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A perspective analysis on municipal solid waste(MSW) energy recovery in China*

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Abstract—The paper analysed the current situation of municipal solid waste(MSW) quantity and quality in China and the changing tendencies of its composition. Further more, the energy value of MSW was discussed. To the point of the technical and economic aspects, the feasibility of the energy recovery from MSW was also analysed. The conclusion is that the energy can be effectively recovered through a landfill gas utilization process and the energy produced by an incineration process. Through a suitable energy recovery process, it is possible to improve the economic viability of a MSW treatment process.

Keywords: perspective analysis; energy recovery; energy value; municipal solid waste(MSW); MSW in China.

1 Introduction

1.1 Generation and outlet

Because of the economic reformation and opening policies established at the end of the seventies, the economy in China has been developing by leaps and bounds. The subsequent urbanization and rapid variation of the residents living mode make a great improvement in the generation of municipal solid waste(MSW). Since the beginning of the eighties, per capita generation of MSW has increased from 0.5kg/(d.capita) to 1.2 kg/(d.capita). For MSW, the increase rate per year exceeds 10%. According to the statistic data in 1994, the collected MSW in whole country exceeds 1.0×10^8 t/a.

In China, it is the municipal environment sanitation administration who takes the responsibility for eliminating and transferring MSW. Moreover, MSW stems dominantly from residential districts, municipal services, commercial departments, office and urban constructions. At present, the outlet of MSW is conducted primarily through piling. However, some processes for the MSW treatment such as the compost, landfill and incineration process have been inducted since the middle of the eighties. The amount of treated MSW accounts for approximately 15% of the total MSW (1994). But most of these treatment facilities are not able to reach the international standard(e.g. impermeable material layer is not installed in the landfill site). The treatment capacity of MSW in China, which are conformed to the international standard, is about 1.0×10^6 t/a.

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1.2 Composition and its changing tendencies

Depending on the physical composition of MSW in China, MSW can be classified into three categories. Fig.1 shows the system issued by the municipal government for enforcement. Based on the investigation of the latest years, the major factors which affect the MSW composition, are the domestic fuel style and the level of residents consumptions.

MSW——
- Organics (garbage, animal, plant)
- Inorganics (ash(< 15 mm), brick tile(15 mm))
- Waste materials (paper, plastic, textile, wood and bamboo, glass, metal)

Fig.1 Physical composition of MSW in China

These factors makes a relatively independent impact on the composition of MSW. Domestic fuel style influences the proportion of the inorganics to the organics, the ratio is about 1:8—10 in domestic fuel gasified areas, and 1:0.2—0.3 in coal fired areas. The level of residents consumption affects proportion of waste materials in total MSW, which is 15%—25% in the most developed areas and 5%—10% in the general cities. Among the waste materials, textile and metal have relatively stable percentage of 1%—2%, the amount of paper and glass increase stably respectively, with the increasing rate of 10% per year in the proportion of composition. The increase rate per year for plastics reaches the maximal percentage of 20%—40%. Totally, organic components appear to increase gradually while inorganic descend. But for some investigated cities, it appears to vary with the development of the domestic fuel gasified areas.

Table 1 shows the investigation results and forecasted data of MSW composition in several most developed cities in China, which provides a quantitative impression.

Table 1 MSW composition(wt%): investigation and forecast(%)

City	Year	Garbage	Paper	Plastics	Textile	Wood/bamboo	Noncombustibles
Shanghai	1993	77.3	7.1	5.8	2.4	1.4	6.0
(Pudong)	2000	57.8	13.9	9.5	1.3	1.6	12.9
Beijing	1995	25.17	3.26	4.88	1.94	7.15	57.58
	2000	27.4	3.65	5.47	2.31	7.23	54.24
Guangzhou	1983	32.4	1.03	0.4	0.74	—	65.43
	1988	37.5	1.7	1.8	1.3	—	57.8
	1994	76.07	2.86	9.6	3.99	—	7.74

Compared with those data, total MSW composition has a lower proportion in organics and waste materials(about 20%—30% and 5%—10%, respectively). This means probably a five year's gap in the development level in accordance with the changes of the composition in recent ten years.

2 Estimation on the energy value of MSW and its property analysis

The energy value of MSW can be depicted with MSW calorific value. Owing to the limitation in the accumulating mode of MSW' composition data, the calorific value can be estimated only on the basis of MSW' physical composition. The estimation data adopted in this paper are shown in Table 2. With those data and in contrast with the data in Table 1, the MSW' energy value of the cities concerned can be calculated by using weighted method; the properties of the energy substances in MSW can be analysed. The results are shown in Table 3, and rapidly biodegradable VS, slowly biodegradable VS and non biodegradable VS are corresponding to the garbage (organics), the paper along with 40% of textile and wood/bamboo and the plastics as well as 60% of textile and wood/bamboo respectively. The evaporation heat of water generated in burning is very little for refuse with the high moisture content. Ignoring this heat proportion, the low heat value is gained through deducting the evaporation heat of moisture from the heat value on the dry-basis. In view of this, the energy value of MSW in China is principally controlled by the proportion of the inorganics. In other words, it is related to the domestic fuel style.

Table 2 Typical proximate and energy data for the components in MSW

Component	Garbage	Paper	Plastics	Wood/bamboo	Textile	Noncombustible
Moisture, %	69.2	42.0	40.0	34.0	46.0	20
Volatile solid, %	95.0	91.6	97.3	99.4	93.5	—
Energy content, MJ/kg, dry	13.9	17.6	33.8	17.2	20.6	—

Table 3 Energy analysis of MSW in China

City	Year	Volatile solid distribution, % wet				Moisture, %	Low heat value, MJ/kg
		Rapidly	Slowly	Non-	Total		
		Biodegradable					
Pudong	2000	16.9	8.1	6.6	31.6	54.0	4.80
Beijing	2000	8.0	4.3	6.7	19.0	37.0	2.81
Guangzhou	2000	22.3	2.3	6.8	31.4	61.0	4.41

In the domestic fuel gasified areas, the MSW heat value can be more than 4.0 MJ/kg, it is below 3.0 MJ/kg in the high coal fired proportion areas. The primary components providing energy in MSW are the rapidly biodegradable and non-biodegradable organics, and the slowly biodegradable organics provides a little energy. In the future, the energy value of MSW will increase, and the energy proportion produced by non-biodegradable organics(such as plastics and so on) will increase too.

3 Methods and efficiencies of MSW energy recovery

In the world, there are two practical methods of MSW energy recovery: one is recovering combustible gas(methane) through an anaerobic biological process, the other is utilizing the waste heat generated by a chemical oxidation process under the high temperature. These two methods are corresponding to the practical technologies of the landfill gas utilization and the incineration process respectively. Since some results and operation data has been obtained in the use of these two technologies, so the efficiency of MSW energy recovery can be estimated. The data concerned are as the follows: gas production is 0.75 Nm^3/kg vs. destroyed for landfill gas utilization; VS degradable ratio is 75% for rapidly biodegradable and 50% for slowly biodegradable; gas collectable ratio is 50%; heat value of the gas is 19 MJ/ Nm^3; thermal efficiency of the gas power generation process is 12 MJ/kWh; thermal efficiency is about 8% for the incineration power generation process (if the middle and low heat value is 4.0—6.0 MJ/kg MSW). The results about the efficiencies of MSW energy recovery of the cities listed in Table 3, are shown in Table 4.

Table 4 Potential MSW energy recovery efficiency

City	Year	Landfill gas utilization		Energy recovery by incineration	
		Energy generated efficiency		Energy generated efficiency	
		kWh/t-refuse	%	kWh/t-refuse	%
Pudong	2000	99	7.5	107	8
Beijing	2000	49	6.3	-*	-*
Guangzhou	2000	107	8.8	98	8

* Unit heat value can not meet the need of the energy inquired in incineration (4.20 MJ/kg)

From Table 4, it is found that at the current stage the major substances providing energy in MSW are biodegradable components, the energy recovery efficiency of landfill gas utilization remains higher than that of incineration.

However, with the increasement of non-biodegradable components in the future, the efficiency of incineration will get higher.

4 Economics on MSW energy recovery

For the economic data of planning MSW treatment facility in China, the investment and operation cost is 12 Yuan(RMB)/t and 10 Yuan(RMB)/t for the sanitary landfill, 37 Yuan(RMB)/t (depreciation period: 15 years and 24 Yuan(RMB)/t) for power generation by incineration. The transfer distance of landfill and incineration is 15 km and 30 km respectively, with the transfer cost 0.6 Yuan(RMB)/(t.km). The cost of landfill gas power generation is 0.2 Yuan(RMB)/kWh. Referring to those data and the data in Table 4, the cost of landfill gas power generation is 0.60 Yuan(RMB)/kWh and the cost of incineration power generation is 0.65 Yuan(RMB)/kWh for Pudong (2000). For Guangzhou (1994), the cost of power generation process is 0.57 Yuan (RMB)/kWh for landfill gas utilization and 0.71 Yuan(RMB)/kWh for incineration. Considering that the present electricity charge in China is 0.5—1.5 Yuan(RMB)/kwh, the cost of power generation in the process of landfill and incineration has certain competition ability. At the same time, it is also found that the variation in the MSW compositions is favorable to strengthen the competition ability of the incineration power generation process. In addition, the cost of land utilization and the interest disbursement of the investment have not been involved in the above discussion, but this part of the cost can be subsidized by the municipal government (as the subsidy for the MSW treatment). In general, energy recovery from MSW is an effective method to reduce the net disbursement of the MSW treatment.

5 Conclusion

The MSW composition of the most developed cities in China is meeting the requirement of recovering energy from MSW.

Most cities in China already have the perspective of energy recovery from MSW through a landfill gas power generation process.

With the variation in distribution of the components providing energy among MSW, energy recovery in an incineration process will become more and more attractive.

The financial support from the municipal government ensure the competition ability of energy recovery from MSW.

The strategy of energy recovery in MSW gives an effective means for cutting down the MSW treatment cost.

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