Abstract

As the fast development of the urbanization and the growth of GDP in China, there is and will be more and more demands for energy consumption. In the meantime, it also creates a growing number of municipal solid waste (MSW), especially in the recent years, MSW has experienced a dramatic increase. However, the MSW management system is poor and cause many pollution problems in the cities of China, especially in the middle and small cities, at the aspects of waste collection, waste sorting, recycling and so on. Therefore, the development and optimization of MSW management is needed to solve the present pollution problems and improve the energy efficiency from the angle of waste handling.

Based on studying the Danish waste treatment and Vestforbrænding, the thesis will compare it with China’s present waste management situation, and the problems and gaps will be clearly seen from the comparison. Then the thesis works on transporting the possible and available experiences from Denmark to optimize China’s MSW management. Finally, the thesis provides recommendations on how China can create MSW management systems and policies by considering the Danish case.
Acknowledgements

Firstly, we are especially grateful to our supervisors: Rikke Bak Lybæk and Børge Klemmensen for their guiding of our thesis and also their comments and suggestions during the work on the thesis. Besides, we will thank our opponent group- Alexandra Osteyee-Hoffman for her helpful information and comments.

Then, we would like to thank our interviewee-Fei Yu, who offers us insightful information and comments and very valuable pictures for the thesis. And we also thank Søren Skov for his information supply and comments on Danish waste treatment model, and Vestforbrænding for its detailed information. In addition, we are thankful to our classmates for the patient discussion on the waste management: David Mckinnon, Vibek Raj Maurya, and Carlos García-Robles.

Last but not least, we are greatly indebted to our family for their love, encouragement and support during the long and hard working period.
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## ACRONYMS AND ABBREVIATIONS

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<thead>
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<th>Full Form</th>
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</thead>
<tbody>
<tr>
<td>CEETA</td>
<td>China Energy and Environmental Technology Association</td>
</tr>
<tr>
<td>CMRC</td>
<td>China Market Research Center</td>
</tr>
<tr>
<td>COP</td>
<td>Conference of the Parties</td>
</tr>
<tr>
<td>COWI</td>
<td>Consultancy within Engineering, Environmental Science and Economics</td>
</tr>
<tr>
<td>DAKOFA</td>
<td>Dansk Kompetencecenter for Affald (Danish Competence Centre on Waste)</td>
</tr>
<tr>
<td>DKK</td>
<td>Danish Krone</td>
</tr>
<tr>
<td>EU</td>
<td>the European Union</td>
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<tr>
<td>EPA</td>
<td>Environment Protection Agency</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>HCI</td>
<td>Hydrochloric acid</td>
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<tr>
<td>MEPPRC</td>
<td>Ministry of Environmental Protection of the People’s Republic of China</td>
</tr>
<tr>
<td>MSW</td>
<td>Municipal Solid Waste</td>
</tr>
<tr>
<td>NBSC</td>
<td>National Bureau of Statistics of China</td>
</tr>
<tr>
<td>NDRC</td>
<td>National Development and Reform Commission</td>
</tr>
<tr>
<td>SICPEP</td>
<td>Sino-Italian Cooperation Program for Environmental Protection</td>
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<tr>
<td>TOC</td>
<td>Total Organic Carbons</td>
</tr>
<tr>
<td>UN</td>
<td>the United Nations</td>
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<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<td>WB</td>
<td>World Bank</td>
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1 Introduction

As the increasing of each country's attention on environmental issues, a lot of environment problems have been proposed, which accelerates the pace of environmental pollution control at the same time.

At the macro level, all countries should strengthen technical cooperation. Take developing countries for instance, they are studying on new energy and renewable energy. On the premise of protecting ecological, many countries speed up to develop hydropower, nuclear power, biomass, solar, geothermal, wind and other new renewable energy sources.

However, we can find a common problem that exists in the developing countries. On the positive side, developing countries make great efforts on energy conservation and utilization of new energy. But it can not be ignored that the great demand for energy in developing countries and the meaning behind growing demand for energy, such as expanding of cities, mixing the old systems with new technologies, poor infrastructure and even the confliction between the interest and environment.

Take China for instance, Chinese recent GDP growth has been maintained at around 8% (NBSC, 2010). A series of GDP figures also means a series of problems behind. In China, there are a large number of carbon-intensive manufacturing. Behind the rapid growth of GDP, there are a large number of factories were established. While the large number of factories means the inevitable expansion of the scale of cities. With the rapid development of modern urban construction, urban population and the people’s consumption are also gowned. However, in the meantime, it also creates a growing number of municipal solid waste (MSW). Although the MSW disposal problem is one of the problems in most of the countries at present, the situation in developing countries are more serious.
1.1 Problem Field

From 1979 to 2005 (it is almost same in recent 5 years) the MSW annually increasing rate is 7.08% in China (see Figure 1-1), which means MSW grows so fast which should be concerned seriously (China Statistical Yearbook, 2006/2009).

Figure 1-1 MSW Increasing Rate from 1979 to 2005

In most of the cities in China, there should be the governance on the waste pollution, which is very necessary. From the aspect of the waste treatment process, there are two main ways related the emissions reduction:

1. First of all, the waste treatment will result the resource use. It means the good waste treatment system will reduce the carbon dioxide emissions. If there is no proper waste treatment system, the waste will release many kinds of greenhouse emissions, like CO2 and methane and so on (Liming Shao et al., 2010).

2. Furthermore is the indirect way. Improving the energy efficiency during the process of waste treatment will results the emissions reduction from the aspects of other industry. This means waste reuse and recycling of products, will save using of resource for the production. In addition, the incineration plant would also
Municipal Solid Waste Management in China

substitute for the normal coal-fired power plant for the emissions reduction (Yoshiaki Matsuzawa et al., 2007).

Mixed collection is the most used way for waste collection in China, no matter in the big, middle, and small cities, which is very hard for the waste treatment. That is also the main reason why the number of the equipments for waste treatment is increased annually, whereas more equipment can not meet demand of the fast development of the cities. By the end of 2008, the rate of the waste treatment is about 2/3 (will be described in chapter 3) (China Statistical Yearbook, 2009). And there is little reuse or recycle of the waste and a large number of resources are wasted.

Moreover, from the China Statistical Yearbook, by the end of 2008, the most treatment way is landfill (81.7%), and 15% of incineration (Ibid). However, the incineration system is not mature in China, which includes:

- **The conflict between the waste reduction and the waste recycling**

  Incineration plant requires a lot of capital investment, but he economic returns less. In order to maintain the normal operating state, the incineration plant needs the continuing waste supply. The incineration plant is the privately owned in China, there is always the long term “put-or-pay” agreement between the incineration plant and the local government to ensure the waste is sufficient for the incineration plant. If the waste supply is insufficient, the government has to give subsidies in order to fulfill the agreement. But such an approach would reduce the local government waste reduction and recycling initiative, but encourage more waste. Additionally, the incineration plant would compete with the recycling system to get the waste, especially the combustible material, such as paper, textiles, plastics and wood, etc., which are precisely the high value recovery (Chitian Wu, 2007).

- **Economic impact because of the shortage of the incineration technology in China**
The cost of the incineration plant with advanced pollution control systems is very high (5-8 billion U.S. dollars). The low cost of the incineration plant is shortage for the pollution control, because the control equipments are the main cost of the incineration plant. Secondly, the disposal of the ash from the incineration plant also requires high cost because of its hazardous nature. In addition, the cost of the pollution emissions testing is also very high. Hence it is difficult to detect the incineration plant and it is hard to guarantee the good functioning of the emission control equipments. In China, most of the incineration plants can not reach the high level as described above, because the incineration plants are always private owned and they always choose the low cost equipments (Chitian Wu, 2007).

But in the developed countries like Denmark, the landfill proportion is even not more than 10% (Henrik Wejdling, 2008). And also Vestforbrænding has the biggest incineration plant in Denmark, which has the mature and advanced incineration system.

Last but not least, there are many problems of the waste management in China. The syncretic of the government and enterprises mechanism is unreasonable, which causes the poor management and not valid monitor system (detailed in chapter 3). In addition, the charge system and the taxation system are not good enough.

Therefore, we want to get some ideas from connecting this situation with the Vestforbrænding and think that if there are some experiences and technology could be transferred to implement the better waste management system in China. There is an old word from Laozi\(^1\)-delegate to the fish, it is better to delegate to fish. The key point is how to delegate to fish. It means teach someone how to fish himself/herself instead of just giving him/her the fish, which also means that it is better to teach someone the methods for solving the problems. From the word, we think that the best way to help

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\(^1\) Laozi (“Old Master,” sixth or third century b.c.e.) The concept of Dao is more often associated with the figure Laozi and the classic Dao de Jing (The Book of the Way and Its Power) than with Confucius ([www.asiasociety.org](http://www.asiasociety.org), 2008).
China optimizing the waste management system is to study the advanced management system from developed countries and how it could be applied in China.

At the same time, once the system could be proved right, and developed greatly. There will be more confident of the China’s government, which will be make the international cooperation more possible, and contribute to the global emissions reduction.

1.2 Research Question

*How to optimize MSW management system and make it more efficient in China?*

*Sub-questions*

*Question 1--What is the present situation of MSW management in China?*

*Question 2--What are the problems of MSW management in China?*

*Question 3--How is waste management in the case city?*

*Question 4--How is Danish MSW management?*

*Question 5--What are the benefits and issues from Danish waste treatment model?*
1.3 Purpose of the Thesis

The aim of this thesis is to optimize the MSW management system in China, by transferring the experiences and the available policy, economic instruments, and mechanisms from Danish waste treatment model. The end goal is to implement a successful waste management system in the city of Tieli and to promote the MSW management in China.
2 Methodology

In this chapter, we will present the research approach, which contains a description of theory, case study, and the project design part.

2.1 Analytical Framework

In the thesis, we will compare the waste management between China and Denmark based on the aspects of waste pre-treatment, waste incineration, types of the waste treatment company, taxation and subsidy mode, public awareness and waste hierarchy to find out the answer of the research question. The aim of the thesis is to workout the solutions to implement the China’s waste management system on the basis of Danish experiences.

Figure 2-1 Analytical Framework
2.2 Project Design

Chapter 1, Introduction
- Fast development of urbanization — emissions reduction — waste problems in China

Chapter 2, Methodology
- Project design, case study, theory, interviews

Chapter 3, Concepts of Waste Handling
- Outlining the used concepts — Danish model, waste hierarchy, theory of “cradle to cradle”.

Chapter 4, MSW Management in China
- Introduction of China’s problems on MSW Management + case study on the city of Tieli

Chapter 5, MSW Management in Denmark
- Introduction of Danish waste treatment model + case study on Vestforbrænding

Chapter 6, Comparison & Analysis
- What can be transferred from Denmark to China? And how to support this?

Chapter 7, Conclusions
- Conclusions of comparison & analysis and recommendations
2.3 Empirical Data

2.3.1 Interview

During the thesis work on the Danish waste management model, we interviewed Fei Yu—a Chinese journalist of Jin Ling Evening News who came to Copenhagen for COP15, and also visited Vestforbrænding. During his visit to Vestforbrænding, he interviewed Søren Skov—the Information Officer of Vestforbrænding and offered us a lot of important information about Vestforbrænding, and some relevant pictures about Vestforbrænding’s waste collection, sorting, recycling and incineration, which are really helpful for our researching on the Danish waste treatment model especially on the Vestforbrænding case.

2.3.2 Case Study

In our thesis, case study is the most important part to support the MSW management. In China’s MSW management part (chapter 3), we choose the city—Tieli of Heilongjiang Province as our case city. We collect the data from each procedure of MSW management in this city, to find out what are the barriers, the shortages and the problems compared to the advanced mechanism, of the waste management in Tieli. Hence we research on Danish Model on the waste management which is the way we need to study. The available experiences, the mechanisms, and some technique could be transferred to promote China’s MSW management. We also have a case study on the Danish incineration-Vestforbrænding, which will introduce the advanced system for the waste incineration.
Why we choose Tieli as our case city?

First of all, the most serious MSW problems in China does not exist in the first-tier cities (Beijing, Shanghai, etc.), but in the second-tier and third-tier cities, especially in the small cities. We choose the city as our case city to support the problems analysis in China. Tieli is the city located in the Heilongjiang province, the population is only about 400 thousand and the total jurisdiction area is only about 1/3 of Beijing, the city urban area are very small, only 15.18 square kilometers. Therefore, Tieli can represent many small cities in China on the status of waste management, which is in the initial stage of waste disposal and there is no strong management and technology (website)

In addition, we choose the city of Tieli for case study on the waste management because it located in the very north of China. In China, the waste problems in the northern China are much serious than the southern China, because the temperature of northern China is much lower compared to the southern China. Especially in the Heilongjiang province, the winter will last about 6 months (average lower than -10 degree Celsius) and the annual average temperature is 5 degree Celsius, which causes that the waste problems are not prominent and not be considered seriously by the local government (website). Whereas in the southern China, because of the average temperature is almost 20 more degree Celsius than northern China (website), and the waste problems are prominent and the awful smell from the waste would spread in the city if the local government does not pay attention to the waste treatment. Therefore, from this perspective of view, the waste management in northern China is much worse than in southern China.

Why we choose Vestforbrænding for case study?

In Denmark, the incineration plant such as Vestforbrænding is not only working alone
on the waste incineration, instead, the incineration plant is one section of the waste treatment system, which could be a good idea for implementation of the China’s waste management system. In addition, Vestforbrænding is the waste treatment company with the biggest incineration plant in Denmark, which could be the good example for researching on the Danish waste treatment model. Besides, Vestforbrænding has the advanced incineration system with the waste pre-treatment, recycling, and recovery, power supply and district heating, which are the key elements should be considered to implement the China’s waste management system.

2.4 Content of Chapters

In this section, the structure of the thesis is outlined with a framework, and we will guide the reader with an introduction from chapter 3 to chapter 7, which makes the thesis clear to the reader.

Chapter 3
The concepts of the thesis we are going to study are outlined in this chapter. Firstly the Danish waste model will be introduced and then there will be a detailed description on the waste hierarchy. And the China’s waste hierarchy and Danish waste hierarchy are also introduced in general. At the same time, we give some options to improve the China’s waste management system with the theory of “cradle to cradle”.

Chapter 4
In this chapter, firstly the present China’s MSW situation will be described, which is very serious in China. Then we will introduce the problems of MSW management because China’s MSW management needs more improvement. We will also research MSW management of our case city to analyze the management shortages in detail.

5 http://www.vestfor.com
Chapter 5

Denmark is the country which is superior on waste treatment and management. So in this chapter, we will study Danish waste management from each aspect of the waste treatment in Danish Model to describe the Danish experiences. In the end of this chapter, we will have a case study of Vestforbrænding, which is an environmental company creating solutions in the waste management area, especially on the Danish incineration.

Chapter 6

This is the comparison and discussion chapter. We will compare the different model of MSW management between China and Denmark. The key of this chapter is what can be transferred from Denmark to China, and how to implement China’s waste management system on the basis of the transferred experiences.

Chapter 7

In this chapter, we will get back to the research question to outline the answers of the sub-questions of each chapter. Base on this, we will workout the conclusion of the thesis, which includes the policy recommendation and the solution on the main question.
3 Concepts of Waste handling

3.1 The Danish Waste Model

Denmark has a close interplay between EU regulation and national regulation on waste. EU regulations lay down overall frameworks and principles, whereas the Danish Folketing\(^6\) desides on organisation and legislation in the area of waste.

**Why we choose Danish model?**

First of all, Denmark is the country which has the high concious of the waste management. The schemes of the waste sorting and source separation enjoy sidespread acceptance and are used extensively by citizens and enterprises. From the collection to the incineration, the waste is treated reasonably in each steps. That is why there is about 65% waste recycling in Denmark (see chapter 4)(DAKOFA, 2008), which is very high even in developed countries. In addition, the waste managment system in Denmark is mature from the perspective of the waste sorting, waste transportation, especially the waste taxation, charges, subsidies, and deposite-return, which is included in Danish Policy Instruments(Danish Ministry of Environment and Energy, 1999).

Vestforbrænding is the waste treatment company which has the biggest incineration in Denmark, and it is representative for the Danish model of MSW management. Besides, Vestforbrænding has the advanced incineration system, especially the waste pre-treatment (Søren Skov, 2009), which is really important for the waste reuse, recycling, and recovery, and could be transferred to China to improve the energy efficiency.

\(^6\) National Parliament of Denmark
Last but not least, Denmark is the world’s leader in district heating, and has already made a great improvement for the energy saving and CO2 emissions reduction. Vestforbrænding’s district heating supply constitutes an integral part of the coherent district heating system in the Greater Copenhagen Area, where environment-friendly and energy-efficient waste-based heat is supplemented with heat from the combined power and heating plants (website of Vestforbrænding)\(^7\). This is one of the important reasons to choose Denmark and Vestforbrænding for case study.

### 3.2 Waste Treatment Hierarchy

The waste hierarchy is extensively used by governments, industry, educators and environment groups as a guiding principle for waste policy and programs, which specifically states that waste should be managed in accordance with the following order of preference: reduce, reuse, recycle, recovery of energy, landfill (J Gertsakis and H lewis, 2003).

![Figure 3-1 the Waste Hierarchy](http://wasteawarebusiness.files.wordpress.com)

Source: [http://wasteawarebusiness.files.wordpress.com](http://wasteawarebusiness.files.wordpress.com)

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\(^7\) [http://www.vestfor.com](http://www.vestfor.com)
The waste hierarchy is a list of approaches to managing waste, arranged in order of preferability. The waste hierarchy is widely used as a simple communication tool for waste management, which is the strategies to avoid products becoming waste and seek to find a use for waste (J Gertsakis and H Lewis, 2003).

In this thesis, we are going to use the waste hierarchy to analyze the China’s MSW management and compare with the Danish waste treatment model, to improve the waste management system in China base on the waste hierarchy.

Figure 3-2 Differences Between the China’s Waste Hierarchy and Danish Waste Hierarchy

From Figure 3-2, we can see that the present China’s waste hierarchy has problems for each aspect, such as landfill is the least priority in the waste hierarchy, but in Chinese present situation, landfill occupied more than 80% for waste disposal (China Statistical Yearbook, 2009). However, in Denmark, landfill only occupied a little—9% (Henrik Wejdling, 2008), because most of the waste is reused and recycled. Therefore, the solutions to improve China’s waste management system is to
change “China’s triangle” into “Danish triangle”, which means to lower the landfill proportion and increase the proportion of waste reduce, reuse, and recycling (3R).

3.2.1 Theory of ”Cradle to Cradle”

As for MSW, it is not just waste, but it is also the resources that we should treat. From the above description, the way that reduces MSW is the first and most important way. Cities should avoid excessive wastage of resources, which includes goods packaging for Products, recycling of material, and the economical use in public life, etc..

”Cradle to cradle” is designed to stop the cycle of use-waste-pollute, which suggests that certain products could be reused endlessly to make similar products (cradle to cradle), rather than recycled into lower-grade products until the last stop is a landfill (cradle to grave) (William McDonough et al., 2002). That means that the products described above can be used, recycled, and used again without losing any material quality—in cradle to cradle cycles (Ibid). Therefore, it could be the good way for reducing the waste from the raw materials of the products instead of using more and more virgin materials. Besides, considering from the waste hierarchy, it also increases the proportion of the waste reuse. Hence when we face the problems of municipal solid waste, this theory can bring us the possibility for the breakthrough. All in all, ”cradle to cradle” plays an important role to develop the China’s waste treatment hierarchy and implement the China’s waste management system.
4 MSW Management in China

In this chapter, firstly we are going to introduce the present situation, the problems, and the shortages of China’s MSW management. Secondly, we will focus a case study on a city to describe the MSW management in the city of Tieli. And then, we are going to find out the main reasons of the China’s waste problems, what are the keys and directions to optimize the MSW management in China, and to summarize them at the end of this chapter.

What is MSW (Municipal Solid Waste)? Generally speaking, MSW is the solid waste from the households and production of the city, which is defined as including different types of waste in different cities (see Table 4-1).

<table>
<thead>
<tr>
<th>Waste types</th>
<th>Countries</th>
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<tbody>
<tr>
<td></td>
<td>households</td>
</tr>
<tr>
<td>Denmark</td>
<td>×</td>
</tr>
<tr>
<td>Finland</td>
<td>×</td>
</tr>
<tr>
<td>Sweden</td>
<td>×</td>
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<tr>
<td>UK</td>
<td>×</td>
</tr>
<tr>
<td>Spain</td>
<td>×</td>
</tr>
<tr>
<td>Italy</td>
<td>×</td>
</tr>
<tr>
<td>Germany</td>
<td>×</td>
</tr>
<tr>
<td>Austria</td>
<td>×</td>
</tr>
<tr>
<td>China</td>
<td>×</td>
</tr>
</tbody>
</table>

Source: Bingxing Bian, etc., MSW Treatment and Technologies, 2005

In this thesis, MSW will be defined based on the waste kinds of households, industry and hazardous. And as the matter of fact, what is included in MSW is not our focus of
the thesis. Instead, the focus is how to solve the waste problems and how to make a waste management system on the whale.

4.1 The MSW Situation and Hazardous to Human Life and Environment in China

*Question 1--What is the present situation of MSW management in China?*

4.1.1 The Waste Covers A Lot of Area

The waste piling up in the suburbs, occupies large tracts of farmland. In some cities, the residents just throw the households waste in the suburbs, such as the coal-residues in Picture 4-1, and this is one of their waste disposal ways. The result is that waste would stay in the nature for a long time, such as the plastic products which is very hard to be degraded even in some hundred years, and there are some waste will take even more to be degraded such as glasses (Li Wang, 2006)

*Picture 4-1 Waste in the suburbs*

Source: China Environmental Protection Foundation, 2009
4.1.2 Polluting Water

If there is not a good waste management system in the cities, the waste will be not just in the suburbs. Instead, the waste would be everywhere around the city. It is shown in Picture 4-2 that the waste polluted the river so seriously.

There are not only a large number of pathogenic microorganisms of the waste, but also releasing many organic pollutants, which would be also dissolved and the heavy metals in the river. The hazardous stuff of the waste would go into the surface water easily through the rain or something, and will also through the rivers, lakes and oceans, which would cause more pollution (Li Wang, 2006).

Picture 4-2 Waste Pollutes Water

Source: China Environmental Protection Foundation, 2009

4.1.3 Air Pollution and Hidden Danger of Fire

The waste is a complex mixture, and the organic matter would be decomposed and release the ammonia to the atmosphere during the open-air transportation.
The waste contains a lot of combustible and even the methane gas if the waste is stacked in the air, which could cause the fire accident (Li Wang, 2006).

**Picture 4.3 Air Pollution of the Waste**

(China Environmental Protection Foundation, 2009)

### 4.1.4 The Waste Hierarchy in China

In China, there are three ways of the waste disposal-landfill, compost and incineration, and mostly used way is landfill. In 2008, there is totally 155 million tons consumption waste collected and transported. However, the volume of waste disposed is only 100 million tons, which accounted for 81.7% of landfill, 15% of incineration, and 3.3% of other kinds of waste disposal including compost (China Statistical Yearbook, 2009).

However, in China, the present level of MSW management is low and disordered and lack of unified organization and management, which causes the shortages and many problems for the waste recycling and reuse. For instance, in some cities, there are some facilities for the waste recycling with few relevant measures and policies on the
recycling system, and there are only some local residents who live by picking up and returning the bottles, paper and scrap metals etc.. It brings the other problem that the people who recycle the waste only depending on the business value of the waste instead of the issues related to the waste reuse and recycling (own descriptions base on seeing from some cities). In addition, there is little awareness on the waste reduction, which whereas should be considered firstly and has the highest priority for the waste management according to the normal waste hierarchy.

**Figure 4-1 China’s Waste Hierarchy**

![China’s Waste Hierarchy Diagram]

**Sum-up of the question 1**

In China, there are plenty of waste not disposed which cause many pollution such as air pollution, water pollution and covering the area. As for the disposed waste, landfill is the most used mode; composting and incineration only occupied less than 20% of the disposed waste.
4.2 The Problem of Landfill

*Question 2-- What are the problems of MSW management in China?*

Landfill is one of the last preferred methods to dispose the waste, but it is still popular in many countries, especially in China.

In China, there are three kinds of landfill sites are used:

- **Simple and easy landfill site (IV class)**
  
The waste would be directly landfilled without any pollution control or other treatment before landfill process. At present, this kind of landfill site occupied around 10% (50% by 2004) of the landfill sites in China, mostly in some small and undeveloped cities. The feature is that there is no consideration on the pollution protection. Obviously, this is the way with most problems and pollution (Yi Zhang, 2004; Ministry of Environmental Protection of the People’s Republic of China, 2009).

- **The controlled landfill site (III class)**
  
  At present, this kind of landfill site occupied 34% (30% by 2004) of all kinds of landfill sites in China. There are some protection measures applied by using this kind of landfill way, which means the government has already paid some attention on the pollution control of the landfill. However, the waste pre-treatment for the landfill is not enough and can not reach the standard, because of the lack of the related technology and knowledge such as the impervious measure and leachate security (protecting the surrounding soil and groundwater) (Ibid).

- **Sanitary landfill site (II & I class)**
  
  These kinds of landfill site are mostly applied by the developed countries, which are the best ways of waste landfill. In China, sanitary landfill site occupied 57% of all the landfill sites. By the way, class I sanitary landfill site has the more advanced disposal equipment and technology and with less impairment than class II class sanitary (Ibid).
There are 4 basic requirements of the sanitary landfill site:

1. Leachate collection and treatment must be stressed as a basic requirement, which can reduce leakage from the base of the site (leachate) and help reduce contamination of groundwater and surrounding soil.

2. Formal engineering preparations. There should be the investigations on the local geological, and also the waste disposal plan and the final restoration plan.

3. Permanent control of the site preparation and construction, and the deposition of waste and the regular operation and maintenance.

4. Planned waste emplacement and covering: waste should be spread in layers and compacted. A small working area which is covered daily helps make the waste less accessible to pests and vermin (Thurgood Maggie, 1999).

From class I to class IV, there are more and more hazards of the landfill sites. And now the class III and class IV landfill sites are required to be closed or reformed (Yi Zhang, 2004).

There are a lot of shortages of landfill in the different aspects. Firstly, landfill could be the way to collect the gas from the waste, but it is only the one-time “recycling”. Secondly, the air pollution of the marsh gas from the waste. Methane is one of the six kinds of gas that required by UN to be limited and reduced, and it has 21 times more harmful than CO2. Thirdly, landfill will result the “second pollution”, which needs more huge investment to manage it. Last but not least, landfill wastes a lot of land resources (Rong Huang et al., 2009).

Normally, the waste management measures are just considered base on the normal rate for the growth of the waste. However, it is not considered that the fast development of the cities causes the high-speed growth of the waste. For example, in 2002, Ministry of Environmental Protection of the People’s Republic of China planed to implement the landfill gas collection systems in the cities, and to use the gas for the electricity generation, which had three steps (SICPEP, 2002). First, there were three pilot cities-Nanjin, Maanshan and Anshan. It means that there would be new landfill
gas collection systems developed in these cities, which would collect the gas for the electricity generation or for the residents use. The second step is spreading the experience to a few cities, which is that in that next 5 years, there would be 30 more landfill gas collection systems built in China. The third step is the large-scale implementation step. The China’s government planned that until 2015, there would be 300 more systems built all over China, which could handle 100 million tons waste annually (SICPEP, 2002).

However, as the fast development of the cities, there are some new problems. As for Beijing, the landfills overload is becoming more and more serious, and there are 2 landfills have been closed. More seriously, the 13 landfills will be full and closed around 2014 (Panming Wei, 2009). As the fast growth of the waste, and new waste disposal facilities implementation is facing various pressures because it is hard to find a “perfect” waste management system. Therefore, the landfills are now under the pressure of being rapidly filled up, which cover 90% of the waste in Beijing. Once they are filled up, where is the waste going to?

This is the only the example of the big cities. However, in some secondary cities and our case city face more serious problems. The waste disposal in some cities is the open-air piled up, which results the serious phenomenon-“waste surrounding the city”. However, in most of the secondary cities (middle and small cities), they have to use the open-air piled up to deal with the waste. The reason is that the landfill site can only be used for 20 years, which can not accommodate the fast development of the cities. Moreover, the more and more waste will result the landfill sites "eating to much” in some cities (own descriptions base on seeing from some cities).

4.3 The Shortages of Composting

Composting is nature's way of recycling. Composting biodegrades organic waste. i.e.
food waste, manure, leaves, grass trimmings, paper, wood, feathers, crop residue etc., and turns it into a valuable organic fertilizer (Son, S.K., 2007). Therefore, the waste sorting is the key pre-treatment for composting to make sure the high quality of the fertilizer. However, in China, due to the lack of waste sorting, it is hard to manage the waste composting.

Basically, waste composting is also the way to dispose the waste for one-time “recycling”. However, as the waste is mixed to be collected, there are many material such as glasses, plastic and metals which is not good for the soil. Hence it is difficult to maintain the high quality of the “fertilizer”, and moreover, the cost of the production is high, which results that it is difficult to implement and expand the composting sites.

4.4 Waste Incineration—Could Not Be the Better Way

As China’s accelerated urbanization and limited land resources, compared with the large landfill area, the waste incineration which covers smaller land will become the first option.

As the experiences from developed countries, many countries recognize that waste incineration is meaningful for saving the land, and especially the countries with fewer land, the waste incineration is chosen as the main method to process the waste. Experts estimate that Japan is home to nearly 70% of the world’s waste incinerators and nearly three-quarters of the nation’s waste is burned in these facilities (Mick Corliss, 2009). In addition, mature processing technology will not cause the secondary pollution when the landfill happens after incineration; and during the incineration process, 90% of the waste volume and 75% of the waste weight could be reduced; in the mean time, the incineration residues can also be reused (Biling Pan, 2009).
In Japan, the incineration technology is so mature that the incineration plant is built near the residential community because the pollution is absolutely controlled (Mick Corliss, 2009). In Denmark, Vestforbrænding has the biggest incineration plant and all waste, which is not recycled and suitable for this treatment option, is incinerated. In addition, it has the mature control of the pollution of the incineration plant, which will be described detailed in Chapter 4.

4.5 The Problems of the Direct Incineration

Waste incineration is one of the important roles of waste management. If there is no space for the landfill in some cities, the incineration sounds the best way to handle the waste. However, there are some shortages and problems of the incineration. We should also consider the harm of it when we use the incineration.

4.5.1 The Incineration Hazard to the Environment

4.5.1.1 Dioxin Emissions

According to the report of UNEP chemicals on a global scale, the incineration plant produced a major source of dioxin. For instance, in Japan, 93% of the dioxin air emissions were from incineration plants; Sweden 85%, UK 79%, Denmark 70% (UNEP, 1999). But in the recent years, most of the developed countries such as the countries of EU and Japan adopt more stringent emission standards for dioxin emissions control, and it made a significant progress that effectively reduced the dioxin emissions (Lijuan Zhou et al., 2006).

4.5.1.2 Hazardous Nature of the Ash from Incineration

A lot of part of the dioxin from the incineration plant is actually produced during the
process of cooling the burning gas (especially in the temperature at 200-400 degrees), rather than just inside the plant. Therefore, it is not correct that a certain temperature for burning the waste will not produce dioxin in the plant. In the now days, there will be the cooling system to cool the burning gas very fast, which however has the contradiction with the purpose of the incineration plant-electricity generation. Whereas, if the activated carbon is used to accumulate the gaseous dioxin and the heavy metals such as mercury to results the adsorption, the high concentration of dioxin, the heavy metals and many kinds of pollutants will be stay in the fly ash which is blocked by the filter layer-the activated carbon. As for the heavy metals, they will not be destroyed or reduced in the incineration process, which will be easier to be into the environment or the human body if the heavy metals become the gaseous state after the incineration (UNEP, 1999).

4.5.1.3 The Treatment of the Ash

The treatment of the ash we mentioned above is really an important problem. At present, the landfill is the mostly used way for the fly ash in the western countries. As for the bottom ash, besides the landfill, it is re-used in construction, paving and so on in many countries and regions. However, this measure also causes certain problems (see the case of Byker city). The heavy metals will be more soluble to lead to leakage and polluting the groundwater source. The dioxin is not soluble like the heavy metals, and it will be firmly attached to the surface of the ashes. But the dioxin can still be detected in the air of the landfill, which means that it is possible that the dioxin would be in the environment in the end (Friends of the Earth, 2002). Therefore, the worse management of the landfill, there will be more problems of the waste incineration and treatment of the ash.

The hazards of the ash from the incineration: the Case of Byker
This is the example to be shown that the ash from the incineration is harmful for the people. From 1994 to 1999, the government of Byker (a city of UK) once mixed the fly ash and bottom ash to pave the road or be used for the farm. The residents doubted required the government to detect it if there are some hazardous substances. The result was that heavy metals and dioxins in the soil are much higher than the normal levels. The average concentration of dioxin was 1373ng TEQ/kg, the maximum even reached 4224ng TEQ/kg. However, as the relevant laws and regulations shown in Germany, if the concentration of the dioxin exceeds 40ng TEQ/kg in the soil, the crop production would be limited in that place (Green Peace, 2001).

4.6 China’s MSW Disposal Problems and Causes

However, it is still a problem in China, why? The main problem is the sorting is not standardized. There will cause the serious secondary pollution if the waste is mixed or only simply treated before the incineration (Yingxu Chen, 2009). However, sorting of waste can be reused. Such as: recycling 1 ton of waste paper can be used to make 850 kilograms of paper, which saves 300 kilograms of wood and produces 74% pollution less than the equivalent paper made; 1 ton of daily kitchen waste, including leftovers, bones, vegetables root and leaves, etc., will cause 0.3 tons of organic fertilizer as long as the biotechnology treatment of the waste (Ibid). So it is necessary to do more investments on the infrastructure of waste sorting, collection and transportation. In addition, the residents should be educated and encouraged to do the waste sorting when they collect and throw the waste.

In China, there is no or not enough waste sorting before the incineration in many cities, and the waste landfill is also the main way. So the problem we are going to analyze and work out in the end is what the best way for the waste disposal is in

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8 ng means nanogram, 1 nanogram= one billionth (1/1,000,000,000) gram; A TEQ is a dioxin Toxic EQuivalent, calculated by looking at all toxic dioxins and furans and measuring them in terms of the most toxic form of dioxin (http://www.ejnet.org/dioxin/)
China? What is the problem for the waste disposal before?

As the accelerated development of urbanization in China, the waste disposal has become a management problem for all levels of the city government. Take Beijing as an example, the city government has had a policy that the waste incineration should be increased to share the pressure of landfill. In accordance with the government plan, the waste disposal capacity will reach 17,000 tons/day in Beijing in 2012, and the proportion of waste landfill will be decreased from 90% to 50%, and furthermore 30% in 2015. And the waste incineration and biological treatment will be used instead of landfill (Jianguo Liu, 2008). However, the incineration only occupied 15% of the total waste treatment in China by the end of 2008 (China Statistical Yearbook, 2009). And also the relevant management systems and technical support of the incineration is still not enough, such as the dioxin control and the treatment of the ash from incineration plant.

In addition, the “waste to fertilizer” would be another good way for the organic waste disposal. According to the statistics, 60% of municipal solid waste is food waste, and has high content of organic matter, which is considered suitable for producing the fertilizer by the biological treatment. However, since the waste is generally collected and mixed together, it causes the higher cost for producing the fertilizer and it is hard to keep the quality (Jianguo Liu, 2008).

In 2004, China surpassed the United States as the world’s largest waste generator, and by 2030 China’s annual solid waste quantities will increase by another 150%-growing from about 190 million tons in 2004 to over 480 million tons in 2030 (see Figure 4-2). No country has ever experienced as large or as fast an increase in solid waste quantities that China is now facing (Word Bank, 2005).
As for the enormous amount of waste in China, the waste innocuous treatment capacity is very limited. In 2009, the rate of the waste treatment is only 66.8% in China (China Statistical Yearbook, 2009), which means nearly 1/3 of the MSW is not properly disposed and causes the environment degradation.

Therefore, people are constantly exploring other effective waste disposal measures. However, it has little effect of the comprehensive utilization such as waste sorting, waste recovery and waste reuse, etc. that has been respected by the environmentalists. It seems that the waste problems are not disappeared even the government invest more money on it.

Although the main MSW problems have been founded, the government has already made great efforts on MSW management in China, the result is that the effect is not as good as been expected.

The following four berries are the main reasons (China Clean Energy, 2009):
1. Unreasonable mechanisms- government and enterprises syncretic

So far in China, MSW disposal companies are managed by the government. The government is also the major “investors” and the main body operation of the waste disposal, which hindered the development of privatization and mercerization.

In addition, separating the government and the private owned companies will optimize the recycling system. During the period between 1950s and 1970s, China has once established the well-functioning waste collection system. However, since the 1980s, the state-owned recycling companies were bankrupt and the individual companies grown rapidly, which causes many new problems. For instance, in the field of waste paper recycling, In order to benefit more for them, the individual sellers mixed waste paper in the sand, water etc., and then selling to the paper mill, which can only be used for manufacturing low-level cardboard. So it is necessary to import waste paper to make sure the raw materials are good enough.

Last but not least, managing from different angles is also important for the waste disposal problem. For example, it had been a few years that the EPA and NDRC (National Development and Reform Commission) worked on the standard of the dioxin emission, but the there is not any policies about this.

2. The “temptation” of the subsidies

The acceleration of the urbanization requires significant increase of the investments on the waste disposal in all sectors of society. High-input, especially the heavily subsidization from the government, caused the waste industry become the “sunrise” industry. However, many enterprises are governed by the interests of the temptation, and results in a number of problems.

At present, the waste is almost collected and transported without waste sorting. Since
2002, waste sorting has been promoted by the China’s government, but until now, the waste sorting only accounts 16% (CEETA, 2009).

It has been suggested that waste sorting is difficult mainly due to the weak of the public’s environmental awareness. In fact, the point is that the trucks will mix them again even though people separate the waste. The reason is that the waste disposal enterprises will get the government subsidies in accordance with the tonnage of the waste, and they do not want the waste to be separated.

In most western countries, the detailed separated waste bin is normally used to facilitate the people to throw the waste. However, it is different in China. As for the enterprises for waste recycling, the more waste sorting the people do, the more waste will be in the recycling system, the less subsidies they will get. This is the main reason that the promoting of the waste sorting is not so successful during the past few years. Secondly, the individual enterprises sometimes do some cheating on the amount of the waste in order to get more subsidies. There is another problem is that it is encouraged to do the waste incineration to generate electricity, which will also get the subsidies from the government. However, some individual incineration plants mix a large number of coal in order for a greater power generation capacity and greater electricity subsidies, which is not the first thought of the government and not only consume more resources, but also generate more pollutions, and more importantly, it is totally opposite to the idea of sustainable development.

3. Lack of the surveillance mechanisms

The government has invested a lot on the waste disposal. But there is not any rational and effective third-party surveillance mechanism established for the waste disposal problem. There is few of the scholars and the media report the data from the government that if it is reasonable. For example, it was reported that the amount of waste is increased at the speed of 8% of each year, and the daily waste disposal
capacity is 10.4 thousand tons in Beijing (People’s Daily Online, 2009). However, some scholars has researched that from 1990 to 2007, the annual increased rate of waste is 2%. And the government did not give any explains about the sudden changes (2% to 8%).

In addition, it is a huge investment for the waste incineration plant. To build a plant plus the ancillary heat recovery equipment with the daily capacity of 1 thousand ton will cost around 1 billion RMB (CMRC, 2009). And it is necessary to improve the burning standards in order to reduce the pollution, which will also request more investment. However, there is not any third party surveillance mechanism during the plant building and working.

4. Simply “copy” from the developed countries

At the moment, it is planed or completed to build the waste incineration plants in the main cities and provinces in China, such as Beijing, Shanghai, Guangdong and Jiangsu etc.. Waste incineration is the most used way to deal with the waste in a lot of developed countries such as Japan, so could it also be the best way for China?

However, only one side from the situation has been seen. The key point is that most developed countries are currently in a trend of closing the waste incineration plants, because the incineration is not the best way to treat the waste, as it is necessary to find and use the more sustainable mechanism for waste management.

During the 70s and 80s of last century, there was a large number of one-off waste, and the plastic products can not be degraded, so the waste incineration is the best way. But the problems are the emission of dioxin and the huge investment on the waste incineration, which means that the waste incineration is not the only and best way.

In the recent 20 years, the technology for the waste recycling is growing rapidly. The
plastic products could be recycled to the resource recycling system. Therefore, it is not desirable for China to simply “copy” the path from the developed countries.

**Sum-up of question 2:**

Because of the weakness of pre-treatment (such as waste sorting, recycling, etc.) and the technique support, the waste incineration and composting are not well managed. Moreover, according to the waste hierarchy in China, landfill occupied too much for waste treatment, which should be the least priority. Last but not least, the mechanism is not so mature that the MSW management system is disordered.

**4.7 Case Study in the City of Tieli**

*Question 3--How is waste management in the case city?*

In the first part of this chapter, the waste problems in China were summarized, and overall introduced the reasons leading to waste problems. From the first part, it can be seen that the different cities have different situation, and the problems are more serious in the small cities. In addition, case study can not completely solve China's problems. For example, the Beijing pilot project mentioned earlier, solved the problems in Beijing at the beginning of trial period, but with the expansion of cities in China, pilot project emerged some problems such as serious shortage of capacity and so on. From which we can see the importance of the selection of pilot projects and the plans for the future.

The most serious MSW problem in China does not exist in the first-tier cities (such as Beijing, Shanghai, etc.), but in the second-tier and third-tier cities, especially in the small cities that lack of technical, management capital and programming. They are basically in the state of no governance for the waste. A large number of MSW have
the phenomenon of piling up anywhere and burning with no pre-disposal, which led to a lot of waste and pollution, such as groundwater and atmosphere pollution, the increasing prevalence of local residents.

In this section, we will select the representative city--Tieli to analyze and find the problem.

### 4.7.1 Urban Location and Natural Overview

Tieli is located in the center of Heilongjiang Province and situated in the southern part of Xiao Hinggan Mountains. The west is Qing'an County, the northeast is Yichun City, the south is the junction with the Tonghe County, and the southeast is Yilan County. Geographical coordinates is that longitude is 124 ° 53'36" -125 ° 54'24", latitude is 46 ° 1'28" -47 ° 3'57". It is under the administration of Yichun City\(^9\) (website)\(^10\)(see Figure 4-3).

**Figure 4-3 Location of Tieli on the Map of China**

Source: [http://www.sznhxx.com](http://www.sznhxx.com)

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\(^9\) Yichun is a prefecture-level city, which includes 15 jurisdictions and a town (Jiayin) and the city of Tieli (http://yc.hljj.net).

\(^10\) [http://www.google.com](http://www.google.com)
Tieli’s administrative area is 6444.49 square kilometers with the population of 400 thousand. Its urban area is 15.18 square kilometers with population of 134 thousand. It is planed that the population is 16 million by the year 2010 and 20 million by 2020 (website)\(^\text{11}\).

### 4.7.2 The Present Waste Management Situation in Tieli

There is also a big problem of the collection, transport and storage of MSW in Tieli. For instance, the transportation volume of MSW in Tieli city is about 60,000 tons / year. However, there are only 15 sets of dump trucks, 2 back fighting machine and 1 bulldozer in sanitation department. MSW collection is based on human tricycles. And there is only one simply equipped landfill site in Tieli, which is the only way to treat the waste. And waste relevant equipments and instruments in the city now are inadequate and not well organized. Therefore, MSW disposal faces great difficulty in this kind of efficiency and energy saving (Ibid).

According to the description of Tieli city we can see that the following points which must not be ignored.

1. The present population of Tieli urban area is 134 thousand. The quantity of MSW collection is about 60,000 T/year, so the average daily output of waste is about 1.5kg /day, which is a relatively high number.
2. There are abundant groundwater resources in Tieli, so, in considering the waste disposal problem, we should pay particular attention to avoid the problem of groundwater pollution.
3. There are not any good solutions for MSW problems. At the present time MSW mainly based on open-air landfill. There is only a simple and crude treatment plant

\(^{11}\) http://www.cls.gov.cn
facility in Tieli.

4. Disposal equipments in the city now are inadequate and transport efficiency is low. The facilities of waste collection, transportation are primitive. Smell, and drift material and exudates will cause secondary pollution.

5. MSW has high water content in Tieli. Compared with developed counties MSW components have relatively low heat value.

6. Slight particles and dust in MSW may fly at all places which can lead to air pollution to the environment (Haerbing University of Technology, 2008).

Based on an overall consideration of the above various factors, we find that Tieli has a wide-range representitiveness. It can represent many small cities in China that have the same situation with Tiel, which is in the initial stage and is weak on the technology and management for waste treatment. Because of China's rapid urbanization and lack of accurate estimation of the growth of MSW, and it is common that the geographical factor is not considered during the waste disposal process; the equipments for waste treatment are so simple and crude and needs to be replaced. So in order to protect groundwater resources, improve the sanitary conditions of the city and create a “healthy” city, it is urgently needs to build a modern and non-pollution waste disposal systems in Tieli.

4.7.3 MSW Output and Prediction in Tieli

The current population of Tieli city urban area is 134 thousand, the total garbage collection is about 60,000 ton per year, and equivalent to average daily output of waste is about 1.5kg/d. The reason of higher per capita waste production is that the proportion of urban buildings is only 30%. Most of residents live in cottage use coal fuel, which means high proportion of ash in the waste (Ibid).
With the urban economic development, population growth and rising living standards, the proportion of buildings will be increased and the output of waste will be changed. At the same time, the universal use of city gas and central heating system will result the decrease of the proportion of inorganic composition in the waste, and thereby the per capita waste will be reduced.

According to the emissions statistics of MSW of partial cities provided by Ministry of Construction and combined with various factors that affect the waste emissions of Tieli, the predicted solid waste per capita production of Tieli city in 2010 is 1.3kg/d, and the predicted number is 1.2kg/d in 2020 (Haerbing University of Technology, 2008).

According to city planning, the population of Tieli in 2010 will be 160 thousand, and 200 thousand in 2020, according to the predicted numbers of per capita production given above, the total urban waste production is 208T/d in 2010, 240T/d in 2020(Ibid).

The dejecta output of ancient toilets in Tieli city is about 50t/d, the current dejecta of ancient toilets is collected by nearby farmers. With the increase of urban buildings, the number of ancient toilets will be decreased, the dejecta will be disposed together with urban sewage, so the urban dejecta disposal will not be considered in the thesis.

Construction waste will be transported to a designated landfill instead of the waste disposal site. Medical waste and toxic industrial products, toxic substances, chemical reactions which can produce harmful substances will be disposed with separate scheme (Ibid).
4.7.4 MSW Composition and Prediction in Tieli

The most important factor that affects MSW is the people’s living standards and consumption structure. Different parts of the same city have different waste components. The recyclable waste (plastics, paper, metal, fabric and glass) of the advanced residents is significantly higher than the normal residential area. As people living standard of China is not high yet, there is high proportion of the kitchen garbage matter in the waste, which results a higher content of water and lower heat value of the waste (Tao Hu et al., 2006).

According to the character of the city, location, natural conditions and economic development of Tieli, the predicted component of MSW of Tieli is given below compared with it in 2005.

Table 4-2 Component of MSW of Tieli

<table>
<thead>
<tr>
<th></th>
<th>Organic (%)</th>
<th>Inorganic (%)</th>
<th>Useless waste (%)</th>
<th>Volume (hg/m³)</th>
<th>Rate of water content (%)</th>
<th>Heat value (KJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>22</td>
<td>76</td>
<td>2</td>
<td>500</td>
<td>38</td>
<td>3500</td>
</tr>
<tr>
<td>2010</td>
<td>25</td>
<td>72</td>
<td>2.6</td>
<td>480</td>
<td>40</td>
<td>3700</td>
</tr>
<tr>
<td>2020</td>
<td>30</td>
<td>66.5</td>
<td>3.5</td>
<td>400</td>
<td>42</td>
<td>4000</td>
</tr>
</tbody>
</table>

Source: Haerbing University of Technology, 2008

Variation trends are as follows:

a. The organic content would be increased, inorganic content would be decreased, and would gradually become stable;

b. Paper, plastic, fabric and metal content have a gradual upward trend;

c. Nitrogen and potassium would be increased with the rise of organic content;

d. Combustible composition would be increased year by year, and the heat value of
waste would be also increased (Haerbing University of Technology, 2008).

**Sum-up of the question 3:**

In the city of Tieli, the most used mode for waste disposal is open-air landfill and there is only one landfill site in Tieli. MSW is collected by the human tricycles and then transported by the trucks. During the collection and transportation process, the waste sorting process is ignored and the waste will be only landfilled directly. Additionally, the waste treatment mechanism in Tieli is not well managed. Last but not least, as the increase of the population, MSW problems will become more prominent.

**4.8 Findings from the Chapter:**

In this chapter, we introduced the hazardous of the waste to the human and its serious situation in China. Then described the shortages from the aspects of landfill, composting, and incineration in China, and based on MSW management problems, we outlined the main barriers for the waste management implementation in China.

The present situation and problems of MSW management in China is not systematic: landfill is the most used mode to dispose the waste, which wastes a lot of resources and energy; composting is the recycling mode, but it is not used widely in China because the important factor for composting is weak—waste sorting, which will cause the low quality of the fertilizer. In addition, there is another reason the cost for the composting process is high; as for incineration in China, first of all, from the waste hierarchy, there are 3 steps of the waste treatment before incineration. However, the pre-treatment is also the key problem in China, which also wastes a lot of resources and energy and is not sustainable. Secondly, the monitor program is not integrity to solve the energy efficiency and dioxin emissions problems of incineration plant.
In addition, there are also four barriers which results the weak of the waste management system and the problems described above in China: unreasonable mechanisms, the “temptation” of the subsidies, lack of the surveillance and simply “copy” from the developed countries.

From the case study, we can see that MSW disposal level is lower and infrastructure is poor in Tieli. No matter the technology, equipment, practical application, or the regulations, laws and regulations of technical standards for waste disposal are all at the stage of beginning implementation. And it is still open-air landfill for waste treatment, which result in serious pollution of the urban environment. Therefore, the treatment of MSW problem has become an urgent and important issues in Tieli that must be solved.

**Ownerships in the waste management sector**

**Important issues related to efficient waste management in China**

- Pre-treatment--waste collection, waste sorting, waste transport
- Waste hierarchy
- Type of the waste treatment company & subsidy
- Public Awareness
- Waste incineration
5 MSW Management in Denmark

In Denmark, the treatment of household, commercial and hazardous waste is responsible by the local authorities (municipalities) (Suzanne Arup Veltze, 2008).

Question 4--How is Danish MSW management?

Question 5--What are the benefits and issues from Danish waste treatment model?

5.1 Waste collection

Collection schemes

The local council is responsible for ensuring that collection, transportation and management of a given fraction is in compliance with the regulation. When a collection scheme has been established, citizens, freeholders and enterprises are, as a rule, under an obligation to use the scheme (Waste Denmark, 2010).

Domestic Waste Collection

In large cities, compactor trucks with lifts for automatic emptying of waste bins and containers are frequently used. Large containers with four small wheels are often used for mixed domestic waste collection from large multistory houses. From smaller dwellings and one-family homes, waste bins as well as paper or plastic bags may be used in combination with compactor trucks or open lorries. In the case of open lorries, the bags are manually thrown and stacked. Besides, separated waste is most frequently collected in containers. Source-sorted waste is frequently collected jointly
from several domestic in large area containers. The frequency of the collection includes: daily, once per week, once per fortnight and once per month, depending on the different types of waste (Poulsen, O.M. et al., 1995).

5.2 Waste Sorting

The sorting efficiency is for a given recyclable defined as the amount of source-separated material in relation to the total amount of that material in the generated waste. The recycling rate is defined as the amount of source-separated waste in relation to the total amount of waste generated, which means the waste sorting so important in the processes of the waste management.

**Awareness rising in Denmark**

Actually, MSW is the mixed waste, but if it is separated, MSW will become to the resources. In Denmark, the civic education is the first way for the waste management. From the primary school, the students are taught from the aspects of environment pollution, waste reuse, turning waste to resource, waste recycling (Soren Skov, 2009).

The waste sorting habits of the residents is a long process. Waste sorting means that there will be several bags for the different kinds of waste, instead of mixed collection with one bag before, which needs a long period to be accepted by the residents and also causes the inconvenience for the residents. For example in the city of Esbjerg, Denmark, the Environmental Protection Agency organized the propaganda by distributing the leaflets to the public to promote the advantage of waste sorting. Until 1996, the detailed plan for waste sorting and recycling was developed. That means the public awareness plays an important role for waste sorting (Ibid).

In Denmark, the young children attach the great importance to the environmental awareness and good habits. From primary school, the students begin to be taught the
concept of environmental protection and eco-cycle, and they will impact and teach their parents at home, thereby will impact the society finally. People have more progressive perception that should reduce consumption, promote green consumption and leave more for future generations of resources such as forests. There is also happened in many European companies that if the products with using little resources for the production and packaging, the certified products will be stamped the green label. The residents will be taught and encouraged to buy these kinds of products (Soren Skov, 2009).

In Denmark, the residents have very progressive awareness on the waste sorting. From the pictures below, we can see that the residents sort their waste when they transport the waste to the waste treatment center.

**Picture 5-1 Public Awareness Education**

Source: Fei Yu, 2009
Picture 5-2 Sort the Different Kinds of Waste When the Residents Transporting It

Source: Fei Yu, 2009

Picture 5-3 The Residents Come to Transport Their Waste by Using Their Own Car

Source: Fei Yu, 2009
Picture 5-4 The Construction Workers Come to Transport Their Construction Waste and Sort It in Different Dust Bins.

Source: Fei Yu, 2009

Waste sorting system

In addition, there is a good waste sorting system from the waste collection to the waste treatment. No matter in the resident area or the public area, there are many different waste bins for the different waste, such as the wood, glasses and papers are going to the different bins. Moreover, in the waste treatment centers such as Vestforbrænding, which is an environmental company creating solutions in the waste management field, will do the waste sorting again to be sure the different resources from the waste are separated as much as they can do (website of Vestforbrænding).
Picture 5-5 the Waste Bin for the Wood Re-use, Vestforbrænding

Source: Fei Yu, 2009

Picture 5-6 The Waste Bin for the Paper Re-uses & Recycle

Source: Fei Yu, 2009
5.3 Waste Transport

In May of 1994, regulations concerning the transportation of the waste were approved in EU. The regulations made a distinction between recyclable waste and non-recyclable waste (Continental Press, 1994).

All transports to treatment facilities are to be done in trucks. The waste transport truck measures the weight of waste it collects from the bins. It adds up these data from the data it collects from a chip built into the bin (owner’s name, address). The information gathered this way is sent to a central database, and billing is sent on this basis (Graczka Sylvia, 2009). In addition, the containers all have wheels, and the trucks have the simple equipment for compressure in order to make transportation easy and efficient.
5.4 Waste Recycling in Denmark

The output from the recycling processes was paper, glass, plastic, aluminum and steel products which in the expanded waste management system substituted similar products made from virgin resources. Loss of mass and quality of the materials during reprocessing was accounted for it. It was assumed that construction of new facilities would not be necessary and that the changes could be implemented immediately. The reuse and recycling of the products will have the other side effects, e.g. wood saved by paper recycling could be used for energy production instead (A.W. Larsen et al., 2009).

In Denmark, the waste hierarchy is the basis for the prioritization of waste management options. According to the hierarchy, recycling ranks higher than incineration with energy recovery and landfill ranks lowest. In Denmark, incineration does not count as recycling (Danish Environmental Protection Agency, Waste in Denmark, 2004). Total recycling of household waste is around 28%, the garden waste is composted with recycling rate of almost 100%, the industry recycling rate is 65%, and the waste from institutions, trade and offices has the recycling rate of 50% (Ibid).

By the way, the packaging waste legislation in Denmark is a detailed packaging system and good for recycling. In Denmark, there are different legislations on different packaging waste, which aims to recycle packaging waste as far as possible. As for the household and commercial packaging waste, the local authorities are required to set up collection schemes for paper and board and for plastics transport packaging from all types of business, and the expenditure on the packaging system are covered by a tax. As for the bottles, there is a deposit-return system for one-way packaging and refillable bottles (Danish Environment Protection Agency, 2009).
Figure 5-1 Waste from Primary Source

Source: DAKOFA

Figure 5-2 Treatment of Waste in Denmark 1994-2008 (targets for 2008)

Source: DAKOFA
Figure 5-3 Treatment of Domestic Waste

Source: DAKOFA

Figure 5-4 Construction & Demolition Waste Treatment

Source: DAKOFA
Danish waste hierarchy

The most important objective of Danish waste management policy is to reduce waste amounts, which is in line with the integrated product policy of the Danish Ministry of Environment and Energy, aiming at limiting resource consumption and environmental impact for all products (Danish Ministry of Environment and Energy, 1999).

By environmental management and cleaner technology it is possible to reduce the generation of waste, for example by taking waste treatment into consideration already at the design of products and by using less environmentally harmful products (Danish Ministry of Environment and Energy, 1999). Moreover, the concept of “cradle to cradle” has already been used for production in Denmark. It means the products could be reused again and again instead of using the virgin materials, which is very helpful for waste reduction. At present, there are more activities for promotion of “cradle to cradle” in Denmark. For instance, the Danish Industry Cluster has the investigating on “cradle to cradle”; additionally, COWI (Consultancy within Engineering, Environmental Science and Economics) Denmark and the Danish firm-Vugge til Vugge were involved in a pilot project in 2009 for develop and promote the “cradle to cradle” products in Denmark according to “cradle to cradle” principles (COWI, 2009; Michael Braungart, 2009).

Secondly, the Danish waste policy has another aim of recycling the waste as much as possible (Danish Ministry of Environment and Energy, 1999). According to the hierarchy, recycling ranks higher than incineration with energy recovery, and landfill ranks lowest. In Denmark, the different kinds of waste are treated detailed in different way. For instance, from Figure 5-3, there is 20% of the domestic waste is recycled and 80% of it is incinerated; from Figure 5-4, Construction & Demolition waste is treated that about 90% is recycled and 8% of the waste is landfill.
In general, in terms of the waste in Denmark, we can see from the Figure 5-2 that there is 65% of the waste is recycled and 26% is incinerated and 9% is landfilled. And incineration does not count as recycling in Denmark.

Therefore, the Danish waste hierarchy should be like:

Figure 5-5 Danish Waste Hierarchy

5.5 Danish Incineration—Case Study of Vestforbrænding

In Denmark, the waste treatment company is working on many aspects for waste disposal. For instance, the incineration plant is only one part of the waste treatment company, which means that the incineration plant should not be separated with other processes of the waste treatment, such as Vestforbrænding.

5.5.1 Introduction of Vestforbrænding

Vestforbrænding is an environmental company creating solutions in the waste management field, which is working to minimise waste page and pollution, and
treating waste as a resource. At the same time, Vestforbrænding has 6 recycling centres and the largest incineration plant of Denmark. It generates both power and district heat by incineration Commercial and MSW (website of Vestforbrænding).

Vestforbrænding handles around 900,000 tonnes of waste a year of which 33% is recycled, 62% goes to energy recovery through incineration and 5% goes to special treatment (including landfill). There are 300 employees service a total of around 865,000 people, which is one sixth of Denmark’s population, and also service around 60,000 businesses for electricity and heat (Ibid).

5.5.2 Incineration Experiences from Vestforbrænding

The big different of the incineration between Denmark and China, is that such companies like, is a 'non-profit cost-coverage’ company, who is owned by 19 municipalities around Copenhagen and Northern Zealand.

Vestforbrænding does the most steps it can do, including collection waste, recycling, separation and management of hazardous waste, research and development in the waste management field. According the "waste hierarchy” of Vestforbrænding, incineration has the least priority but one-landfill (Ibid).

In addition, there is a full automatic control centre working for the waste treatment and incineration. After the waste sorting and recycling, the left non-recyclable and combustible waste will be transfered to the bottom layer of the incineration plant, and then the waste will continued to be mixed and sifted. After 4 more working procedures for the waste treatment, finally the waste will go into the incineration plant. All these processes are observed and controlled by 4 workers in the control center (Søren Skov, 2009).
Picture 5-8, 5-9 Waste Treatment Before Incineration (Vestforbrænding)

Source: Fei Yu, 2009

Picture 5-10 the Control Center of the Incineration (Vestforbrænding)

Source: Fei Yu, 2009
The technology is an important ability to solve the pollution problems. Ammonia is used to reduce the emissions of nitrous gases through the flue-gas stack. They put activated carbon into their filter bags to dispose dioxins and other harmful substances. Fly ash is also collected in the filter bags. All flue-gases such as HCl (Hydrochloric acid), heavy metals, and SO2 are washed to be removed in the scrubber system. In addition, Sulphur precipitates as gypsum is landfilled, which occupied around 0.3% of total waste input. Water from the flue-gas washing processes is led to the in-plant water treatment facility where it is neutralised, among others with lime, and cleaned for heavy metals and harmful substances. Then the water is led to a municipal waste water treatment plant. Sludge from waste water treatment will be sent to landfill together with fly ash, which occupied 3% of total waste. Moreover, Vestforbrænding also measure flue-gas flow, flue-gas temperature in different locations in the incineration plant, and also measure the oxygen rate, water rate, CO contents, Nox, dust, SO2, and TOC (Total Organic Carbons) (website of Vestforbrænding).
5.5.2.2 The Efficiency of the Incineration Plant of Vestforbrænding

Vestforbrænding operates Denmark’s largest plant for incineration of waste including 4 incineration furnaces at the plant with a total capacity of 600,000 tonnes a year. There are 2 old furnaces, and each can incinerate around 12 tonnes of waste per hour, which were commissioned in 1970. The other two incineration furnaces were commissioned in 1999 and 2005, and can incinerates respectively around 26 tonnes and 35 tonnes per hour. In 2008, Vestforbrænding incinerated around 563,000 tonnes of waste (website of Vestforbrænding).

After the waste has passed through the furnace it is completely burned out only left the bottom ash, which makes up around 17% of waste input measured in weight and the volume is only around 5% of the original amount of waste. In 2008 the 563,000 tones of waste resulted in just below 100,000 tonnes of bottom ash. Bottom ash is reprocessed by a contractor ensuring that 95% of ash volumes are recycled. It is used as a filler material in major construction works such as motor ways, roads, and bridges (Ibid).

Vestforbrænding generated the energy around 20% becomes power and 80% to heating distribution, which substitutes fossil fuels elsewhere. In 2008, Vestforbrænding generated 245 GWh of power and 1.390 GWh of district heating, which correspond to the power consumption in 80,000 homes and the heat consumption in 75,000 homes (Ibid).

It also meets the requirements of the Danish national waste management plan by sorting waste many categories and continues its efforts to increase efficiency in waste management for the benefit of the environment in these years (website)\(^\text{12}\).

\(^{12}\) http://www.denmark.dk
5.5.3 Distric Heating

5.5.3.1 What is District Heating?

When waste is incinerated in the furnaces, the flue-gas is cooled with water, which is covered into steam under high pressure and high temperature in the modern boilers and the steam turns into movement, power and heating in turbines, generator and heat exchangers.

The power is distributed in the national grid to residents and other consumers, whereas heat is distributed through Vestforbrænding’s own grid and other district heating grids in the form of hot water through insulated underground pipes (one supply pipe and one return pipe). Transfer takes place in a heat exchanger transferring heat without direct contact between the water from the grid and the water in the in-house systems. When the district heating water was given off its heat, it will be returned to Vestforbrænding to be re-heated in the incineration plant. Hence the district heating grid is a closed system where water is alternately heated and cooled(website)\(^{13}\).

As a matter of fact, Vestforbrænding is expanding its district heating network dramatically, which not only benefits for the customers, but also socially substitute for more CO2 intensive energy source such as oil and natural gas (see the next part), which is also saving the in energy budget at the same time. As for the consumers, the conversion from natural gas to district heating will in general give them saving of 10-20% of their heating costs (website of Vestforbrænding).

\(^{13}\) http://www.vestfor.com, http://www.denmark.dk
5.5.3.2 CO2 Emissions Reduction and District Heating

District heating generated through incineration of waste causes much lower CO2 emissions than most other heating forms. Radically Extending of Vestforbrænding’s district heating grid towards the north and the west will substitute heating with oil or gas, and will be estimated at a 20,000 tonnes reduction of CO2 a year. In the conversion from natural gas to district heating each single house hold can generally reduce its heat-based CO2 emissions by 86% (website of Vestforbrænding).

At present, Denmark is world leader in district heating, which covers 46% of Danish heating needs. It is also proposed that in order to comply with CO2 targets, Denmark is going to extend district heating to cover up to 70% of Danish heating needs (Ibid).

5.5.4 Waste Taxation

In addition, the success of Danish waste treatment model also can be shown that Denmark has already made a significant improvement by carrying out its waste taxation mechanism.

Since 1987, considering the problems of landfill sites, especially in the greater Copenhagen area, and problems with dioxin emissions from incineration, the tax was levied to support the waste management and recycling; and also to increase the proportion on waste managed by techniques towards the top of the waste management hierarchy. The waste disposal tax has been a very important instrument and has lead to a significant increase in recycling, and a significant decrease in the amount of waste landfill (COWI, 2001). Another purpose of the taxation is to promote incineration over landfill (Nordic Council, 2006).

The waste tax was levied on both household waste and industrial waste. Initially the
rate for landfill and incineration was same, but higher rate for landfill was applied since 1993. And the taxes was continuously increased at the year of 1997, 1999, 2003 (see Table 5-1). By the way, in 2000 the charges for the incinerated waste with energy recovery was 280 DKK, and incinerated waste without energy recovery was 330 DKK (COWI, 2001). But since 2001, there was no difference of these two situations, and the charge for the incineration was 330 DKK (Nordic Council, 2006) (see Figure 5-6). In addition, there is no tax on recycled waste (Ibid), which would encourage the promotion of the technologies development on the waste recycling. And all households are obliged to pay a fixed price for their waste bin. The local municipality is responsible for managing the waste collection and for paying waste tax. However, the effects of the waste tax on the industrial and construction & demolition waste are small and the importance is less. The more important thing on these two kinds of waste is the bureaucratic regulation and consultancy services, waste tax are only a small part (Christoffersen et al., 2000).

**Figure 5-6 Waste Taxes in Denmark**

![Waste Taxes in Denmark](source: DAKOFA)

***Only changes are shown***

*Source: DAKOFA*

**Table 5-1 Waste rates 1987-2005**
Overall, the achievement that the taxation results from 1987 is that there has been a 26% reduction in net solid waste from 1987 to 1998 and overall recycling rate of 61% was achieved (Andersen and Dengsoe, 2002). Moreover, the proportion of the landfill in the total waste disposal was decreased dramatically, which is from around 40% to 10% from 1987 to 2005, even less (see Figure 5-7) (DAKOFA, 2008). And from the perspective of the waste recycling, the taxation is one of the important roles to promote the technologies for the waste disposal and to increase the proportion of the waste recycling (see Figure 5-7).

Figure 5-7 the Changes After Taxation in 1987
5.6 Findings from the Chapter (Sum-up of the question 4)

First of all, we study the Danish waste treatment model from the aspects of waste collection, waste sorting, waste transport waste recycling and incineration. From the Danish waste treatment model, we can clearly see that the procedure that waste goes from the containers to the waste recycling or to the incineration plant. All the steps are monitored by the local council with the strict system and management. The systematic waste collection and waste sorting are the key factors which cause the high proportion of waste recycling (65%).

As for the incineration, we analyzed Vestforbrænding as Danish incineration case. Vestforbrænding is not only working on incineration, but also the pre-treatment of the waste is also the important section before the waste goes to the incineration plant. Next, during the incineration process, has the advanced system for the pollution control.
control and high efficiency of the energy recovery. Furthermore, Vestforbrænding has the leading system for the district heating, which not only benefit for saving the energy consumption and heating cost, but also contribute to the CO2 emissions reduction.

**Benefits and issues from the Danish waste treatment model & Vestforbrænding:**

- Waste collection, waste sorting, waste transport
- Waste hierarchy
- Taxation
- Awareness rising
- Danish incineration
- District heating
6 Comparision and Analysis

In the above 2 chapter, there is a comparision of MSW managment between China and Denmark. At the same time, the case study of Tieli and Vestforbrænding are also described and well supported the comparision anlysis. Hence in this chapter, we will analyze the above 2 chapters and outline the comparision issues and find out what are the gaps or diffrences from different aspects of the waste treatment procedure.

6.1 Analysis of MSW Management Problems Faced by Tieli and China

Pre-treatment

In China, the present level of MSW management is low and disordered and lack of unified organization and management on waste collection, waste transportation and waste sorting.

In Tieli, there are only 15 sets of dump trucks, 2 back fighting machine and 1 bulldozer in sanitation department, MSW collection is based on human tricycles, and there is almost no waste sorting, which would be piled up outside or landfilled in the only one simple equipped landfill site. Waste relevant equipments and instruments in the city now are inadequate and not well organized and transport efficiency is low. The facilities of waste collection, transportation are primitive. Smell, and drift material and exudates will cause secondary pollution.

Waste Hierarchy

At present, landfill is the most used mode to dispose the waste in China, which
occupied around 80%, and in the small cities, it occupied even more. And there is about 15% of incineration for waste disposal in China. However, from the waste hierarchy, the landfill and incineration is the last two priorities for waste treatment.

In the city of Tieli, there are not any good solutions for MSW problems. At the present time MSW mainly based on open-air landfill. There is only a simple and crude treatment site facility for landfill in Tieli, which is the only way for waste treatment.

Due to the lack of governance and management, and more importantly the lack of waste sorting, there are few special measures on waste recycling and reuse, especially in some middle and small cities. In addition, there is less awareness on the waste reduction, which whereas should be considered firstly and has the highest priority for the waste management according to the normal waste hierarchy.

Waste Incineration

In China, there is no or not enough waste sorting before the incineration in many cities. And also the relevant management systems and technical support of the incineration is still not enough, such as the dioxin control and the treatment of the ash from incineration plant.

Mechanisms and Subsidy

In China, the MSW management mechanism—government and enterprises syncretic is unreasonable. From the perspective of the local government, in order for encouraging more investment on the waste disposal, the government offers the subsidies for the private-owned waste treatment companies. However, from the perspective of the investors—the private-owned companies, the first consideration for the investors is the benefit, so the waste sorting and recycling is not important and necessary for them if there is no benefit from these process. In addition, in order to get
the subsidies from the government, the privated-owned incineration plant would use the fuel or coal to get a greater power generation capacity and greater electricity subsidies.

The government has invested a lot on the waste disposal. But there is not any rational and effective third-party surveillance mechanism established for the waste disposal problem. It is a huge investment for the waste incineration plant, but there is there is not any third party surveillance mechanism for the incineration plant.

Public Awareness

There is poor awareness for waste sorting, waste recycling, waste reuse and reduction.

6.2 Analysis of Danish and Vestforbrænding MSW Management System

Pre-treatment

- Large container with four small wheels is the most used container for the waste collection, and it also can be hooked by the truck for waste transport, which increase the quality of the waste collection and transport and improve the waste treatment efficiency.
- Different containers are used for different kinds of MSW for the first step of waste sorting in the resident area. Moreover, in the waste treatment centers such as Vestforbrænding, which has the large containers for the different kinds of resources from the waste, such as wood, paper, bottles etc., and will do the waste sorting again to be sure the different resources from the waste are separated as much as possible, and they only incinerate the waste which should be incinerated.
- The trucks for the waste transportation have the simple equipment for
compressure, which can reduce the volume of the waste and transport more waste to improve the transport efficiency.

Besides, separated waste is most frequently collected in containers. Source-sorted waste is frequently collected jointly from several domestic in large area containers. The frequency of the collection includes: daily, once per week, once per fortnight and once per month, depending on the different types of waste.

**Waste Hierarchy**

The waste hierarchy in Denmark has been clearly and well implemented. The recycling rate for MSW is 65%, the incineration rate for MSW is 26% and there is only 9% of the waste is landfilled in Denmark.

The most important objective of Danish waste management policy is to reduce waste amounts. It has already happened in Denmark that taking waste treatment into consideration at the design of products and by using less environmentally harmful products. Moreover, the concept of “cradle to cradle” has already been used for production in Denmark, which means the products could be reused again and again, instead of the “cradle to grave” way--treating them as real waste and using the new virgin materials.

Secondly, the Danish waste policy has another aim of recycling the waste as much as possible. In Denmark, the different kinds of waste are treated detailed in different way. For instance, there is 20% of the domestic waste is recycled and 80% of it is incinerated; Construction & Demolition waste is treated that about 90% is recycled and 8% of the waste is landfilled.
Waste Incineration

Danish incineration--Vestforbrænding does the most steps, including collection waste, recycling, separation and management of hazardous waste, research and development in the waste management field. According the “waste hierarchy” of Vestforbrænding, incineration has the least priority but one-landfill. And there is a full automatic control centre working for the waste treatment and incineration.

In addition, there is a mature system for solving the pollution problems including the ash, flue-gases, SO2, etc.. Vestforbrænding generated the energy around 20% becomes power and 80% to heating distribution. It also meets the requirements of the Danish national waste management plan by sorting waste many categories and continues its efforts to increase efficiency in waste management.

At present, Denmark is world leader in district heating, which covers 46% of Danish heating needs. It is also proposed that in order to comply with CO2 targets, Denmark is going to extend district heating to cover up to 70% of Danish heating needs. As a matter of fact, Vestforbrænding is expanding its district heating network dramatically, which not only benefits for the customers, but also socially substitute for more CO2 intensive energy source such as oil and natural gas.

Mechanisms and Taxation

Denmark has a close interplay between EU regulation and national regulation on waste. EU regulations lay down overall frameworks and principles, whereas the Danish Folketing desides on organisation and legislation in the area of waste. Vestforbrænding is a ‘non-profit cost-coverage’ company, who is owned by 19 municipalities around Copenhagen and Northern Zealand.

Since 1987, considering the problems of landfill sites, especially in the greater
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Copenhagen area, and problems with dioxin emissions from incineration, the tax was levied to support the waste management and recycling. Compared with the situation before the year of 1987, Denmark has reached a great achievement on waste reduction and waste recycling, and also the dramatic decrease of incineration and landfill.

Public Awareness

In Denmark, the civic education is the first way for the waste management. From the primary school, the students are taught from the aspects of environment pollution, waste sorting, waste reuse, turning waste to resource, waste recycling, and they will impact and teach their parents at home, thereby will impact the society finally. Among the awareness on the above description, waste sorting is the most important first step for the other awareness. At present, the residents have very progressive awareness on the waste sorting in Denmark. For example, they will sort their waste by themselves when they transport their waste to the waste treatment center.

The issues of the problems in China and differences with the Danish Model

From the comparison and analysis between Chinese and Danish model above, we can clearly see the problems and differences in China on the issues of waste pre-treatment, Waste Hierarchy, waste incineration, mechanisms and public awareness by comparing and analyzing from the aspects of the technology, the processes, the facts and the figures etc.
7 Conclusions

Main Question:

*How to optimize MSW management system and make it more efficient in China?*

In this thesis, the aim is to promote China’s MSW management by transferring the available and possible experiences of Danish waste treatment model, depending on the comparison and analysis chapter.

7.1 Transferring Quotable Danish Experiences to Implement MSW Management of Tieli, China.

Pre-treatment

Different containers for different kinds of waste with wheels should used in the resident area for the waste collection, and it also can be hooked by the special trucks with the simple equipment for compression for waste transport, which is good to increase the quality of the waste collection and transport instead of using the normal trucks or even the human tricycles in Tieli. More importantly, it can also improve the waste treatment efficiency by adopting such as Danish containers and trucks.

Additionally, different containers are used for different kinds of MSW which is aim to sort the waste for the first time, which is really important for improving the efficiency of waste recycling and recovery.
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Waste Hierarchy, Waste Incineration and Mechanisms

Waste Hierarchy

In order to promote the waste hierarchy in China, the system should be built in terms of each step of the waste hierarchy. First of all, the most basic and best way for controlling and minimise the waste arisings and turning the waste into resources (reuse and recycle), is to follow the rules of “cradle to cradle” for production instead of the traditional rules for production—“cradle to grave”, which means it should be considered from the planning or designing of the products in the beginning. A products should be designed for the future that if it could be recycled and could be reused as the raw material, instead of waste for nothing. In addition, the raw material of the products is the key element for reducing the waste, which means that fewer kinds of materials used could cause easier collection and sorting for the waste reuse and recycling. For example, if a product could be manufactured by using only one kind of material, that will facilitate the collection and using the waste. For some special products, the waste of them should be treated specially, such as that the plastic and the electronic waste should be reused again and again. All these described should be supervised and encouraged by the government.

Secondly, the government should encourage and subsidy the enterprises for recycling paper, glass, plastic, aluminum and steel, etc., and also subsidy the enterprises for using the materials from the recycling system instead of using virgin resources. What is more, the government could also conduct propaganda by using the identification for the products and encourage the people to purchase the products with the identification.

Waste Incineration

Thirdly, Danish incineration system such as Vestforbrænding is so mature and advanced, which has the integrated procedure including the pre-treatment of waste for reuse and recycling, pollution control of the incinerate furnaces, high energy recovery...
efficiency and distribution of power and district heating. By the way, one of the important part of Vestforbrænding is district heating, which could save the energy resources by substituting the use of coal, oil and natural gas. At the same time, it is so interesting for China that the district heating could also contribute to the CO2 emissions reduction. Therefore, it is necessary to transport the Vestforbrænding’s incineration system from Denmark to China, and more importantly, cooperate with the local power plant in the Southern China or cooperate with the local power plant and heating supply system in the Northern China, which not only help to dispose the waste which could not be recycled for incineration instead of landfill, but also can contribute to the power and heat generation in the district, save the energy consumption for the normal power plant and heating supply system and also contribute to improvement of the energy efficiency and the CO2 emissions reduction.

Mechanisms

In Denmark, the waste management is responsible of the local government, which is the “non-profit cost-coverage” company such as Vestforbrænding and of course will strictly follow the mode and rules of the government. But in China, if all the private-owned waste management companies are changed to “non-profit”, that will be a hard and long period project and would also bring more problems. Therefore, based on the situation in China, the solution is that keep the private-owned character of the waste management company, the focus point is to implement and optimize a subsidy and surveillance system to encourage and supervise the private-owned companies for waste management, which is an easier and more efficient way for the Chinese situation.

Taxation and Subsidy

From the Danish taxation experience on the waste management, and combining with the ideas of Chinese solutions, implementation for Chinese taxation and subsidy

14 There is no heating supply system in the Southern China, because the winter is short and not so cold.


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system should be:

- Firstly, the landfill sites should pay more taxes and the amount of the tax they are supposed to pay should depend on the weight of the waste;
- Furthermore, the government should lower the tax and subsidy the enterprises which are working on waste collection, waste sorting and waste transport, waste recycling, etc..
- Additionally, the government should also subsidy the enterprises which support and contribute to the waste management in China. Such as the production enterprises which have the recycling products system or reuse the materials from the waste substitute the virgin resources; and also the incineration plants contributing to the power and heat supply.
- Last but not least, the amount of the tax and subsidy should follow the priorities of the waste hierarchy.

Public Awareness

Awareness rising is also important to optimize the waste management in China. Based on the situation in China and consideration of the experiences from Denmark, there are some proposals for promoting the public awareness in China:

- Education is the first way to enhance the awareness of the waste problems and waste management. On the one hand, from the primary school to the university, the students should be taught from the aspects of pollution, waste sorting, recycling, energy saving, etc.. On the other hand, the local government should also organize some education activities for the residents and the enterprises on the waste management, basically and especially on the knowledge of waste sorting, waste reuse and recycling.
- Besides, organizing the social activities to propagandize the importance of waste sorting, energy saving and waste recycling, etc.; propagandize the knowledge about daily consumption and encourage people to buy the products with
identification of products reusing and recycling.

- Finally, giving more the publicity to the waste management through the media such as advertisement, TV, magazine, etc., which could impact and rise people’s awareness in their daily life.

The main discussed issues are as follows (question 1,2,3 are from Chapter 3, question 4 is from Chapter 4, and question 5 is from Chapter 5):

1. What is the present situation of MSW management in China?
2. What are the problems of MSW management in China?
3. How is waste management in the case city?
4. How is Danish MSW management?
5. What are the benefits and issues from Danish waste treatment model?

We have already researched and discussed them in the above paper for these questions which will be summarized next. In addition, we would like to add some of our own perspectives to have the further options.

1. The present situation and problems of MSW management in China is not systematic and also with many problems of landfill, composting and especially the incineration.

2. The problems include: too much occupation of landfill, behindhand of the incineration, lake of waste sorting and weak of the mechanisms.

3. No matter the technology, equipment, practical application, or the regulations, laws and regulations of technical standards for waste disposal are all at the stage of beginning implementation.

4. The systematic waste collection and waste sorting are the key factors which cause the high proportion of waste recycling. Vestforbrænding which represent the Danish model has the advanced system for the pollution control, high efficiency of the energy recovery and the leading system for the district heating.

5. The benefits and issues from Danish waste treatment model includes: the “cradle to cradle” idea for minimizing, reusing and recycling the waste; the facilities for waste collection, sorting and transport; advanced technology from Danish incineration; mechanisms and waste taxation; public awareness rising; waste hierarchy.

Main Question:

How to optimize MSW management system and make it more efficient in China?

First of all, Separate collection is the foundation and prerequisite, so the waste should
be collected in different waste bins in the residential areas like Denmark. Large containers with wheels should be used for waste collection, which also can be hooked by the special trucks for waste transport. The trucks for the waste transport should have the simple equipment for compressure. Secondly, Vestforbrænding’s incineration system could be transported to China, and cooperate with the local power plant and heating supply system to implement China’s system. Thirdly, Danish taxation could be transported, improved and developed with the subsidy program, which is more suitable for China’s situation. Finally, public awareness rising from Danish experiences on the waste management also helps to promote China’s awareness proposals from the aspects of education, activities and publicity. All in all, the issues described above is the possible solutions to improve and optimize China’s MSW management system, and to get more closer to the Danish Waste Hierarchy.

7.2 Policy Recommendations

7.2.1 To Set Up the New System for Waste Collection, Sorting and Transportation.

Mixed collection of the waste causes the difficulty of the waste sorting; no uniform containers for the waste collection cause the inconvenient for collecting the waste in the trucks; normal trucks without the simple equipment for compressure cause the low efficiency for waste transportation. Due to the above issues, it is recommended to set up a new system for the waste pre-treatment: to change the present containers with uniform containers with wheels in order to be moved easily; the containers should be same size but different colors in the resident’s area in order for the different kinds of waste; the containers should be with the accompanying trucks and could be hooked by the trucks in order to transport the different kinds of waste separately with the high efficiency
7.2.2 To Set Up the New Incineration System

By considering the advanced and mature system of Danish incineration such as Vestforbrænding, it is necessary to import and study the Danish incineration system and transport it to China. The reason is: firstly, integrated procedure including the pre-treatment of waste for reuse and recycling, pollution control of the incinerate furnaces and high energy recovery efficiency are all the issues that can optimize the China’s incineration plant; secondly, district heating could save the energy resources by substituting the use of coal, oil and natural gas and could also reduce CO2 emissions, which can contribute to China’s CO2 targets.

In addition, by considering the enormous amount of waste in China, and the high demands of electricity and heat supply, it could be better to connecting the incineration plant with the local power plant and heating supply system to improve the energy efficiency and more contribution to CO2 emissions reduction. By the way, the local government should play the guide role for the cooperation, and also subsidy the cooperation with the taxation policies to encourage and support it, and at the same time, the government should set up an organization for surveillance to make sure the right operation of the cooperation.

7.2.3 To Set Up the Subsidy Policy

The waste treatment companies in China are private-owned. The local government should subsidy the private-owned enterprises, such as waste collection, sorting, transporting or waste recycling, etc., in order to encourage the private-owned companies to contribute to the waste management. Moreover, the government should set up the specialized organization for surveillance on the private-owned companies to make sure the waste will go to the right place.
7.2.4 To Set Up the Identification Policy

The government should set up the respective identifications on the products depending on the products reused the sources, the products could be recycled or the products use the reused and recycled packaging, which could also help to encourage to use the materials which can be reused and recycled for the products and packaging. And to help to give publicity to these kinds of products and encourage more residents buy these kinds of products, is one of the important and efficient ways for reducing and reusing the waste.

7.2.5 To Provide Education and Activities for Awareness Rising.

The school should add some courses or activities in the spare time to enhance the education on the waste collection, waste sorting, waste reuse and recycling, etc.. Besides, the local government should also organize some education activities for the residents and the enterprises on the above aspects of waste handling. Because the relevant knowledge is the basis for people to sort, reuse or recycle the waste on their own. Last but not least, to organize the social activities to propagandize the importance of waste handling, or through the media, in order to let people get into the habit of it.
Reference


(J Gertsakis and H lewis, 2003) J Gertsakis, H lewis, Sustainability and the Waste Management Hierarchy, 2003: a discussion paper for EcoRecycle Victoria, RMIT,
Municipal Solid Waste Management in China

Melbourne.

(William McDonough, etc., 2002) William McDonough, FAIA, Michael Braungart, Cradle to Cradle, 2002: Remarking the Way We Make Things.

(Bingxing Bian, etc., 2005) Bingxing Bian, Hongbo Zhang, Cai Zhao: MSW Treatment and Technology, 2005.

(Li Wang, 2006) Shanghai Environmental online. http://www.envir.gov.cn

(Yi Zhang, 2004) Shanghai Institute for Design & Research on Environmental Engineering, 2004: MSW Assessment and Treatment Situation in China


(Rong Huang, etc., 2009) Rong Huang, Xiaoli Zhou 2009, Environment Protection Monitoring Center in Zhenzhou city: MSW Governance Exploration.


(Panming Wei, 2009) Panming Wei, Municipal Administration Committee of Beijing, 2009


(Mick Corliss, 2009) Mick Corliss, Japan Times: Dioxin: Levels high in
incinerator-happy Japan

(Biling Pan, 2009), Biling Pan-The Vice Director of Environment Protection Agency of Hunan Province, Member of the National Committee of CPPCC

(UNEP, 1999) UNEP Chemicals, Dioxin and Furan Inventories, National and Regional Emissions of PCDD/PCDF, 1999


(Green Peace, 2001) Green Peace, 2001: Incineration and Human Health

(Yingxu Chen, 2009) Yingxu Chen-member of the National Committee of CPPCC (Chinese People’s Political Consultative Conference), Professor of Zhejiang University, 2009

(Jianguo Liu, 2008) Jianguo Liu from Department of Environmental Science and Engineering, Tsinghua University, 2008


(People’s Daily Online, 2009) People’s Daily Online: http://www.people.com.cn


(Haarbing University of Technology, 2008) Haarbing University of Technology, MSW disposal project in Tieli, November 2008

(Tao Hu, etc., 2006) Tao Hu, Yuping Wu, Lingyun Zhang, China’s MSW Management Mechanisms Analysis, 2006

(Suzanne Arup Veltze, 2008) Suzanne Arup Veltze-Director of DAKOFA, Danish Waste management Association


(Ming Wei, 2009) http://www.ce.cn


(Graczka Sylvia, 2009) Graczka Sylvia, 2009, Landfills Shutting Down in Hungary-A
Civil Option


(COWI, 2001) COWI Consulting Engineers and Planners AS, Environmental Factors and Health, The Danish Experience, Danish Environmental Protection Agency, 2001

(COWI, 2009) COWI, 2009: “Cradle to Cradle” as a globally sustainable principle


(Nordic Council, 2006) The Use of Economic Instruments in Nordic Environmental Policy 2001-2005, National Environmental Research Institute, Denmark
