Country Report

Municipal solid waste management in Pudong New Area, China

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A R T I C L E   I N F O

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A B S T R A C T

The increase in population, the rapid economic growth and the rise in community living standards accelerate municipal solid waste (MSW) generation in developing cities. This problem is especially serious in Pudong New Area, Shanghai, China. The daily amount of MSW generated in Pudong was about 1.11 kg per person in 2006. According to the current population growth trend, the solid waste quantity generated will continue to increase with the city’s development. In this paper, we describe a waste generation and composition analysis and provide a comprehensive review of municipal solid waste management (MSWM) in Pudong. Some of the important aspects of waste management, such as the current status of waste collection, transport and disposal in Pudong, will be illustrated. Also, the current situation will be evaluated, and its problems will be identified.

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1. Introduction

With continuous economic development and an increase in living standards, the demand for goods and services is increasing quickly, resulting in an increase in per capita generation of solid waste. Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste (MSW) generation rate in developing countries, especially in China. The World Bank pointed out that no country had ever experienced as large or as fast an increase in solid waste quantity as China (Yuan et al., 2006). China recently surpassed the United States as the world’s largest MSW generator. Furthermore, China’s annual solid waste generation is expected to grow from about 190 million tons in 2004 to over 480 million tons by 2030 (The World Bank, 2005). This poses enormous challenges for environmental protection and sustainable development. One of the effective solutions to such a problem is to adopt an efficient municipal solid waste management (MSWM) system. All aspects of China’s waste management systems must undergo great changes in order to meet this challenge. The state’s eleventh five-year plan (2007–2012) has allocated approximately 140 billion Euros to be invested in environmental protection, reflecting the determination and effort of the Chinese government in protecting the environment.

Pudong New Area (Pudong) is located in the eastern part of Shanghai and is one of China’s most economically active cities. Massive governmental investment has helped Pudong grow from mere pastures to a modern city within 18 years. The waste characteristics and the solid waste management system in Pudong is representative of most Chinese cities. In this paper, MSW characteristics and the current status of MSWM in Pudong will be detailed to evaluate the current situation and identify problems.

2. Current situation of solid waste management in Pudong

2.1. A brief introduction of Pudong

On April 18, 1990, the Chinese government decided to allow large-scale development and construction in Pudong. After 18 years of development and construction, Pudong has undergone amazing changes, becoming a model of an externally oriented, multifunctional and modern urban district.

Pudong is situated at the middle latitude of China’s coastal areas and is located in an estuary where the Yangtze River enters the sea, as shown in Fig. 1. Pudong lies adjacent to Shanghai’s urban districts, with a solid and strong economic foundation, backed up by the Yangtze River Delta with rich resources and facing the Pacific and East Asian Region. It covers an area of 569.57 km², and has a pleasant climate year-round with an average annual temperature of 16.2°C and an average annual rainfall of 1183 mm (Pudong Gov-
Pudong is characterized by both urban and suburban areas. In 1990, the population of the Pudong was about 1.4 million, but had increased to 2.8 million by 2005.

In order to perform effective city administration, Pudong is divided into six functional areas geographically, as shown in Fig. 2. The functional area (FA) is an economic and administrative division aimed to eliminate dual urban–rural structure, increase linkage between development zones and townships, and introduce greater reforms. Furthermore, FAs represent an institutional innovation for waste management. At present, there are six functional areas in Pudong New Area (Table 1), namely:

- Lujiazui Functional Area (LFA),
- Jinqiao Functional Area (JFA),
- Zhangjiang Functional Area (ZFA),
- Waigaoqiao Functional Area (WFA),
- Sanlin World Expo Functional Area (SFA), and
- Chunsha Functional Area (CFA).

For each FA, a dedicated truck company is in charge of waste collection and transportation to the waste disposal facility.

### Table 1: Fundamental data of functional areas of Pudong, 2005

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Land area (km²)</th>
<th>Registered population by year-end (person)</th>
<th>Population density (person km⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFA</td>
<td>42.77</td>
<td>453,049</td>
<td>10,593</td>
</tr>
<tr>
<td>JFA</td>
<td>90.52</td>
<td>368,859</td>
<td>4,075</td>
</tr>
<tr>
<td>ZFA</td>
<td>119.31</td>
<td>149,395</td>
<td>1,252</td>
</tr>
<tr>
<td>WFA</td>
<td>97.13</td>
<td>157,277</td>
<td>1,619</td>
</tr>
<tr>
<td>SFA</td>
<td>80.11</td>
<td>556,903</td>
<td>6,952</td>
</tr>
<tr>
<td>CFA</td>
<td>139.73</td>
<td>162,571</td>
<td>1,164</td>
</tr>
<tr>
<td>Total</td>
<td>569.57</td>
<td>1,848,054</td>
<td>3,245</td>
</tr>
</tbody>
</table>

Data source: (PSWAO [2006]).

### 2.2. Solid waste management in Pudong

#### 2.2.1. Waste generation

As cities grow, land use becomes increasingly complex, and the waste generated increases in volume and variety (Omuta, 1987). In 2006, Pudong witnessed a steady economic growth, realizing a GDP close to 23.7 billion Euros, an increase of 13.4 Euros from the prior year. Accordingly, the quantity of solid waste generated in Pudong increased from 2418 tons/day in 2004 to 2854 tons/day in 2005. MSW is classified into three categories: urban waste, suburban waste and other waste (waste from street sweeping, businesses and public institutions) (Table 2).

In 2006, the amount of MSW generated in Pudong was about 3,108 tons/day, approximately one-fifth of the total amount produced in Shanghai. Based on the current population growth trend, the solid waste quantity generated in Pudong will continue increasing with the city’s development according to the projected municipal waste generation for China (The World Bank, 2005). The daily output of MSW from 2004 to 2006 is shown in Fig. 3 (PSWAO, 2006).

The urban area in Pudong includes all of the LFA, and most of the JFA and SFA. The Puhuan company is responsible for the waste collection in these areas. The calorific value of urban waste is approximately 5,080 kJ/kg (PSWAO, 2006), which makes it suitable for combustion, so most waste is incinerated. However, suburban waste is usually first transported to suburban transfer stations and then to disposal facilities after compaction.

#### 2.2.2. Waste composition

Compared with other cities in developing countries, MSW in Pudong has a high organic content and low calorific value, containing a large percentage of organic waste. Fig. 4 shows the composition data for solid wastes tested at the Dezhou waste collection point. The main components are food residues, plastics, fruit, paper, textiles, glass and wood. The waste has a heterogeneous composition comprising both degradable and non-degradable materials, and is collected without sorting. The majority of the non-degradable...
waste fraction consists of potentially recyclable materials, and the degradable fraction could be composted.

2.2.3. Waste collection, transportation and treatment

The collection, transport and disposal of MSW are all important aspects of waste management for public health, aesthetic, and environmental reasons. China’s solid waste infrastructure is struggling to cope with unprecedented levels of waste generation, and Pudong is a typical example. In 2006, waste treatment facilities (incineration, composting, and landfilling) were only capable of handling 2500 tons per day; the daily handling operating capacity of each plant was 1000, 1000, and 1000–1500 tons, respectively. Hazardous waste is disposed of separately. The current MSW treatment capacity is inadequate for the quantity of waste generated. Being aware of these issues, the state government has tightened environmental regulations, increased public investment, introduced “marketization” reforms, and encouraged private sector participation. It is expected that operational, managerial, financial and legislative reform will improve the investment climate sufficiently enough to attract funding, technology, and managerial expertise from the private sector.

The Pudong Solid Waste Administration Office (PSWAO), a branch of the Environment Protection Bureau (EPB) of Pudong, is in charge of MSWM and has the overall control of the waste flow.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Waste source</th>
<th>Calorific value (2006)</th>
<th>Collection units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban waste</td>
<td>LFA, JFA, SFA</td>
<td>5.080 kJ/kg</td>
<td>Puhuan company</td>
</tr>
<tr>
<td>Suburban waste</td>
<td>ZFA, WFA, CFA</td>
<td>4.710 kJ/kg</td>
<td>Qingdaoyuan company</td>
</tr>
<tr>
<td>Other waste</td>
<td>Street sweeping,</td>
<td>–</td>
<td>Assigned by each street</td>
</tr>
<tr>
<td></td>
<td>businesses, and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>public institutions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2. Functional areas in Pudong.

Fig. 3. Pudong daily output of MSW from 2004–2006.

Fig. 4. Composition of MSW tested in Dezhou waste collection point.

Table 2
Three categories of MSW in Pudong
Containers, which vary depending on location (residential areas, for example, have 240-L plastic containers), were available at every collection point, along the street and public places according to the sanitation standards. Fig. 5 shows the waste infrastructure setup of Pudong. The solid waste disposal process can be classified into three stages: storage, collection and transportation, and final disposal.

2.2.3.1. Storage. A key aspect of effective waste management is proper waste storage on the premises where the waste is generated (Oluwande, 1984). In residential areas, the fixed collection point is set for waste storage. It consists of setting containers in designated locations for scheduled pickups. As shown in Fig. 6, the collection point is a room with a window that is opened to allow waste to be deposited. Generally, there are several waste collection points in a residential area, each with several 240 L plastic containers inside the room; the number of the containers is decided by PSWAO.

2.2.3.2. Collection and transportation. Collection of solid waste is carried out by using various types of vehicles, with the type of vehicle depending on the type of collection bin and width of the road (Chiplunkar et al., 1981). There are three large private companies currently involved in collection and transportation. PSWAO assigns waste collection tasks and signs contracts with the private companies, which promise that collection facilities are be rehabilitated to realize airtight and prompt transportation; in addition, they are to make sure all the wastes are cleaned up every day. The private companies are responsible for collecting waste from every fixed waste collection point and transporting the waste to transfer stations and disposal sites. Although the collection and transportation process is a major cost in the waste management process due to the large amount of waste, the collection points are visited once per day in the early morning in order to decrease potential impacts on the environment (e.g. odor and flies). Efficient collection depends on proper selection of vehicles. There are two kinds of trucks used for waste collection in Pudong. One is an automated compactor truck, as shown in Fig. 7, which is commonly used and is efficient. This kind of truck can accommodate two 240 L containers at the same time, and it has a capacity of 3.5 tons. Each truck is assigned too many fixed collection points; the vehicle starts at the parking lot of its company in the morning and then visits the collection points one by one. When the truck is full, it travels either to the transfer station (TS, Fig. 8) or a disposal site. After visiting all the required collection points, the truck returns to its company. Generally, the visiting sequence and route of the truck will not change except when the disposal site becomes full or if there is some emergency. As shown in Fig. 9, the other type of garbage truck used in Pudong contains a swinging arm for self-loading and has a capacity of 5 tons. It carries only one container at a time and travels on major roads. This truck can transport...
waste from small compaction stations (SCS, Fig. 10) to transfer stations. Taking the road conditions, servicing requirements and haulage distances into consideration, a handcart is also used in some areas. Using a handcart, the operator collects the waste along the containers by hand and unloads it in the SCS, from where the swinging arm self-loading truck transports the waste to the TS, and then ultimately to the disposal site.

2.2.3.3. Final disposal. Three important waste disposal methods are adopted in Pudong: incineration, biochemical treatment, and landfilling.

The Yuqiao incineration facility became operational in 2001. It has three MSW incinerators and two 8500 kW power units, and is China's first modern MSW incineration plant capable of processing over 1000 tons/day of waste. In 2006, the Yuqiao incineration facility processed a total amount of 437000 tons of crude waste, accounting for 40% of the city’s total solid waste. As illustrated in Fig. 11, incineration has a significant impact on the waste disposal in Pudong.

The Meisheng biochemical treatment plant, which opened in 2003, is responsible for the treatment of organic waste and food residues. Composting generally plays an important role in China. This may be driven by the value of carbon emission reductions, the high percentage of organic waste in MSW, and the potential market for finished compost (The World Bank, 2005).

Since the two alternatives above produce some residues that must be disposed of, landfilling is a necessary component of MSWM, although it causes serious environmental degradation. The Liming landfill site in Pudong was built in 1999 and upgraded in 2004. As of 2006, 240800 tons of crude waste has been disposed of in this landfill.

2.2.4. MSW substance flows

Only qualitative descriptions of Pudong’s waste management system are mentioned above. Quantitative data will be introduced in the following section. As shown in Fig. 12, in the urban TS and at all the disposal sites, weighbridges are installed at the entrance and can be operated in two directions, weighing the waste efficiently and automatically while uploading data to PSWAO. The waste flow of 2006 is shown in Fig. 13. It can be seen that 35.2% of the urban waste is directly incinerated, while the rest is first separated in the transfer station. Hazardous waste is disposed of separately, and the majority is directly treated by composting, incineration or landfilling. As for suburban waste, data cannot be obtained until the waste reaches the final disposal site because suburban transfer stations do not have weighbridges. The waste...
from businesses is not included in this flow. Secondary waste includes wastewater, gaseous waste and solid waste emitted from MSW treatment (Hong et al., 2006). In the incineration facility, 39 tons of fly ash, 291 tons of bottom slag and 140 tons of leachate are produced per day. Some of the secondary waste materials can be recycled as raw materials, while most are landfilled or discharged after incineration.

2.3. GIS-based information management system

There are about 200 trucks equipped with the GPS sets. All coordinate data are uploaded and then integrated into the city’s web-based geographic information system (GIS) in order to monitor the trucks in an efficient way. Also, dynamic scheduling for the truck can be accomplished to minimize cost if necessary. This allows trucks to decrease their operating time, thus reducing their fuel consumption. A general outline of the current information management system of PSWAO is given in Fig. 14. The truck’s route and the real-time status can be displayed on the web.

3. Recommendations

A number of recommendations are made here, aimed at improving solid waste management in Pudong.

In consideration of the current MSWM status, source separation should be a key priority. Waste needs to be sorted at the source as much as possible to reduce the amount of waste requiring disposal. Additionally, the government should encourage markets for recycled materials, such as waste trade platforms. The recycling industry needs to be improved through increased professionalization, improved product standards, market development and better operating standards. At present, the EPB of Shanghai municipal is trying to encourage the use of a new classification pattern. Four containers, each of a different color, appeared in some residential areas of Shanghai for source separation to minimize waste and maximizing recycling. However, the collection vehicles and the collection methods have not yet been able to accommodate this new innovation. The collection trucks used by private companies should be upgraded to support the new container system, and col-
lection methods should also be adapted accordingly. In addition, education about waste sorting and recycling is necessary to promote this policy.

Source separation and collection of MSW is not well implemented in Pudong or the rest of China. Consistent national policies on MSW legislation are needed. Policies should be adopted to encourage cross-jurisdiction and inter-agency coordination and to facilitate implementation of economic instruments for improving waste management. The supervision of private enterprises should be strengthened by regulations. An integrated sustainable waste management system from generation to final disposal is needed. The system should enhance the planning and decision-making process and take a holistic view of the entire system: waste collection, transfer, resource recycling and disposal. The state council of the Chinese government issued a ban on free plastics bags in all supermarkets, department stores and other stores on Jan 1, 2008. Although the Government has been aware of the ban, it must also continue to strengthen and improve its regulations and policies.

Finally, when discussing solid waste management, we must realize that waste management is a complex and long-term process. Adequate understanding the characteristics of MSW and its management status is required for effective MSWM. The government should support pilot programs to obtain valuable and comprehensive data on waste characteristics, waste management technologies and implementation experience. The ultimate goal is to implement and promote practical and feasible methods to improve the environment.

4. Conclusions

Waste management is a global environmental issue and a significant problem today. This paper presents the current waste generation, collection and transportation, and disposal situation in Pudong, China. The implementation of the MSWM system depends on several important factors such as the country statutes, strategies in environmental management, economic and technological capabilities, and the education and environmental awareness of citizens. Increased information is required to remedy the public’s lack of awareness and concern regarding waste issues. Although a comprehensive waste management system has been established in Pudong, it fails to achieve the greatest degree of recycling and reuse of resources. The existing system suffers from unfavorable legislative and technical and operational constraints. Source separation, effective supervision and involvement of the private sector have been recommended. An integrated MSWM system adapted to Pudong’s situation is identified for further development.

Acknowledgments

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