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Solid waste characterization and management within university campuses case study: university of Tabriz

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ABSTRACT

The aim of this study was to determine the amount and composition of wastes generated within all key campus operational areas to approach the best strategy for waste management. Samples were taken daily, across the main campus, for a week with one month interval in 2010. Sampling as well as determination of waste composition methods was according to standard for determining unprocessed municipal solid waste composition (ASTM D5231-92). To estimate the amount of wastes produced daily in the campus, waste handling trucks were weighed. The results showed that the campus of University of Tabriz produced 2.5 metric tons of wastes per day that more than 80% of it could be diverted through waste reduction, recycling and composting activities. Compostable organic material was the most significant waste type. Compostable organic material, plastic wastes, paper and paper products were the other important materials for the targeted waste reduction and recycling efforts. Various educational and policy strategies, that can be used to propound campus community waste minimization behaviors in the long term, are discussed.

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Introduction

Nowadays, management and recycling of waste materials is one of the important economic and environment issues that must be considered by policy makers to attain sustainable development of a society. Effective management of solid wastes requires a complete understanding of composition of wastes as well as activities involved in its generation (Farmer et al., 1997). Compositions and properties of wastes are different depending on their source of production, life style, etc, and those management programs of wastes are more successful that are somehow site specific (Tchobanoglous et al., 1996; Armijo de Vega et al., 2008; Smyth et al., 2010). Different management methods of solid wastes are practiced in developing countries (Berkun et al., 2005; Sharholy et al., 2008; Imam et al., 2008; Chung et al., 2008; Alavi Moghadam et al., 2009). Attempts have also been made in Iran to evaluate the recycling potential of garbage produced (Abdoli,1995., Samadi and Morshedi Seif, 2003; Mohammadi, 2003; Ghaffari and Shirmard, 2003; Alavi Moghadam et al., 2009).

In some developed countries, management of wastes within universities is considered as a part of urban activities and there are comprehensive programs for wastes management within universities (Oskamp, 1995; Viebahn, 2002; Armijo de Vega et al., 2003; Savely et al., 2007; Espinosa et al., 2008). In USA 80% of colleges and universities have their own waste management programs (Allen, 1999). For example, during year 2007, a waste characterization study performed in the Campus "Mexicali I" of the Autonomous University of Baja California (UABC). The goal was to set the basis for implementation of a recovery, reduction and recycling waste management program at the campus (Armijo de Vega et al., 2008). In 2000, MASY University conducted a program to study the wastes produced in the university campus and to assess the potential present in the wastes for reuse, recovery and composting (Mason et al., 2004). Study at the Prince George campus of the University of Northern British Columbia (UNBC) during the 2007-2008 academic year showed that more than 70% of wastes could be dealt with waste reduction, recycling and composting (Smyth et al., 2010).

Analysis of waste flows within universities and institutions is the first step in designing successful and comprehensive management system (Armijo de Vega et al., 2008) towards environmental protection (Smyth et al., 2010). However because of inattention to waste management at universities, there isn't any formal study to determine the quantity and quality of wastes produced within Iranian universities. This study is the first study for solid waste management strategies within Iranian universities. The aim of the present study was to determine the quality and quantity of solid wastes within University of Tabriz main campus in order to carry out management practices for minimizing, recycling, and recovering the wastes.

Material and Methods

This study was conducted during the 2009-2010 academic year on the main campus of the University of Tabriz, Iran (38°,2´ N latitude, and 46°,25´ E longitude), with the area of 247 hectares. The university had, approximately, 17000 students and 2000 staff work in the year of study. The research consisted of five main stages as below:

a. Estimation of amount of daily generated solid wastes
b. Solid waste sampling
c. Waste characterization
d. Data collection and analysis of the amounts and types of wastes.
e. Determining the best strategy for solid waste management within university campus.

Estimation of amount of daily generated solid wastes

In order to determine the weight of the solid wastes the empty as well as loaded trucks were weighed for a period of

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50 days (about two times a month), during a year.

Solid waste sampling

A random sample was taken for this study. Prior to sampling, waste disposal spots were identified and campus was divided into nine subareas according to the type of activity. These subareas included academic departments of the university (faculties, labs and workshops), administration buildings, health center, sport center, dormitories, staff residential area, conference halls, canteen and cafeterias and university gardens. Sampling methods and procedures for characterization of the wastes were derived through using Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste (ASTM D 5231-92).

Furthermore the reviews of studies performed by different universities and countries were used.

According to ASTM recommendations, samples weighed 200 to 300 pound (91 to 136 kg) can be chosen and a single sample of 100 kg is a good representative of the total waste characteristics (ASTM, 2001).

All samples were taken during on working days to ensure that the sampling results represent the normal university operations during the academic year.

A total of nine sampling loads, one for each subarea, were scheduled over one week during each month of year. Samples were weighted by manual fish scale (accuracy ±0.1 kg) and kept in plastic bags for the analyses.

Waste characterization

In the separation site, all samples were hand sorted into 11 primary waste categories and weighted. In order to assess the recycling potential of the wastes, each category was further subdivided into subcategories.

Waste characterization of categories and subcategories were adapted from various waste characterization methodologies, mainly from ASTM standards.

Waste categories included paper and paper products, plastics, organic (compostable) materials, glass, metals, textiles, construction and demolition wastes, wood, hazardous wastes, electronic wastes and others. Table 1 shows composition of each waste category and subcategory.

Data collection and analysis of the amount and type of waste generated in the campus

Completed forms were checked for errors and data were inserted into Excel's spreadsheet and saved as data files. The percentage for each category was calculated using the following equation:

$$PC = \left(\frac{PL}{PT}\right) \times 100$$

Where PC is the percentage of each category, PL is the amount of category present in kg, and PT is the total weight of the sample in kg (Armijo et al., 2008).

Subsequent analysis included computing and analyzing the mean waste composition within each activity area, across the campus. Then the normality of data distribution was verified by the Kolmogorov-Smirnov method.

Homogeneity of intragroup variances was examined by the Leven's test. Since the distribution of the data was not normal and intragroup variances were not homogenous, then the Kruskal-Wallis test, a non-parametric one-way analysis of variance was performed to analyze the data. Statistical analyses was carried out by Excel and SPSS softwares.

Determining the best strategy for solid waste management within university

Considering to obtained results from the study, the strategies for waste management within Tabriz University were survived. Also the best strategy was attained.

Results

Waste generation rate

As the average weight of a full- truck waste load in a single trip was 2.5 tonnes and only one trip was made to the sanitary disposal (landfill) per day, therefore, the rate of daily generation of waste in main campus of the University of Tabriz was 2.5 tonnes/day.

Waste characterization

In general, 11500 kg of waste were separated from the whole activity areas of which, 4850 kg originated from samples taken from academic departments, 1510 kg from administration buildings, 600 kg from health center, 300 kg from sport center, 1220 kg from dormitories, 600 kg from staff residential area, 600 kg from conference halls, 1220 kg from canteen and cafeterias and 600 kg from university gardens. This corresponded to approximately 30% of the waste characterized per day. The results for the waste analysis are shown in Table 2.

Determining recycling potential of the university solid wastes

Out of 11500 kg of wastes, 5209.5 kg were compostable biomaterials, 4220.4 kg recyclable materials and 2070.1 kg non-recyclables (Fig. 1). More than 80% of solid wastes generated in the campus can be dealt with through waste reduction, recycling and composting activities. Compostable organic materials had the highest amount of wastes flows (45.3%). The second largest portion of the waste stream belonged to plastics (19.23%) and third was paper and paper productions (14.45%). Percentage of glass, other materials, metals, textiles, hazardous wastes, construction and demolition wastes, electronic wastes, and wood were 8.87, 5.04, 3.03, 1.32, 0.95, 0.69, 0.55 and 0.57, respectively.

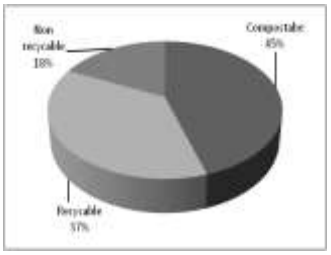

Fig. 1. Waste percentages (by wt.) according to the recycling category

Based on sub-categories classification in Table 1, results presented in Fig. 1 and percentages shown in Table 2, it is evident that a large proportion of the waste generated in the University of Tabriz Campus can be recycled or is potentially recyclable.

The best strategy for Solid Waste Management at the University of Tabriz

As the results show compostable organic material, plastic and paper wastes were three important categories of materials for the targeted waste reduction and recycling efforts. But the quantity of compostable organic material was salient and it was the most significant waste type. Considering to the economical and environmental benefits of composting, it is the best way for organic waste management (Diaz et al., 1993). Also, whereas there was a board arid land near the university campus that was perfect for settling a composting reactor, compost production was the best idea and strategy for organic solid waste management. Therefore the studies of feasibility of composting of organic wastes were conducted and humidity percent, carbon to nitrogen (C/N) ratio, pH and micronutrients level were determined. Finally in August 2011, the primary stages to build

a vertical composting reactor have been started and it will be finished in early 2012.

Discussion

Conducting a waste characterization study is the first step if an effective waste management program and sustainable development of a university are to be attained. It is estimated that the University of Tabriz main campus buildings generate approximately 2500 kg (2.5 metric tonnes) of waste per day, of which more than 80% may possibly be dealt with through waste reduction, recycling and composting activities. Compostable organic material was the most significant waste type. Therefore some strategies should be taken to manage these organic wastes. In addition, to manage other components of generated wastes in the university, there should be some plans to reuse and/or recycle them. The general schedule to manage the wastes in the University of Tabriz should include:

a. Avoiding of waste generation
b. Reducing waste generation
c. Reuse of generated wastes
d. Composting of organic wastes
e. Recycling of recyclable wastes
f. Sanitary disposal (landfill) of non-recyclable wastes

Compostable organic materials

Organic wastes are typically the greatest component of a waste stream, take the highest disposal cost and when they landfill have the highest potential to emit green house gases. (Diaz et al., 1993). Using institutional organic waste to make compost, on the university campus site or outside, has become a common practice within the higher education sector (Creighton, 1998; Smyth et al., 2010). As an example, universities in United States such as Allegheny college (Meadville, PA), Appalachian State University (Boone, NC) and Guilford College (Greensboro, NC) execute the composting program of their wastes at their sites (Sullivan, 2010). Some universities, such as Michoacán University of San Nicolas Hidalgo (Mexico), are using the wastes generated in the gardens to produce compost in order to help programs for reforestation and preservation of green areas within the campus (Sánchez-Yánez et al., 2005).

Daily production of compostable wastes at the University of Tabriz was about 1399.8 kg. These organic wastes originated from food wastes and gardening wastes. Gardening wastes include grass mowing wastes, branches, leaves and other plant materials produced in the university gardens. The largest amount of organic waste generation was from leftovers of prepared food waste produced in student dormitories and in canteen (Table 2). One main reason for high food wastes in dormitories is that the amount of food distributed in dormitories daily is much more than students need. This waste is generated throughout the day and is mixed with all different types of waste inside the same container. Using a good presidency for food distribution can help to better management of food wastes. Wastes produced in canteens and cafeterias can be sold to animal producers for feed. Other choice for managing these organic residues is the composting of food and garden wastes mixtures. In USA, most colleges and universities use the organic waste from their gardens and dining room areas to make compost. For example, Appalachian State University puts food waste in a composting system which uses close to 105 tonnes of waste per year (Sullivan, 2010). For this, the Feasibility studies to set up an experimental composting pile to produce compost from organic wastes within the university campus have carried out. The humidity percent, carbon to nitrogen (C/N) ratio, pH and micronutrients level were determined. The results were reviewed and analyzed. The aim of these results was to control and balance the amount of humidity, pH and micronutrients in beginning and during composting process. For example the C/N ratio for organic wastes produced in the University of Tabriz was about 23.50, with compared to 30 to 35 which is considered ideal. This amount was corrected by adding sawdust (with 500:1 ratio) (Gupta, 2003).

Finally after initial studies on organic wastes, the primary stages to build a vertical composting reactor has been started in August 2011and it will be finished in early 2012.

Paper and paper products

It is important to point out that, besides their recycling potential, wastes such as papers have a high reduction potential (Armijo de Vega et al., 2008). This need to education students and staff how to use paper correctly. In many universities there are special communities to educate people to not waste paper and use it correctly (Armijo de Vega et al., 2008; Armijo de Vega et al., 2003; Smyth et al., 2010). Also it needs to awareness about paper recycling benefits. Although in corridors and buildings and, also, studying halls of dormitories at the University of Tabriz, special containers for gathering the paper wastes are provided, but increasing the awareness of students about environmental benefits of paper recycling is still necessary.

Plastic wastes

Most part of plastic wastes in the University of Tabriz includes disposable containers and drink cups. With regard to non-biodegradability of plastics and its extensive harm to environment, the best approach to manage this category of waste is to avoid and/or decrease producing these wastes in the university. Use of special glass cups can be substituted for these plastic materials. Further broad environmental management considerations, reusable cup campaigns must also take into account factors that are special to the higher education context, such as the market and knowledge of effective financial incentives (Harris and Probert, 2009). Some universities such as Autonomous University of Metropolitana, has implemented recycling programs for their recyclable plastics (Espinosa et al., 2008). Providing especial containers for initial separation of recyclable plastic wastes and, also, other waste components may provide valuable help in optimal management of the wastes produced in the University of Tabriz.

Other wastes

The category of other wastes includes type of waste that cannot be recycled or reused, such as sanitary wastes. To manage these wastes, there is no way except avoiding and/or decreasing the production of these wastes.

Sampling method

The methodology for this study was derived from the Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste (ASTM D 5231-92) including the review of waste characterization studies performed by institutions. Indeed the sampling and characterization of the solid wastes were performed using the modified methodology for the solid waste. In this methodology, about a quarter of the waste produced during one whole day, was analyzed.

The composition and the amount of municipal solid wastes vary due to seasonal variability (Tchobanolous, 1996). The wastes analyzed in this study were generated within a university; however, one should envisage that there will be changes all along the year similar to those reported for municipal solid waste. Although the academic and administrative activities in the campus are similar all year around (except during summer vacations), there is a marked difference in the temperature between summer and winter in Tabriz city. This temperature

difference can be up to 40° C. Thus during the warm season, there is a greater consumption of beverages and bottled water and the generation of pet and glass bottles is high. On the other hand, grass mowing and tree pruning is more intensive during spring and summer, which lead to a higher production of waste from gardens than autumn and winter, hence higher production of organic residues. During summer, due to vacations in the university, the amount of wastes produced is different from other seasons. Therefore, the proportions of wastes that generate in each season are different from another season and so the sampling results do. Thus, for comprehensive solid waste management strategies, we need to carry out one sampling per season to obtain the trend of each of the categories during a year.

Conclusion

Effective management of waste stream generated in universities, requires complete understanding of the amount and composition of wastes as well as properties of these materials. This study visualizes a method and tools that can be used to assess quantity and quality of wastes for sustainable management of waste flow in the University of Tabriz and determined the best strategy for the waste management. The daily generation of solid waste in the main campus is around 2.5 tonnes, 80% of which can be reduced, recycled or composted. The percentages of wastes that are compostable or recyclable are 45% and 37%, respectively. Various educational and practical strategies, for the management and reuse of wastes that could be used were discussed. The results show that compost production from the organic wastes is the best strategy for solid waste management within the University of Tabriz campus.

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Table 1. Specifications of the waste in the site of the University of Tabriz, Iran

Waste Categories and subcategories	Specifications of representative material
paper and paper products:	
Printer papers	One sided printed paper, two sided printed paper, unprinted paper
Mixed paper	Office paper, magazines, newspapers, catalogues, colored paper, envelopes, glossy paper, waxed paper
Cardboard	Corrugated cardboard, cereal and tissue boxes, other cardboards
Refundable paper	Tetra drink packs
Disposable hot beverage paper cups	Single-use coffee and tea cups
Paper towel	White paper towel from bathrooms
Plastics:	
Refundable	Plastic beverage containers
Recyclable	All recyclable plastics
Soft plastics	Plastic bags and packages
Durable plastics	Pens, cafeteria tray, plastic utensils
Dairy milk and milk products	Milk containers, yoghurt, ice cream, cheese, sour cream
Organic (compostable) materials:	
Food waste	All food waste except bones, raw fruits, vegetables, coffee grounds, tea bags
Yard waste	Branches, leaves and grasses, twigs and other plant material
Glass:	
Recyclable	Jars not including glass beverage containers
Refundable	Glass beverage containers
Other	Incandescent bulbs, other types of glass not included above
Metals:	
Ferrous metals	
Recyclable	Tin cans from food and drink preparation, steel, iron
Other ferrous	Cutlery from cafeteria
Non - ferrous metal	
Refundable	Aluminum soda, juice and beer cans
Other	Aluminum foil
Textiles:	Clothing, cleaning rags
Construction/ Demolition:	Gravel, rocks, sand, ceramics, other
Wood:	Lumber, wood products, pallets and furniture
Hazardous waste:	Batteries, paint cans, autoclaved biology
Electronic waste:	Electronic cables and wires, electronics packaging
Other:	Non-recyclable wastes

Table 2. Composition (% by weight) of solid waste generated in the main campus of the University of Tabriz

Waste Category	Academic departments (%)	Administration buildings (%)	Health center (%)	Sport center (%)	Dormitories (%)	Staff residential area (%)	Conference halls (%)	Canteen and cafeterias (%)	University gardens (%)
Paper and paper products	18.20	19.71	17.54	7.22	6.45	5.86	26.73	9.85	0.00
Plastics	22.15	21.75	38.83	22.53	9.45	12.44	32.48	10.56	0.11
Organic materials	25.76	33.13	23.39	29.28	74.04	54.67	23.18	70.06	89.69
Glass	10.54	12.40	6.68	19.15	2.57	11.24	3.33	6.85	0.00
Metals	8.89	4.52	3.28	8.01	2.55	2.41	2.67	0.76	0.00
Textiles	1.28	0.85	0.22	1.33	0.78	0.13	0.70	0.10	0.00
Construction/ demolition	1.52	0.07	0.01	0.00	0.00	0.00	0.00	0.00	6.15
Wood	0.49	0.11	0.00	1.65	0.01	0.00	3.16	0.00	0.01
Hazardous waste	0.39	1.92	2.98	3.59	0.25	2.99	1.11	0.00	0.00
Electronic waste	1.31	0.10	0.05	2.04	1.26	1.21	0.29	0.00	0.02
Others	9.47	5.44	7.02	5.20	2.64	9.05	6.35	1.82	4.02
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00