Scenario Analysis of Municipal Solid Waste Management System in Shanghai

盧　克宇　（ロコクウ）**Lu Keyu, University of TSUKUBA**

Instructor: 水野谷　剛; 徐　峰; Helmut YABAR; 氷鉋　揚四郎;

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ABSTRACT

With the rapid development of its economy and population, Shanghai also experienced an increase in Municipal Solid Waste (MSW). The reported generation of MSW in 2007 was 7 million ton, and its treatment and disposal had become an imperative problem. This thesis was wrote under the ISO1400 framework through life-cycle assessment and calculated by IWM-II software, raised shanghai municipal solid waste management system as a research case, proposed 4 scenarios focused on current situation, thermal treatment, Bio-treatment and recycling separately and calculated environmental impact load including four aspects: global warming potential; acidification potential; eutrophication and human toxicity. This paper proposes four scenarios through a Waste Management Assessment Model that focuses on RDF and thermal incineration, bio-treatment, and recycling to analyze the environmental impact. The latter includes global warming and acidification potentials, eutrophication, and human toxicity. Calculation of the impact weighting provided the environmental impact load, and after comparisons, Scenario III was found to provide the best way forward for MSW management evaluation in Shanghai.

1.Introduction

1.1 Background

Municipal solid waste (MSW) consists of two parts: one part is generated by the citizens as they live and work in the city (like garbage, waste paper, waste plastic, old furniture, discarded appliances, cans, and bottles). The second part is generated by the service sector (such as restaurants, hotels, hospitals, and shops)[1]. MSW does not include industrial waste, agricultural waste, and sewage sludge. The treatment of MSW is an important issue that affects the city's sustainable development. The history of its treatment worldwide reveals four mature approaches: incineration (including RDF), bio-treatment (gasification and composting), recycling, and landfill. There are advantages and limitations to every treatment option, so to realize the goal of 'reduce, reuse, recycle' it is necessary to take into account the conditions within the city in order to improve its integrated MSW treatment system.

1.2 Shanghai

Shanghai is located in the Yangtze River Delta in eastern China, and sits at the mouth of the Yangtze River in the middle portion of the Chinese coast. The municipality borders Jiangsu and Zhejiang provinces to the west, and is bounded to the east by the East China Sea.

1.3 Objective of the study

This paper discusses the current MSW system and treatment options in Shanghai, and suggests an evolution of that system side by side with sustainable development and environmentally friendly solutions, through analyzing four scenarios generated by life cycle assessment (LCA).

1.4 Method of the study

In this study, I obtained data on the MSW system of Shanghai, and treatment options, from the literature. I built models using LCA, and devised four scenarios for analysis (including environmental and economic aspects), and proposed the most suitable scenario for Shanghai.

2. Modeling by LCA

2.1 Goal & Scope

In this study I assumed that the LCA scope for the environmental assessment comprised the MSW generated, and all stages throughout waste collection, transfer, treatment, and final disposal in Shanghai in 2007. This was compared and analyzed with other scenarios. The goal of my LCA study is to analyze and compare the environmental impact and cost of every scenario.

2.2 Waste generation

Table 2.1 shows waste generation from 2003 to 2007. Although the rate of increase in 2005 was a little less than that in 2004, the amount of waste in Shanghai continued to increase until 2007, when it reached the huge amount of 7,019,524 tons.

Table 2-1 Waste generation from 2003 to 2007 of shanghai

	2003	**2004**	**2005**	**2006**	**2007**
Generation (million ton)	5.85	6.10	6.22	6.52	7.02
Increasing Rate (%)	**/**	**4.27**	**1.96**	**5.78**	**6.68**

Source: city hall[2]

In 2007, waste was classified as 42.22% combustible, 21.12% organic, 11.82% paper, 9.98% plastics, 5.36% glass, 0.98% metal, 3.11% garden wastes, and 3.21% textiles (Fig. 2-1).

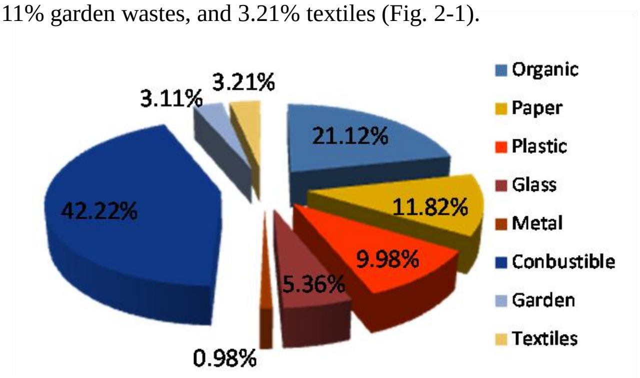

Fig 2-1 Waste proportion in 2007

Source: city hall[2]

2.3 Final disposal in 2007

In 2007, there were still some problems with waste treatment, the major one being unsanitary landfill; 19% of the waste (1,333,713 tons) were treated in this way. However, all of the treatment facilities were overloaded. In addition, 2.5% recycling was inadequate (Table 2-2).

Table 2-2 Final treatment conditions in 2007

	Rate	Amount	Capacity
Sanitary landfill	50% + residue	3,809,652	3,650,000
Unsanitary landfill	19%	1,333,713	/
Incineration	18.3%	1,287,282	1,095,000
Bio-treatment	10.2%	713,472	547,500
Recycling	2.5%	176,138	/

Source: city hall[2]

3. Scenarios

3.1 Scenario I

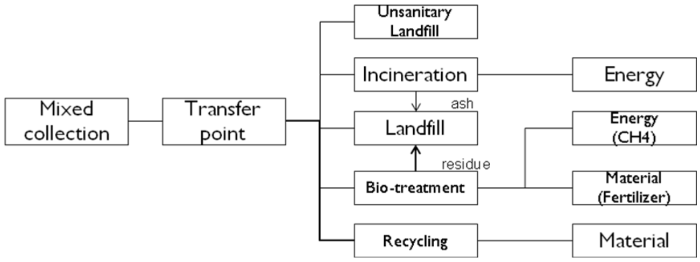

Fig 3-1 Waste flow and energy recovery of scenario I
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Scenario I (Fig. 3-1) is the current situation; waste is collected at the curbside and moved to a transfer point for pre-treatment and brief separation, then delivered to treatment facilities. In the incineration facility, a portion of the materials can be recycled after pre-treatment, with the remaining combustibles being incinerated and producing electricity. The ash will be moved to landfill.

3.2 Scenario II

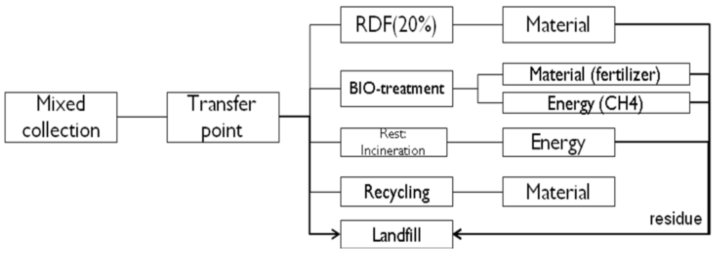

Fig 3-2 Waste flow and energy recovery of scenario II

Scenario II (Fig. 3-2) uses the same type of collection as Scenario I but focuses on different features: RDF and thermal treatment. As we know, the Shanghai government is increasing the number of thermal facilities to five from 2015, so I assumed that 20% of the waste (mainly plastic, paper, and a portion of the combustible waste) will become RDF fuel. The amount of bio-treatment and recycling is the same as in the present situation, but unsanitary landfill would be cut to zero in the following scenarios.

3.3 Scenario III

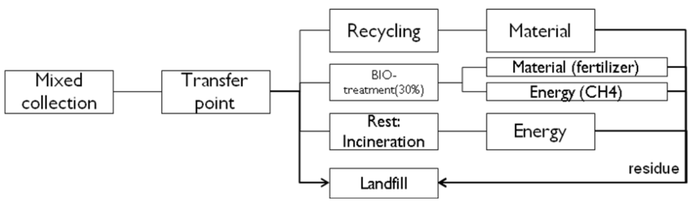

Fig 3-3 Waste flow and energy recovery of scenario III

Scenario III (Fig. 3-3) focuses on bio-treatment, dealing with 30% of the waste. It is assumed that gasification and composting are the main treatments for the MSW (which contains organic waste, paper and plastic, and garden waste). The recycling rate is the same as in Scenario I, and the remaining waste is sent for thermal treatment.

Finally, the residue is removed to landfill.

3.4 scenario IV

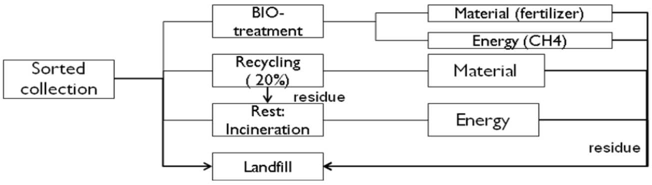

Fig 3-4 waste flow and energy recovery of scenario IV

Scenario IV (Fig. 3-4) focuses on materials recycling, mainly metal, paper, plastic, and appliances. A sorted collection has been assumed for recyclable materials, and curbside collection for the remaining waste. The bio-treatment rate remains the same as Scenario I. Finally, all the residue and bottom ash from incineration are moved to a sanitary landfill.

3.5 Characterization

Through characterization, we can transform the result to same unit and combine with results to one digital indicator. There are many ways of conducting a characterization, however, and researchers utilize different equivalency factors to express environmental impacts.

The equivalency factor varies, depending upon the different types of effect. Generally, a reference substance is used to calculate the relative amount of other factors. For instance, factors which could affect global warming include CO_2, CO, and CH_4. Usually, CO_2 is proposed as a target value to express global warming potential. For acidification, it would be SOx. Table 3-5 show four types of environmental impact factors.

4. Results & Analysis

This chapter describes results and analysis from IWM-II® including waste flow, final disposal amount, gas emission, human toxicity, and waste 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.

In Scenario I (Fig. 4-1), a total of 7,019,524 tons of waste is generated. Of this, 19% (1,333,713 tons) unfortunately goes straight to unsanitary landfills; the rest (5,685,811 tons of waste) is moved to transfer points for pre-treatment and brief separation. Next, 356,736 tons of waste (5.1%) are moved to a bio-treatment facility for gasification, and 26,309 tons of residue are taken to landfill sites after treatment. Bio-treatment facilities receive 356,736 tons of waste (5.1%) for composting, and the residue (26,310 tons) goes to landfill. Only 175,138 tons (2.5%) of recyclable waste are recycled by social communities, of which 53,106 tons are moved to an incineration facility after recycling; 5,901 tons of recycling residues are moved to landfill. Combustible waste of 1,287,282 tons (18.3%) is delivered to an incineration facility, of which 120,836 tons go to landfill and 5,768 tons go for recycling after pre-treatment; 1,160,678 tons will be incinerated, and finally the bottom ash (121,378 tons) will go to landfill.

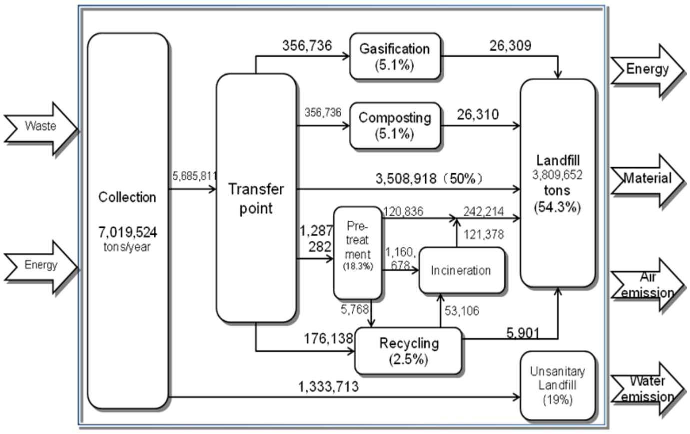

Fig 4-1 Boundary of scenario I

This section discusses the final results of environmental impact including GWP, acidification potential, eutrophication, and human toxicity for every scenario proposed in this research. The total environmental impact amount (for every 1 kg) was 0.0354, 0.0285, 0.0230, and 0.0232 for Scenarios I, II, III, and IV, respectively. From these digital indicators 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, lost out because of the GWP. And Scenario I, the current situation, had the highest environmental impact because of unsanitary landfill (Table 4-1).

Table 4-1 Environmental impact

Environmental impact type	Scenario I	Scenario II	Scenario III	Scenario IV
Global Warming Potential	1.63E-02	5.94E-03	3.57E-03	3.97E-03
Acidification Potential	1.53E-02	1.81E-02	1.55E-02	1.56E-02
Eutrophication	3.81E-03	4.40E-03	3.89E-03	3.75E-03
Human toxicity	2.63E-08	2.49E-08	2.73E-08	4.39E-08
Total environmental impact	3.54E-02 (0.0354)	2.85E-02 (0.0285)	2.30E-02 (0.0230)	2.32E-02 (0.0232)

5. Conclusion

This thesis was written under the ISO1400 framework through LCA and calculated by IWM-II software, using the Shanghai MSW management system as a research case. It proposed four scenarios focusing on the current situation, thermal treatment, bio-treatment, and recycling, separately. The calculated EIL included four aspects: GWP; acidification potential; eutrophication; and human toxicity. Additionally, this thesis expressed the application of LCA methods for MSW management systems. The conclusions were as follows:

(1) There are many ways of evaluating an MSW management system. It could be broadly grouped into three methods according to different theories: cost benefit analysis (CBA), multicriteria decision analysis (MCDA), and life cycle assessment (LCA). These three methods focus on different points in the analysis of a waste problem, and the LCA method was the most suitable for this thesis because it focuses on analyzing the relationship between the material and its environmental impact, consistent with the goal of MSW management.

(2) The current MSW situation in Shanghai was so poor that its citizens were concerned about it. The major problem was open dumping (unsanitary landfill), caused by limited waste treatment capacity and lack of participation (illegal dumping) by citizens.

(3) Four scenarios (including the current situation) were proposed in this thesis. They focus separately on thermal and RDF burning, bio-treatment, and recycling. The EILs (per 1 kg) were: Scenario I: 0.0354; Scenario II: 0.0285; Scenario III: 0.0230; and Scenario IV: 0.0232. When considering environmental impact, bio-treatment is seen to be the best means of addressing the MSW situation in Shanghai in order to meet national objectives, on paper at least. The current situation was found to be the worst, so government must take action to deal with it. The landfill use of Scenario II was found to be the best; government could adopt this scenario to meet the land shortage. Discovering that the EIL of recycling was a little higher than bio-treatment was an unexpected finding; Scenario IV also could be a good solution if the recycling technology could be upgraded. The present situation in Shanghai is that space for landfill is limited, so from a local governmental viewpoint, Scenario IV could be the best MSW solution if attention is paid to landfill use.

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There are certainly many limitations in using the LCA method to analyze MSW. First, the EIL—which was the only indicator to be quantized—is not the only base point from which to examine the MSW system. It should be based on other indicators—social, technological, and economic—as well. On the other hand, detailed data for the MSW were incomplete, thus many data adopted in this research were acquired from some developed countries; the result could be more accurate if detailed data for Shanghai were available.

It was different from developed countries that built LCA models for MSW management with the use of software such as IWM, IWM-II, and WISARD. In general, much research in China focuses on literature reviews alone. I suggest that China should standardize the LCA model of MSW management and build a detailed database for it, to enable researchers to obtain data more easily and work out more accurate research results for China, with the aim of establishing a sustainable society.

References

[1] Department of Environmental Protection of the People's Republic of China "Law of The Peoples Republic of China on Prevention of Environmental Pollution Caused by Solid Waste", 2004 revision.p.37-39.

[2] Date collected by an interview at Shanghai city hall.September.2011.