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Municipal solid waste management in Beijing City

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ABSTRACT

This paper presents an overview of municipal solid waste (MSW) management in Beijing City. Beijing, the capital of China, has a land area of approximately 1368.32 km^2 with an urban population of about 13.33 million in 2006. Over the past three decades, MSW generation in Beijing City has increased tremendously from 1.04 million tons in 1978 to 4.134 million tons in 2006. The average generation rate of MSW in 2006 was 0.85 kg/capita/day. Food waste comprised 63.39%, followed by paper (11.07%), plastics (12.7%) and dust (5.78%). While all other wastes including tiles, textiles, glass, metals and wood accounted for less than 3%. Currently, 90% of MSW generated in Beijing is landfilled, 8% is incinerated and 2% is composted. Source separation collection, as a waste reduction method, has been carried out in a total of 2255 demonstration residential and commercial areas (covering about 4.7 million people) up to the end of 2007. Demonstration districts should be promoted over a wider range instead of demonstration communities. The capacity of transfer stations and treatment plants is an urgent problem as these sites are seriously overloaded. These problems should first be solved by constructing more sites and converting to new treatment technologies. Improvements in legislation, public education and the management of waste pickers are problematic issues which need to be addressed.

1. Introduction

Municipal solid waste (MSW) management is a major challenge in urban areas throughout the world, especially in the cities of developing countries (Jin et al., 2006). Being a densely populated city, and the host city of the 2008 Olympic Games, Beijing, for example, is faced with serious environmental and administrative challenges. Beijing is located on the northern edge of the North China Plain, and has an area of 1368.32 km^2 with an urban population of 13.33 million in 2006 (BMBS, 2007). Therefore, it must handle the issue of MSW management peremptorily and effectively.

There have been few overview studies of MSW management at a city level such as in Beijing City. This paper presents an overview of current MSW management in Beijing City, firstly, with regard to basic information and the MSW management status in terms of collection, transportation, disposal and recycling. Secondly, the impact of MSW on the environment and health is discussed and finally, future challenges and recommendations are discussed.

2. Background of MSW management in Beijing City

2.1. MSW generation and characteristics

The total MSW generated in Beijing City (Table 1) has increased steadily over the last 15 years, from 2.473 million tons in 1992 to 4.134 million tons in 2006. This can be attributed to a rapid population increase and economic development. The urban population was 8.19 million in 1992 and was 13.333 million in 2006, and showed an average annual increase of 3.54%. GDP, an economic development index, is also listed in Table 1, and has increased more quickly than the population with an average annual increase of 20.82%. Fig. 1 shows the logarithmic relationships between GDP, population and MSW generation. By combining the relationships, we can deduce that:

$$\mathrm{MSW} = 0.487\ \mathrm{GDP}^{0.434} \times \mathrm{Population}^{0.723} \quad (1)$$

MSW: million tons/year; GDP: billion US$; Population: million.

Similar relationships have been found in Europe and America, respectively (Daskalopoulos et al., 1998). It can be calculated that the average per capita rate of solid waste generated was 0.85 kg/day. In comparison, the per capita MSW generation rate was 0.917 kg/day in Mexico (Buenrostro and Bocco, 2003), 1.51 kg/day in Palestinian districts (Al-Khatib et al., 2007) and 0.565 kg/day in Nepal (Pokhrel and Viraraghavan, 2005).

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Table 1
Urban population, GDP and total MSW generated in Beijing City.

Year	Urban population (million capita)[a]	GDP (billion US$)[a]	MSW generated (million tons/year)
1992	8.19	7.733	2.473[b]
1993	8.31	9.727	2.565[b]
1994	8.46	12.665	2.685[b]
1995	9.462	17.555	2.777[b]
1996	9.579	19.962	2.78[b]
1997	9.483	23.027	2.818[b]
1998	9.577	26.768	2.847[b]
1999	9.717	28.132	2.904[b]
2000	10.574	34.01	2.96[b]
2001	10.812	39.992	3.02[b]
2002	11.18	45.351	3.21[c]
2003	11.513	53.211	3.41[c]
2004	11.872	78.051	3.57[c]
2005	12.861	93.082	3.833[c]
2006	13.333	109.245	4.134[c]

[a] BMBS (2007).
[b] Liang et al., 2003.
[c] BMBS (2003–2007).

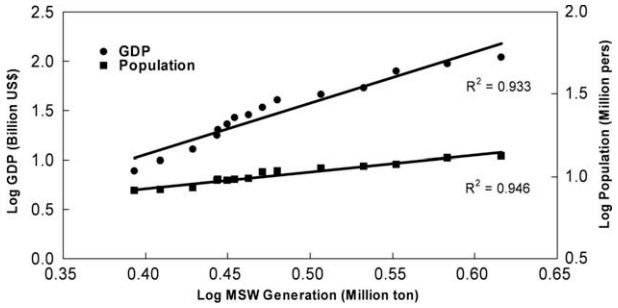

Fig. 1. Relationship between GDP, population and MSW generation.

The respective composition of MSW over time in Beijing City is shown in Table 2. It can be seen that the composition of the waste generated has changed greatly. The most remarkable change is that related to the percentage of food waste which has increased from 32.6% in 1989 to 63.39% in 2006 and has been the major waste in the MSW composition since 1990. A high proportion of food waste in MSW has been reported in many other regions such as Nepal (70%) (Pokhrel and Viraraghavan, 2005), and Rasht City (80.2%) (Moghadam et al., 2008). These figures are in contrast to Mexico (52.4%) (Buenrostro and Bocco, 2003) and Singapore (38.83%) (Bai and Sutanto, 2002), but are very different to those in England (20.2%) (Burnley, 2007) and Macao (14.5%) (Jin et al., 2006).

With regard to the recyclables generated in Beijing City, the percentage of recyclable waste has undergone a complex change over the past few years. Very little plastic was observed in MSW before 1990, however, a relatively steady rate of about 12% has been noted since 1995. From 1995 to 2000, wood waste accounted for a higher rate compared with previous years. Glass waste was more than 5% from 1995 to 2002, and in 2001 accounted for 18.18%. Paper waste showed an abrupt increase in 1995 and has remained at about 10% with the exception of 2002. Textile waste had two peak values in 2000 and 2002, at 9.58% and 8.8% respectively, but generally accounted for less than 5%. Metal is uncommon in MSW and never exceeds 4%. With the exception of plastic (12.7%) and paper (11.07%), all the other recyclables accounted for less than 3% in 2006.

The typical characteristics of MSW in Beijing City include moisture content (61.21%), combustible waste (91.51%), recyclable waste (25.18%), compostable waste (77.08%) and low calorific value (4564 kJ/kg) (BMAC, 2007a). Although the combustible waste accounted for 91.51% in 2006, the low calorific value and high moisture content of MSW both indicated that it could not be incinerated effectively, without the addition of fuel or meticulous separation.

Table 2
Composition of MSW in Beijing City, 1989–2006.

Composition (%)	1989[a]	1990[b]	1995[b]	1998		2000[a]	2001[d]	2002[e]	2005		2006[g]
				[b]	[c]				[e]	[f]	
Food	32.6	24.89	35.96	37.12	35.4	44.15	39	45.77	54.55	63.79	63.39
Plastic	1.88	5.08	10.35	10.35	15.8	13.61	10.35	15.49	11.26	11.76	12.7
Construction debris	4.79	4.11	1.5	1.11	1.4	0.88	10.93	14.59	19.62	0.43	0.62
Dust	47.2	52.22	10.92	5.64	12.8	2.02		0.89		9.1	5.87
Wood	1.17	4.13	8.32	9.12	5.3	7.47	–	2.92	3.04	1.26	1.78
Glass	3.79	3.10	10.22	10.70	5.8	6.34	18.18	6.45	1.51	1.7	1.76
Paper	6.04	4.56	16.18	17.89	19.2	14.28	18.18	4.32	7.55	9.75	11.07
Textiles	1.74	1.82	3.56	4.11	2.90	9.58	3.56	8.8	1.83	1.69	2.46
Metal	0.76	0.09	2.96	3.34	1.40	1.17	2.96	0.71	0.54	0.33	0.27
Other	0.2	–	–	–	–	0.5	2	0.06	–	0.19	0.08

[a] Rong et al. (2004).
[b] Wang and Wu (2001).
[c] Pei (2003).
[d] Huang et al. (2001).
[e] Liu (2006).
[f] BMAC (2006).
[g] BMAC (2007a).

2.2. Evolution of MSW management

Over the last three decades, MSW management in Beijing City has gone through five stages. Before 1979, MSW was transported out of the city and dumped in the open air without any restrictions. Waste disposal was not seen as a problem so its management was just part of the routine work of the Ministry of Public Health (MPH). MSW generation increased gradually from 1979 to 1994 and the Ministry of City Construction (MCC) was responsible for MSW management instead of the MPH. During this period, composting was strongly recommended by the authority. For example, two composting plants were constructed with investment from the government. Great changes occurred during stage 3. Sanitary landfill was suggested as the major disposal technology instead of composting. In 1994, the first sanitary landfill site (Asuwei Landfill Site) was established in Beijing. Four transfer stations and six sanitary landfill sites were then constructed. At the end of 2001, Beijing Municipal Administration Commission (BMAC), an independent and special department, took over responsibility for MSW management. This is perceived as a significant innovation in the evolution of MSW management. From 2008, MSW management in Beijing City has focused on reduction and resource conservation, and incineration and composting will gradually substitute sanitary landfill.

2.3. Local authorities and budget

Nowadays, MSW management is undertaken by BMAC, with participation from Beijing Municipal Environmental Protection Bureau (BMEPB) and Beijing Municipal Bureau of Commerce (BMBC). BMAC is the uppermost organization in the MSW management system. BMEPB is responsible for environmental monitoring at the final disposal sites and BMBC is responsible for material recovery.

Another important issue in waste management is budget. In 2006, Beijing City expended approximately 242.8 million US$ on MSW management. Staff costs were the major expense accounting for 107.9 million US$. 46.7 million and 32.5 million US$ were spent on waste collection-transportation and treatment, respectively, followed by street sweeping and equipment maintenance and repair which cost 31.7 million and 17.6 million US$. Other outgoings were 6.3 million US$.

3. The status of MSW management in Beijing City

The flow chart of MSW in Beijing City is shown in Fig. 2. Collection, transportation, disposal and recycling are part of the primary system of MSW material flow in Beijing City.

3.1. MSW collection

Source separation collection is the preferred method of reduction and has been carried out for about 12 years. Nowadays, MSW in Beijing City is broadly separated into kitchen waste, recyclables and other wastes at the source.

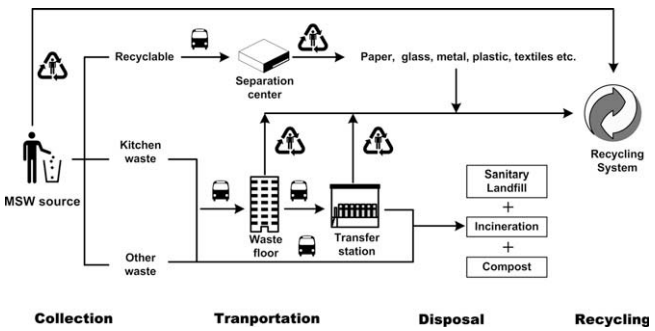

Fig. 2. Flow chart of MSW in Beijing City.

Dachengxiang Community was the first demonstration community to collect the separated MSW which were initiated in 1996; demonstration communities increased gradually from 1997 to 1999; Beijing was selected as one of eight demonstration cities in China for MSW separation by the Ministry of Construction in April, 2000, and Beijing promised to achieve a separate MSW collection rate of 50% before 2008 in the Olympic bid report; further separation regulations and activities were promoted from 2000 to 2007; up to the end of 2007, a total of 2255 residential areas and enterprises (covering approximately 4.7 million people) had taken part in source separation, which represented a separate collection rate of 52% (BMAC, 2007a).

3.2. MSW transportation

All the treatment plants in Beijing City are a distance from where the waste is generated, therefore transfer station is a very important part of the MSW transportation system.

There are six transfer stations in Beijing. The purpose of these stations is not only to transfer the waste but also to compress and separate the waste to ensure efficient transport and an efficient recycling rate. With the exception of Xiaowuji and Majialou, the other stations are not equipped with sorting machines for further separation. The two separation transfer stations are unable to separate all wastes generated as they have a limited designed capacity of 980 tons/day.

3.3. MSW disposal

There are 13 landfill sites and four incineration/composting plants in Beijing City, with a total designed capacity of 10350 tons/day. According to statistical data, the waste generation rate in Beijing City is 11326 tons/day. Obviously, there is a large gap between the designed capacity and the actual generation rate, so almost all the landfill sites and treatment plants are overloaded.

In 2006, sanitary landfill accounted for 90% of MSW disposal. Incineration and composting comprised 8% and 2%. Incineration is considered the preferred technology for waste disposal and will be quickly developed during the period of the 11th Five-Year Plan of China (BMAC, 2007b). The total incineration ratio is expected to reach 30% in near future.

3.4. MSW recycling

At the end of 2005, there were 1242 formal recycling sites in Beijing City including 704 community-based sites and 538 floating sites. According to data from BMAC (2007a), approximately 1.638 million tons of materials were recycled in 2006, 7.3% higher than in 2005. This included 0.364 million tons of paper, 0.868 million tons of metal, 0.168 million tons of plastic and 0.077 million tons of glass. However, it was estimated that there are 0.362 million tons of plastic, 0.388 million tons of paper, 0.15 million tons of glass and 0.035 million tons of metal in total generated every year (Wang and Wang, 2005). Therefore, there is a large gap between the materials generated and those recycled, which may be attributed to a lack of source separation. Table 3 lists the recycling price of each recyclable in Beijing City in 2006. It can be seen that recycling targets focus on high-value materials such as paper, plastic bottles, tin and steel. Approximately 1.43 million US$ was saved through the formal recycling channel in 2006.

In addition to the formal recycling system mentioned above, there is another system which consists of waste pickers, who play an important role in the recycling system and are considered to make the greatest contribution to waste recycling. There is a float-

Table 3
Material recovery price in Beijing City, 2008.

Material	Price	Material	Price
Steel	2–2.8 RMB/kg	Aluminum	8–13 RMB/kg
Copper	45–50 RMB/kg	Scrap iron	2–2.8 RMB/kg
Pop can	0.05–0.1 RMB/per	Brass	20–30 RMB/kg
Newspaper	1.1–1.5 RMB/kg	Book	1–1.4 RMB/kg
Cardboard	0.4–0.7 RMB/kg	Plastic bottle	1–1.5 RMB/kg
Edible oil bottle (5 l)	0.3–0.5 RMB/per	Water bottle (600 ml)	0.05–0.08 RMB/per
Glass	0.1 RMB/kg	Beer bottle	0.05–0.11 RMB/per

Currency conversion: 100 US$ = 684 RMB.

ing population of about 300 thousand individuals living on the proceeds of waste recycling in Beijing City. Most of this population is from Henan, Hebei and Anhui provinces. According to a report from the Chinese Academy of Social Sciences, materials recycled by these waste pickers are worth 0.438 million US$.

4. The impact of MSW on the environment and health

Transfer stations, landfill sites, incineration plants and composting plants have a significant impact on the environment. Here we use Majialou transfer station and Asuwei landfill site as examples to outline the process of pollution control.

Majialou transfer station is one of two transfer stations which have second separation function in Beijing City, therefore pollution control is comparatively more complex, especially in relation to smell, dust and waste water control. Aeration is the most popular method of improving bad smells in separation workshop, and sprinklers are used to control dust. These are both operated automatically using manual monitoring. There are about 50 tons of waste water (including leachate and sewage) generated each day. The leachate is mainly from waste compression, water used for dust control and from fine waste with a diameter less than 15 mm. The core technologies used here is the Anaerobic–Anoxic–Aerobic (A^2O) reactor followed by a membrane filtration.

Green house gas emission is another environment issue which can not be ignored at landfill sites. Asuwei landfill site is the earliest and biggest landfill site in Beijing City with a designed capacity of 2000 tons/day. Wang et al. (2006) calculated that 5000 m^3 of landfill gas was generated every day in 2006 including CH_4 (52.4%–60.4%), CO_2 (31.9%–38.4%) and O_2 (0.2%–1.8%). Before 2001, the landfill gas was discharged directly, however, it is now used to generate electricity. Other landfill sites in Beijing City are in the process of installing generating equipment.

5. Conclusions

(1) The quantity of MSW has increased markedly in the last three decades and will continue to increase in the future. The gap between total designed capacity of these facilities and actual MSW generation rate should be solved. Constructing new plants and the conversion of treatment technology are effective ways of solving this problem.
(2) It has been proved that establishing demonstration communities is a successful measure to promote waste reduction at the source. Establishing demonstration districts based on the existing communities should be recommended to widen and expand the demonstration range.
(3) Designed capacity of existing transfer stations can not cope with the actual waste transferred. It is necessary to construct adequate transfer stations especially stations with separation and compression facilities because source separation can not be promoted at the city level immediately.
(4) Low-value materials have been badly neglected. The government needs to pay more attention and provide more investment to focus on these materials. Another problematic issue in waste recycling relates to the waste pickers. It would be helpful if the waste pickers were organized into formal teams with periodic training. This may result in both the survival and security of these individuals.

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