Life Cycle Assessment of Municipal Solid Waste Management in Chinese urban areas: case study in Chongqing City

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Abstract

Chongqing city, a major city in Southwest China, has experienced a rapid increase in municipal waste generation. Currently only 38.3% of the waste is treated through incineration and bio-treatment and from the remainder 54.7% is directly sent to the landfill site and 7% is sent to open dumping. Since the landfill site, located near the ChangJiang River, is reaching its full capacity it is urgent to introduce alternative waste management options to minimize the amount of final disposal waste. In order to address this problem, this paper proposes different viable alternative options based on the integrated waste management approach and evaluates their environmental and economic performance by means of Life cycle assessment (LCA). The scenarios include different collection options, pre-treatment and treatment technologies that focus on material recycling, organic and energy recovery as well as final disposal. The Life Cycle Inventory analysis was carried out with the aid of IWM-2 Model. Based on these analysis results, a sustainable waste management strategy that has environmental, economic and social advantage is proposed and recommended.

Keywords: Municipal Solid Waste Management, Life Cycle Assessment, Life Cycle Cost, Integrated Approach, Recycling

1. Introduction

Chongqing is located near the ChangJiang River in Southwest of China. The main urban areas of Chongqing city, with a population of approximately 7 million in 2001, generate 1.08kg/capita/day waste [1]. Landfills are the main method of disposal in Chongqing, but pollution caused by simple landfills and lack of backup municipal solid waste (MSW) disposal capacity are becoming major problems in the urban areas of Chongqing. This paper discusses the current MSW system and treatment options in Chongqing city, and suggests integrated and environmental friendly solutions, through different viable alternative options generated by life cycle assessment (LCA).

2. Current treatment processes in Chongqing

2.1 Generation

The amount of MSW generated in the main districts of Chongqing has increased sharply with the growth of the economy and urban population (Fig.1). In 2011, approximately 2.75 million tons waste was generated. [2 and 3]

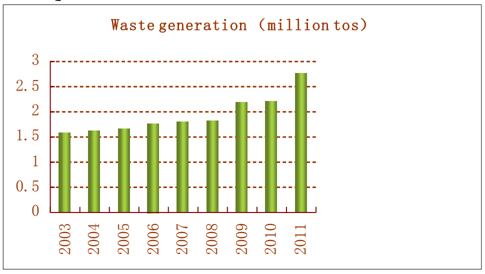

Fig.1: Waste generation of Chongqing urban areas

As shown in Fig. 2, in 2011 waste was classified as 59.2% organic, 10.10% paper, 15.7% plastics, 3.40% glass, 1.10% metal, 4.20% garden wastes, 6.1% textiles and 0.2% others [4].

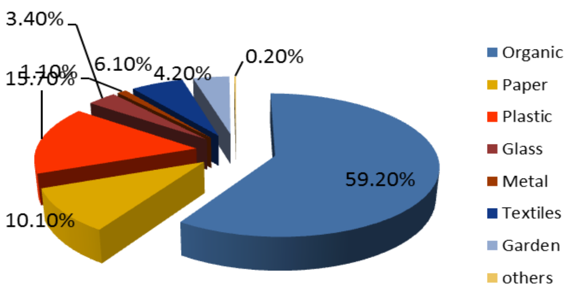

Fig.2: Urban solid waste composition in Chongqing

2.2 Collection& Separation

2.2.1 Waste Collection

In Chongqing, waste is collected in curbside way. Residents send their mixed household waste to the collection site without separation. Most of the waste will be collected and transported to the transfer station by the Chongqing Municipal Administration Commission [5]. Commercial waste will be directly sent to the transfer station.

2.2.2 Waste Separation

After that, waste is moved to a transfer point for pre-treatment and brief separation, and then delivered to treatment facilities. Until 2010, Chongqing has only one secondary transfer station with a capacity of 1300t/day. [6] Other than that, residents may sold recyclable materials (include plastics, paper and metal)to some private companies for money.

2.3 Treatment Facilities

At present, there are several treatment options in the world, including incineration, composting, gasification, recycling, pyrolysis, combined pyrolysis-gasification, anaerobic digestion and landfill.[7]

2.3.1 Incineration & Composting & Landfill

By 2011, there were five large treatment centers, including two landfill centers with an annual treatment capacity of 2500 tons a year, two incineration centers with an annual treatment capacity of 1500 tons a year, and one Bio-treatment center with an annual treatment capacity of 500 tons a year (Table 1). [8]

Table 1 Waste treatment facilities Chongqing

	year	Capacity(t)	location
Tongxing Incineration	2005	1200	Bei'bei
Fengsheng Incineration	2012	2400(300)	Ba'nan
Heishizi kitchen waste Treatment	2010	500	Yubei
Heishizi Landfill	2006	1000	Jiang'bei
Changshengqiao Landfill	2003	1500	Nan'an

2.3.2 Recycling

Recyclable materials include many kinds of glass, paper, metal, plastic, and textiles. As the special collection system—curbside without sorting—in China, Waste always recycled by the private company. Residents usually sell paper, plastic, metal, and cans. The recycle rate is very low in Chongqing.

2.4 Final disposal

Currently, 2759400 tons of waste is generated, Of this, 27.96% (771615 tons) unfortunately goes straight to unsanitary landfills; the rest is transported to transfer stations for pre-treatment and brief separation. Next, 231000 tons of waste (8.37%) are moved to a food waste facility for composting, and 18480 tons of residue are taken to landfill sites after treatment. Only 68985 tons (2.5%) of recyclable waste are recycled by social communities, of which 20695 tons residues are moved to landfill. Combustible waste of 561500 tons (20.35%) is delivered to an incineration facility, of which 101070 tons (18%) bottom ash will go to landfill.

3. Modeling by LCA

3.1 LCA

Life Cycle Assessment (LCA) is an environmental management tool increasingly used to understand and compare how a product or service is provided ‘from cradle to grave. The emissions from the system studied are classified and characterized using methodology from LCA into the following environmental impact categories: Global warming potential (GWP), Acidification potential (AP), Eutrophication potential (EP), Formation of photochemical oxidants (excluding NOx), NOx-emissions, Heavy metals (input/output analysis). [9]

The environmental results are also aggregated using monetary weightings for emissions. The aim of standardization is to eliminate the difference between the dimension and the series, but not to affect the nature of the original results [10]. The monetary weightings are based on willingness-to-pay estimates. [11]

3.2 Goal & Scope

The goal of LCA is to compare the full range of environmental effects assignable to products and services in order to improve processes, support policy, and provide a sound basis for informed decisions. [12] In this paper we assumed that the MSW generated, and all stages throughout waste collection, transfer, treatment, and final disposal in Chongqing in 2011 as the LCA scope . The goal of the LCA study is to analyze and compare the environmental impact of every scenario.

3.3 Scenarios

This chapter describes results and analysis from Integrated Waste Management (IWM-II), including waste flow, final disposal amount, gas emission, human toxicity, and waste emission [13]. Due to the current situation (2011 as current situation in this research), we assumed that government plan as Scenario I. Based upon this, four separate scenarios, including the current situation focus on sorting, incineration, Bio-treatment, and recycling, were proposed. I also assumed that if with sorting, the dumping will be zero.

3.3.1 Scenario I

The Five Action Plan for Environmental Protection covers all environmental fields. Currently, the Eleven Five Action Plan was carried out for the next (2010–2015) . The Government wants to construct another incineration plant and Bio-treatment plant to reduce the landfill amount. [14] The boundary of waste treatment flow is showed in Fig.3.

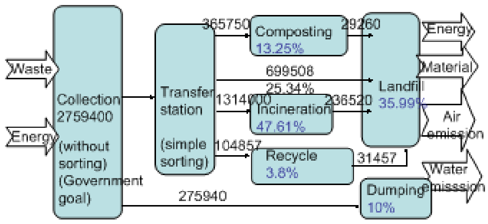

Fig.3: Boundary of waste treatment flow

3.3.2 Scenario II

In Scenario II (Fig. 4), I assumed no unsanitary landfill, so all the waste generated will be moved to a transfer station. the amount of waste for Bio-treatment and recycling is assumed to be the same as Scenario I. As the proportion of plastic (15.6%) and paper (10.10%), 551880 tons RDF (20%) are assumed. In this scenario, the amount of waste moved directly to landfill is obviously smaller than in Scenario I .

3.3.3 Scenario III

Scenario III (Fig. 5) focuses on Bi0bio-treatment. Because the food waste now collected in the urban areas is about 26.5% of the total waste.. so I assumed all of the organic waste will go to Bio-treatment with the technology of gasification.

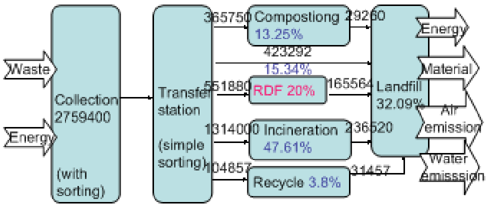

Fig. 4: Boundary of waste treatment flow

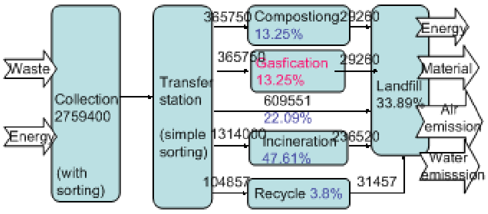

Fig. 5: Boundary of waste treatment flow

3.3.4 Scenario IV

Scenario IV (Fig. 6) focuses on recycling and tries to maintain the others proportions as in Scenario I. Paper, plastic, glass, metal, and textiles are assumed to be recycled. 551880 tons of recyclable wastes are moved to recycling facilities.

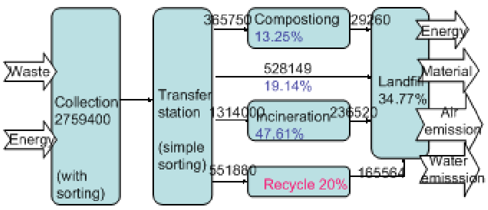

Fig. 6: Boundary of waste treatment flow

4. Results & Analysis

4.2 Amount & Final Disposal

This Paper describes results and analysis from IWM-II including waste flow, final disposal amount, gas emission, human toxicity, and waster emission. The Waste flow of each scenario formed the basic data for analysis; the research parameters of every scenario could be carried out in this part, based on the waste flow.

4.3 Gas Emission

4.3.1 Global Warming Potential

In the thermal ,Scenarios I, III, and IV, CO_2 emissions are nearly the same. The long-term effect on climate of reducing methane emissions is relatively small [15] and the concentration of the CO and CH_4 is very low. Nevertheless nearly all of the carbon content in the waste is emitted as CO_2 to the atmosphere. MSW contains approximately the same mass fraction of carbon as CO_2 itself, so incineration of 1 ton of MSW produces approximately 1 ton of CO_2 [16]. So，CO_2 is the main factor of global warming in these Scenarios. However, Scenario I has high level of unsanitary landfill, its CO_2 landfill emission are the highest. As Scenarios II focusing on RDF burning, it discharged a large amount of CO_2 (Fig.7). landfill contributes most to the GWP of the studied scenarios. Recycling of materials and nutrients shows slightly lower impact than incineration.

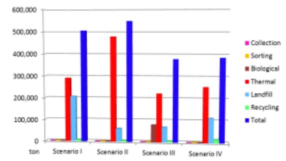

Fig. 7: CO2 emission

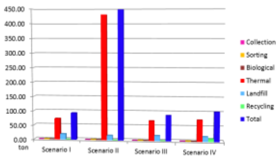

Fig. 8: CO emission

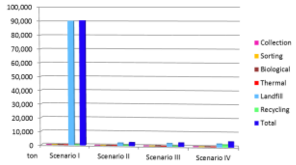

Fig. 9: CH4 emission

4.3.2 Eutrophication

Acidification potentials are mainly affected by SOx and NOx emissions (Figs. 10 and 11) [17]. Although emissions of other gases，such as HCL, HF,H_2S, and NH_3 will also cause acid rain also, the amounts are very small. The proportions of equivalent factors are 1:0.7:0.88:0.6:1.88:1.88, respectiv separately.

The acidification potential in this research does not vary greatly between each scenario, but Scenario II does not score well at acidification impact.

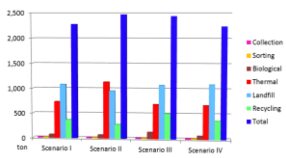

Fig 10: NOX emission

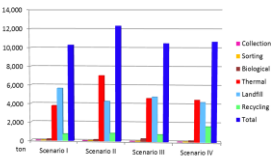

Fig. 11: SOX emission

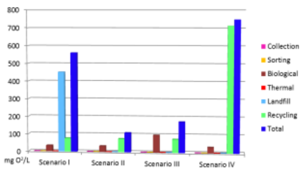

Fig. 12: BOD emission

4.3.3 Human toxicity

For metals, flows of lead, cadmium, mercury, copper, chrome, nickel and zinc were nearly the same. There are no big differences between the scenarios. The big sink for metals is in recycled materials (mostly metal containers) or in landfill after the surveyable time period. In all scenarios, almost the same amount of metals end up in the landfill, but emissions in Scenario IV were higher. Because recycling phase we should use some chemical ways to recycle materials, compared to other scenarios, Scenario IV produce more toxicity.

4.4 Integrated Evaluate

This research discusses the final results of environmental impact including GWP, acidification potential, eutrophication for every scenario proposed in this research. From these analysis we can immediately see that Scenario III was the best performer. Because of its GWP, Scenario IV was in second place, just behind Scenario III. Scenario II, which focuses on thermal treatment, accounts for 3. And Scenario I, the current situation, had the highest environmental impact because of unsanitary landfill.

5. Conclusion

The overall conclusion from the study is for the po purse of avoiding the large amount of the landfill, several waste treatments are possible and have less adverse environmental impact, using of energy resources and economy. A combination of anaerobic digestion, materials recycling and incineration would probably be the best solution to avoid landfilling as much as possible. if considering of the costs and environmental impact, the integrated waste management will be a wise choice.

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