Int. J. Environ. Res., 3(4):681-690, Autumn 2009
ISSN: 1735-6865

Evaluating the Recovery Potential of Solid Wastes

Sadugh, M.B.[1], Jalili Ghazizadeh, M. [2*], Pezeshk, H. [3] and Jalili Ghazizadeh, V. [4]

[1]Department of Environmental Sciences, IA University of Arak, Arak, Iran
[2]Graduate Faculty of Environment, University of Tehran, P.O.B. 14155-6135, Tehran, Iran
[3]School of Mathematics, Statistics and Computer Science, College of Science, University of Tehran, Tehran, Iran
[4] Faculty of Engineering, IA University of Mashhad, Mashhad, Iran

Received 26 Sep. 2008; Revised 20 May 2009; Accepted 27 May 2009

ABSTRACT: The purpose of this research was to evaluate the recovery potential of solid waste in Mashhad. The solid waste generated in the regions 4, 5 and 6 has been quantified and characterized using direct weighing, physical testing and truckload sampling methods. To determine the quantity and quality of waste generated and its seasonal variations, chemical and physical analysis were carried out for one year. The current situation concerning resource recovery and disposal of solid waste in Mashhad is also described. Results show that the average solid waste generation rate is around 0.58 kg/capita per day in these regions. Statistical studies reveal that the quantity of waste generated differ significantly in various seasons. The composition (on a weight basis) of the solid wastes sampled was as follows: food wastes 46%, yard waste 8%, plastics 12%, paper and cardboard 6%, textiles 15%, metals 2%, glass 6% and rubber 4% indicating a high amount of organic matter. Vegetable and food wastes from the kitchen and yard wastes accounted for more than 50% of the waste stream. The moisture content was around 45% and the heating value of the mixed wastes around 4228 KJ/Kg (as-discarded basis). The nature of the wastes indicate that amongst the recovery options, composting at household level would be most appropriate as it would divert more than 50% of the wastes from the traditional waste stream and provide households with compost which could be used to enrich soils in the gardens.

Key words: Waste composition, Waste generation rate, Recovery, Composting, Mashhad

INTRODUCTION

Mashhad is situated in northeast of Iran with the total area of more than 200 square kilometers and the population was measured to be around 2.4 million inhabitants in 2006 (www.sci.org.ir). One of the most important points which must be considered is the number of tourists who annually arrive to this city that according to given statistics was more than 14 million in 2006 and the average of their staying was about 3 days. This objective can be problematic for municipal solid waste management system (Jalili Ghazizade & Noori, 2008). Currently, management of municipal solid waste system is under inspection of Recycle Organization of Mashhad Municipality. According to this organization report, waste generation quantity in Mashhad is about 1600 tons per day which 1% of it be recovered, 6.5% be converted to compost and 92.5% be sent to landfills.

Mashhad has tow landfills: a) Old landfill situated in southeastern of Mashhad where 75% of generated waste is dumped (around 1200 tons/ day). b) Mayamey landfill located in northeastern of Mashhad where the rest of generated waste is disposed (around 400 tons/day). Old landfill will be closed in around 2 years because this landfill is close to urban area and causes many problems related to producing odor. Since capacity of Mayamey landfill will be full in 20 years based on the present waste generation rate, so we must

*Corresponding author E-mail: mjalili@ut.ac.ir

reduce the waste stream to landfills. Environmental and public health awareness in Iran have resulted in national legislation concerning solid waste (Abduli *et al.,* 2008). In Mashhad, solid waste was traditionally disposed in Old landfill by open dumping method. From 1998, the policy of Mashhad municipality in solid waste management has been to stop dumping and adopt landfilling as the main treatment/disposal strategy. Presently, the mixed household wastes generated on the city (around 1600 tons/day) are being collected by public and private companies. Collected waste brought to transfer station where they are compacted before being sent to the Miami landfill situated in the northeastern of city. Presently there is very little recovery of solid waste in Mashhad. The two existing recycling factories (paper and plastic) operate entirely as profit making organizations and there is presently no incentive schemes designed to promote recycling or reuse. The cornerstone of successful planning for a waste management program is the availability of reliable information about the quantity and the type of material being generated and an understanding about how much of that material those collection program managers can except to prevent or capture. Effective waste management through MSW composition studies is important for numerous reasons, including the need to estimate material recovery potential, to identify sources of component generation and to facilitate design of processing equipment (Gidarakos *et al.,* 2006). Also how waste is best recovered, treated or disposed of depends on the nature of the materials in the waste, not on the original use of the discarded object (White *et al.,* 1995).

Many researches have been carried out in the field of recovery potential of solid waste in developed and developing countries. Research findings of Chang and Davila in Texas indicate that high fractions of plastics and paper in the waste stream imply a strong potential for energy recovery (Chang & Devila, 2008). Assessing the recovery potential of solid waste in Mauritius shows that amongst the recovery options, composting at household level would be most appropriate due to the nature of generated waste (Mohee, 2002). Also research of Metin et al. in Turkey indicate that although paper, including cardboard, is the main constituent, the composition of recyclable waste varies strongly by the source or the type of collection point (Metin *et al.,* 2003). Another study which have been done in Greece by using field and experimental data revels that recycling, perhaps the most positively received of all waste management practices, is going to be an essential part of contemporary waste management strategies, composting can play an important role, while incineration seems to be a conditionally feasible solution (koufodimos & Samaras, 2002). Furthermore, other studies in this field have been carried out in recent years (Zhang *et al.,* 2007; Troschinetz & Mihelcic, in press; Buenrostro & Bocco, 2003; Hui *et al.,* 2006; Hansen *et al.,* 2007).

For city like Mashhad, the management of solid waste is a critical issue for various reasons such as high population density, competition between land uses, limited domestic markets and high tourist numbers. Limited land areas make the option of landfill disposal unsustainable in the long time. Incineration, while reducing the volume of waste is prohibitive in terms of cost and still requires disposal of ash containing potential hazardous substances in high concentration. Over the past, inappropriately sited and poorly managed garbage dumps have significantly contributed to groundwater pollution and environment degradation.

A study was initiated within urban residential area situated in east of Mashhad (regions 4, 5 and 6) to characterize the solid waste generated as well as provide a general assessment of the recovery potential of the wastes.

MATERIALS & METHODS

There are two general approaches taken to analyze solid waste stream composition, the ‘material flows approach’ and the ‘output method’ (McCauley-Bell *et al.,* 1997). The material flows approach considers the production and expected lifecycles of products and, from these, estimates the waste stream percentages (by weight) within the various categories of waste. This approach considers waste as the end result of a production lifecycle. An advantage of the material flows approach is the broad geographical scope for which the solid waste stream can be estimated, but criticisms of this method include its focus on product categories, and not on waste stream categories. Another problem with the material flows method is that it excludes some waste components because they do not originate from a product sector (e.g., yard waste). The general consensus is that the material flows approach is more applicable for large geographical areas, e.g., a country-wide basis, rather than local studies (Reinhart and McCauley-Bell, 1996). The 'output method' for estimating the composition of the solid waste stream generally occurs at a disposal site and involves the sampling, sorting, and weighing of individual categories of the waste stream (Tchobanoglous *et al.,* 1993). The output approach may be used to provide information regarding the condition of the waste components prior to separation or disposal (e.g., regarding the cleanliness, and hence value of cardboard for recycling purposes (CRA and CAS, 1999)). Following the sampling, sorting, and weighing procedures, statistical analyses are performed on the data.

Presently, there are three sampling methods belong to out put approach (Sharma & McBean, 2007): a) ASTM; b) VSEPA; c) CIWMB. In this research, sampling was carried out according to international standard ASTM D 5231-92(2003). Vehicles for sampling were selected at random during each day of the one-week sampling period, as to be representative of the waste stream. According ASTM D5231-92, for a weekly sampling period of k days, the number of vehicles sampled each day should be approximately n/k, where n is the total number of vehicle loads to be selected for the determination of waste composition. A weekly period is defined as 5 days. According ASTM D5231-92, the number of sorting samples (that is, vehicle loads (n) required to achieve a desired level of measurement precision) is a function of the component(s) under consideration and the confidence level. The governing equation for n is as follows:

$$n = \left(\frac{t^* s}{e\bar{x}} \right)^2 \qquad (1)$$

where t* is the student t statistic corresponding to the desired level of confidence, s the estimated standard deviation, e the desired level of precision, and $\bar{x}$ is the estimated mean. Suggested values of s and x for waste components are listed in Table 1. Values of t* are given in statistical tables. (Table 1). is the result of one-week sampling at Mayamey landfill, performed by the investigators, prior to the main sampling period.

Table 1. Values of mean ($\bar{x}$) and standard deviation (s) for within-week sampling to determine MSW component composition (Mayamey landfill, Mashhad, 2006)

Component	Standard Deviation (s)	Mean Value ($\bar{x}$)
Food waste	0.15	49.02
Paper and Cardboard	0.07	5.68
Plastic	0.1	9.57
Glass	0.06	7.08
Metal	0.02	2.07
Yard waste	0.45	6.18
Leather	12.4	0.57
Rubber	0.05	4.05
Textile	1.4	15.78
		100

At the station the semi-trailers were weighed and then brought to a free space on the floor for sorting. A truckload of wastes was unloaded in that controlled area and the truckload sampling method was used to reduce the quantities of waste to be sampled. The waste load was quartered. One of the quarters was selected and again quartered until a weight ranging from 100 to 200 kg was obtained. One of the quartered quarters was selected and all of the individual components separated manually into pre selected components such as paper, plastics, glass, food waste, yard waste, metals, textiles and miscellaneous. The separated components were weighted by a weighing machine. The mean waste composition was calculated using the results of the composition of each of the sorting samples.The following tests were carried out on the samples of solid waste in the laboratory at the Compost factory.

- Moisture content (MC)

Samples of 50–70 g were taken in triplicate, and dried to constant weight in an oven at 105 °C for 24 h, cooled in a desiccator and the difference in weight recorded. The moisture content was calculated as follows:

Moisture content (wet weight basis),

$$\% = \frac{\text{Loss in weight} \times 100}{\text{Net wet weight}} \qquad (2)$$

- Total volatile solids (organic matter)

A weighed sample of dried material obtained from the determination of total dry solids or that dried separately were ignited at 550 °C for 2 h in a muffle furnace. The difference in weight between before and after heating gave the volatile solids content (%) of the sample.

Volatite Solids (VS),

$$\% = \frac{\text{Loss in weight} \times 100}{\text{Net dry weight}} \qquad (3)$$

RESULTS & DISCUSSION

The quantity of waste obtained from April 2007 to March 2008 is shown in (Fig. 1). An average of 341.175 tons of wastes was obtained on a daily basis. Since there are 142931 households in regions 4, 5 and 6, it was found that every household would generate around 2.39 kg per day. The average household size in these regions was taken to be 4.12 showing that the quantity of solid waste generated was around 0.58 kg/capita per day. In Comparison with average of generated waste in the whole of city (0.66 kg/capita per day), it shows that the income of people who live in these regions is low.

A statistical analysis was carried out to determine: (1) weekly and (2) seasonal variations in solid waste generation rates. An ANOVA test carried out on the weekly variations showed that within a month, there was no significant difference between the wastes generated at a level of significance of 0.05. However, for the seasonal variations, daily data for the month May 2007, August 2007, November 2007 and February 2008, was collected. The ANOVA test (Table 2). showed a significant difference ($F>F_{crit}$) at a level of significance of 0.05, indicating that waste generation rates differ during four seasons.

This analysis provides sufficient evidence to conclude at the 95% confidence level that the means of the four seasons are not equal. This analysis does not tell us whether one season is different from the other three or whether all four are different.For determining existence of waste generation difference between seasons, we should

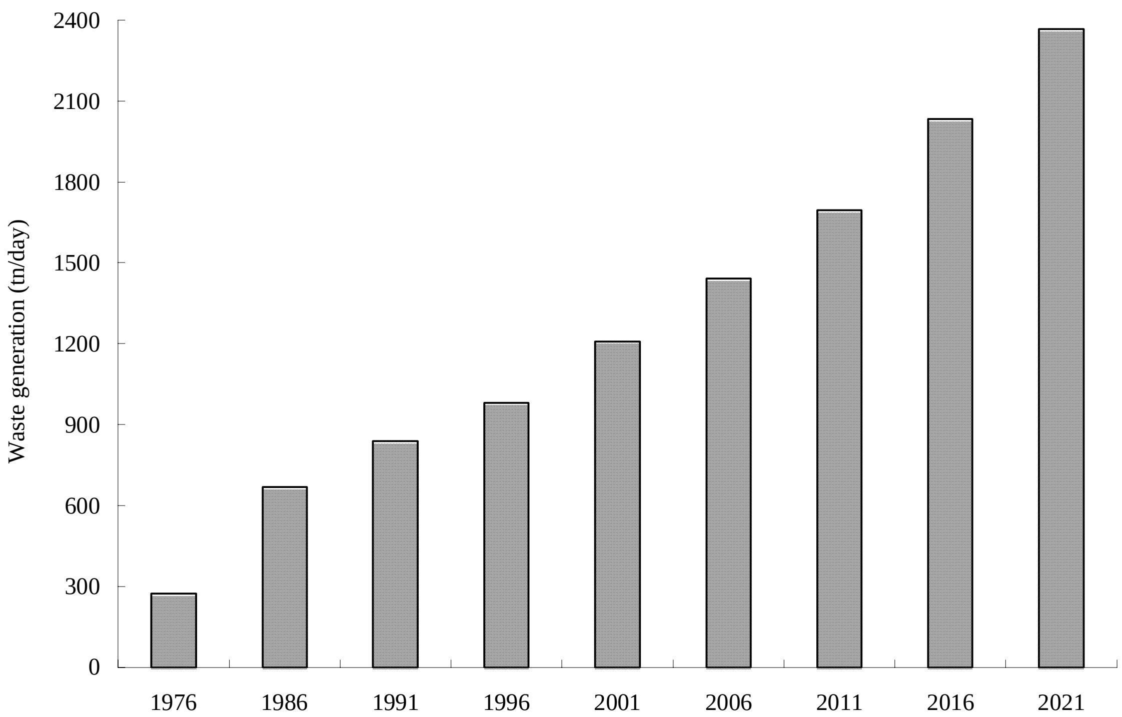

Fig. 1. Monthly variations of MSW production (April 2007-March 2008)

Table 2. ANOVA table for seasonal variations

ANOVA : Single factor Groups	(seasonal analysis)				
	count	Sum	Averages	Variance	
Summary					
May	31	10074.48	324.98	137.25	
August	31	11641.73	375.54	957.09	
November	30	10312.7	343.76	548.25	
February	29	854.64	294.30	1775.66	
Source of variation	SS	df	MS	F	F_{crit}
ANOVA					
Between groups	107581.28	3	35860.43	42.618435	2.684
Within groups	98447.93	117	841.43		
Total	206029.21	120			

use method of "independent t-test for assessing the difference of two averages" (Mac Berthouex & Brown, 2002). It must be noted that mentioned method is used for comparison of two averages with same variances and if they do not have same variances, we should apply another method. Therefore, variances proportion analysis must be done by use of F-distribution at first. If two independently distributed random variables X and Y have, respectively, mean value η_X and η_Y and variances $\sigma_X{}^2$ and $\sigma_Y{}^2$, then $100(1-\alpha)\%$ percent confidence interval for $\frac{\sigma_X{}^2}{\sigma_Y{}^2}$ is equal to

$$\left[\frac{1}{F_{\frac{\alpha}{2},\ (n-1,,m-1)}}\frac{S_X{}^2}{S_Y{}^2}\ ,\ F_{\frac{\alpha}{2},\ (m-1,,n-1)}\frac{S_X{}^2}{S_Y{}^2}\right]$$

Where n, m are sample sizes and $S_X{}^2$, $S_Y{}^2$ are sample variances of X and Y, respectively. Also α is tail probability.If this confidence interval includes one, it can be said that variances of tow population are same. Confidence intervals of variances proportion analysis for each two seasons are shown in Table 3.

According to Table 3, February-August and November-August have same variances. So method of "independent t-test for assessing the difference of two averages" is valid for them. Since sample sizes are more than 30, so $100(1-\alpha)\%$ percent confidence interval for difference of means is:

$$[\bar{X}-\bar{Y}-Z_{\frac{\alpha}{2}}\sqrt{\frac{S_X{}^2}{n}+\frac{S_Y{}^2}{m}}\ ,$$

$$\bar{X}-\bar{Y}+Z_{\frac{\alpha}{2}}\sqrt{\frac{S_X{}^2}{n}+\frac{S_Y{}^2}{m}}]$$

Where $\bar{X}$, $\bar{Y}$ are sample means of X and Y, respectively. Also Z is normal distribution. If this confidence interval include zero so there is no persuasive evidence in these data that the solid waste generation are different in the two seasons and if not, we can say waste generation in the two seasons are different. For seasons with different variances (obtained from Table 3), $100(1-\alpha)\%$ percent confidence interval for difference of means is calculated by below formula (Walpole, 1982):

Table 3. Confidence intervals of variances proportion analysis for different seasons

	May	August	November	February
May		Not Ok	Not Ok	Not Ok
August	[0.07 , 0.30]		Ok	Ok
November	[0.12 , 0.53]	[0.84 , 3.65]		Not Ok
February	[5.27 , 27.08]	[0.76 , 3.88]	[1.52 , 7.93]	

$$[\overline{X}-\overline{Y}-t_{\frac{\alpha}{2}}(\upsilon)\sqrt{\frac{S_X{}^2}{n}+\frac{S_Y{}^2}{m}}\ ,$$

$$\overline{X}-\overline{Y}+t_{\frac{\alpha}{2}}(\upsilon)\sqrt{\frac{S_X{}^2}{n}+\frac{S_Y{}^2}{m}}]$$

Where t is student's t distribution and υ is degree of freedom that calculated by equation (4).

$$\upsilon=\frac{\left(\frac{S_X{}^2}{n}+\frac{S_Y{}^2}{m}\right)^2}{\frac{1}{n-1}\left(\frac{S_X{}^2}{n}\right)^2+\frac{1}{m-1}\left(\frac{S_Y{}^2}{m}\right)^2} \qquad (4)$$

Confidence intervals of average difference (with same or different variances) for each two seasons are shown in Table 4.

Table 4 shows that different quantity of Mashhad generated waste in each season in comparison with other season is statistically significant. Therefore, waste management system design in this city must be flexible for controlling of waste generation fluctuation.Based on Table 1 and equation 1, number of samples for determining of waste composition is 28 with a precision value (e) of 10%. In this equation, food waste was considered as a governing component.The determination of the mean composition of MSW was based on the collection and manual sorting of a number of samples of waste over a selected time period covering one week for each season. Therefore, four phases of seven sampling days (twenty eight days in total) were carried out. The wastes for semi trailers sampled were analyzed and sorted. All percentages are reported on a weight basis. The average results (Figure 2) for each category were as follows:

- Green waste and food waste occupied a large proportion of the waste (54%). In comparison with average of putrescible wastes in whole of city (70%), it reveals that the income of people in these regions is lower than the average of Mashhad inhabitants' income. However, this amount of putrescible wastes in these regions is significant in comparison with developed countries. This can be explained by the fact that the regions constituted of houses with gardens and also, there is minimum use of processed food in the eating habits in these regions. An important difference, usually noted for municipal solid waste generated by developed and industrialized countries is the percentage of organic material. The amount of biodegradable materials is generally less in industrialized countries. In other countries with the same system for municipal solid waste management, this phenomenon is seemed. According to an analysis made by Mistry (Mistry, 1997), it was found that countries like India and Nepal had high amounts of vegetable wastes (50–70%) as compared with highly industrialized countries like UK and USA where percentages as low as 25% have been reported for putrescible wastes.
- The weight percentage illustrated for metals and glass appeared to be lower than the values usually reported in other studies (8%). After investigation, it was found that there were markets for these items whereby they were recuperated for reprocessing. This was particularly the case with metal cans and ferrous materials. As for glass, the main source of which is bottles, the main reason for this low percentage is due to the fact that people favor the use of bottles that hold a return price. There is presently a deposit/refund scheme on glass bottles. These bottles are recollected and reused by their manufacturers. There has also been a shift from glass bottles to plastic bottles over the years especially for soft drinks.
- The weight percentage for plastics can be taken to be relatively high. A high percentage for

Table 4. Confidence intervals of average difference

	May	August	November	February
May		Not Ok	Not Ok	Not Ok
August	[44.62 , 56.50]		Not Ok	Not Ok
November	[14.01 , 23.48]	[18.04 , 45.52]		Not Ok
February	[-38.78 , -22.58]	[62.43 , 100.05]	[-58.38 , -40.54]	

plastics (12%) in the residential region was noted. The main source of plastics in residential areas is plastic bottles and packaging. The increasing use of plastic bottles is likely to become a major environment issue in the future. The percentage for paper (6%) is low compared with industrialized countries. Also it must be considered that due to existence of many weaving and sewing factories in this area, there is high percentage of textiles (15%) in waste composition.

- Laboratory analysis showed that the moisture content was around 45.28% while the average volatile solids were 82% on a dry weight basis. These analyses indicated that the wastes are generally moist as compared with typical moisture contents of residential wastes in the range of 21–40 (Tchobanoglous et al., 1993). The high value can be explained by the fact that the wastes are composed of a high percentage of vegetable putrescible matter. The high value of volatile solids indicates a good potential for biological treatment.
- Waste chemical formula was calculated by using of waste composition (Fig. 2). Also heating value of waste is determined by using equation 5, known as a modified Dulong formula.

$$HV = 145.4C + 620(H - \frac{1}{8}O) + 41S \qquad (5)$$

Where C, H, O and S are percentage of carbon, hydrogen, oxygen and sulfur, respectively, and HV is heating value (Btu/Ib). According to equation 5, heating value of generated waste (as-discarded basis) in these regions is equal to 4228 KJ/Kg. Since the minimum amount of heating value for incineration is equal to 11600 KJ/Kg (Tchobanoglous *et al.*, 1993), so incineration option is not suitable for solid waste management in these regions.

Assessing recovery potential of solid wastes

Fig. 2 shows that the main sources of municipal solid waste in Mashhad are of domestic nature. Around 90% of the MSW reaching the landfill come from households, commercial sectors and hotels. Figure 3 shows the changes of waste generation average (on daily basis) in Mashhad for different years. Fig. 3 shows the increscent of waste generation from 1976 (274 ton/day) to 2006 (1442 Ton/day). With rising population, tourist numbers, incomes and little waste diversion, it is being projected that the quantity of solid waste generated will continue to increase and total municipal solid waste going for final disposal will reach 2367 tons per day by 2021. Based on this

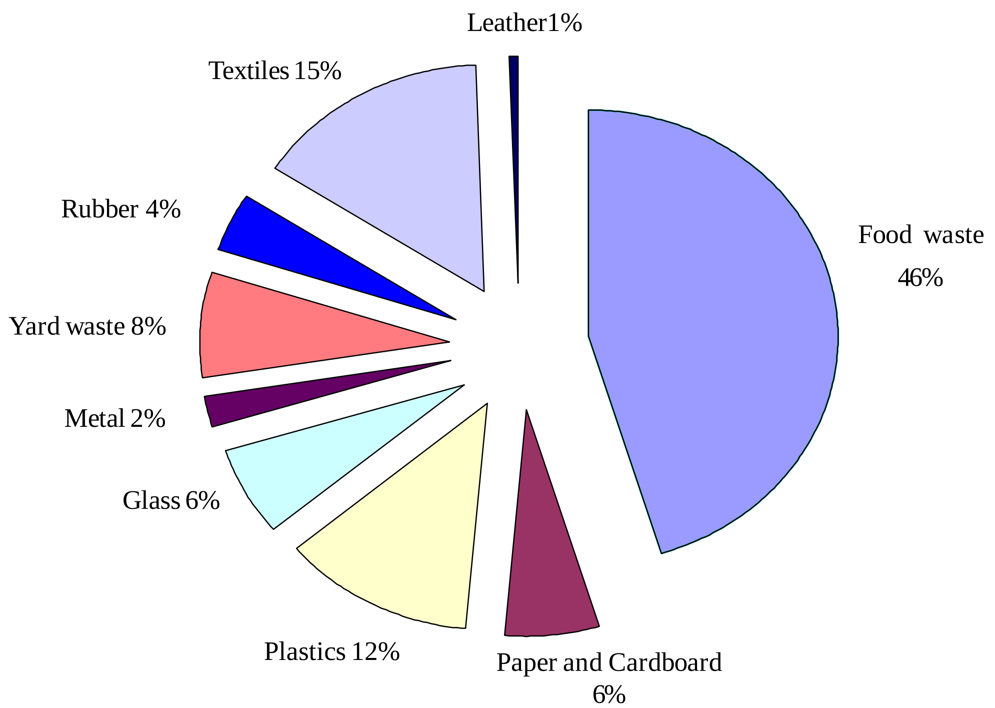

Fig. 2. Solid waste composition (on a weight basis)

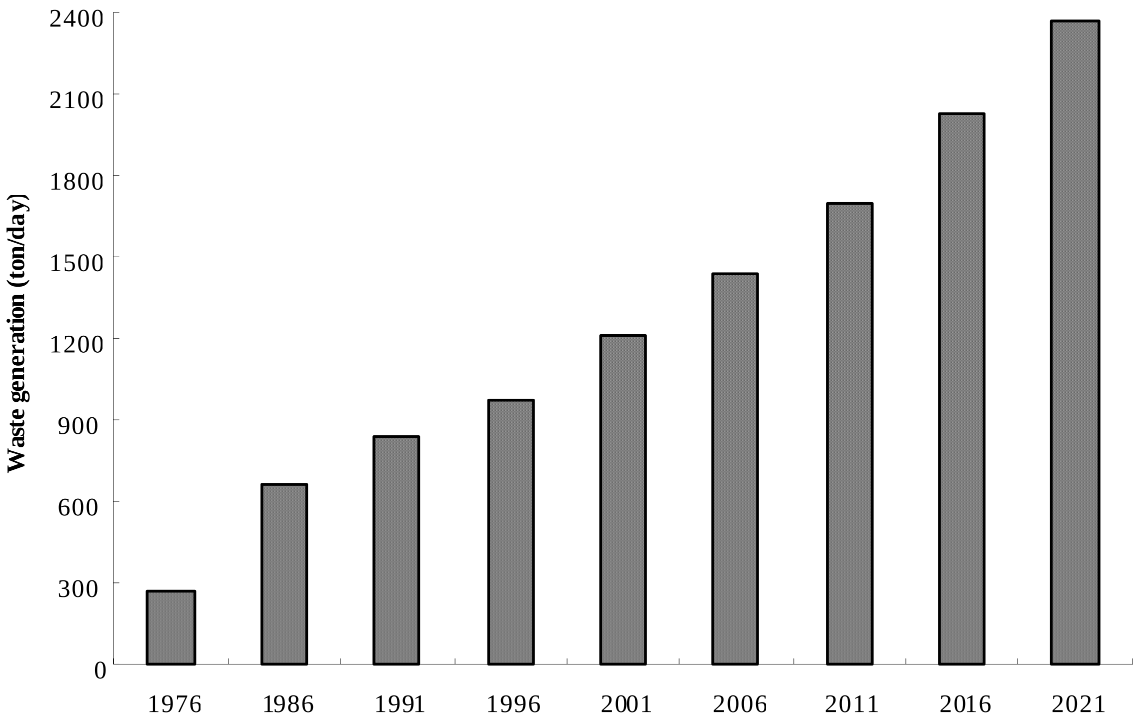

Fig. 3. Changes of waste generation in Mashhad from 1976 to 2021

figure and the present strategy of waste disposal through landfilling, an overall disposal capacity of almost 715000 tons per year will be required. This will prove to be very difficult in the local context as land is limited and there is already severe competition between land uses especially for residential and commercial purposes such as development of hotels.

Identification of appropriate and publicly acceptable sites for waste disposal has proven to be extremely difficult in the past. After a long selection process for potential sites in 2000, a site was selected in the northeastern of the city (Mayamey). After 6 years, waste transfer was begun to this site at 1st November 2006. Since Old landfill will be closed until 2010, so Mashhad waste generation will transfer to this site totally. Scenarios have shown that Mayamey landfill will be full in around 20 years based on the present waste generation rate. Therefore another landfill should be selected after this date. It is, therefore, imperative for Mashhad to find alternative means for treatment such as materials recovery and also to minimize waste generation. These measures will help to extend the potential life span of the existing landfill as well as reduce the demand for imported materials.

While analyzing the findings of this study and considering the integrated solid waste management hierarchy, it can be said that:

- There is the need to adopt within Mashhad an integrated waste management system that focuses on waste minimization and resource recovery as shown in Fig. 4.
- Waste Reduction is the first element in the ISWM hierarchy. Although implementation of source reduction programs for tourists is a hard task, but inhabitants through their purchasing habits such as increase in use of locally produced goods and the use of goods with low amounts of packaging can still decrease the quantity of wastes generated at source.
- Waste Reuse, in the form of Home composting could be a viable solution as:

1. Home composting consists of a proactive method to divert organics from the waste stream, thus leading to cost savings associated to storage, transport and ultimate disposal.
2. Huge amounts of organic wastes are generated in Mashhad and a large amount of compost would

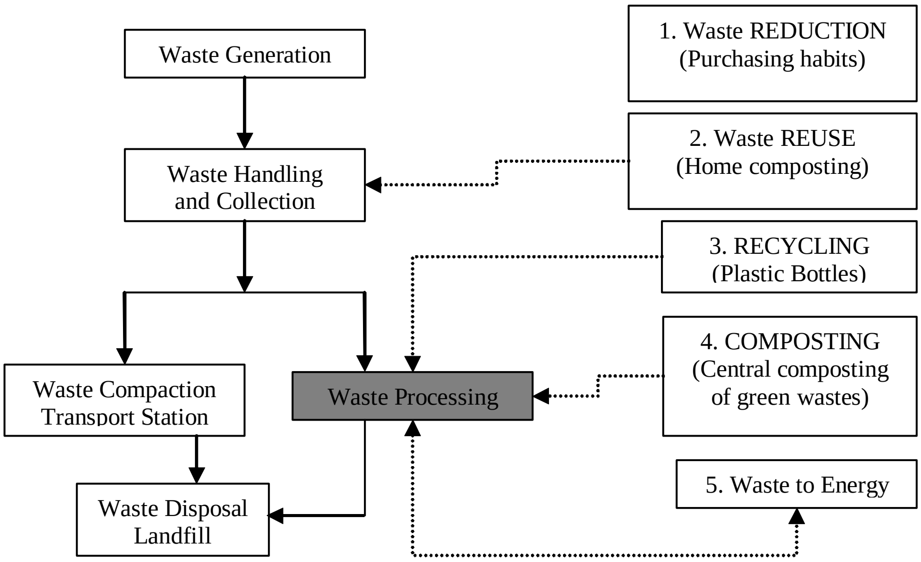

Fig. 4. Integrated solid waste management measures (Mohee, 2002)

be produced which would be beneficial for agriculture.

3. Waste collection facilities are not easily available and are quite expensive. Home composting would allow for a lesser amount of wastes to be collected.

• Plastics recycling. The quantity of plastics is around 12%, which is quite high. Presently, there is a recovery factory on plastic bottles of type polyethylene terephthalalte (PET) with the capacity of 5 tons per day. In addition, there is a factory for plastic recovery with the capacity of 1 ton per day. However, more Incentives should be given to encourage private companies to implement the scheme, as it will have a significant impact on the plastic waste stream on a national level.

• Centralized composting for putrescible wastes. This option has a big potential in Mashhad because food wastes represent a high proportion in the waste stream (46%). The putrescible wastes could be composted in a central facility, for example at the transfer stations.

• The incineration option should be studied further as the heating value of mixed municipal solid waste is quite low. However it must be considered that if the wet organics part of the waste stream is removed and composted, the remaining part of the wastes will have a higher calorific value and this will render incineration more suitable.

• The landfill at Mayamey has to be upgraded and additional protection brought to the existing liner system to render the landfill capable of accepting wastes of a more hazardous nature as facilities for hazardous waste do not exist in Mashhad.

• In parallel, effective legal and economic instruments to promote waste reduction and resource recovery should be developed. Economic instruments to facilitate small enterprises and public/private partnership to implement waste minimization and product responsibility schemes must be made available.

CONCLUSION

This study has shown that an average of 0.58 kg/capita per day of solid waste is generated within the Regions 4, 5 and 6 of urban residential areas in Mashhad. Statistical studies in this research show that the amounts of waste generation in various seasons differ significantly in these regions. The composition of the wastes is largely organic in nature, with food, vegetable and yard wastes occupying more than 50%. The wastes are moist and have a low calorific value. Based on the above, it can be said that the first element to consider in the recovery of solid waste is composting the organic fraction, either through home composting or centralized composting of putrescible wastes. This would help to divert more than 50% of wastes from the waste stream and lead to enormous cost savings in terms of waste collection, transport and disposal. Furthermore, at household level, home composting would give a product, which could help to enrich the soils of the gardens, and boost vegetable/fruit yields. Measures should be taken to inform the public on the benefits of such recovery options and incentives given.

ACKNOWLEDGMENTS

The authors are grateful for the cooperation of the Recycle Organization of Mashhad Municipality for providing information. Thanks are extended to Farzaneh Tajabadi for her review and comments.

REFERENCES

Abduli, M. A., Samieifard, R. and Jalili Ghazizade, M. (2008). Rural solid waste management. Int. J. Environ. Res., **2(4)**, 425-430.

American Society for Testing and Materials, (2003). Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste. Test Method D5231-92.

Buenrostro, O. and Bocco, G. (2003). Solid waste management in municipalities in Mexico: goals and perspectives. Resources, Conservation and Recycling, **39**, 251-263.

Chang, N. B. and Devila, E. (2008). Municipal solid waste characterizations and management strategies for the Lower Rio Grande Valley, Texas. Waste Manage, **28**, 776-794.

CRA and CAS, (1999). Waste Composition Study for the Burnaby Incinerator. Report to the Greater Vancouver Regional District, May.

Gidarakos, E., Havas, G. and Ntzamilis, P. (2006). Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste Manage., **26**, 668–679.

Hansen, T. L., Jansen, J. L. C., Spliid, H., Davidsson, A. and Christensen, T. H. (2007). Composition of source-sorted municipal organic waste collected in Danish cities. Waste Manage., **27**, 510-518.

Hui, Y., Liao, W., Fenwei, S. and Gang, H. (2006). Urban solid waste management in Chongqing: Challenges and opportunities. Waste Manage., **26**, 1052–1062.

Jalili Ghazizade, M. and Noori, R. (2008). Prediction of municipal solid waste generation by use of artificial neural network: A case study of Mashhad. Int. J. Environ. Res., **2(1)**, 13-22.

Koufodimos, G. and Samaras, Z. (2002). Waste management options in southern Europe using field and experimental data. Waste Manage., **22**, 47-59.

Mac Berthouex, P. and Brown, L. C. (2002). Statistics for environmental engineers. Lewis Publishers, 2nd edition, Florida.

McCauley-Bell, P., Reinhart, D. R., Steir, H. and Ryan, B. O. (1997). Municipal solid waste composition studies. ASCE Journal of Practice Periodial of Hazardous, Toxic, and Radioactive Waste Manage., **1(4)**, 158-163.

Metin, E., Erozturk, A. and Neyim, C. (2003). Solid waste management practices and review of recovery and recycling operations in Turkey. Waste Manage., **23**, 425-432.

Mistry, P. B. (1997). Energy recovery from organic waste in developing countries. Organic Recovery and Biological Treatment., **97**, 59–65.

Mohee, R. (2002). Assessing the recovery potential of solid waste in Mauritius. Resources, Conservation and Recycling., **36**, 33-43.

Reinhart, D. R. and McCauley-Bell, P. (1996). Methodology for Conducting Composition Study for Discarded Solid Waste. University of Central Florida, Florida Center for Solid and Hazardous Waste Management, Report No. 96-1.

Sharma, M. and McBean, E. (2007). A methodology for solid waste characterization based on diminishing marginal returns. Waste Manage., **27**, 337-344.

Tchobanoglous, G., Theisen, H. and Vigil, S. (1993). Integrated Solid Waste Management: Engineering Principles and Management Issues. McGraw-Hill, New York.

Troschinetz, A. M. and Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. Waste Manage., **29(2)**, 915-923

Walpole, R. E. (1982). Introduction to statistics. Macmillan Publication Company.

White, P., Dranke, P. and Hindle, P. R. (1995). Integrated Solid Waste Management: a Lifecycle Inventor. Chapman and Hall.

Zhang, R., El-Mashad, H. M., Hartman, K., Wang, F., Liu, G., Choate, C. and Gamble, P. (2007). Characterization of food waste as feedstock for anaerobic digestion. Bioresource Technol., **98**, 929-035.