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Municipal solid waste treatment in China: a case study of Chengdu city

Yating He

School of Public Administration, Southwest Jiaotong University, Chengdu(610031), P. R. China

**Corresponding Author: Yating He ; Email:* anette37@163.com

Abstract: Municipal solid waste has become an important factor restricting the development of cities in China, and it is necessary to solve it and promote municipal solid waste industry in urban areas. This paper takes a case study of Chengdu city in China, analyzing its current situation, problems and constraints in municipal solid waste disposal. At the same time, this paper also provides feasible suggestions to the marketization and industrialization treatment of Chengdu's municipal solid waste, suggesting from the several aspects of technical methods, construction and management, paying system and recovery system to do it.

Keywords: Chengdu city, municipal solid waste, marketization treatment, industrialization treatment, technology methods, management measures

INTRODUCTION

Municipal solid waste (MSW) is produced in residents' daily life and industrial production, including paper, plastic, metal, glass, textiles, food, discarded furniture and so on. With the development of urbanization, increasing MSW has gradually become a serious problem which affects economic development and ecological environment, restricting the sustainable development of cities. In China's case, the average annual growth of transported MSWs from 2004 to 2011 is 1.1075 million tons, but its total amount reached 163.953 million tons in 2011 and thus many cities are struggling against severe MSW problems. How to effectively reduce MSW and promote waste recycling has become an emergency work for China [1].

As we can see from the world experience and practice, the key to MSW treatment is source reduction, recycling in process and harmless in outcome, and harmless is regarded as a primary goal. The idea of circular economy runs through the whole MSW disposing process from production to disappear to achieve environmental objectives as well as economic benefits.

To accomplish these goals of MSW disposal, things are needed to be done in two ways. One is the technical methods of waste disposal, while the second is management measures. Nowadays, sanitary landfill, composting and incineration are widely applied technology methods for MSW disposal, and each of them has its own advantages and disadvantages, respectively. Thus, MSW composition, local economic development and geographical conditions should be taken into full account when choosing specific method. For example, when municipal solid waste in a city contains high organic matter and local agriculture needs large amount of fertilizer, compositing would be a best choice. Sanitary landfill requires high inorganic share and few hazards in waste components to avoid the pollution of land and water, while it also requires a lot of idle lands around the city. As for incineration, high technology and enough funds are premises. In addition, incineration sets high standard on processing facilities and environmental equipments, especially needs to avoid possible pollution caused by dioxin.

As early as the 1970s, foreign scholars began to study on MSW, those researches explored the effects of waste charging system [2]. With the growing awareness of environmental protection and sustainable development, more and more researches began to focus on the comprehensive treatment of MSW, which means to pay attention to MSW reduction as well as the improvement of recovery and recycling rates, so they conducted in-depth and thorough studies in waste classification recycling system [3-5].

In China, studies about MSW focus on technical methods of waste disposal [6-7], or to explore current status of MSW to improve existing management policies[8-9]. These studies attempt to solve China's MSW problems from different aspects.

Due to the differences in geographical location, economic development level and humanities between different cities, research goal based on the characteristics of a certain city is much more scientific and practical. Therefore, this paper conducts a case study of Chengdu city in China, which starts from its current situation of MSW pointing out the existing problems and restrictions, and provides feasible

proposals from the aspects of technical measures and management methods.

PRESENT SITUATION OF MSW IN CHENGDU CITY

Chengdu locates in southwest China, and its population reached 14.178 million by 2012. As the economic and financial center of west China, Chengdu is facing both economic development and increasing population densities, which mean more and more MSW problems at the same time, too.

MSW removal and disposal

As the provincial capital and largest city of Sichuan province, Chengdu's transported MSWs usually account for around 1/3 of the whole province, and the huge amount of MSWs in Chengdu have brought great pressure on urban environment and resident's life, becoming an important factor restricting the development of Chengdu. From the situation of transported MSW in Chengdu, we can see a generally growing trend with relatively decreasing in some years. The change rate of transported volume presents great fluctuations, and the growth rate exceeded 20% in 2004, 2007 and 2010, while negative growth appeared in 2006, 2008, and 2010 (Chengdu statistical yearbook, 2003-2012) (see Fig 1).

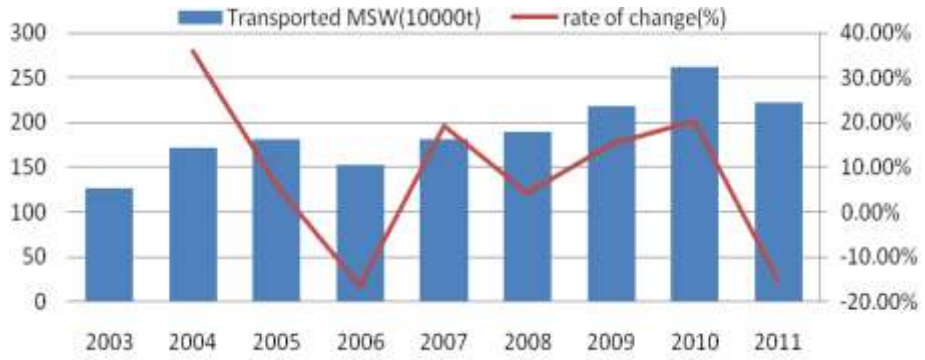

Fig-1: Transported MSW and the change rate of Chengdu

Harmless treatment rate reflects the environmental effect of MSW treatment. It can be seen from Figure 2 that harmless treatment rate of Chengdu's MSW has always been at a very high level, which is much higher than the average rate of Sichuan province or the whole country during the same period, and it even achieved 100% in 2009 (Chengdu statistical yearbook, 2003-2012).

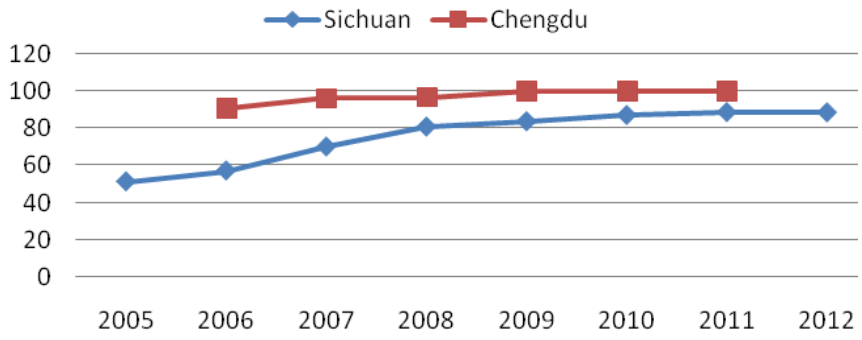

Fig-2: Harmless Processing rate (%)

Current situation of MSW treatment technology

Technological methods being widely used in MSW treatment are sanitary landfills, incineration and composting, and among them, sanitary landfill is the main approach for MSW disposal in Chengdu. Taking an example of 2011, the total amount of MSWs generated in Chengdu was 2.2188 million tons, and 1.7188 million tons were disposed through landfill, accounting for 77.44%. Incineration was used for the disposal of only 500,000 tons of solid wastes, which occupies 22.53% of the total amount [10], and composting has not been applied in Chengdu yet.

At present, Chengdu and its subordinate counties have 8 MSW treatment plants, including 1comprehensive treatment plant, 5 sanitary landfill sites and 2 incinerators. Most of these plants locate in the suburbs, which makes it convenient to deliver wastes, and it wouldn't cause too much bad effects on urban environment. The technological level of these 5 sanitary

landfill plants is not high, and they all face the danger of leakage of landfill pollutants. 2 incineration plants are available for thermal power generation, but the cost is very high, and the gas pollutants for incineration treatment does not meet international standards.

MSW management system

Currently, the environmental protection agency and the urban administration of Chengdu are responsible for the city's MSW management. BOT mode has been commonly used in the construction and operation of solid waste treatment facilities, and a large number of business investments have been introduced to this public utility. For instance, the incineration and power generation project started from 2012 in Chongzhou (a subordinate city of Chengdu) is the cooperation of local government and the Sea Knoll group. In this case, government gives the group a franchise to operate the incinerator, and this group will play an important role in solving local MSW problems.

Chengdu urban administration classifies MSW into 4 groups, for example, kitchen waste, recyclable waste, toxic waste and other waste, and makes different policies for the removal and disposal of different types of waste. Due to the high content of organic matter, kitchen waste would be delivered to biogas pools for processing, and a collection and transportation system of kitchen waste will be set up after the completion of kitchen waste treatment centre. In this system, specialized vehicles/containers for kitchen waste are well equipped, and separate collection and transportation of restaurant, hotel and cafeteria food waste will be accomplished. After recyclable waste and other waste being transported to waste transfer stations, they will be transferred into recyclable waste sorting centers or other waste sorting centers respectively. Then recyclable waste will be transported into recycling business while the treatment for other waste depends on specific circumstances, and they will be dealt by landfill or sent to waste incineration plants, while the toxic part will be transported to Sichuan Hazardous Waste Disposal Center with toxic wastes.

In the classification recycling of household waste, Chengdu chose 8 communities with better economic conditions and higher resident's quality as sorting experimental units. Recycling experiments include publicity of waste sorting knowledge, the application of classified garbage bags, classification settings, recycling incentives and feedbacks, and the usage of separate collection vehicles, etc. If the experiment works well, the experience will be extended to the MSW management of Chengdu, and the range of separation and recovery will be gradually expanded. At the same time, existing curbside recycling system has been improved in Chengdu city. In public places and streets, waste separation and recycling bins are used to displace the old ones.

Chengdu's urban government promulgated and implemented "Administrative Measures for the Management of Municipal Solid Waste Charge" in 2005, introducing a charging system with the principle of fixed fees combined with pay-by-amount, charging different types of waste generators with different ways. The detailed charging patterns are as follows:

(a) For urban residents (including temporary ones), charging a fixed fees for ¥ 8/ household /month.

(b) For government offices, institutions and social organizations, charging for ¥ 2/person/ month.

(c) For production and business operation entities, self-employed households, hospitals, schools, and military units, the waste disposal fee is charged by the amount of wastes generated according to ¥ 110/t. And those have difficulties in paying by weight would be charged by operating areas .

(d) Self-collected and self-transported units would pay by the amount of wastes delivered to processing plants. Units charged according to (b) or (c) can pay waste disposal fees monthly or quarterly or annually [11].

THE PROBLEMS AND RESTRICTED FACTORS OF CHENGDU'S MSW TREATMENT

Chengdu has made some efforts in MSW, such as the adoption of BOT mode in MSW disposal, experimental communities for waste classification and recovery, promulgations of related administrative regulations, making more specific requirements for waste transportation and charge, etc. These measures have some effects on the controlling of MSW growth and environmental protection. Nevertheless, there are still many problems in Chengdu's MSW disposal.

Unscientific and laggard technical approaches

We can learn from above that sanitary landfill is most commonly used in MSW processing of Chengdu, although this approach has some advantages like relatively less investment, lower cost, and higher reliability, it is also a kind of backward processing technology which has a lot of flaws and problems.

First of all, though sanitary landfill has low standards in the composition of waste, the moisture in waste should not be too high, otherwise it would be troublesome once leakage happens. However, Chengdu is a city with much precipitation, so it faces considerably risks of leakage. Secondly, landfill requires huge tracts of land. Since Chengdu is located in the plain areas of Sichuan basin, it owns vast areas of land, but most of them are fertile soils and suitable for agricultural production, and the massive usage of lands for landfill not only results in a waste of land resources, but also causes soil pollution in some areas.

It can be seen from international trend that landfill will no longer be the main method used in MSW disposal, instead, it will be the final process to digest

waste which cannot be eliminated by incineration or composting [12]. Thus, the share of landfill used in treatment of MSW should be determined by the ratio of composition and incineration. The MSW disposal for Chengdu overly depends on sanitary landfill while the practice of incineration is too little, and composition is barely used. The technological level of MSW treatment in Chengdu is far behind developed countries and cities, which is not conducive to the effective operation of MSW industry in Chengdu.

Insufficient management

In the construction of waste treatment projects, Chengdu government relies too much on BOT pattern, so the capital sources are relatively homogeneous. Under a single investment mode like this, Government focuses on how to mitigate the financial burden, ignoring the provision of sufficient legal basis and guarantee of relative contracts, which makes it likely to be stuck in a situation of weak implementation during the process of project construction and operation [10]. Currently, many incinerators and landfill plants in Chengdu are operated by enterprises, and most of them are faced with high costs and poor economic conditions. In addition, there is no related law or regulation to set market access in the construction of MSW projects or disposal business, which causes bidding chaos, the lack of industry standardizations and other issues.

MSW treatment fees imposed on residents can be the supplement to the city's MSW disposal funds, however, despite a charging system combined with fixed fees and charging by volume has been implemented in Chengdu, the fee rates are too low, so it is difficult to make compensations for the cost of waste collection and treatment. Charging by household or person and low fee rates are not conducive to achieve source reduction of MSWs, and adopting different fee rates for different subjects doesn't reflect the principle of fairness which a charging system should be of.

In a megacity with the population of more than 10 millions like Chengdu, there are many large communities, and it would be more flexible if a community can decide its own MSW collection and disposal, which is also convenient for community management. Also, it transfers the responsibility of MSW disposal to each community, making communities to be more aware of their obligations as waste producers. However, MSW disposal in different districts and counties of Chengdu is a responsibility of the government or private contractors. Without considering the specific situation of each place and the diverse needs of residents, low efficiency and high operating costs become general in MSW disposal industry.

From the successful experience of MSW disposal in developed countries, we can learn that it is very important to make full use of industrial organizations. These organizations have their own specialties. Some of them are committed to the environmental education to residents, and some focus on management throughout the process of MSW disposal, and others are devoted to the use of recyclable materials. Involving themselves in MSW disposal, social organizations and enterprises play a significant role in reducing financial burden on the government as well as promoting the entire waste treatment industry. Some industry organizations have made great influence on MSW disposal in their own countries , such as Germany's DSD system, the coordinated organization of Netherland and the private sector Eco-Emballages in France. At present, the government and its contractors are in charge of MSW in Chengdu , and it is rarely to see the participation of relevant industry organizations, even these few existing environmental groups are limited to environmental education, but the government has not guaranteed proper protections and their rights in environmental business.

Problems in waste collection and recycling system

In Chengdu, although MSW is classified into kitchen waste, recyclable waste, hazardous waste and other waste, and classification collection has been experimented in some communities, these methods don't work well while the costs are significantly increased. The goal of waste reduction and recovery hasn't been achieved.

First of all, the classification is so rough that multiple times of classification are still made after the initial sorting. Residents know little about waste classification, so it is likely for them to mix up different types of wastes. In pilot areas, each community property centre is responsible for environmental education to residents and secondary sorting. But most of these centers don't do their works well, and the costs of community MSW management has increased enormously.

Secondly, although collection vehicles specialized for different categories of wastes are well equipped, non-procedural collection and transportation often happens in pilot communities. In other communities, mixed wastes are collected, and the recyclables in collections would be sorted by pickers. In this way, a large amount of recyclable resources would be wasted because of improper classification, and it greatly affects the quality and effectiveness of MSW disposal, increasing the risk of secondary pollution.

There are two severe problems in the current situation of MSW disposal in Chengdu. One is the rough classification, while the other is that the separate collection has not been well coordinated with the treatment system, making classification invalid. Even if the classification is well done, the sorted wastes would be mixed during transportation and be processed uniformly. Sorting, transportation and disposal do not

form a consistent system, which leads to the inefficiency of waste classification [13].

The lack of environmental protection knowledge

Many residents are lack of knowledge about environmental protection, especially about waste classification, and few of them realize the importance of initial classification. Even in pilot communities, waste classification doesn't seem to be working. In fact, family classification is inadequate in Chengdu, though it is an important link in source control (It may not only absorb the part of the wastes, but also save a lot of costs).

In Chengdu, environmental education is merely a formality, and there is no law to regulate the responsibilities of waste producers, so residents don't realize their responsibilities in MSW disposal. Instead, most of them think MSW disposal is a public project which is only undertaken by the government, and individuals do not have to participate. Although curbside recycling system has been preliminary established in Chengdu, and recycling bins marked as 'recyclable' or 'unrecyclable' have been set up on both sides of streets, passages still put garbage into the wrong bin because they don't know how to do classification rightly. Worse still, as many people have no consciousness of classification, so they just throw garbage randomly.

CORRESPONDING MEASURES TO SOLVE THE PROBLEMS OF MSW TREATMENT IN CHENGDU

Problems of MSW disposal in Chengdu exist in technology, management and resident's quality. In order to solve these problems, geographical location as well as economic and social development level of the city should be taken into account, adopting suitable measures to promote the MSW industry in Chengdu.

Improvement of treatment technologies

Different methods are suitable for different wastes. For instance, wastes with high organic matter are fit for being composted while incineration is suitable for those with high calorific value. As for wastes with high inorganic substance and few hazards , sanitary landfill is the best choice. In the composition of MSW in Chengdu, kitchen food, leaves, paper, plastic, fabric, wood, slag, glass and the rest account for 65. 7%, 13. 0%, 12. 0%, 2. 5%, 0. 30%, 0. 58%, 2. 1%, 0.80%, 2.9%, respectively. The calorific value is 5,260 kJ/kg while the moisture content is 57% [14]. MSW in Chengdu has the characteristic of high calorific value and low inorganic matter.

Kitchen waste accounts for a large share in MSW generated in Chengdu, and the MSW is of high water content, so it is not appropriate to excessively use sanitary landfill as a treatment method. Kitchen wastes contain high levels of organic matter, which makes composting a suitable measure. What's more, areas around Chengdu are agriculturally developed, so there is a large demand of organic fertilizers produced by compositing, which compensates treatment costs to some extent. Chengdu is located in basin areas, and it is hard for polluting gases to dissipate. So despite MSW in this city is of high calorific value, it should be very cautious when using incineration, and higher emission standards should be developed to prevent secondary pollution.

When deciding the scale of sanitary landfill, incineration and composting, sanitary landfill should be considered as the supplement to the formers and only when there still remains wastes cannot be digested by incineration or composting, sanitary landfill is needed. Thus, more incinerators and composting plants should be built to realize harmlessness of MSW disposal, and it is also necessary to set up several landfill plants as the complementary of the formers. Incineration plants are mainly for the disposal of hazardous wastes and wastes with high calorific value; the major treatment for organic wastes should be composition; remaining ashes after incineration and materials isolated from composting can be carried out together with the other wastes and be sanitary land-filled [6].

The marketization and industrialization treatment of MSW

Introducing the effect of market mechanism into MSW management and promoting the industrialization of high efficiency and sustainable development of MSW disposal are the only way to solve the MSW problems in Chengdu. To achieve this goal, it must be guided by the concept of circular economy, regarding wastes as a resource that can be recycled while ensuring the object of harmless treatment at the same time, and also make full use of their economic values. This object not only needs to strengthen the technical researches and applications to MSW treatment, establishing a suitable processing system for Chengdu, but also calls for the establishment of new management methods and industry development [15].

In terms of the construction and operation of MSW treatment facilities, it cannot overly depend on a single BOT mode, and multiple types of financing patterns like PPP (Public-Private-Participation) mode or raising funds from the public should be adopted, too. The diversification of financing not only can reduce the financial pressure on government, but also can reduce potential risks of single financing pattern engaged in the construction and operation of MSW. It is extremely important that no matter what the financing pattern is, there must be related legal and institutional framework to maintain market order and guarantee subsequent operation.

For the removal and treatment of MSW, it cannot be conducted solely by government or private sector,

otherwise uncertain costs and low efficiency in MSW management would happen. There are two management patterns for MSW treatment in Chengdu. In the first pattern, the city would be divided into different areas, and contractors would be responsible for waste disposal in some areas, while the government should be in charge of the rest areas. In the second pattern, government can let each community decide its own MSW removal and disposal pattern: outsourcing this obligation to the government or private sectors or by itself. However, since communities are usually small-scaled, each of these two choices may lead to high costs, so the cooperation with neighboring communities to expand the scale and share the costs becomes a viable option [1]. In this way, there is competition between different areas, so each part would be more committed to improve efficiency and reduce costs. The government could understand the costs and difficulties more clearly during the process.

In addition, the original MSW charging system in Chengdu should be gradually improved to a pay-by-amount system with a higher fee rate. The principle of 'pay-as-you-throw' would be implemented in this charging system, which is fair to residents and a good way for source control. The research of Dahlén and Lagerkvist [16] shows that in charging-by-volume areas of Norway, the recovery rate reduced 15%-90%. What's more, the implementation of this system increases the transparency of MSW management costs, strengthening the recycling system. For Chengdu, a proper fee rate should be determined to charge residents for the amount of wastes generated by them, and the charging is in a segmented pricing way, meaning that more wastes have higher fee rate. As for business units and self-employed households have difficulties in paying waste disposal fees by amount, charging them according to their operation areas would be appropriate. In terms of actual operation, workers would be responsible for weighting and recording.

Efficiency recovery system and environmental education

Recycling system is essential to a city's MSW disposal industry, and a good classification collection system can greatly reduce the amount of waste generation. What's more, the system provides a lot of convenience for subsequent recycling, and it also improves waste recycling rate. Since the key of MSW recovery is initial classification before collection, resident's participation of family classification is very important.

A primary factor causes the chaos in Chengdu's MSW management is that residents in Chengdu are lack of classification knowledge, and they don't realize its importance. Thus, it is necessary to build a scientific classification collection system and popularize classification knowledge at the same time. About MSW classification, Chengdu can learn from Japan's practice, dividing wastes into more detailed categories, issuing brochures with details about how to sort household wastes, and so on. Meanwhile, environmental groups should spread those knowledge to community residents regularly.

However, MSW classification is troublesome and would be difficult to residents, so many of them may refuse to classify their household waste, which makes it necessarily to implement mandatory recovery system and stimulus measures to improve the efficiency of family classification. For example, municipal department can issue garbage bags with household numbers and specific labels of waste categories to residents, and residents are required to sort household wastes and put them into different types of garbage bags according to the regulations. For mixed waste or those not meeting the requirements, waste removal workers would decline to collect. Meanwhile, it should be regulated that each category of waste would be collected and removed in specific time, like Monday morning for kitchen wastes, Tuesday morning for recyclable wastes and so on. Government should offer some incentives to residents who do well in waste classification, such as providing them with prizes or reducing their waste disposal fees, and let them disseminate classification knowledge to the whole community. Of course, pay-by-amount charging system is one of the economic stimulus measures to promote recycling. In addition, municipal department can also provide subsidies to residents for recycling their recyclable waste, which would increase the recycling rate to some degree.

Environmental education to residents is crucial for ensuring the effectiveness of waste classification, and it is also significant to the higher efficiency of MSW industry. Callan and Thomas [17] found that communities putting massive investments into environmental education have much better recycling results than those investing less. Chengdu should increase investment in environmental education, and provide some financial supports to environmental organizations, making them come into communities to carry out environmental knowledge educations regularly. At the same time, the education can also be spread through internet, newspapers and advertisements. In addition, attention should be paid to children's environmental education. Schools could organize outdoor activities to develop children's emotions to nature and their love for environment, and some activities about waste classification are also necessary.

CONCLUSION

As the largest city in the west China, Chengdu is facing the great pressure of MSW, and it has to deal with many problems occurred in MSW disposal. In order to solve these issues, Chengdu should stick to the idea of circular economy and make effort in both

management and technology to establish a scientific and complete system of MSW disposal and to lead it to the direction of marketization and industrialization.

On the side of technology, a comprehensive treatment approach should be taken. Sanitary landfill should be adopted as the supplement of incineration and compositing, and the scale of each method depends on the specific situation of Chengdu. What's more, it is clear that the first goal of MSW disposal is harmless, then followed by reduction and recycling. When establishing or evaluating a MSW disposal system, these goals should be fully taken into consideration.

To achieve scientific management of MSW, efforts should be made from the following aspects. The marketization and pluralism of management and operation, pay-by-amount charging system, and classification recovery system. In each process, fairness and feasibility are very important, and each should be tightly linked with another.

It requires the participation of government, enterprises and residents when comes to MSW disposal, and each part has an important role to play. Enterprises and residents must be aware of their responsibilities as waste producers, and they would produce less and recycle more wastes under pay-by-amount charging system and mandatory recovery policies, while government should be a supervisor to guide the behaviors of MSW producers.

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