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Country Report

Municipal solid waste management in Tehran: Current practices, opportunities and challenges

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Abstract

Tehran, the capital city of Iran and a metropolis with a population of 8.2 million and containing 2.4 million households, generated 2,626,519 tons of solid waste in 2005. The present study is aimed at evaluating the generation, characteristics and management of solid waste in Tehran. Municipal solid waste comprises more than 97% of Tehran's solid waste, while three other types of solid waste comprise less than 3% of it, namely hospital waste (1.0%), industrial waste (0.6%) and construction and demolition waste (0.5%). The contribution of household solid waste to total municipal solid waste is about 62.5%. The municipality of Tehran is responsible for the solid waste management of the city; the waste is mainly landfilled in three centers in Tehran, with a small part of it usually recycled or processed as compost. However, an informal sector is also active in collecting recyclable materials from solid waste. The municipality has recently initiated some activities to mechanize solid waste management and reduce waste generation. There remain important challenges in solid waste management in Tehran which include: the proper collection and management of hospital waste; public education aimed at reducing and separating household waste and educating municipal workers in order to optimize the waste collection system; and the participation of other related organizations and the private sector in solid waste management.

1. Introduction

Solid waste (SW) management is becoming a problem for major cities worldwide. This is especially true in developing countries as a result of the rapid increase in SW generation caused by rapid population growth, urbanization, rapid industrialization and economic development (Suocheng et al., 2001). Municipal solid waste (MSW) generation in Asia in 1998 was 0.76 million tons per day (Jin et al., 2006), with an annual growth rate of 2–3% in developing countries and 3.2–4.5% in developed countries. In many metropolitan areas in developing countries, government and local authorities are responsible for the management of the SW system from the initial point of collection to final processing, but most organizations fail to provide good service, due to several reasons (Kassim and Ali, 2006). This may result in such consequences as pollution, reduction of aesthetic values and economic losses due to failures in recycling and composting valuable components of MSW. Furthermore, poor management of SW may result in serious urban, sanitary and environmental problems such as an unpleasant odor and the risk of explosion in landfill areas, as well as groundwater contamination because of leachate percolation (Mor et al., 2006). Unsuitable SW collection and management practices also result in the loss of resources and energy, which could be recycled and produced from a large part of the solid waste. Therefore, over

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the past few decades, particular attention has been paid to the optimization of solid waste management as a response to the increase in the cost of both the collection and disposal of waste (Badran and El-Haggar, 2006).

The objective of this paper is to assess the situation of SW management in Tehran and to identify any gaps in the system as currently applied. This was achieved by reviewing the quantity of waste produced in Tehran. Current requirements and challenges in relation to the optimization of Tehran's SW collection and management system have also been discussed, and some suggestions for solving the problems identified are presented.

2. Municipal solid waste management

2.1. Background information about the city

Tehran, the 220 year-old capital of Iran, lies on the southern foothills of the Alborz Mountains and is located in the center of the country, lying between latitude 35° 34′–35° 50′ North and longitude 51° 08′–51° 37′ East. Its altitude varies from 1700 m in the North to 1200 m in the center and 1100 m in the South. Tehran's climate overall is hot and dry, and the mean air temperature is 18 °C with a mean maximum and minimum of 38.7 and −7.4 °C, respectively, and annual precipitation of 245–316 mm.

Its 664 km^2 territory comprises 22 urban regions. According to the latest census conducted in 2006, it has a population of 8.2 million with 2.4 million households. The average population density in this metropolis is about 12,350 inhabitants per km^2. The population dispersion throughout the different regions of the city is shown on Table 1.

Table 1
Population of different urban regions of Tehran in 1996 and 2006[a]

Urban region	Population	
	1996	2006
1	286,917	307,001
2	526,416	563,265
3	297,654	318,490
4	762,082	815,428
5	491,788	526,213
6	253,195	270,919
7	344,991	369,140
8	386,662	413,728
9	199,358	213,313
10	324,416	347,125
11	259,526	277,693
12	217,909	233,163
13	281,707	301,426
14	453,470	485,213
15	715,370	765,446
16	342,920	366,924
17	330,230	353,346
18	240,430	257,260
19	261,306	279,597
20	409,191	437,834
21	217,064	232,258
22	64,376	68,882
Total	7,666,978	8,203,666

[a] The population in 2006 is estimated on the basis of the city's population in 1996 and a population growth rate of 1.22 (OWRC, 2006a,b).

2.2. Solid waste generation and its characteristics

Solid waste generation in Tehran over a 15 year period is shown in Fig. 1. The total amount of solid waste generated in Tehran during 2004 and 2005 was 2,614,904 and 2,626,519 tons, respectively and the total amount of MSW in these years was 2,561,069 and 2,570,988 tons, respectively. The amount of solid waste produced in Tehran during 2004 and 2005 is shown on Table 2; the results show that per capita SW generation rate in Tehran in 2005 was 0.88 kg day^{-1}. In comparison, the per capita SW generation rate is 1.21 kg day^{-1} in China (Suocheng et al., 2001) and 0.95 kg day^{-1} in Turkey (Metin et al., 2003). The solid waste produced in Tehran can be classified into the following four groups:

- Municipal solid waste – solid waste generated by households, offices, shops and hotels;
- Hospital solid waste – waste from hospitals and healthcare facilities;
- Industrial solid waste – solid waste generated by industrial units; and
- Construction and demolition solid waste.

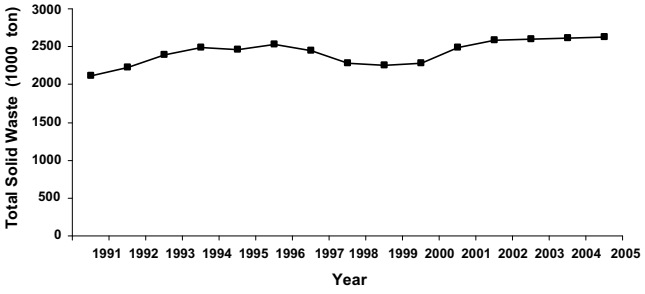

Fig. 1. Total solid waste generation in Tehran over a 15 year period (OWRC, 2006a).

More than 97% of Tehran's solid waste is made up of MSW, and the other three types of solid waste comprise less than 3% of it (hospital waste, 1.0%; industrial waste, 0.6%; and construction waste, 0.5%). The contribution of household solid waste to total MSW is about 62.5%.

The composition of household SW in Tehran is shown in Table 3, and the total amount of household solid waste generated is given in Table 4. Household SW composition depends on several factors including dietary habits, cultural traditions, lifestyle, climate and income (Jin et al., 2006). As shown in Table 3, the major element in Tehran's household MSW is stale bread (42.6%). Wheat bread is one of primary sources of food in Iran, especially in medium and low income households. A considerable amount of bread will finally be treated as waste because of inappropriate production methods, as well as inappro-

Table 2
Total solid waste (ton) received by the Aradkuh (Kahrizak) landfill center in different seasons of 2004 and 2005

Components	2004					2005				
	Spring	Summer	Autumn	Winter	Total	Spring	Summer	Autumn	Winter	Total
MSW	654,848	643,552	645,681	616,988	2,561,069	629,189	676,360	644,379	621,060	2,570,988
Hospital waste	6418	6816	6606	6643	26,483	6365	7047	6732	7054	27,198
Industrial waste	4006	3455	3685	4446	15,592	3685	4633	3870	3861	16,049
Construction waste	3098	3197	2864	2601	11,760	3334	3197	2888	2865	12,284
Total	668,370	657,020	658,836	630,678	2,614,904	642,573	691,237	657,869	634,840	2,626,519

OWRC (2005, 2006b).

Table 3
Composition of household solid waste in Tehran (%) in different seasons of 2005

Season	Stale bread	Plastic	Paper and cardboard	Metal	Glass	PET[a]	Others[b]
Spring	42.4	9.8	20.1	8.8	1.5	1.1	16.3
Summer	44.1	10.7	20.2	8.8	1.6	0.7	13.9
Autumn	43.1	10.1	24.5	8.5	1.6	0.8	11.5
Winter	40.7	11.5	24.5	9.9	1.9	1.1	10.5
Average	42.6	10.5	22.3	9.0	1.6	0.9	13.0

Source: OWRC (2006b).
[a] Polyethylene Terephthalate bottles and dishes.
[b] Refers to any unknown or hardly classified material in solid waste.

Table 4
Household solid waste (SW) generation (ton) in Tehran in different seasons of 2005

Season	Household SW	Stale bread	Plastic	Paper and cardboard	Metal	Glass	PET[a]	Others[b]	Recycled[c]
Spring	448,811.4	8522.0	1970.9	4043.1	1758.4	291.7	220.7	3275.5	20,082.4
Summer	396,612.6	9696.9	2351.8	4445.0	1936.7	360.2	158.8	3057.0	22,006.3
Autumn	382,441.0	8982.2	2107.8	5106.3	1770.2	326.6	159.6	2389.0	20,841.6
Winter	379,612.5	8408.5	2368.2	5049.4	2049.7	385.1	220.5	2163.7	20,645.1
Average	401,869.4	8902.4	2199.7	4661.0	1878.7	340.9	189.9	2721.3	20,893.9
Total	1,607,477.6	35,609.7	8798.6	18,643.8	7515.0	1363.5	759.6	10,885.2	83,575.4

Source: OWRC (2006b).
[a] Polyethylene Terephthalate bottles and dishes.
[b] Refers to any unknown or hardly classified material in solid waste.
[c] Data include only formal recycling by Tehran municipality or in pilot parts of the city and exclude informal recycling activities.

priate storage and consumption by households. Stale bread is usually sent to traditional and semi-industrialized livestock husbandries as a feed, especially in winter when forage availability is limited due to the country's harsh climatic conditions. As a result, there is a high demand for stale bread and its price increases in winter; the price of each ton of stale bread in summer and winter is about 80 and 110 USD, respectively. Increasing public awareness about better consumption patterns and storage methods and improving bakery facilities are the best ways for minimizing stale bread. However, installing special receptacles for collecting bread on an occasional basis either in the home or on the street seems to be an appropriate mechanism for collecting more stale bread for feeding animals. Other than stale bread, paper and cardboard (22.3%) and polyethylene terephthalate bottles and dishes (PET, 0.9%) comprise the highest and lowest percentages of household MSW in Tehran. The physical analysis of MSW is important for characterizing and classifying it to allow for its proper management and for an accurate estimation of its economic value as well as its potential for recycling, composting and biogas production (Mor et al., 2006).

2.3. Municipal solid waste collection system

Tehran municipality is responsible for SW management. This consists of: daily SW collection from households, hospitals and healthcare centers, offices, shops and hotels; transporting the MSW to landfill sites and recycling or composting centers; and cleaning the city. Household SW is collected using two methods. First, municipal employees collect the household SW door-to-door, which is done once every night at 21:00. Second, Tehran municipality has recently provided public waste containers as a part of its Program for the Mechanization of the SW Management System in Tehran. Using this method, households put their solid waste in these

containers every night and municipality-owned machines collect the SW from these public containers at about 21:00. Each day, 700 tons of SW is collected by Tehran municipality.

Hospital waste is now collected by Tehran municipality and, in most cases, is transported to landfill sites without any separation. Hospital waste usually includes sharps, human tissues and other infectious materials. If the infectious components are not separated and stored carefully, and if they become mixed with the general non-infectious waste, the entire mass becomes potentially infectious (Patil and Pokhrel, 2005). Hence, hospital waste is potentially dangerous and may possess pathogenic agents. Some of these pathogenic organisms are dangerous, because they may be resistant to treatment and possess a high level of pathogenicity. Their improper collection and treatment will cause environmental pollution, an unpleasant smell, the growth and multiplication of insects, rodents and worms and may lead to the transmission of diseases like AIDS through injuries from syringes and needles contaminated with human blood (Askarian et al., 2004).

For these reasons, the proper collection and disposal of hospital waste is of great importance as it can decrease both direct and indirect health risks to people, as well as damage to flora, fauna and the environment. The participation of other organizations such as the Ministry of Health, as well as the adoption of rules and regulations for the proper disposal of hospital waste, will result in minimizing these risks.

Unfortunately in Iran, as in many other developing countries, no or limited rules have been developed for the management of hospital waste. Furthermore, accurate information about the amount of waste produced and the method of treatment and disposal in hospitals is often not readily available. A few hospitals and healthcare centers in Tehran are now separating their waste and are equipped with waste incinerators. According to recent regulations, all hospitals and healthcare centers are obliged to install waste incinerators by the end of 2007. Despite these advances, some reports have shown that the main problem of hospital solid waste management in Khuzestan Province in the South of the country is improper solid waste storage, packing and transportation rather than the absence of facilities (Karamouz et al., 2006). It should be noted, however, that in Iranian hospitals, anatomical parts that are attached to bones are given to the patient's guardians and are buried according to religious rites (Askarian et al., 2004).

2.4. Solid waste landfilling

Solid waste landfilling is a common method of SW management in developing countries (Mor et al., 2006), and most of Tehran's solid waste is landfilled in the Aradkuh Center (Kahrizak). The amount of landfilled waste is shown in Table 2. This 500 ha center is located in the southern part of the city and has been used for waste landfilling for more than 40 years.

The total amount of Tehran's solid waste and its recyclable materials are shown in Table 4. As we see from this table, a considerable part of Tehran's solid waste consists of recyclable materials such as plastic, paper and cardboard, metal, glass and PET. In 2005, only about 5% of recyclable materials was recycled, which can be attributed mainly to a lack of waste separation at the source and the failure of the Tehran municipality to provide facilities for proper recycling. It should be noted, however, that an informal economy exists where some people make money from the recovery of recyclable materials in solid waste. Generally, this informal economy produces little benefit for the population and avoids taxation by the public authorities, resulting in no real improvement in the sanitary, environmental and economic conditions of the city (Kapepula et al., 2006). Furthermore, since no control is exercised over the activity of these groups, unsanitary recycled materials may enter society and result in irreversible health consequences. It should be noted that, since there is no valid or reliable information about the quantity and quality of this informal sector, the authors did not have access to any reliable data about its activity. In addition to the health and environmental issues, the activity of this sector is illegal. For these reasons, the government and municipality should encourage the participation of the private sector and NGOs in solid waste management within a legal framework that consider health issues.

It is now generally accepted worldwide that SW landfilling is not an efficient approach for the management of SW because of the limited availability of land, especially in large cities where land values have increased during the last decades because of population growth (Bai and Sutanto, 2002; Jin et al., 2006). Therefore, in May 2006, Tehran municipality initiated a 5 year program to landfill the SW received at Kahrizak Center in a correct manner based on environmental engineering methods. Some benefits of this program will be:

- Controlling the production of biogas (methane) from volatilized gases from landfilled SW (CO_2 and CH_4); its use for household consumption through piping systems will limit gas emissions into the atmosphere and thereby prevent greenhouse gas emissions;
- Improving national and local environmental indices by reducing the health and environmental risks of previous SW landfilling practices;
- Enhancing the biodegradation rate of SW through introducing microorganisms involved in the degradation of the biodegradable component of landfilled waste to facilitate the landfilling of newly arriving SW;
- Facilitating biogas production at the landfilling center.

There are also two other landfills that receive construction and demolition wastes in Tehran – the Ab'ali Center

for landfilling of construction wastes to the East of the city (7 km along the Tehran-Ab'ali road) and the Khavaran Center to the South of the city (20 km on the Tehran–Garmsar road). Some activities have recently been started at the Ab'ali center for the recycling of construction waste, but most of the waste is still landfilled in these two centers without any recycling.

2.5. Recycling and composting

As shown in Table 4, a considerable part of Tehran's solid waste consists of recyclable materials such as plastic, paper and cardboard, metal, glass and PET. Three centers in Tehran (the Aradkuh, Karko and Biomechanical Centers) produce compost from the solid waste collected by the municipality. The amount of compost produced in these centers was 25,969 and 6097 tons in 2004 and 2005, respectively (Table 5). It should be noted that there was no data from the biomechanical center available in 2005. In both years, the highest amount of SW received and compost produced is recorded for the Aradkuh center. A comparison of composting data in the two consecutive years shows that compost production showed a 3.6% growth in 2005. Given the presence of a high proportion of biodegradable organics in Tehran's solid waste stream, composting should be considered as an appropriate option for solid waste management. However, few composting centers have been developed over the two last decades and there is a clear need to raise awareness in order to promote composting on a large scale in Tehran. This would offer some environmental and economic advantages such as: diverting a large proportion of MSW from the landfill sites, which will minimize the emissions produced from such waste under unsanitary landfilling conditions; supplementing fertilizers used in the agricultural sector in the area surrounding Tehran; and decreasing expenditures on imported fertilizers. Thus, it seems there is a need to increase the number of composting centers. Further to this, increasing the source separation of compostable waste by households, facilitating government and private sector investment and educating farmers about the benefits of compost for crop and soil health and nutrition would all result in more compost production.

According to Table 4, only about 5% of recyclable SW material has been recycled; this can be attributed mainly to the lack of waste separation at source and the lack of facilities available in Tehran municipality for proper recycling.

Tehran municipality has recently initiated a program for producing fertilizer from SW to supply part of the increasing demand for agrochemicals in the agricultural sector. MSW contains significant organic matter that is rich in nutrients and that could be used for soil improvement and crop nutrition. However, solid waste also contains pathogens, weed seeds, heavy metals and other kind of pollutants which could harm the environment if applied directly (Zeng et al., 2007). Therefore, environmental care and elemental analysis should be carried out on the final compost soil amendment before its application to the soil in order to prevent any undesirable consequences.

2.6. Waste reduction

It is now clear that it is an onerous task for Tehran municipality to manage Tehran SW effectively. Moreover, data indicates that as the population and economy grow, per capita SW generation will increase. Therefore, the most important approach for the management of MSW in the future is to achieve a reduction in the generation of waste. Source separation of waste into biodegradable and non-biodegradable components is now regarded as a priority action by the authorities. This will be a lengthy exercise since it involves attitudinal changes in people and will have to be carried out with careful planning (Gupta et al., 1998). The general public will first have to be sensitized towards the whole concept and educated about the need for and advantages of separating waste. Household waste separation and source reduction are two of the main methods for reducing the amount of waste landfilled. During 2004 and 2005, Tehran municipality undertook the following activities aimed at achieving this objective and increasing public awareness of the several benefits of waste reduction and separation.

- Preparation and distribution of more than 700,000 brochures and posters on solid waste recycling.

Table 5
Compost production (ton) in three composting centers in Tehran during 2004 and 2005

Composting center	2004			2005[a]		
	Total MSW	Compost production (ton)	Percentage of compost	Total MSW	Compost production (ton)	Percentage of compost
Aradkuh	117,411	11,157	9.5	29,006	5460	18.8
Karko	18,553	4460	24.0	9177	637	6.9
Biomechanical[b]	75,534	10,351	13.7	–	–	–
Total	211,498	25,968	12.3	38,183	6,097	15.9

Source: OWRC (2005, 2006b).
[a] Only in spring.
[b] Data for biomechanical center includes only the second half of the year.

- Holding meetings and giving lectures in schools and mosques (the main centers for public gatherings).
- Preparation and installation of more than 90,000 containers for solid waste collection in the city.
- Establishment of 23 solid waste collection centers in 19 urban areas, resulting in the collection of 98,548 tons of solid waste over 17 months.

3. Future challenges and perspectives

The research on which the present paper is based has generated some crucial data for future planning and decision-making related to SW management in Tehran. It also indicates some significant challenges lying ahead.

First, while there is no doubt that the municipality and other authorities should aim to achieve sustainable waste management over the long-term, the adoption of waste disposal and management targets that can be reached by policy-makers in order to allow for improvement and to prevent further public health risks and environmental impacts is urgently needed, as has been demonstrated by other case studies undertaken worldwide (Vidanaarachchi et al., 2006).

Second, it is obvious that Tehran municipality cannot provide for the proper collection and management of hospital waste without the participation of other authorities and organizations, owing to several reasons including a lack of financial resources. Tehran municipality is currently negotiating with the Ministry of Health and Medical Education to secure its participation in hospital waste management in order to optimize the system and minimize its health and environmental risks.

Municipal workers, who are responsible for collecting and transporting SW from the source to final disposal or recovery, usually have a low level of education; and it appears that they are not properly trained to recognize waste characteristics and to carry out sanitary disposal and new methods of SW management (Musavizadeh, 2006). Sufficient funding must be allocated so that the authorities responsible are able to hire trained personnel to administer and carry out the management of SW (Buenrostro and Bocco, 2003). Educating personnel will also improve the efficiency of the SW management system and minimize its possible health and environmental risks.

4. Conclusion

The promotion of a high quality SW management system not only enhances social, economic and environmental efficiency, and promotes sustainable development, but can also help resolve the dual crisis of resource shortages and environmental deterioration. The world has already recognized environmental protection-related industries as a key economic growth point in every field (Suocheng et al., 2001; Rathi, 2006). The development of an efficient SW management approach will help explore new opportunities for urban, environmental and industrial health in Tehran.

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