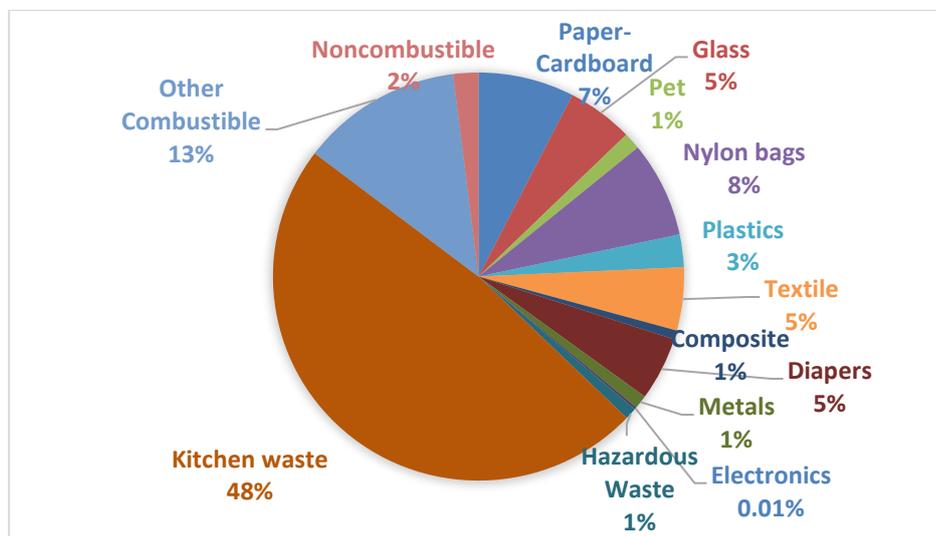
Fig 2. The municipal solid waste characterization results for Istanbul in 2017

The recyclable packaging waste content (glass, paper-cardboard, metals, plastics, PET, composite etc.) is over 15% in Istanbul. In order not to ignore the potential of the street collectors, waste samples should not be taken only from the garbage collection vehicles. The content of biodegradable waste (kitchen waste, park-garden wastes) was found to be 48.17%. It should be noted that even though the park-garden wastes are collected separately, some negligible amount of trimmings have been encountered in the study.

There is a significant difference, especially in terms of the recyclable waste content, between the waste samples taken from the commercial area and the high income areas and the samples taken from the low income areas in 2017 (18.12 %, 15.04 % and 13.73%,

respectively). The results of characterization of municipal solid waste in Istanbul from years 2005 to 2017 are shown in Table 2.

The waste characteristics vary remarkably over long periods (10-15 years). However, it may also vary considerably due to some factors (changes in consumption habits, changes in income level, migration, etc.) in shorter periods. In this respect,

monitoring waste characteristics is a necessity in terms of effective waste management. It is most advisable to perform the waste characterization process in 5-year periods unless there are major changes in social, socio-economic, urban structuring etc. When the results of the characterization studies are evaluated, they should be based on the cause-effect relationship.

Table 2. Istanbul municipal solid waste characterization results for years 2005-2017

Period	2005 Summer	2006 Winter	2007 Summer	2009 Winter	2010 Summer	2017 Winter	2017 Summer
Material				%			
Paper-Cardboard	13,30	12,06	12,37	15,57	11,05	10,32	4,79
Glass	5,82	5,93	3,97	3,03	3,72	4,67	5,72
Pet	1,52	1,21	1,02	1,13	1,36	1,45	1,24
Nylon bags	9,48	7,83	8,42	9,96	9,47	9,67	5,50
Plastics	3,39	2,56	2,60	2,62	2,28	2,60	2,56
Textile	5,28	1,93	4,08	3,42	5,74	4,89	5,11
Composite	0,64	0,77	0,49	0,86	0,66	0,88	0,54
Diapers	3,90	4,19	4,49	5,45	5,03	5,17	4,90
Metals	1,63	1,49	0,66	1,12	1,10	1,01	1,13
Electronics	0,15	0,01	0,00	0,03	0,17	0,17	0,19
Hazardous Waste	0,01	0,02	0,00	0,01	0,31	0,94	0,90
Kitchen waste	50,22	56,34	59,75	54,09	51,71	47,93	48,36
Other Combustible	2,97	2,00	2,14	2,09	6,16	8,31	17,09
Noncombustible	1,70	3,66	0,01	0,63	1,23	1,99	1,96

According to the laboratory analysis, the waste moisture content is 61.22 % for the winter season and 51.03 % for the summer season in 2017. Even though the difference seems to be high, these results are expected as the sampling was conducted during the wet season. The high calorific value within the municipal solid waste is around 4000 kcal kg⁻¹. The lower calorific value, which is a function of the waste moisture content, is 1558 kcal kg⁻¹ on average during the winter season and is the value that needs to be taken into consideration in the case of precipitation especially in terms of thermal disposal methods. In the summer season, the lower calorific value was calculated as 1587 kcal/kg. The values of ignition loss are calculated as 84.62% in the winter season and 79.36 % in the summer season, which represents thermally loss of mass. Calorific value should be monitored in terms of thermal methods if the moisture content is around 55% or lower as minimum calorific value should meet certain requirements depending on the technology and operation efficiency. 80% of the heat loss values indicate that the volatile organics are high, which emphasize biological and thermal methods. This value represents the amount of ash which will be transferred to the landfill after thermal processes.

2.2. Recommendations on the management of biodegradable waste of Istanbul

Considering the amount of waste produced in Istanbul is over 18000 tons day⁻¹, approximately 9000 tons of kitchen waste is disposed at the landfills daily. It is important to note that the samples for the characterization study were collected from the transfer stations, thus the minimizing effect of scavengers could not have been taken into consideration.

This study focused on the roadmap of the management of biodegradable solid waste management. A pilot district of Istanbul shall be selected and biodegradable bags are to be proposed to be distributed to each household in that pilot district as a suggestion for collecting biodegradable waste separately. Istorba is suggested to be the name of the biodegradable bags. Regulatory framework should make separate collection compulsory at a household level. Waste separation not only increases the quality of produced compost and recyclables, and optimizes incineration but also enables better financing of waste management activities and minimizes the energy and labor inputs to any downstream processes [4].

The presentation of the bags in addition to the importance of separate collection will be promoted by the media. Public education will put emphasis on the separate collection of biodegradable municipal solid

waste. Five biodegradable bags will be distributed for each household/week. In case extra bags are required, Istorba, which come with a grid imprint, will be available at retailers and the disposal of biodegradable waste using another kind of bag will be strictly prohibited.

Two different types of bins will be distributed for each building where applicable; and as frequent as possible elsewhere. The size of the bins will be depending on the number of inhibitants for every building. There will be one container for organic material and one container for recyclables in front of the buildings. The organics will be collected seperately and will be stored at the Istorba and will be thrown at the bin, the recyclables will also be collected seperately and be thrown at the respective bin.

The scavangers will be employed by the local municipalities and are going to collect the waste from the bins to the community bins. One scavenger will be assigned for a neighborhood of 500 inhibitants. A new-design truck will be provided for every scavenger. The scavenger will be in charge of taking the trash to the community bins and the fate of the recyclables will be under the scavenger's responsibility. The scavenger can either transfer the recyclables to the community recylable bin or sell them directly to the stakeholders.

The public shall be informed by reminders about the use of Istorba and shall be asked to collect their waste separately at home. By collecting biodegradable waste separately, the amount of trash in the Istorba will decrease. Thus the inhibitants will need fewer bags, which has a noticeable impact on their wallet.

Each neighborhood shall be informed about the collection times of the trucks. As meat and fish wastes quickly turn into bad odors; people shall be asked to place these in the biodegradable waste container just before the container is emptied at the collection time off the truck. In order for the biodegradable waste to attract fewer flies; the container should be emptied and washed on a regular basis. As the lack of ventilation sets off the fermentation process, biodegradable waste in the collection bin or container should not be compressed. To absorb moisture, wet biodegradable waste should be dried or wrapped in ordinary newspaper and the bottom of personal collection bins should be lined with a layer of paper towels or newspaper.

3. RESULTS AND DISCUSSION

There are some difficulties in the separate collection of waste and some factors have been mentioned in the literature. It has been indicated that, socio-economic characteristics, behavioural attitudes, peer influence and institutional arrangements; in detail; gender, peer influence, land size, location of household and membership of environmental organization explain household waste utilization and separation behaviour [5]. Moreover, good moral values and situational factors such as storage convenience and collection times are also mentioned to have encouraged public's involvement and consequently, the participations rate and local authorities should take into consideration of

individuals personal beliefs about the moral correctness and incorrectness of performing waste separation and factors that may motivate and inhibit waste separation behaviour [6]. Inconvenience has always been cited as a major barrier toward recycling and convenience as a major motivator [7].

Biodegradable waste, which can 'biodegrade' by natural processes, accounts for approximately three quarters of the municipal solid waste produced by homes and businesses and comprises 'organic' or natural materials which will break down over time. The principal 'biodegradable' components of municipal waste are paper and cardboard, food wastes and garden wastes.

The European Union (EU) Directive 'Landfill Directive' (2018/850) dealing with the landfilling of waste, imposes that the restrictions should be strengthened in order to move to a circular economy [8]. The Directive imposes restrictions on the consignment of certain waste materials to landfill. Although Directive 1999/31/EC already sets landfill diversion targets for biodegradable waste, it is reasonable to put in place further restrictions on the landfilling of biodegradable waste by prohibiting the landfilling of biodegradable waste that has been separately collected for recycling in accordance with Directive 2008/98/EC [9, 10]. To drive policy reforms, the EU Commission shall organise high-level exchanges on the circular economy and waste and step up cooperation with Member States, regions and cities in making the best use of EU funds and where necessary, the Commission shall use its enforcement powers [11].

4. CONCLUSIONS

This paper not only included the characterization of municipal solid waste in Istanbul but also provided suggestions biodegradable municipal solid waste for Istanbul, as a pilot city for Turkey. The proposal for the improvement of biowaste management following the authors' research for ISTAC was introduced. It is important to suggest the employment of the scavengers to the waste collection system legally by the local municipalities. The proposal of biodegradable bags is also a promising solution to increase the rate of source separation of organic waste.

The suggested solution consists of a logistically interconnected integrated biowaste management system of technologies that would manage optimally the specifications of individual groups of biological wastes, the needs of customers, and the possible sale of the final products and/or energies.

The separate collection of organic waste at source not only will increase the quality of product at the composting and biomethanization facilities, but also will improve the efficiency of the incineration plant. In the recent years, more emphasis was placed on the recycling of packaging waste. With the decline of the packaging waste with respect to the overall waste, the importance of focusing on the management of biodegradable waste has emerged. Success stories regarding the separate collection of organic waste should be deliberately examined and must be adopted

to the national conditions. With the necessity of mandatory organic seperation at household level, each local authority will require to adapt to its own socio-economic conditions; thus, it is not possible to develop one recycling system that can be adopted by all. However, in order to establish a sustainable biodegredable solid waste management system, general principles have to be identified, restrictions should be appplied.

Further studies such as the implementation of campaigns on environment awareness from the earliest years of school, to spread and improve recycling habits at the household level, reforming the current tax-deductible system that incentivizes reusing solid waste at the household level should be implemented. The recommendations could be applied by other countries as well.

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