Research Journal of Environmental and Earth Sciences 2(3): 153-158, 2010
ISSN: 2041-0492

Submitted Date: May 13, 2010 Accepted Date: May 26, 2010 Published Date: July 10, 2010

A Scrutiny of Feasibility of Recycling Materials from Municipal Solid Waste: A Case Study of Hamedan City, Iran

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Abstract: This study presents the amount of daily production of waste material, its physical analysis in four divided districts of Hamedan city by municipality along the four seasons of the year as well as contribution of citizens in recycling programs. For the purpose of determining the daily average amount of waste material, a weight-volume method was carried out as well as randomized quota method to determine physical analysis. During the four seasons of the year and one week a season, 5 samples, totally 20 samples of 0.5 m^3 volume, were chosen. Besides, density and humidity weight percentage were calculated to be prepared for analyzing by SAS software. In order to determine contribution of citizens in recycling programs, 500 questionnaires were distributed in the four districts and were completed using personal interview. Results showed an average production of 482.93 tons/day waste material having a density of 268.96 kg/m^3, a density of 46.76% and 0.96 kg per capita of waste material in Hamedan city. The results of municipal waste physical analysis also revealed that approximately 72.76 tons/year (15.07%) of total daily production of waste material included recyclable materials like plastic, metal, glass, paper and etc., while 379.93 tons/year (78.97%) were compostable organic materials. Results of the carried out survey also showed that 84% of Hamedan citizens had acquaintance with the issue of recycling, 89% tended the program to operate and 90% were ready to cooperate with the recycling program.

Key words: Composting, hamedan, municipal solid waste, people contribution, recycling

INTRODUCTION

Basic principles of Integrated Solid Waste Management (ISWM) are (Malakootian *et al*., 2005): Reduction, Reuse, Recycling and Recovery (4Rs).

In order to recycle solid waste materials, awareness of the amount of quantitative and qualitative specifics of waste materials as well as contribution of citizens is important.

The worldwide socio-economic development of several countries has the direct outcome to produce large quantities of wastes from urban, municipal and industrial sectors (Rapti-Caputo *et al*., 2006). Municipal Solid Waste (MSW) is commonly known as trash or garbage. It comprises everyday items, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, batteries, and other consumer-related product forms. The composition of MSW depends on a number of factors such as the lifestyles of the population, their relative standards of living, general consumer patterns, and the level of technological advancement of a particular country (Cheremisinoff, 2003).

Today the recovery and reuse from huge amount of municipal wastes produced have become must for health hazards posed by the wastes and economic benefit (Nag and Vizayakumar, 2005). Waste management for municipal waste is considered a public service, providing citizens with a system of disposing of their waste in an environmentally sound and economically feasible way. The amount and composition of waste generated comprise the basic information needed for the planning, operation and optimization of waste management systems. The demand for reliable data concerning waste arising (waste generation) is implicitly included in the majority of national waste management laws (Beigl *et al*., 2008).

There is an increased attention from the population for toxicological aspects due to Municipal Solid Waste (MSW) landfilling (Davoli *et al*., 2009). Municipal waste management systems that rely exclusively on landfills have little need to characterize the types and quantities of material disposed, unless the waste streams comprise significant quantities of hazardous wastes. As communities rely more on source reduction, recycling, composting, and Waste- to-Energy (WTE) technologies, the need for reliable data about what is in the waste

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Fig. 1: Hamedan county, Iran - Hamedan city is located in

stream becomes paramount to the waste management program's success. Each of these technologies addresses discrete segments of the waste stream.

These data assist municipalities in:

- Determining the best management methods for different materials
- Planning recycling and composting programs by identifying the amounts of recyclables and organic materials generated by residential, commercial, and possibly industrial sectors
- Sizing of WTE facilities based on the amount of wastes remaining in the waste stream after recycling and composting
- Estimating waste transportation and separation costs using local estimates of total municipal waste volume and weight

The first requirement, therefore, is that not all the compostable part of municipal waste should be composted -only raw materials, which produce high-quality compost. Compost produced from clean metropolitan green wastes is an extremely beneficial product for many soils, which are generally low in humus.

The most powerful motivation for the general public to recycle is considered to be the ability to make a personal contribution to the quality of the environment. Social pressure to conform is also a strong influence. Materials are recovered from the municipal waste streams for recycling more because they are obvious or easy to isolate than because there is sustained demand for them as essential raw materials. Most plastics, papers, cardboards, metals or glasses are technically recyclable, but few qualify on economic grounds because the combined costs of collection, sorting, transporting, cleaning and reformulating are greater than those of virgin extraction, especially to achieve a comparable quality and usefulness (Cheremisinoff, 2003).

According to daily increase of municipality services due to expanding amount of development in Hamadan city, there is a must to apply sound statistics and information using scientific method in managing wastes produced in this city like other cities of Iran. This research carried out achieving the mentioned objectives.

MATERIALS AND METHODS

Study area: Being located in Iran, Hamedan is one of the population grown counties of the country (Fig. 1). The study area is the capital of the Hamedan County and is entitled Hamedan as well. This study carried out during early October 2007 until late October 2008.

Table 1: Daily average production of waste materials in different districts and different seasons (measured in kg)

	Seasons				
Districts	Fall	Winter	Spring	Summer	Sum of seasons
District 1	129521.14	125757.07	123992.99	130321.53	127398.18
District 2	125789.57	128598.35	123407.13	12493.68	125681.68
District 3	10970.28	101788.71	90507.13	102455.37	100955.37
District 4	130853.85	128877.78	126901.7	128944.11	128894.36
Sum of districts	4951234.84	485021.91	464808.95	486658.69	482929.59

Table 2: Weight percentage average of physical analysis of waste materials in the four districts of Hamedan city in the fall of 2007

	Weight percentage average of non compostable waste materials Waste materials											Weight percentage average of compostable waste materials (percentage of organic matters)
Districts	Plastic	Glass	Metal	Wood	Bread	Rubber	Disposable products	Paper	Cardboard and pasteboard	Fabric	Others materials	
District 1	5.56	1.34	1.74	1.13	0.56	1.06	1.53	1.47	3.39	1.88	5.99	73.98
District 2	4.20	1.17	1.54	1.10	0.11	0.63	0.81	1.18	2.80	1.43	5.13	79.62
District 3	4.04	0.77	1.13	0.84	0.03	0.80	0.65	0.69	2.39	2.37	5.58	79.62
District 4	3.61	1.23	1.16	0.56	0.05	1.11	0.59	0.6	1.60	1.59	4.47	83.36
Average of districts	4.35	1.12	1.39	0.9	0.18	0.9	0.89	0.98	2.54	1.81	5.29	79.36

Table 3: Weight percentage average of physical analysis of waste materials in the four districts of Hamedan city in the winter of 2008

	Weight percentage average of non compostable waste materials Waste materials											Weight percentage average of compostable waste materials (percentage of organic matters)
Districts	Plastic	Glass	Metal	Wood	Bread	Rubber	Disposable products&PET	Paper	Cardboard & pasteboard	Fabric	Others materials	
District 1	5.62	1.56	1.87	1.15	0.24	0.87	1.79	2.07	3.19	1.71	5.38	74.40
District 2	4.16	1.25	1.42	0.94	0	0.85	1.22	1.70	2.68	1.45	4.74	79.00
District 3	3.76	0.87	1.22	0.8	0.01	1.21	0.86	1.17	2.18	3.09	5.00	79.24
District 4	3.95	1.19	1.2	0.77	0.02	1.00	0.87	1.05	1.75	2.34	4.45	81.27
Average of districts	4.37	1.21	1.42	0.91	0.06	0.98	1.18	1.49	2.45	2.14	4.89	78.47

The method used in this study is experimental-periodical as well as applied. In order to realize potential of recycling in Hamedan city and its economical justification three issues were considered:

Physical analysis and estimate the quantity of waste material: For this purpose, a weight-volume method was carried out; So that in order to comparing produced waste materials in different districts of the city and future basic and scientific programming, trash transporting vehicles in four divided districts of Hamedan city by municipality were weighed distinctly during one week in middle of every season. Then, with adding up pure weight of the waste materials in every district, total weight of the city production of waste materials during a year was calculated (Table 1).

Physical analysis of waste materials includes the following stages:

- Sampling of waste materials in a determined period so that seasonal changes in waste materials is considered.
- Determining the quality of samples taken into consideration and determining the percentage of its forming materials as well as sampling methods and statistical formations of the data obtained.

In this study in order to analyze the waste materials physically, sampling method from waste materials transporting station was adopted because of its large area and spatial suitability, presence of a roofed area, and consequently prevention of the weather conditions to affect as well as the four districts to be separate. After determining the place of sampling, because of inconsiderable difference between the four districts of the city, regarding to area and population, using a special vehicle to measure the volume of the waste materials, 5 randomized selected samples from each area with an exact volume of 0.5 m^3 from different parts of the disposed waste materials selected daily from the site (totally twenty samples from the city).

Afterwards, the selected samples from each area manually separated out of local weather conditions effect like wind blowing distinctly (these samplings were carried out during the 7 days of every season).

In this study, trash separated into 12 parts including: 1- organic matter, 2- paper, 3- cardboard and pasteboard, 4- rubber, 5-plastic, 6- disposable products and PET, 7- fabric, 8- glass, 9- metals, 10- wood, 11-bread, 12-other materials. The obtained results from physical analysis of waste materials in the four districts during the four seasons were prepared in Table 2-5.

In measuring the density, in each area after filling the container (the special 0.5 m^3 vehicle) with 0.5 m^3 of waste materials, in order to better loading and proper filling of the container angles, the container was shaken three times forward and backward and after that was strictly weighed, measuring the difference of the full and empty container and palpably knowing the volume of the container (0.5 m^3), the density of each sample measured as kg/m^3.

In order to determining humidity weight percentage and compost production possibility, the collected samples from every district were divided into four parts and a two

Table 4: Weight percentage average of physical analysis of waste materials in the four districts of Hamedan city in the spring of 2008

	Weight percentage average of non compostable waste materials Waste materials											Weight percentage average of compostable waste materials (percentage of organic matters)
Districts	Plastic	Glass	Metal	Wood	Bread	Rubber	Disposable products and PET	Paper	Cardboard and pasteboard	Fabric	Others materials	
District 1	5.83	1.81	1.81	1.39	0	0.79	2.16	1.89	3.01	1.39	4.93	74..81
District 2	4.96	1.26	1.24	0.81	0	1.06	1.42	1.35	2.33	1.47	4.44	79.51
District 3	4.53	0.95	1.31	0.69	0	1.73	1.04	1.17	2.25	3.63	4.64	77.91
District 4	4.19	1.02	1.14	0.85	0	0.69	1.10	0.86	1.81	3.10	4.31	80.82
Average of districts	4.87	1.26	1.37	0.93	0	1.06	1.43	1.31	2.35	2.39	4.58	78.26

Table 5: Weight percentage average of physical analysis of waste materials in the four districts of Hamedan city in the summer of 2008

	Weight percentage average of non compostable waste materials Waste materials											Weight percentage average of compostable waste materials (percentage of organic matters)
Districts	Plastic	Glass	Metal	Wood	Bread	Rubber	Disposable products	Paper	Cardboard and pasteboard	Fabric	Others materials	
District 1	4.74	1.47	1.59	1.05	0.14	0.73	1.18	1.71	4.03	2.96	7.01	73.26
District 2	3.82	0.86	1.32	0.86	0.04	1.29	1.07	0.96	2.65	2.47	5.63	78.88
District 3	3.76	1.06	1.22	0.58	0	0.76	0.81	1.32	2.59	2.15	4.12	81.42
District 4	3.82	0.85	1.31	0.50	0	0.61	0.79	0.98	2.90	1.83	4.48	81.64
Average of districts	4.04	1.06	1.36	0.75	0.04	0.82	0.96	1.24	3.04	2.35	5.46	79.09

Table 6: The amount of waste materials humidity in the four districts of Hamedan city in different seasons (measured by percentage)

	Seasons				
Districts	Fall	Winter	Spring	Summer	Average of seasons
District 1	43.25	39.91	41.13	39.25	40.89
District 2	46.97	41.36	41.6	47.68	44.40
District 3	41.38	51.21	48.14	53.60	48.58
District 4	55.18	52.00	52.37	52.78	53.08
Average of districts	46.69	46.12	45.81	48.33	46.74

Table 7: Point of view of the people asked about recycling waste materials (trash)

	Choices (%)			
Districts	Separating valuable materials of trash	Separating the trash as wet and dry	Producing materials and energy from trash	I don't know!
District 1	25	7	40	28
District 2	64	3	22	11
District 3	55	4	23	18
District 4	64	7	22	7
Sum of districts	52	5	27	16

kilogram sample was separated, blended and finally from every district a two kilogram sample was immediately transferred to laboratory in a plastic bag and to get assured of the operation precision, the mentioned operation was carried out four times a season considering their average as humidity weight percentage. Thereafter, the transferred samples were settled in fur vehicle in 105ºC for 24 h and after incubation were weighed and their humidity weight percentage calculated using the following formula:

$$Humidity\ weight\ percentage = \left(\frac{a-b}{a}\right) \times 100$$

a: the (primary) weight of the sample before incubation
b: the (secondary) weight of the sample after incubation

It is worthwhile mentioning that measuring humidity weight was carried out according to the usual waste materials collecting system, that is to say, exiting of the waste latex during the transporting vehicle movement was not prevented (Table 6).

Contribution level of people in recycling solid waste materials programs: In order to present a proper operational pattern for recycling waste materials in four divided districts of Hamedan city by municipality, a questionnaire including 26 questions was designed and a cluster analysis (Lovett, *et al*., 2001; Hidalgob, *et al*., 2008) carried out to distribute 500 questionnaires over the city (120 sheets in district 1, 140 sheets in district 2, 110 sheets in district 3 and 130 sheets in district 4) so that completing them using personal interview. Afterwards, Table 7-10 obtained.

Table 8: Tendency of the people asked about carrying out of "source separation" program

	Choices (%)	
Districts	Yes	No
District 1	90	10
District 2	95	5
District 3	90	10
District 4	82	18
Average of districts	89	11

Table 9: Tendency of the people asked about cooperating in "source separation" program

	Choices (%)	
Districts	Yes	No
District 1	93	7
District 2	99	1
District 3	88	12
District 4	79	21
Average of districts	90	10

Table 10: Analysis of Variance (ANOVA) of physical analysis of waste materials in the four districts of Hamedan city in four seasons of the year 2007-2008

		Mean of squares												
SOV	df	Plastic	Glass	Metal	Wood	Bread	Rubber	Disposable products and PET	Paper	Cardboard and pasteboard	Fabric	Others Materials	Organic matter	Density
Season	3	*	n.s	n.s	n.s	n.s	n.s	**	**	**	**	**	**	**
		8.4	0.4	0.7	0.2	1.0	1.0	9.9	10.1	25.4	19.6	53.1	2652.43	19787.5
District	3	**	**	**	n.s	n.s	n.s	**	**	**	**	n.s	**	**
		13.1	13.1	4.1	3.2	1.6	6.4	15.2	15.3	36.6	88.2	3.4	29774.4	103521.1
Season&	9	n.s	n.s	n.s	n.s	n.s	n.s	*	n.s	n.s	**	**	n.s	n.s
Interaction District		1.7	1.7	0.7	1.1	0.3	6.3	0.9	6.4	6.4	24.6	16.8	6.4	6.4
Error	544	3.07	1.1	0.5	1.6	0.1	3.2	0.4	0.9	3.1	4.3	4.0	564.6	3118.8

*: Significant difference at the 95% level, **: Highly significant difference at the 99% level, n.s: non-significant difference at the 95% level

RESULTS AND DISCUSSION

The obtained results presented in Table 1-9. Population of Hamedan city with a growing rate of 1% is increasing resulting in an increase in municipal waste materials is also inevitable. Daily production rate of waste materials in the district four had the highest rate in every season, except the summer, that was due to its higher population in comparison to other districts.

The average waste material per capita was 1.11 kg per capita in district one that was the highest among all. The cause of the mentioned matter was the better relative economical and financial situation of its people and consequently producing more waste materials.

Comparing the seasons, from point of view of daily average waste materials in different seasons, revealed that the most amounts were 495.23 tons/day in fall and the least amounts were 464.81 tons/day appertained spring. The difference between maximum and minimum amounts was 30.42 tons/day. Apropos of the high rate of daily average waste materials in fall can notice the increase in waste materials from gardens, falling leaves from trees, and other waste materials due to green space maintenance.

The amount of daily average waste materials in Hamedan city during the four seasons was estimated 482.93 tons/day.

For the purpose of comparing the density of waste materials in the four districts and the four seasons, one-way analysis of variance (ANOVA) carried out using SAS software that became specified there is significant difference among the four districts and the four seasons ($p<0.01$).

From point of view of comparing seasons, the density of waste materials in summer has significant difference with other seasons that can be related to existence of decomposable waste materials with high moist like fruit peels, vegetables, and etc. resulting in an increase in the weight of waste materials.

Considering the density, there is significant difference between all districts ($p<0.01$) that is due to culture diversity and municipal texture in different districts of the city. Average density of Hamedan city during the period of sampling was estimated 268.96 kg/m^3.

The percentage of waste material during the study period in different seasons had a range of 45.81-48.33% that the most percentage appertained summer and the least of it appertained spring that can be justified due to high moist organic decomposable waste materials in summer than the same in spring.

In order to determine the significance difference between materials and components of the four districts, one-way analysis of variance (ANOVA) carried out using SAS software (Table 10).

In this study, it became specified that in Hamedan city about 379.93 $tons.day^{-1}$ of compostable organic materials is produced that its largest amount appertains district four and its least amount to district one. Considering possibility of transforming 40% of compostable waste materials into applicable compost, a possibility of producing 152 tons/day of compost would be provided.

Except decomposable waste materials, 72.76 tons/day of recyclable waste materials including plastic, glass, metal, wood, PET, paper, pasteboard and cardboard, fabric, and bread are produced that the largest amount appertains plastic (21.39 tons/day) and the least amount appertains bread (0.37 tons/day).

Noticing the amounts and tonnage of daily production of recyclable waste materials and compostable organic materials shows that investing and programming in recycling sector and providing its facilities from economical or environmental point of view is essential and inevitable.

While a percentage of 77.08% compostable organic materials was reported for Beijing, the same amount in Hamedan was 78.97% (Zhen-Shan *et al*., 2002).

A study carried out by Vidanaarachchi *et al*. (2006) has revealed that there is a high willingness of people for home composting. While in Hamedan people were most likely to contribute to recycling programs and not directly carry out such a work.

In the past, the people of Taiwan were not aware of waste problems and recycling as well but now, most people are aware of such problem (Weng *et al*., 2009). In the present study it was revealed that approximately more than 80% of people have recognized the problem like that in Taiwan.

It is worthwhile mentioning that the land value is so high that landfilling is not an absolutely rational option. Hence as in the study by Sarkhel and Banerjee (2009) was revealed, from the point of view of the municipality, composting has been found to be the most relevant option and one of the reasons has been land scarcity. From the other side people who thought collective action was possible in local community projects were more likely to subscribe to the proposed service as well as the people interviewed in the present study.

It is suggested that awareness programs educating people regarding the problems as well as significance of MSW disposal through NGOs as the study carried out by Pattnaik and Reddy (2010) and its results were in concordance with those of ours.

Besides, the results showed that the willingness of people to contribute in recycling programs was relatively high as is in concordance with the point of view people of Nepal's capital - Kathmandu -that has been evident by Alam *et al*. (2008).

CONCLUSION AND RECOMMENDATION

The aim of this study was to carry out a scrutiny on feasibility of recycling materials from municipal solid waste in Hamedan city of Iran. Based on the results of the investigations, the following conclusions were drawn:

- Due to relatively high amounts of compostable products, composting is a suitable option to be carried out.
- People should be considered as an important part because of their actively willingness to contribute in the recycling programs.
- It is suggested that new policies are to be implemented to facilitate the contribution of people in recycling programs and composting programs as well.

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