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An overview of municipal solid waste management in China

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ABSTRACT

Municipal solid waste management (MSWM) in China warrants particular attention as China has become the largest MSW generator in the world and the total amount of MSW it produces continues to increase. In recent years, central and local governments have made great efforts to improve MSWM in China. New regulations and policies have been issued, urban infrastructure has been improved, and commercialization and international cooperation have been encouraged. Considering these developments, an overview is necessary to analyze the current state as well as new opportunities and challenges regarding MSWM in China. This paper shows that since the late 1990s, the amount of MSW collected has been largely decoupled from economic growth and incineration has become an increasingly widespread treatment method for MSW. We identify and discuss four major challenges and barriers related to China's MSWM, and propose an integrated management framework to improve the overall eco-efficiency of MSWM.

1. Introduction

Municipal solid waste management (MSWM) has been and will continue to be a major issue facing countries worldwide. This holds particularly true for developing countries, where the total amount of municipal solid waste (MSW) has increased dramatically due to rapid industrialization and increasing urban population. Meanwhile, with limited resources, only basic technologies for treatment and disposal, and deficient enforcement of relevant regulations, serious problems remain for MSWM in developing countries, especially in regard to safe disposal and recycling of MSW (ISWA and UNEP, 2002).

As the largest developing country, China deserves special attention. According to the World Bank (2005), China produced 190 million metric tons of MSW in 2004 and became the world's largest MSW generator. Facing this pressure, China has devoted considerable effort to managing its MSW. From 1990 to 2004, investment in MSW treatment equipment and infrastructure increased 21 times and over 30 times more MSW is now treated or disposed of safely (SEPA, 2006). However, as safe disposal in 1990 was highly limited, the safe disposal rate reached only 53% in 2006 and various challenges remain. Several overviews have been written to discuss the status of and challenges to MSWM in China (e.g. Jiang et al., 2003; The World Bank, 2005; Wang and Nie, 2001a). In the last few years, progress and improvements in MSWM continue with the implementation of new regulations and policies. For example, the Law on Circular Economy Promotion, effective from January 1, 2009, established a legal framework on waste reduction, reuse, and recycling (People's Congress, 2008). Management Measures on Urban Waste, issued in 2007, highlighted the following principles for MSWM: volume reduction, hazard reduction (ensuring that no hazardous compounds are released into the environment), resource recovery (transferring valuable wastes into alternative resources), and producer responsibility (MOC, 2007). The National Eleventh Five-Year Plan on Urban Environment and Sanitization released in 2006 also stipulated that the goal of MSWM should gradually move from end-of-pipe treatments to integrated management strategies (MOC, 2006). The guidelines for "environmental protection model cities" and "eco-cities" set particularly strict standards for MSW safe disposal rates of 85% and 90%, respectively (MOEP, 2008a,b). Cities that aim at obtaining these titles usually include waste minimization and safe disposal in their action plans (Geng et al., 2008). Model cities can provide an example of success to other cities that attempt to improve their MSWM practices. Other relevant policies, such as those regarding waste treatment fees and subsidies for electric power produced from waste incineration were issued in 2002 and 2006, respectively (NDRC, 2006b; SDPC et al., 2002). Considering these developments, it is useful to review the current state of MSWM and identify the challenges as well as opportunities for MSWM in China. This paper first addresses the areas of concern, and then presents several possible and appropriate solutions that might facilitate the application of integrated waste management in China. Finally, a summary of the paper's major findings is presented.

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2. Overview of the current situation

2.1. Regulations and policies

Regulations and policies are important tools for MSWM. In China, the Law of the PR China on the Prevention of Environmental Pollution Caused by Solid Waste (hereinafter referred to as the Law on Solid Waste) is the main legislation specifically pertaining to solid waste management and pollution control. This law stipulates the principles of waste management, responsibilities for waste supervision and administration, pollution control measures, and associated legal responsibilities. All administrative and ministerial regulations of MSWM must comply with this law. In December 2004, the Law on Solid Waste was amended for the first time since its enactment in 1996. One important amendment was the establishment of extended producer responsibility (EPR) as a key principle of MSWM. The previous version specified only the producer's responsibility in the production process, whereas the amendment highlights the entire life cycle by extending the producer's responsibility to include the consumption and disposal of goods, thereby establishing a legal foundation for an integrated solid waste management system.

Under the Law on Solid Waste, relevant administrative and ministerial regulations are issued by various governmental agencies. Two major ministries are involved in MSWM, as stipulated in the Law. The first is the Ministry of Construction (MOC), which supervises and administers the cleaning, collection, storage, transportation, and final disposal of MSW. The second is the Ministry of Environmental Protection (MOEP), which administers and monitors the collection, treatment, and final disposal of hazardous wastes, waste trade, and secondary pollution generated by the construction and operation of MSW treatment and disposal facilities. In addition, at least seven other governmental agencies are involved in MSWM. These agencies and several recent regulations issued by them are listed in Table 1. At least four of these regulations are issued specifically for promoting commercialization of waste treatment and related services, in an attempt to transfer responsibilities from government to the private sector and to improve the effectiveness and efficiencies of MSWM. For example, the Notice on Charging Urban Waste Treatment Fee and Promoting Industrialization of the Waste Treatment Industry and the Opinion on Accelerating Marketization in the Municipal Public Utility Industry issued in 2002 laid the legislative foundation for charging the waste treatment fee as an economic measure to promote the institutional change in waste treatment. The Opinion on Accelerating Marketization in the Municipal Public Utility Industry issued in 2002 and the Management Measure on Franchise of the Municipal Public Utility Industry issued in 2004 regulated municipal governments as the authority to designate franchised enterprises and the guidelines for franchised services.

Recent national policies have also addressed waste reduction, recycling, and recovery, for example, the policies to "actively promote incineration, composting, and other comprehensive utilization of MSW" (NDRC, 2006a), and to "establish waste separation and collection systems and continuously improve renewable resource recycling systems" (The State Council, 2005). Guided by these regulations and policies, the MOC published the National Eleventh Five-Year Plan on Urban Environment and Sanitation and asked all provincial governments to prepare their own plans and to integrate them with their economic development plans (MOC, 2006). The national plan established a target rate of safe MSW disposal of 60% to be reached by 2010. The plan also encourages waste minimization and source separation, promotes commercialization and franchised operations, and aims to complete the establishment of relevant regulatory and planning systems. In addition, the central government instituted policies to promote waste reduction. For example, plastic shopping bags that were provided free in retail stores and supermarkets prior to June 1, 2008 must now be purchased by consumers (The State Council, 2007).

In addition to laws and regulations, there are a series of technical standards pertaining to MSWM. The Pollution Control Standard for MSW Landfills (GB 16889-1997) was amended by the Ministry of Environmental Protection in July 2008. The new standard (GB 16889-2008) placed stricter regulations on the construction of landfill sites and established more rigorous pollution controls. For example, new landfill sites must be equipped with landfill gas collection and treatment facilities (if the total capacity is greater than 2.5 million tons and the depth of landfilling is greater than 20 m, recommended for smaller landfills), be surrounded by a green belt at least 10 m in width as a buffer zone, and meet stricter discharge standards on leachate. In addition, the Pollution Control Standard for Municipal Solid Waste Incineration (GB 18485-2001) was passed in 2001. It sets up the standards for air emissions and articulated that whereas the bottom ash should be treated as general municipal solid waste, the fly ash should be treated as hazardous waste according to relative standards.

While progress in legislation and policies regarding MSWM in China has been substantial, practice varies across the country. Recently released regulations and policies have devoted increased attention to waste reduction and recycling under the umbrella of a circular economy, as well as to the encouragement and administration of the private sector involved in MSWM. However,

Table 1
Recent regulations concerning MSWM in China.

Regulations and policies	Issue date	Issuing division
Management Measure on Prevention of Environmental Pollution Caused by Electronic Waste	2007/09/27	SEPA
Management Measure on Urban Waste	2007/04/28	MOC
Management Measure on Prevention of Environmental Pollution Caused by Electronic and Information Industry	2006/02/28	MII, NDRC, MOCom, China Customs, SAIC, GAQSIQ, SEPA
Stipulation on Urban Construction Waste Management	2005/03/01	MOC
Management Measure on Franchise of the Municipal Public Utility Industry[a]	2004/03/19	MOC
Policy on Technology of Prevention of Pollution Caused by Waste Battery	2003/10/09	SEPA, NDRC, MOC, MOST, MOCom
Opinion on Accelerating Marketization in the Municipal Public Utility Industry[a]	2002/12/27	MOC
Opinion on Promoting Industrialization of Urban Sewage and Garbage Treatment[a]	2002/09/10	SDPC, MOC, SEPA
Notice on Charging Urban Waste Treatment Fee and Promoting Industrialization of the Waste Treatment Industry[a]	2002/06/07	SDPC, MOF, MOC, SEPA

Note: SEPA (State Environmental Protection Association changed to Ministry of Environmental Protection in March 2008), MOC (Ministry of Construction), MII (Ministry of Information Industry, changed to Ministry of Industry and Information Technology in June 2008), NDRC (National Development and Reform Commission), MOCom (Ministry of Commerce), SAIC (State Administration for Industry and Commerce), GAQSIQ (General Administration of Quality Supervision, Inspection and Quarantine), MOST (Ministry of Science and Technology), SDPC (State Development and Planning Commission, replaced by NDRC in March 2003).

[a] Regulations that concern the promotion of commercialization of waste services.

Table 2
Government investment in urban sanitation and waste disposal (unit: 100 million RMB). Source: Database of National Bureau of Statistics of China.

	91–95	96–00	2001	2002	2003	2004	2005	2006
Urban sanitation	45.3	191.5	50.6	64.8	96.0	107.8	147.7	175.8
MSW treatment and disposal	–	–	–	–	35.3	53.0	56.7	51.8

in practice, safe disposal and treatment are still the focus of the municipal authorities.

2.2. Financial resources

With progress in the commercialization of waste treatment and services, funds for MSWM have become more abundant and diversified as they include local investments from both government and private companies, as well as financial aid from international organizations. Investments from government on MSW treatment and disposal, which constitute a portion of the public spending on urban sanitation, have been over 5 billion RMB since 2004 (Table 2). However, funds for MSWM are distributed unevenly between cities. Cities with greater fiscal income and greater concerns about the environment are able to allocate more funds to MSWM and therefore achieve better performance. For example, the budget for MSWM in urban districts in Dalian, one of the "environmental protection model cities", was 8.5 million RMB[2] in 2006. On a per capita basis, this budget is 4.5 times higher than the national average (Chen, 2008).

Another source of financing is the private sector, which has increased in importance in recent years. The private sector has more experience and flexibility in terms of financing, especially for projects that are expensive to build and operate, such as incineration plants. Such projects are long-term investments and can usually bring stable returns under franchised operations, usually via Build-Operate-Transfer (BOT) contracts. Table 3 lists a number of large treatment and disposal facilities built by private companies via BOT contracts. Among these treatment and disposal facilities, large landfill sites and incineration plants are the primary types of project that have attracted private investors in recent years. We will discuss in Section 2.5 the reasons why such facilities are attractive to private investors while composting is not.

In addition to the two above-mentioned sources, assistance from international organizations is also important. Due to increasing concerns regarding MSW in China, a number of international organizations are providing financial and technical support at various levels. Table 4 lists recent projects funded by the World Bank and the Global Environmental Facility, including the promotion of waste collection, the construction of landfill sites, and energy recovery from landfill gases. In addition, the Canadian International Development Agency funded several waste management projects in China, such as a composting program in Baisha, Hannan province (Ichim, 2007). The National Institute for Environmental Studies in Japan, to which two of the authors belong, is supporting research on waste management in Dalian and Shenyang, Liaoning province. Capacity-building projects related to waste management have also received funds from the United Nations Environmental Programme (UNEP), and the Asian Development Bank (ADB), among other international organizations (Geng et al., 2007).

2.3. Waste generation and composition

To gain a better understanding of the current situation of MSWM in China, it is necessary to present data on waste generation and composition. Data were derived from an analysis of secondary sources (i.e. previously published editions of the China Statistical Yearbook (2001–2007), the China Environmental Statistical Yearbook (2007), and the database of the National Statistical Bureau of China) and the authors' personal involvement in MSWM research. The World Bank (2005) estimated that MSW generation in China in 2004 reached 190 million tons, 23% more than the amount of waste published in the official statistics. The most recent official data reveal that 148.4 million tons of MSW were collected and disposed of in 2006, a slight decline from 155.8 to 155.1 million tons in 2005 and 2004, respectively (Fig. 1). The data shown in Fig. 1 do not include recyclable wastes that were diverted by informal agents (e.g. scavengers). Precise data on MSW generation in China remain elusive. Wang and Nie (2001a) estimated that recyclable wastes accounted for 8–10% of the total amount of MSW in general.

On average, the annual rate of increase from 1976 to 2006 was 7.1%. It has been argued that the rapid growth of the urban population and GDP (i.e. economic activity) were the major drivers of this increase. In a regression analysis, Wang and Nie (2001a) showed a good fit ($R^2 = 0.9858$) relating urban population and GDP to the amount of MSW collected until 1998. However, since the late 1990s, the collected MSWM amount has been relatively stable on a per capita basis (Fig. 2), which indicates that urban population has a greater impact than GDP on the total amount of MSW. We conducted a segmented regression analysis to test this hypothesis statistically, and the result shows that GDP was not significantly correlated with MSW generation between 1996 and 2006 (Table 5). This result suggests that the total MSW collected has been largely decoupled from urban economic activity. With increasing income and quality of life, MSW has changed in composition rather than increased in total amount. One major factor in this change is the reduced consumption of coal for cooking and heating in homes due to the expanding coverage of cooking gas and district heating supply systems (Table 6). Another factor appears to be the increase in recyclable wastes that are not fully reflected in the official statistics as they are collected by informal agents. Some obsolete durable goods, such as cell phones, computers, and television sets, are sold to the second-hand market and thus are also not included in the official statistics.

Waste composition can differ significantly between cities owing to differences such as climate, culture, living standards, and dietary habits. Yet, to some extent, the difference may be attributable to differences in sampling and categorization, since waste composition reported in the literature for the same cities of, for example, Beijing, Tianjin, Shanghai, Guangzhou, and Shenzhen, differ dramatically during similar periods (e.g. Wang and Nie, 2001a; Yuan et al., 2006; Zou et al., 2001). At the national level, the overall trend indicates that recyclables, especially waste paper and plastics, have increased while organic wastes have decreased in the MSW stream. Two estimated waste compositions as generated in 1996 and 2000 are compared in Fig. 3. This trend is similar to those observed in other industrialized countries.

2.4. Waste collection

Prior to the recent commercialization of waste services in several large cities, garbage was collected only by local governments. As a result of increasing investments in urban sanitation facilities

[2] The abbreviation of the Chinese Currency, Ren Min Bi or Yuan; 1 RMB was equivalent to US$ 0.146 as of January 19, 2009.

Table 3
Examples of MSW treatment and disposal facilities built via BOT contracts. Source: Summarized by authors from news coverage at http://www.solidwaste.com.cn/.

Facility type	Location	Year	Capacity (*t*/*d*)	Investment (million RMB)
Landfill	Jiujiang, Jiangxi	2006	1600	144
Landfill	Shanghai	2005	4900	960
Landfill	Foshan, Guangdong	2005	2000	250
Incineration	Qingdao, Shandong	2007	1200	500
Incineration	Haikou, Hainan	2007	1200	420
Incineration	Chengdu, Sichuan	2007	1800	780
Incineration	Nanjing, Jiangsu	2006	1200	500
Incineration	Lanzhou, Gansu	2006	1600	576
Incineration	Shanghai	2005	3000	1478
Incineration	Shenzhen, Guangdong	2005	1750	260
Incineration	Tianjin	2004	1000	500
Incineration	Fuzhou, Fujian	2004	1200	350
Composting	Huhehaote, Inner Mongolia	2004	800	147
Composting	Shanghai	2002	1000	230
Composting	Fushun, Liaoning	2001	800	154
Comprehensive	Beijing	2006	2000	146
Comprehensive	Beijing	2005	2000	270

Table 4
Examples of projects funded by the World Bank and the Global Environmental Facility concerning MSWM in China.

Year	Location	Role in MSWM
2007	Liaoning	Construction of new landfill sites and closure of dumps in medium cities[a]
2007	Tianjin	Landfill gas collection and utilization[a]
2003	Shanghai	Establishing environmentally cost-effective municipal solid waste management services[a]
2000	Chongqing	Promoting solid waste collection services and expanding to areas that are underserved[a]
1997	Anshan	Reducing emissions of methane; reducing pollution associated with refuse dumping; and promoting utilization energy from landfill gas[b]

[a] The World Bank. Retrieved on November 2008 from http://go.worldbank.org/0FRO32VEI0.
[b] The Global Environmental Facility. Retrieved on November 2008 from http://www.gefonline.org/.

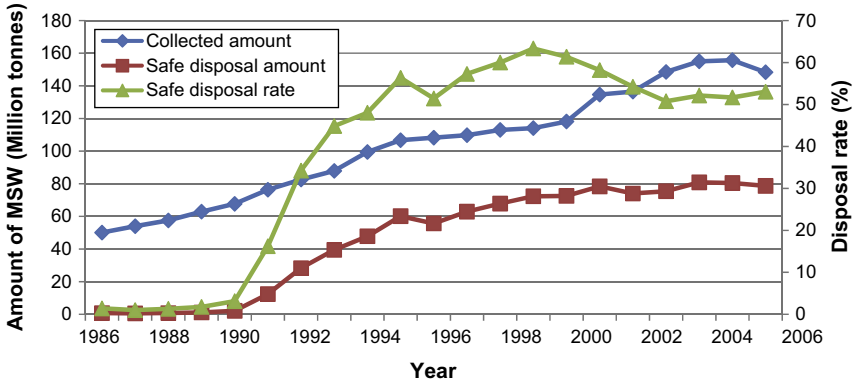

Fig. 1. MSW collected amount, safe disposal amount, and safe disposal rate from 1986 to 2006. Data source: Database of Statistical Bureau of China.

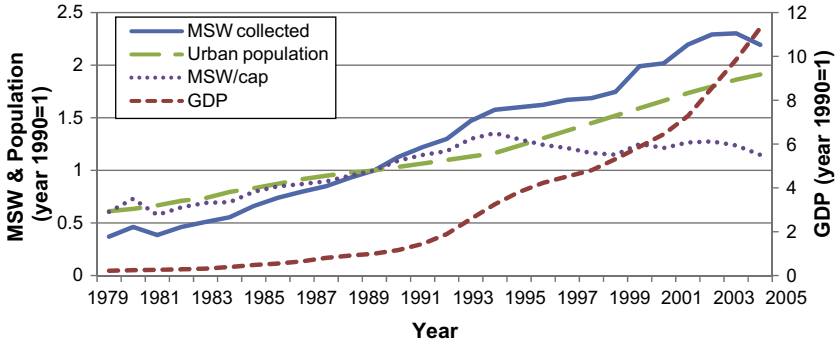

Fig. 2. Trend of MSW collected, urban population, and GDP from 1979 to 2006. Data source: Chinese Statistical Yearbook, 2007; Database of Statistical Bureau of China.

Table 5
Segmented regression results. Source: the authors.

Year	R^2	Constant			Urban population (10 k)			GDP (100 million RMB)		
			t	Sig.		*t*	Sig.		*t*	Sig.
79–95	0.989	−3406.277	−5.678	.000	0.295	10.915	.000	0.66	7.420	.000
96–06	0.919	−667.634	−0.241	.816	0.305	3.401	.009	−0.007	−0.489	.638

and infrastructure, waste collection capacity and service quality have been improved considerably since the mid 1990s (Fig. 4). The total number of waste collection and transport vehicles reached 66,200 in 2006, 1.6 times higher than in 1990. Sealed compact vehicles have been employed to collect and transport bagged garbage in large cities in order to avoid additional pollution during the transportation process (Chen, 2008; MOC, 2006). Due to the dual roles of government in service delivery and administration, the efficiency and quality of services have been criticized and commercialization has been suggested (Dong et al., 2001; Wang and Nie, 2001b; Yuan et al., 2006). Complying with standards set by the MOC (e.g. Management Measure on Franchise of the Municipal Public Utility Industry), private companies began to provide waste collection and street sweeping services in large cities such as Beijing, Shanghai, Guangzhou, and Shijiazhuang (MOC, 2006).

Separating waste at source is critical for waste diversion, and methods of changing the waste handling practices of residents are also an important topic of waste management research (Qu et al., 2007). Source separation in China is still at an early stage and has not yet been widely implemented (Chen, 2008). Informal agents remain the major collectors of recyclables, having been involved in this field since the mid 1990s when the government stopped offering the waste redemption services previously offered under the planned economy system. The number of scavengers in China is estimated to be over 2 million (The World Bank, 2005; Zhang, 2004, p. 231). Most informal agents are not under the administration of any governmental agency, resulting in many problems such as second-hand pollution, conflicts among them, and social safety concerns. In order to overcome these problems, some local governments have initiated pilot programs to "formalize" these scavengers. For example, Lin'an city in Zhejiang province attempted to manage scavengers by asking them to register with a government designated agency. However, few scavengers ultimately registered as most could not afford the registration fee owing to their limited income from selling recyclables (Qian and Wang, 2004). In some cases, scavengers are paid as low as 5% of the price that industry pays for recyclables (Medina, 2000). Another method that some local governments employ is to expel scavengers from the city (Chen, 2008). Such a method is also common in other developing countries, such as the "social cleaning" campaign in Colombia that aimed to expel scavengers from certain neighbourhoods and towns (Medina, 2000). However, this can hardly be considered an appropriate approach as most scavengers are poor and rely solely on revenue from selling valuable wastes.

Table 6
Cooking gas supply rates and collective heating areas in China. Source: China Statistical Yearbook, 2007.

	1990	1995	2000	2005
Cooking gas supply rate (%)	19.1	34.3	45.4	82.1
Collective heating area (100 million m^2)	2.1	6.5	11.1	25.2

2.5. Waste treatment and disposal

In spite of the increase in safe disposal capacity, safe disposal rates in China have been below 55% since 2002 (Fig. 1). Safe disposal in this paper consists of landfilling, incineration, composting, and recycling. These stable rates, together with the growth in total MSW generation, indicate that the amount of MSW without safe disposal has also increased, thus increasing the impact on the environmental. In terms of the differences between regions, provinces in the coastal region (Beijing, Tianjin, Shandong, Fujian, Jiangsu,

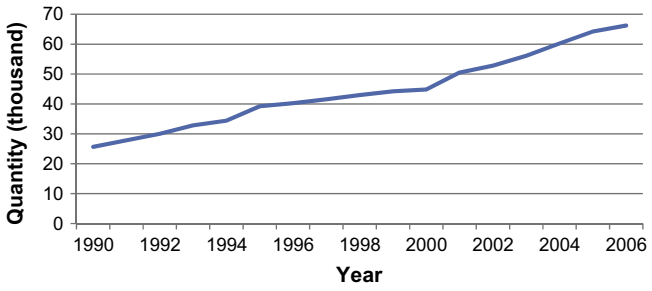

Fig. 4. MSW collection and transport vehicles in China. Data source: China Statistical Yearbook.

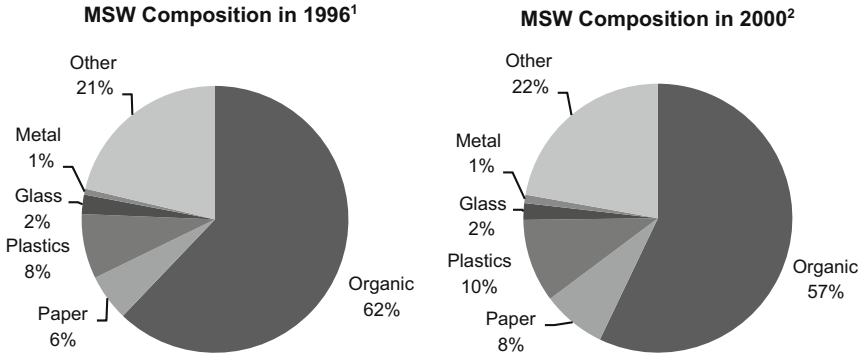

Fig. 3. Waste composition in China – as generated. Note: Organic includes food waste, waste textiles and wood; ash is categorized in "other". Source: 1: Wang and Nie, 2001; 2: The World Bank, 2005.

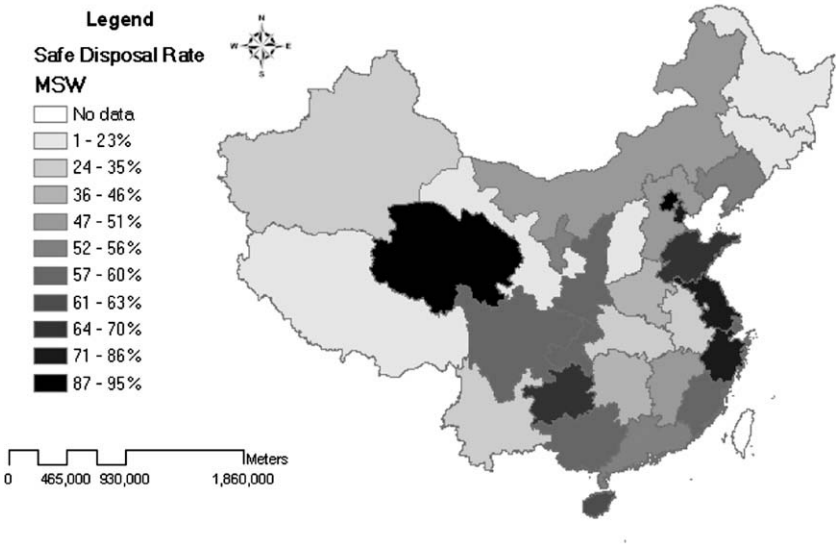

Fig. 5. Safe disposal rates in mainland China at the provincial level. Data source: China Environmental Statistical Yearbook (2007).

Zhejiang, and Shanghai) and western region (Qinghai, Sichuan, Guizhou, Yunnan, and Shaanxi) have higher safe disposal rates than the central inland region (Shanxi, Henan, Anhui, Hunan, and Hubei) (Fig. 5). Each of the major treatment and disposal methods will be analyzed in the remainder of this section.

2.5.1. Sanitary landfill

As of 2006, 324 MSW landfill sites existed in China and received 64.1 million tons of MSW, accounting for 81.4% of the total amount of safe disposal. Landfills have been the dominant disposal method for MSWM in China as they are cost-effective and can accept mixed waste without requirements for separation. With increasing support from international organizations and the private sector, the capacity as well as quality of newly constructed landfills has improved. The increase in capacity of individual landfill sites is mirrored by the increase in total disposal capacity, in contrast with the decrease in the total number of landfill sites (Fig. 6). While meeting demands for waste disposal, larger landfills can reduce the costs of land acquirement and environmental assessments, and can be equipped with better pollution control facilities. For example, the Laogang landfill site in Shanghai has a daily capacity of 4900 tons, with an estimated service period of 45 years, and is equipped with leachate treatment and landfill gas collection facilities. With the implementation of the amended landfill technical standards, the overall pollution caused by landfill sites will decrease as more new landfills replace existing ones.

2.5.2. Incineration

The treatment capacity of incineration reached nearly 40,000 tons per day in 2006, more than six times the capacity in 2001; the number of incinerators almost doubled in the same period (Fig. 6). Over 11 million tons of MSW was incinerated in 2006, accounting for 14.5% of the total amount of safe disposal. The rapid development of incineration can be attributed primarily to three reasons. First, incineration is encouraged and subsidized by the government. Electricity generated from renewable energy sources including MSW incineration will be subsidized at 0.25 RMB per KWh for 15 years (NDRC, 2006b). Second, the private sector has become the major investor in incineration plants through BOT contracts (see examples in Table 3), thus lifting the financial burden on the government. With more flexibility in financing and more expertise in management, the private sector can shorten construction times and improve efficiency during operation. Third, incineration is a mature and widely accepted technology which can significantly reduce the total amount of residue to landfill and recover energy from waste. Moreover, incineration does not require complex pre-separation and pre-treatment steps. However, the development of incineration, especially incineration with electricity or heat production, is mostly limited to large cities owing to the low heat value of wastes in small cities.

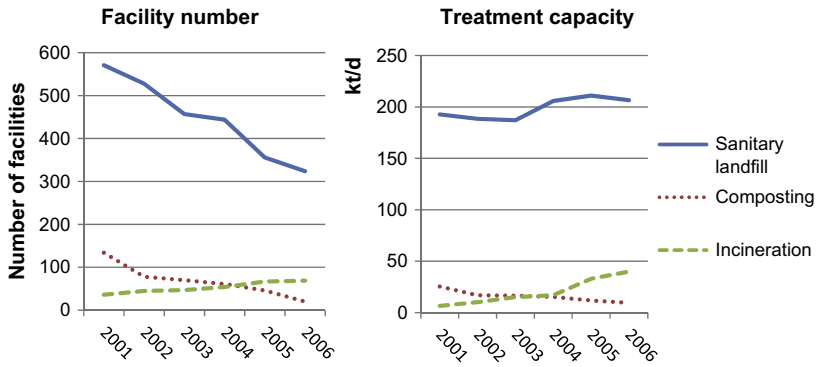

Fig. 6. Number and capacity of MSW treatment and disposal facilities in China. Data source: China Statistical Yearbook.

2.5.3. Composting

As opposed to incineration, composting is not a widespread treatment method in China. The treatment capacity in 2006 decreased to about 9000 tons per day or 37% of that in 2001 (Fig. 6). In spite of the large proportion of organic waste in MSW, only 2.9 million tons was composted in 2006. This declining market demand for compost is the major obstacle to the development of composting. The week demand can be attributed to a variety of reasons. For one, because organic waste that are proper for composting, mainly food leftover, is usually not source separated, sorting equipment or, in a small scale, manual works are required to separate the proper organics prior to composting (Chen, 2008). This process creates additional cost and makes composts less competitive in price compared with fertilizers. For another reason, Yuan et al. (2006) argued that farmers often have psychological resistance to compost made from waste materials. Owing to its lower profitability, composting has been unattractive to private investors in recent years and can not gain sufficient financial investment.

3. Barriers and challenges

While acknowledging the efforts being made to improve MSWM, there remain challenges and barriers related to MSWM in China. First, safe disposal rates have remained relatively unchanged since the late 1990s and the need to increase treatment capacity is therefore required, especially in the less developed central inland region. In this region are the provinces of Henan, Anhui, Hebei, Hunan, and Hubei, each of which has a large population of over 50 million people. Cities in these provinces must clean up the pollution caused by unsafe disposal, while at the same time facing the future demands of urban population growth that will result in further generation of MSW. Compared with the relatively developed coastal region, financial resources in these provinces are more limited, and the infrastructure for general environmental protection has lower capacity and is poorer in quality. One indicator of these challenges is that only two cities from these provinces were selected as "environmental protection model cities" of a total 68 such cities as of 2006.

Second, local conditions differ considerably between Chinese cities, and thus a one-size-fits-all solution would be ineffective. Policies that are successfully enforced in some areas might be ineffective and inefficient in other areas where the local infrastructure is weak. For example, 3 years after the policy of charging waste treatment fees was introduced, it had been implemented in only about 40% of 661 cities as of 2005 (MOC, 2006). In some cities where treatment fees have been charged, the efficiency is low and the revenue is insufficient to cover the budget for MSWM. In such cities, only 20% households paid the mandatory fee and the fees collected typically covered only 20–50% of the total MSWM budget (Hu et al., 2006). Moreover, treatment methods must be adopted according to local waste compositions. For example, the low calorific value of MSW impedes incineration in small and less developed cities. Although the proportion of incombustible ash decreases, high moisture content, typically 45–65%, decreases the average lower calorific value (LCV) of MSW to only about 4200 kJ/kg, which is too low for efficient incineration (MOC, 2006). Large cities often produce MSW with a higher LCV than average (e.g. Wang and Nie, 2001a), and therefore large incineration plants have been built in these localities, whereas small cities often operate MSW incinerators inefficiently.

Third, surveys and research on waste generation and waste properties are still insufficient and public consultation in waste planning is inadequate. The necessity of improving research and public consultation became particularly evident when the MOC required urban environment and sanitation plans to be prepared by provincial governments. Reliable data on the generation and composition of waste, as well as on its physical and chemical properties (e.g. moisture content and calorific value), are critical for supporting waste planning. One area in which more investigation is needed is the amount and final destination of recyclables that are currently diverted by the informal sector. In addition, a uniform standard for sampling and categorizing waste must be used in order to facilitate comparisons between cities. Public participation is also essential to support waste planning. Legislation, such as The Law on Environmental Impact Assessment (enacted in 2003), currently in effect provides the public with a forum in which to express their opinions. For example, due to impropriate site selection and insufficient public participation, the construction of the Liulitun incineration plant in Beijing was halted by the State Environmental Protection Association (SEPA, currently the MOEP) after residents requested SEPA to review the project's environmental impact assessment report (SEPA, 2007). With growing public awareness of environmental issues, the lack of public participation in the planning stage might result in NIMBY (Not In My Back Yard) syndrome. As has been demonstrated in developed countries, NIMBY could impede the construction of waste treatment and disposal facilities (Hostovsky, 2006).

Fourth, although a number of encouraging policies have been enacted, commercialization still faces multiple risks in the market that could hinder its development. MSWM in China has huge market potential, with the total market for MSWM estimated to be US$ 600 million (The World Bank, 2005). However, neither the potential market size nor supporting policies and regulations can guarantee the development of the waste industry. Risks in the waste service and treatment markets have yet to be systematically studied. These risks include vague policies, conventional ways of thinking in local government, and uncertainty in waste product markets. A report from the World Bank pointed out that inconsistencies and conflicts are present in China's regulations on MSWM because they were issued by individual administrative bodies without full consideration of others (The World Bank, 2005). Conventional ways of thinking in local government may increase the risk for investors in MSWM if local governments deem waste recycling as a type of public service and thus lower the profitability of businesses. A case study in Dalian showed that the local government, from a perspective of public service, required private companies to recycle as many types of waste as possible during the pilot period whether they were profitable or not (Chen, 2008). Since recycling has economies of scale but diseconomies of scope (Porter, 2002), a strategy that attempts to divert only a few types of wastes will make the waste industry more viable than trying to recycle many types of waste at one time. Moreover, risks in product markets are inevitable. Composting is mainly hindered by the risk of weak demand for compost, which is influenced by both economic and psychological factors. However, no particular strategy has been proposed to emphasize market promotion and risk elimination.

4. Possible solutions

As discussed above, the barriers and challenges relating to MSWM include the various processes from waste planning to waste collection and treatment to market development for recycled products. Furthermore, due to differences in local conditions, as well as in the infrastructure upon which local capacity relies, cities face diverse challenges. Thus, an integrated MSWM approach is necessary to solve such a complex issue. An integrated approach does not depend on a single tool or agent to solve all problems, but rather views the system as a whole and seeks solutions through the employment of multiple

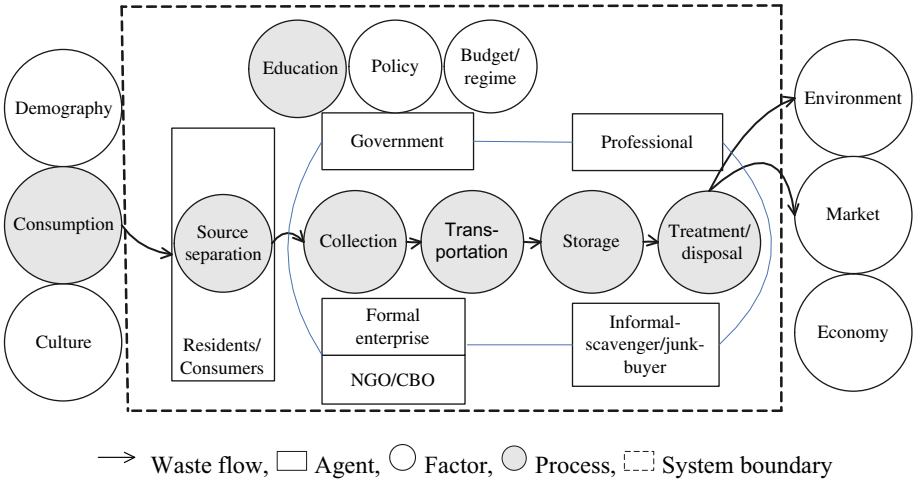

Fig. 7. Framework for integrated waste management.

methods and collaboration among all stakeholders (Seadon, 2006). A framework for integrated waste management must recognize the major concerns of all stakeholders within the system as well as the closely related local conditions outside the system (Fig. 7). The challenges and barriers discussed in the previous section are in fact interconnected. For example, the shortage of treatment and safe disposal capacity can be improved if the waste management system is better planned, thus allowing more private companies to enter the waste service and treatment market at low risk. As the regulatory and financial aspects of MSWM have received the most attention to date, the following three aspects must be further addressed to achieve a more integrated approach to MSWM: (1) system status, to better investigate and monitor the status of the waste management system; (2) dynamics within the system, to coordinate stakeholders and to build partnerships among them; and (3) dynamics between the system and the environment, to plan the MSWM system with consideration of local conditions.

To address these three aspects in practice, city and provincial governments need to alter their role and mindset, no longer acting only as service providers but rather as managers and coordinators. MSWM is an expensive undertaking if it is conducted in an environmentally sound manner. Involving the private sector should result in greater efficiencies. As the private sector can be contracted for waste service and treatment, local governments need to focus more on administration, monitoring, public education, and planning. Local governments need to enhance their capacities to arrange and support waste planning by coordinating with various agencies within the government, improving information transparency for public consultation, and collecting reliable basic data on waste properties and market demand for recycled products.

Coordination among stakeholders is critical to integrated waste management. The recent attempts to encourage commercialization and waste separation have largely been fragmented. While source separation is encouraged, the reality is that landfills and incineration plants have become the major tools and do not require intricate separation of waste. At the present time, local recycling centers are inadequate and the continuing participation of informal agents who actually perform waste separation has not been formalized. In order to build strong partnerships between various stakeholders, it will be necessary to establish a mechanism in which all stakeholders can share their concerns, knowledge, and information. An integrated management framework, in which all stakeholders participate, as described in this paper, needs to be created and agreed upon by stakeholders so that they can gain a wider perspective beyond their own roles and responsibilities.

In addition, it is also important that an integrated waste management system be suitably planned for local conditions such as the MSW composition and the demand in local markets for possible recycled products. Accordingly, programs to separate waste, reduce its contamination and measures to help enterprises become more viable in the market should be established, such as coordinating waste collection in various districts to support enterprises operating on large scales, and creating demand for recycled products. Evaluation and analysis of successful practices and case studies in various contexts will contribute to the further implementation of IWM in China. In this regard, the "environmental protection model cities" and "eco-cities" will be useful case studies.

5. Conclusions

In the past decade, China has devoted considerable effort to achieving noticeable progress in MSWM. As a result of investments in infrastructure, regulations, and international cooperation on MSWM, the increasing amount of MSW collected has been largely decoupled from the growth of the economy since the late 1990s. Waste services and waste treatment, especially in large cities, have also improved in terms of both quality and capacity. New landfill sites are built in accordance with higher standards, while incineration that recovers energy from waste has become a widespread treatment method. However, challenges for MSWM still remain and differ by region. In the central region, resources and suitable technologies remain lacking. In the coastal region where safe disposal rates are relatively high, recycling and resourcification should be encouraged. The challenges and barriers related to MSWM in different regions are highly diverse. Major points identified in this study concern various aspects of the waste management system: the shortage of treatment and safe disposal capacity, policy implementation and technological feasibility in different regions, baseline investigation and public consultation in waste planning, and market development for recycled products. No single policy or stakeholder can overcome all these barriers alone, and thus a more integrated approach should be adopted. From a systematic perspective, three aspects that currently receive insufficient attention which should be further addressed are better investigation

of the status of the system, coordination of stakeholders by considering their needs and reaching agreements on their roles and responsibilities, and system planning in a way that is suited to local conditions.

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