

Assessing the challenges and potential of implementing composting as part of a municipal solid waste management system in Baisha, Hainan, China

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

China currently produces the largest quantity of municipal solid waste (MSW) in the world at 190, 000, 000 metric tones (World Bank 2005). China faces the continuing challenge of increased waste generation due to population growth, increased income, and increased urbanization. As part of environmental protection initiatives, the central government has issued many policy commitments at the national level to address waste management. In concurrence with the national objectives of addressing the problem of waste management, Hainan province has developed an integrated waste management plan that it hopes to implement by 2020 (The Hainan City Environment and Sanitary Association, in association with *Hua Zhong University of Science and Technology of Environmental Science and Engineering*, 2005).

Organic waste, which accounts for a significant proportion of the waste stream in China, poses both challenges and opportunities in terms of disposal and recovery. While the final disposal of organics may present significant challenges, recovery of organic waste through composting is one alternative. Composting is widely recognized as an effective method of turning organic waste into a useful product. Nevertheless, the implementation of composting as part of a Municipal Solid Waste Management (MSWM) strategy faces challenges. Broadly, these challenges include administrative/policy, human acceptance and participation, management, technological and logistical, and marketing as well as composting process, source separation, contamination, quality of the final product, appropriate composting technologies and final demand and distribution of the final product (Schubeler et al. 1996, Hoornweg et al. 1999).

This thesis uses a case study approach in implementing a composting pilot project in cooperation with the local and provincial government in Baisha Hainan China. Labor intensive, low technological, windrow composting is used so as to assess the challenges and potential of implementing composting

as part of a municipal solid waste management strategy in Baisha Hainan China. The research uses a participatory action research approach incorporating research methods such as participant observation, key informant interviews (n=122), and rapid rural appraisals.

The research objectives are to understand the current waste management system, understand how implementing composting affects the waste management system entails, understand the barriers to implementation, understand the implications: impact of implementation, potential, and finally to propose recommendations on how to implement composting.

The research identified seven necessary key factors that if not given sufficient attention could potentially jeopardize the successful implementation and operation of composting: governmental support must be present, funds must be made available since operating cost of the waste management system will increase, best practices for composting must be established, training for waste workers must be provided, a market (or end use) for the final product must be established, NIMBY needs to be addressed, source separation should be applied.

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Dedication

On a personal level this thesis is dedicated to my father Dumirtu Ichim for teaching me the importance of education and inspiring me to search for knowledge and my mother Florica Batu Ichim for instilling in me a healthy dose of skepticism and encouraging me to question. On a practical level this thesis is dedicated to the all the Chinese people who continue to “serve the people”.

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Chapter 1

Introduction

China currently produces the largest quantity of municipal solid waste (MSW) in the world (World Bank 2005). China faces the continuing challenge of increased waste generation due to population growth, increased income, and increased urbanization. Consequently, the issues of sustainable and effective municipal solid waste management (MSWM) are becoming increasingly important. The waste management systems in most cities in China are suboptimal, producing environmental and human hazards and not recovering potential resources (ibid). Thus, MSWM in China faces two challenges: the first is the final disposal of waste, and the second is resource recovery.

China produces an estimated 190,000,000 metric tons of MSW per year and is expected to increase the amount of waste generation; this will pose a significant planning challenge in the future. Although the waste generation rate per capita is 0.8 kg per person per day, one of the lowest rates in the world; the United States (3.5 kg per person per day) and Luxemburg (4.8 kg per person per day) are among the highest (World Bank 2005). Projections indicate that by 2030 the rate of waste generation will be 480,000,000 metric tons per year (World Bank 2005). These projections are attributed to expected continual population increase, economic development, and urbanization in China (ibid).

In the year 2007, China had the largest population in the world. The population of China is expected to grow, and due to the strong correlation between increases in population and increases in waste, waste in China is also expected to increase. Despite the population control mechanisms that have been implemented¹, China's population is expected to peak in the coming 30-40 years before stabilizing and declining (Shen, 1998). Even though the individual rate of waste generation is low,

¹ In terms of dealing with the issue of population growth China has taken perhaps the most drastic population control policy the world has ever seen; the one child policy. This policy stipulated that each family must have only one child except under special circumstances (Shen, 1998).

the effect of the scale of population in terms of the overall impact of the waste produced is significant. Moreover, the fact that the population will continue to increase before decreasing makes waste management an increasingly urgent issue.

Increased income in China is also expected to contribute to increases in waste generation. The correlation between increased income and increased waste generation is a well-documented phenomenon (ISWA & UNEP 2002, World Bank 2005). Since Deng Xiao Ping introduced the *Reform and Open Policy* (*Gai Ge Kai Fang*) in 1978, which instilled free market mechanisms into China, China's economy has experienced a globally unprecedented annual average growth rate of 10% (Wu 2000). Chinese projections anticipate that by 2020 GDP will have quadrupled over current levels, and per capita income will stand at \$3000 USD (Yuan et al 2006). Given the projected economic growth and the empirical observation that economic growth translates into increased waste generation, this provides reason to believe that waste generation in China will likely increase.

Increased urbanization occurring in China will contribute to increased MSW production as the centralization of human population in urban space leads to increased MSW (ISWA & UNEP 2002) since urban residents produce two to three times more waste than rural residents (World Bank 2005). With China's gradual transition from a planned to a free market economy, and a gradual end to policies that attempt to curtail the growth of cities by restricting migration², there will likely be a greater transition of people from rural areas to urban areas. In 1988, the rural-urban distribution was 70% rural and 30% urban; by the year 2040 this demographic photo is expected to reverse with 30% rural and 70% urban (Shen, 1998). With this dramatic population transfer from rural to urban settings,

² Policies which restrict human migration from rural to urban areas are known as the hu kou system (Davis 1989).

there will be an unprecedented number of people living in urban areas; thus the amount of MSW will increase and the needs and challenges presented in urban contexts will require attention³.

While the state of MSWM in China differs greatly according to place, in most urban areas there remains substantial room for improvement in final disposal of waste and recovery of resources (World Bank 2005, Wang and Nie 2001). Of the MSW collected 79% is disposed in landfills (including centralized dumping and simple landfills), 19% is composted or recycled, and 2% is incinerated (Wang and Nie 2001). It is estimated that 59% of MSW collected in Chinese municipalities is disposed of in simple landfills (centralized dumpsite or landfills with *some features* of an engineered landfill) (Suocheng 2001). Simple landfills are the most prevalent technology used for waste disposal. In China overall 660 cities have an estimated 1000 simple landfills that operate in non ideal conditions⁴ (World Bank 2005). This translates into 77 900 000 metric tons⁵ of waste that are currently disposed of in a manner that poses hazards to the environment such as dumping and/or burning.

Waste management reconciles two important and inseparable issues that are increasingly significant in the Chinese context: resource recovery and final disposal. Recovery issues are significant because the materials recovered represent potential revenues and savings from a resource and environmental perspective. Due to the size of the Chinese population, resources recovery if practiced on a large enough scale can affect the consumption patterns and supply and demand of virgin resources (World Bank 2005). Furthermore, recovery of resources represents access to resources that contribute to

³ Historically Chinese farmers composted their organic waste on a household scale (Dazhong and Pimentel 1986, Paoletti 1999).

⁴ Non-ideal conditions refers to simple landfills with one or more of the following conditions: waste pickers are present at the landfill, sloping requirements are inadequate, leachate collection and treatment system, present design problems, waste is not compact, covering system is not adequate, lack of landfill gas recovery (World Bank 2005).

resource inventory and security⁶. This is particularly significant in the Chinese context because projected increases in population, income, and urbanization will likely trigger increased demands for resources.

Improper final disposal of waste affects the environment, human health and also poses hazards to the occupational health of sanitation worker (Cointreau, 2005). Environmental impacts of improper waste management include odor, explosions and fires at dumpsites, air pollution, ground water pollution, and global warming (El- Fadel et al. 1995). With respect to direct human impacts, the issue of vectors and the spread of illness are significant in the vicinity of unengineered landfills (Cointreau, 2005). Occupational hazards which workers are afflicted by include: infectious disease, allergy, pneumonia, chronic bronchitis, hepatitis, parasites, acute diarrhea, coronary disease, injuries accidents, puncture wounds and musculoskeletal problems (ibid). Thus, hazardous waste management has significant environmental and human impacts, and merits attention when dealing with issues of final disposal of waste.

Organic waste, which accounts for a significant proportion of the waste stream in China, poses both challenges and opportunities in terms of disposal and recovery. In terms of final disposal, neither incineration nor landfilling are optimal solutions. The high proportion of organics in the current wastes stream in most Chinese cities limits the appropriateness of employing incineration as an option for disposal (World Bank 2005). The low caloric value further contributes to difficulties in incineration as the waste stream is barely autogenic and requires extra fuel to continue burning (Jones, 2007). When disposed of in landfills, organic waste decomposes. This poses a significant

⁵ Total waste produced is 190 000 000 metric tones, if 59% is disposed of in a relatively safe manner than 41% is not disposed of in a sustainable manner this indicates that 77 900 000 metric tones are disposed of in environmentally hazardous manner.

⁶ Currently the issue of resource security is a significant in terms of international geopolitical reasons. For instance in order to quell China's high economic growth rate the United States has ban the sale of scrap metal to

challenge as degraded organic waste shrinks, resulting in the formation of voids and compromising the physical integrity of the landfill. Organics can shrink to as little as 40% of their original size (El-Fadel 1995), causing structural and physical instability which can result in a wide range of problems for landfill management. The leachate produced by organic waste is also significant in simple landfills, and when not properly collected can pose a significant hazard to water quality (ibid). Furthermore, organics may also be sources of environmental and human hazards if they contain pathogens or if disease-bearing vectors are not controlled (Cointreau, 2005).

Unregulated decomposition of organic waste also leads to the production of methane (CH_4). Methane is highly flammable and may lead to explosions in underdeveloped landfills (El-Fadel 2005). The production of methane also contributes to global warming since methane is a greenhouse gas twenty two fold more potent than carbon dioxide (World Bank 2005). Globally, methane produced by landfills is a noteworthy contributor to global warming (ibid).

While the final disposal of organics may present significant challenges, recovery of organic waste through composting is one alternative. Composting is the management of the decomposition of organic waste with the intention of producing compost, an organic soil enhancer (Haight and Taylor 2000). Composting is widely recognized as an effective method of turning organic waste into a useful product. Nevertheless, the implementation of composting as part of a MSWM strategy faces challenges. Broadly, these challenges include administrative/policy challenges, human acceptance and participation, management challenges, technological and logistical challenges as well as marketing challenges (Schubeler et al. 1996). It is also important to consider specific composting challenges, including challenges associated with source separation, contamination, quality of the final

China (World Bank 2005), the idea is that by curbing access to metal China's economic growth rate will be slowed, making American industries more competitive relative to the Chinese industries.

product, appropriate composting technologies and final demand and distribution of the final product (Hoornweg et al. 1999).

1.1 Chinese government's growing awareness of environmental problems and responses

The government of China is aware of the current and future challenges that China faces regarding environmental degradation and resource management (Shen et al. 2002). China has recognized the environmental cost of economic development and embarked upon a path committed to reconciling environmental protection and economic development (Shen et al. 2002, Yuan et al. 2006, An Outline Program for Building Hainan into an Ecological Province, Revised 2005). To address the projected shortage of resources China has begun to promote an industrial ecological approach (Yuan et al. 2006). The central government has formally accepted circular economic structures which aim at “loop closing” as underlying the method of economic development for the 21st century (ibid). The emphasis on “loop closing” represents the mainstreaming of environmental policy in economic development policy (ibid.).

The linkage between increased economic development and environmental protection is best exemplified in Hainan provinces policy statement: *“preserving the environment means safeguarding the productive power, improving the environment means developing the productive power and damaging the environment equals damaging the productive power”* (An Outline Program for Building Hainan into an Ecological Province, Revised 2005). In 1999, Hainan province was designated as a *“shen tai sheng”* (ecological province) in order to preserve the fragile ecosystem as well as to provide a conceptual model for ecological preservation (ibid).

As part of environmental protection initiatives, there have been many policy commitments made at the national level to address waste management. For example, the “China 21st Century Agenda”

makes a commitment to the aim of 100% MSW treatment and disposal before 2010 and decrees that every municipality must establish local MSW treatment facilities (Wang, Nie 2001). In concurrence with this plan, Hainan province has developed an integrated waste management plan that it hopes to implement by 2020 (The Hainan City Environment and Sanitary Association, in association with *Hua Zhong University of Science and Technology of Environmental Science and Engineering*, 2005).

The Hainan City Environment and Sanitary Association, in association with *Hua Zhong University of Science and Technology of Environmental Science and Engineering*, have developed an integrated waste management (IWM) plan. This plan is accepted as the blue print for developing waste management from 2005-2020. This IWM plan entails the usage of landfills, incineration and composting. It does not entail any recycling initiatives *per se* since recycling at the informal and semiformal level is operated by the private sector using free market incentives. This plan addresses the MSW according to the specific demands of each city and municipality with regards to the composition, and amount of waste produced. According to this report, Hainan province produces an estimated 5096 metric tons of municipal solid waste per day. Of this waste an estimated 50%- 60% of the waste is organic⁷ that is between 2548 – 3057 metric tons of organics per day.

The fifteen-year plan aims to incorporate composting in a comprehensive way throughout Hainan Province. According to the provincial plan, organic waste will be handled by means of “high temperature composting” (The Hainan City Environment and Sanitary Association, in association with *Hua Zhong University of Science and Technology of Environmental Science and Engineering*, 2005, page 9). Four large composting facilities will be created as well as eight medium size composting facilities and an undetermined number of small sites. While the plan describes where the

⁷ It is fair to estimated that 50% of the waste produced in Hainan province is organic based on reasoned argumentation given the following information overall 50% of the waste generated in China is organic (World Bank 2005), 60% of Haikou’s waste is organic (Hainan Province Municipal Waste Management Regulation

composting will occur and the capacity, specific details about the technology that will be used are not yet established.

The first IWM facility with composting was developed in Sanya, Hainan (Ichim 2006). This facility is a capital-intensive project that draws criticism and faces challenges since it is heavily government subsidized (ibid). Even though this facility has been operating for several years the composting aspect has been heavily criticized by local and provincial government officials. It faces problems due to improper source separation, technological problems and a lack of developed of composting market (ibid). The challenges that were presented in Sanya indicate that there are many aspects that need to be considered when incorporating composting as a part of a MSWM plan. Thus, there is a demand for appropriate and feasible technology as well as consideration to the implementation of the technology.

In response to the demand for appropriate and feasible technology, a pilot waste composting case was established in the Township of Baisha. This pilot project was established through the Hainan provincial government agency Department of Land, Environment, and Resources of Hainan Province in cooperation with the faculty of Environmental Studies at the University of Waterloo in a project headed by Dr. Murray Haight as part of Eco-Plan China. At the local level there was cooperation between three local departments in Baisha Township: the Department of Land (*hou tu ju*), the Department of Environmental Protection (*huan bao ju*) and the Department of Sanitation (*wei shen ju*). The purpose of this one time pilot composting project was to explore the ability of local institutions to implement composting, and to identify the issues, challenges and potential of implementing composting as part of an integrated waste management system in Baisha, Hainan. This research will be used to inform the next step, which is the construction of a longer term composting

Plan, 2005) , 54% of Sanya's waste is organic (ibid) and 47 % of Baisha's waste is organic (Wen and Jing, 2005).

facilitate to act as a model for the development of other waste management facilities in Hainan province.

1.2 Statement of problem and research aims:

Best practices in MSWM suggest that composting is usually the most suitable method of handling organic waste (SITA 2004, Gertsakis, Lewis 2003). The literature on implementation of composting in developing countries however, indicates that there are many challenges which are highly contextual: these challenges include administrative/policy challenges, human acceptance and participation, management challenges, technological and logistical challenges as well as marketing challenges (Schubeler et al. 1996). This research traced the implementation of a composting pilot project, which involved composting solid waste produced by the central market place. The objective was to identify and propose recommendations on human and technological issues that may arise when implementing composting as part of a MSWM strategy.

Given the specific challenges of organic waste management, as well as Hainan's commitment to developing an IWM system employing composting, the current research is an exploratory study aimed at identifying the challenges and potential of implementing composting in Hainan province at the township level. Although the local government and provincial government aim to eventually compost residential and commercial waste, only market waste was composted as part of this pilot project. The reason that the pilot project was implemented at the market level was because limited source separation was occurring at the market level and that the experience gained from this case could be transferred to the residential and commercial level if the governments chose to expand composting to the residential and commercial levels.

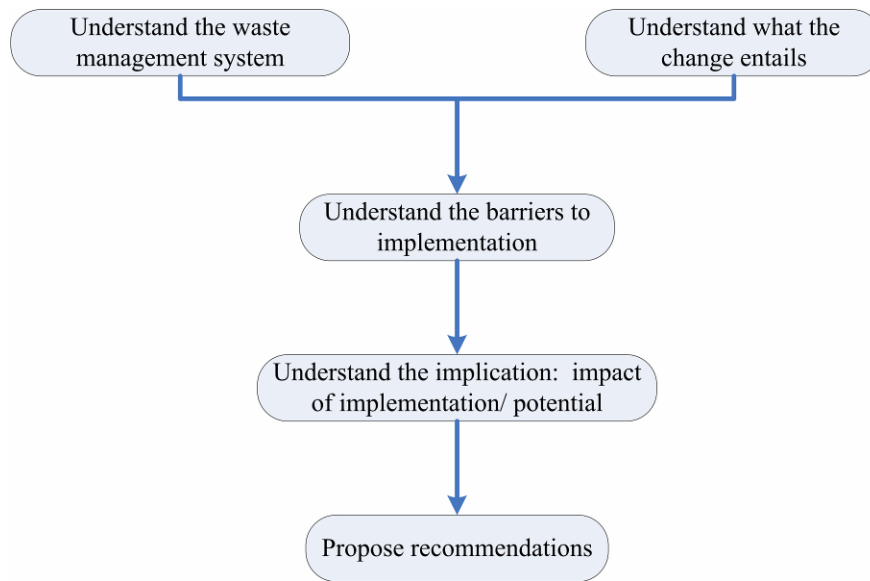


Figure 1.1: Research approach

In order to assess the extent to which composting is an appropriate method for treatment of organic waste and what the issues and challenges to implementing composting in Baisha Hainan are, the following research objectives were chosen.

1. Understand the current waste management system
2. Understand what the change in the waste management system entails: human and technical issues
3. Understand the barriers to implementation
4. Understand the implications: impact of implementation/ potential
5. Propose recommendations

1.3 Approach and limitations

This section will give an overview of the general approach that this research employed and the limitations that affected the research design and results. A detailed account of the theoretical and methodological underpinnings of the research methods will be described in chapter three.

A multiple method approach was used to gain a deeper understanding of the complexity of the issues as well as to enable triangulation of the results (Flowerdew and Martin, 2005). The results are both qualitative and quantitative. The analysis used both inductive and deductive reasoning to derive meaning from the data collected. The understanding of the current waste management system and the human dimensions of composting implementation uses inductive reasoning based on empirical observation. The theory of integrated waste management and composting employs deductive reasoning.

Three approaches were employed to gain knowledge: the first was a literature review of previous research and policy; the second was participatory action research that focused on the case study of composting; the third was semi-structured key informant interviews (n=122).

Time, resources, language, and access to information were factors which limited the scope of this research and which influenced the research finding. There are limitations in replicability and generalizability when employing action research based on one time case study. Time acted as a limiting constrain on the researcher's ability to gauge the physical quality of the compost, since the field work was slightly less than three months and we did not start the composting process until the end of the second month. The researcher was not able to judge the quality of the final product, by conducting seed germination studies or vegetation studies⁸, because the compost had not fully cured. Time also prevented the assessment of potential markets for the final composting product because it

was too early to establish the quality of the final product. It was also too early to establish how market integration would occur.

Limited resources: insufficient funds and access to laboratory facilities limited the ability to do heavy metal testing of the final composting product and of the market waste. Thus, knowledge of heavy metal content was derived from the work of *Wen and Jiao (2006)* who only tested the heavy metal content of residential and commercial waste in Baisha.

Language was a factor that shaped the research design. Despite the fact that the researcher had previously lived in China and studied Mandarin for two years, a lack of proficiency in Mandarin affected the researcher's ability to fully comprehend Mandarin, and this obliged the researcher to rely on a translator, for the translation of texts and interviews. The translator did not speak the local dialect so the researcher employed local translators to translate answers offered in the local dialect to Mandarin and then to English. This issue did not prevail in most interviews, however interviews with people from remote places required as many as three levels of translations. For instance, most informal waste workers in Baisha only spoke *Dang Zhou Hua* therefore, it was necessary to translate *Dang Zhou Hua* to *Hai Nan Hua* to Mandarin to English.

The language barriers potentially prevented deep qualitative analysis. Having anticipated this, questions were structured similar to surveys and simple questions were asked. This limitation potentially affected the depth of the understanding. In order to compensate for this shortcoming, a total of 122 interviews were conducted and some quantitative aspects were studied.

Lack of access to information and time prevented the ability to carry out a statistically random survey. Due to a lack of reliable information about the number of commercial and residential waste producers

⁸ One method to assess the quality of compost is to conduct seed germination studies (Troi et al., 2001) or vegetation studies- that is to assess the impact of compost on crop yield (Murillo et al. 1995).

it was difficult to carry out a random sample because the p value would not be known. In order to overcome this barrier more primary research would need to have been carried out.

Another limitation of this study is it is challenging to replicate and generalize based on data obtained from a one time case study because of difficulties making controlled observation, and controlled deductions (lee 1989).

Another limitation of this study is that it does not examine the role of gender in the formal waste management system.

1.4 Thesis organization

This thesis consists of seven chapters: introduction; literature review; research methods; introduction to case study; results; discussion: impacts, barriers and potential; recommendations and conclusion. The literature review encompasses four broad themes: 1) waste and resources 2)waste management theory; 3) distinguishing features pertaining to waste management in developing countries; 4) composting: process and challenges in developing countries. The methods section discusses the theoretical and methodological assumptions of the research as well as the specific method used in this study. The results describe the current waste management system, the proposed change and place specific issues. The discussion focuses on the implications of the results: the impacts, barriers and potential of composting. Finally, the last chapter offers some recommendations to be considered, contribution of this work to the field, and direction for future research.

Chapter 2

Review of the Literature

This chapter is an exploratory review that establishes the conceptual and empirical grounding for research on the pilot composting project. The purpose of this review is to identify and assess the issues and challenges that pertain to implementing composting systems in developing countries. This literature review critically assesses key findings of the theoretical and empirical work regarding four broad themes that are related to successful implementation of waste management systems, and have direct relevance to the pilot case. The first theme is the relationship between *waste and resources* the second is *waste management theory*, the third is *distinguishing features pertaining to waste management in developing countries*, and the fourth is *composting: process and challenges in developing countries*. A review of the literature on the above themes identifies key factors that affect implementing composting as part of a waste management system in developing countries. These factors were used to inform and contextualize the research conducted.

2.1 Waste and resources

2.1.1 Waste resource continuum

Waste is defined as an item that lacks utility to the current user, or something that has ‘no value’ to the current user. This is to say, there is greater economic utility gained from disposing of the object, than in the value that the object possess to the current user (Porter 2002). Waste can be a by-product of a productive process or it can be an object that has reached the end of its life cycle and that no longer posses any value to the current user (Ferguson 1995). While waste may be valueless to the primary user, it may possess a value to other users in its current state or if value is added to it, it can becomes useful to its current user or to another user (McDougall et al. 1995).

Waste and resources can be viewed as part of a cycle or a continuum, as depicted below, with resources on one side and waste on the other (ibid). Through use, a resource undergoes to a process of devaluation or depreciation, and unusable or unappreciated components become waste. On the other side, waste can undergo a value-adding process and becomes a resource or a useful product. The devaluation process can be incidental or unintentional, as in the case where waste is a by-product that is more economical to dispose of than to add value to. The devaluation can also be an intentional or foreseeable depreciation process in the sense that a product has reached the end of its life cycle.

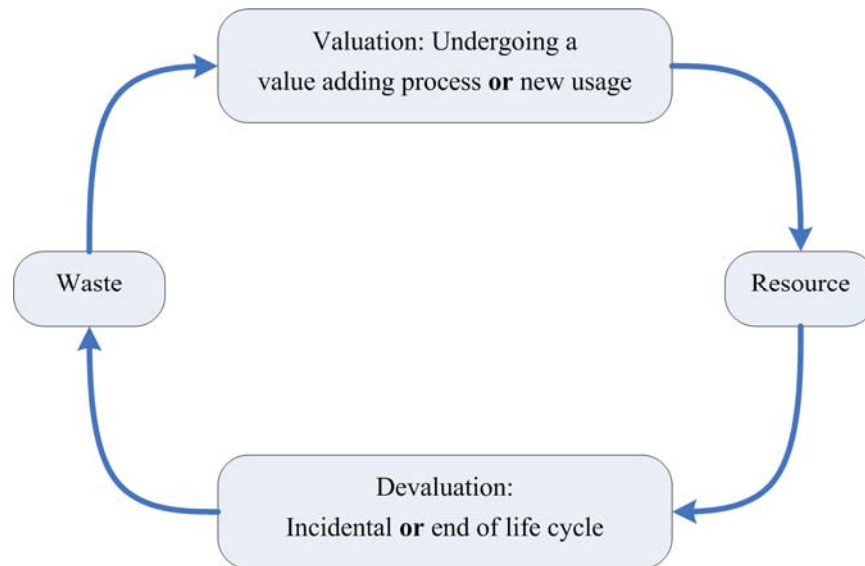


Figure 2.1: The waste resource continuum

Adapted from McDougall Et al. 1995 and White PR, Franke M, Hindle P 1999

According to the International Solid Waste Association (ISWA) part of sustainability entails viewing waste as a resource (ISWA & UNEP 2002). If waste is viewed as a resource, resource management theory can be used to enlighten the underlying waste management theory. Zimmerman proposed:

“Resources are not, they become; they are not static but **expand and contract** in response to human wants and actions... they evolve out of the triune interaction of nature, man, and culture, in which nature sets outer limits, but man and culture are largely responsible for the portion of physical totality that is made available for human use.” **(Zimmermann 1951).**

Using Zimmerman’s definition of resource as the paradigm for what resources are, three underlying principles relevant to the linkage between waste and resources can be inferred. The first and most important principle is that resources are anthropocentric. Secondly, resources are shaped by the interaction between humans and resources, which implies process and technology. Thirdly, resources are not static, but expand and contract in response to human want and action, indicating the fundamental role of economics and human values in resource management.

When applying these principles to waste management, three assumptions can be inferred that contribute to how one can view the relationship between waste and resources. Waste is a subjective matter relative to humans, and fundamentally, it is anthropocentric. A plastic bag is not a resource or waste in itself: it depends on a human’s ascription of value to it. Secondly, the relationship between humans and waste is shaped by the interaction between humans, nature, and culture: that is, economics, process and technology. Processes such as recycling change the availability of plastics, metals, and paper in absolute terms. Finally, the definition of waste and resource expands and contracts in response to human want and action. Thus, if there were shortages in virgin products, then the value of the recycled products would likely increase and there would be more demand for recycled products (Di Vita 2004). In many cases, value can be added and some utility can be restored to the waste, either through process or through a new type of usage (McDougall et al. 1995). In either

situation, economics often plays a determinant role in the decision of whether resources are recycled or recovered.

Strictly speaking, according to Zimmerman, waste by definition is not a resource; however, depending upon who is conducting the valuation of the resources, waste can potentially fall into the category of resource. Zimmerman is clear that resources need to be assigned value by humans in order to be considered as such. According to its definition, waste is something that is not valued by humans since waste contributes more utility to the present user if disposed of than if retained or reused. It may seem that these definitions are irreconcilable; however the question of who assigns value must be considered. It is in the gap between the subjective and potential societal reuse of waste, that waste can be viewed as a resource. Waste is essentially a subjective matter because waste to one person may not be waste to another person. Thus, an item may be waste to one user; however, since another user may ascribe value to the item it may be viewed as a resource; in addition, if society values that waste as a resource then it can be viewed as a resource not as waste.

Furthermore, the impact of technology on the valuation process must also be considered. If technology enables efficient recovery/ reuse of a product that has lost value, then the primary user may decide that the object has greater utility in recovery/ reuse than in disposal. While there is an underlying economic equilibrium that must be considered (Porter 2002), technology can change the economic viability of the recovery of resources.

2.1.2 Waste as opportunity cost forgone

Waste and resources are subject to anthropocentric subjective valuation, technological processes, and the day-by-day fluctuations of value as expressed in the free market; conservation and reuse of resources are intrinsic to this equation. In cases in which utility *can be* restored to 'waste', absence of utility restoration represents an opportunity cost forgone (Porter and Van der Linde, 1995). The

economic reason for this opportunity cost is often that the perceived utility gained is less than the perceived utility expended through reassigning value to the waste. More simply, it ‘costs more to reuse than it does to discard’. The choice not to restore value to waste could be due to real or perceived high transaction and process costs which make the recovery of waste economically unprofitable. What may be economically unprofitable for one party may be economically profitable for another party depending on factors such as the availability of technology, the size of the firm, economies of scale and government regulations (Bansel and Roth, 2000).

Strict economic valuation of resources overlooks the intrinsic value of conservation. Often, the real value of resources is not accounted for by the free market valuation processes. Virgin resources are often viewed as free commodities supplied by nature, and full cost accounting is not factored into the cost of the resource or final products (Conrad 1999). Thus, if real cost valuation was factored into the cost of the virgin resources, then the cost of production in many industries would increase (ibid). An increase in the cost of virgin resources would have a corresponding effect of making recycled materials an economically attractive alternative, relative to the cost of virgin resources (Di Vita 2004).

2.1.3 Loop closing: waste to resource

The industrial ecology paradigm uses the practice of loop closing and industrial symbiosis to increase resource productivity and reduce waste (Ehrenfeld and Gertler 1997). Loop closing is the practice of reusing waste as a resource. An open system arises when a resource is used and discarded, however if the waste produced is reused in another productive process or for another usage a circle is formed and the waste loop is closed.

Industrial symbiosis takes place when loop-closing activities occur between industrial producers such that the waste generated by one industry is used as a productive input in another industry. Loop

closing and industrial symbiosis may be employed as a waste management strategy or as an increased environmental-economic efficiency strategy (Shi et al. 2003). While reuse of waste and recycling are common examples of loop closing, these types of loop closing occur at the end of the life cycle and waste management is generally the incentive for reuse and recycling. Recently examples of loop closing where economic efficiency has been the incentive for reuse and recycling have developed in eco-industrial parks in Denmark (Kalundborg), (Ehrenfeld and Gertler 1997), Germany (Emscher Park) (Gibbs, 2003), and most recently China (*Guitang Group* sugar industrial cluster, and *Nan hai National Eco-Industrial Park* in Guangdong) (Shi et al. 2003). These parks attempt to stimulate the symbiotic relationship between industries, where the waste produced by one industry is used as productive inputs into other industries.

2.2 Waste management theory and practice

2.2.1 Waste management approaches

Currently waste management practice is disposal focused, complemented by recovery, reuse and recycling. Despite efforts to reduce, reuse and recover waste, waste is eventually disposed of in landfills. Landfills are “the essential end point for every waste management system” (Rushbrook, 1999). In developed countries,⁹ engineered landfills¹⁰ are usually employed (ibid). In developing countries simple landfills/open dumping is the principal disposal method (ibid).

⁹ Rushbrook (1999) estimates that only 30 countries out of 170 countries employ engineered landfills.

¹⁰ According to the Technical Guidelines on Specially Engineered Landfill, established at the Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal, Engineered Landfills which are used to dispose of household waste an Engineered landfill must be attentive to the following dimensions: Site Selection- geographic, geological, hydrological and urbanization features should be considered; Design of Operations- control contaminant or construct the site in a way so that the contaminants will not affect the surrounding environment; Design of Landfill, should have a liner system leachate control features, landfill gas management strategy, including collection system,; Control of Incoming Waste, security management; Landfill closure plan, closure of the site, long term care, site monitoring (UNEP 1995). UNEP gives specific recommendations for each of these dimensions.

In an attempt to reduce the amount of waste that ends up in landfills options to reduce, reuse, recovery and recycling have developed. Waste reduction is a producer focused method to reduce waste by focusing on the production of goods, the waste produced during the process of production, as well as at the end of the life cycle (Kreith, 2002). Waste reuse entails the reuse of waste by another user or by the same user in another form (ibid). Waste can be reused by another resources user, as in cases of waste exchanges or used good stores. Waste can also be reused by the same user in a different form if a new use is ascribed to it. Recovery is often an end-of-pipe option. Other end-of-pipe methods include composting, landfill gas recovery, as well as incineration with energy recovery systems (ibid). Recycling is also an end-of-pipe approach that entails the reprocessing of recyclable waste such as glass, plastic, metal, paper and rubber into raw material (ibid). Secondary raw materials are usually a lower quality than virgin materials (Ishii 1994).

2.2.2 Hierarchy of waste management

The waste management hierarchy is a conceptual tool that prescribes the preferred choices of waste management, starting with prevention and ending with disposal (Gertsakis 2003, Maclaren 2005, SITA 2004). Maclaren makes a distinction between waste management hierarchies in developed countries versus developing countries because the priorities of developing countries often differ from the priorities of developed countries (Maclaren 2005).

Gertsakis dates the hierarchy model to the 1940s. It is based on broad concepts that are now referred to as sustainability, and the precautionary principle (SITA 2004). It entails a practical and philosophical move from a disposal-based waste management system to a preventative waste management system (Gertsakis 2003). In 1975, it was integrated into the European Union's waste framework directive, formalized in 1989 and endorsed in 1996 (SITA 2004). The hierarchy as applied in the United Kingdom is provided below.

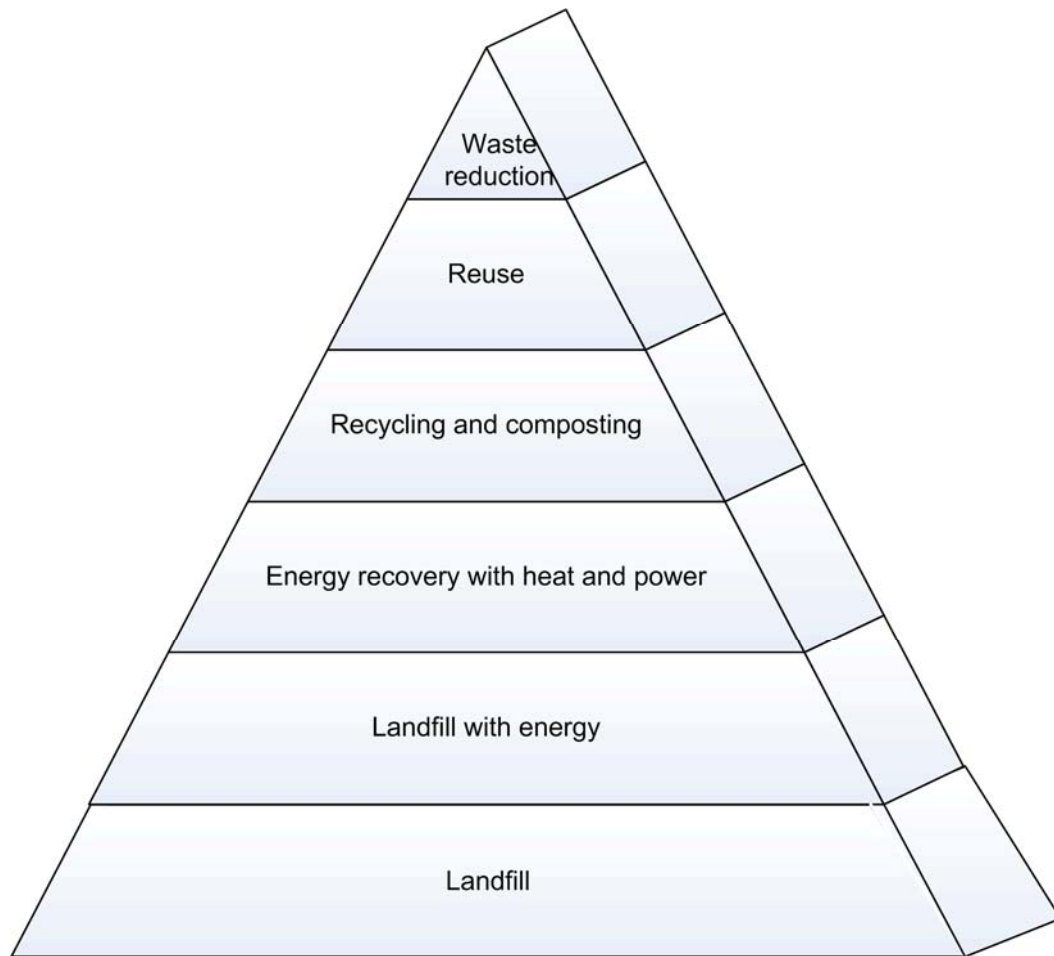


Figure 2.2: The waste management hierarchy as applied in the United Kingdom

SITA 2004

The hierarchy proceeds from most desirable to least desirable. The most preferred option is waste reduction (cleaner production, less consumption or use of more durable materials), the second most desirable option is to reuse putative waste (reuse of waste in other ways; direct reuse without process), third is recycling and composting (which entails some processing), fourth is energy recovery with heat and power (incineration), next is landfilling with energy recovery, the least preferred option is disposal of waste in a landfill without energy recovery (SITA 2004).

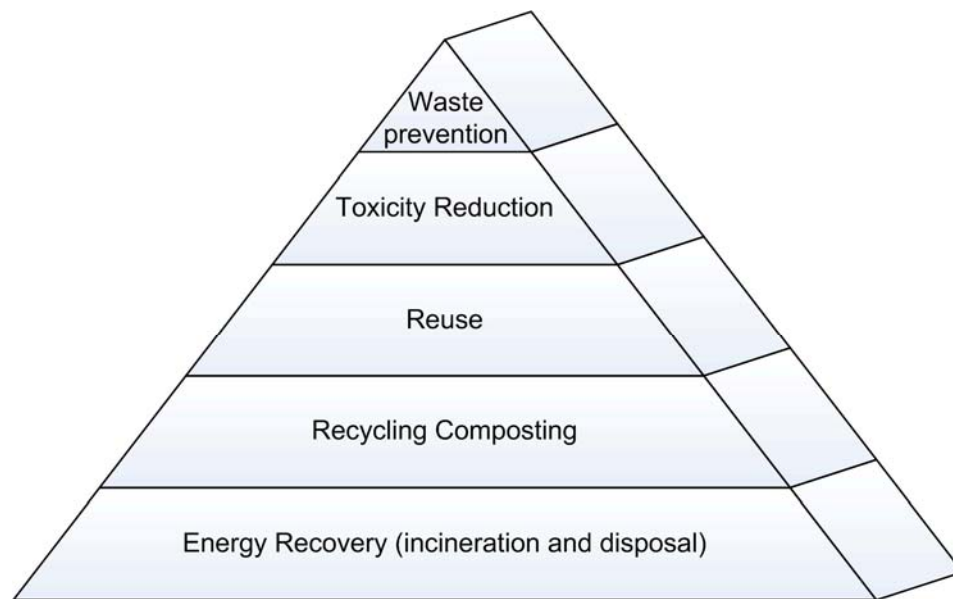


Figure 2.3: Suggested waste management hierarchy for developing countries

Maclaren 2005

Maclaren synthesizes the literature on waste management systems in developing countries, she presents two approaches which describe preferred objectives of waste management systems (Maclaren 2005). The first approach she proposes is similar to applying the waste management hierarchy of developed countries. The developing country waste management hierarchy begins with waste prevention, toxicity reduction, reuse, recycling and composting, incineration, and disposal of any remaining wastes, ideally with energy recovery systems. The unique feature is toxicity reduction, which may be a paramount concern in developing countries.

The second approach recognizes the pragmatic reality of the situation of waste management in many developing countries that 30-60% of waste is not collected (Zurbrugg 2002). This position holds that there are both short-term and long-term objectives. The short-term objectives are waste collection and disposal; while the longer-term objectives are waste reduction and recycling.



Figure 2.4: Alternative approach to waste management for developing countries

Maclaren 2005

The second approach that Maclaren proposes differs from both the waste management hierarchies in developed and developing countries in that it identifies collection and disposal as the most immediate need. Thus, the priority in the second approach is not waste reduction and recovery but collection and disposal. This is an end-of-pipe disposal oriented method of waste management. Although this second approach may be an accurate portrayal of the de facto priorities of waste management in developing countries, it may be criticized because it does not take a normative stance on the imperative of waste reduction and recycling in the short-term.

2.2.3 Integrated waste management

Integrated waste management (IWM) grew out of the literature on the waste management hierarchy combined with a systems approach to waste management (McDougall et al. 1995). While the waste management hierarchy is a prescriptive tool that provides recommended best practices, IWM provides a flexible framework for how to manage and optimize waste management (Seadon 2006). According to United Nations Environment Program (UNEP) IWM is “a framework of reference for designing and implementing new waste management systems and for analysis and optimizing existing systems” (Seadon 2006). Lynn was one of the earliest proponents of this systems approach to waste management: “view the problem in its entirety as an interconnected system of component operations

and functions” (Lynn 1962, McDougall et al. 1995, Seadon 2006). During the 1970s, American waste management practices reflected the integration of solid waste transportation and waste management strategies (McDougall et al. 1995). Thus, initially IWM had a narrow definition as the integration of waste management strategies (ibid). Out of this integration of waste management strategies grew a more holistic integration of waste management strategies, social, economic, political contexts and stakeholders (Maclaren 2005).

McDougall describes the narrow definition as specific steps in the waste management system:

“Waste collection and sorting, and one or more of the following options: recovery of secondary material (recycling); biological treatment of organic materials; thermal treatment and landfill”
(McDougall et al.)

This definition is useful for MSWM planning in terms of choosing appropriate waste management strategies. However, it lacks depth in implementing waste management systems in specific contexts. This definition is not considerate of the institutional, economic and human factors that shape and influence waste management practices. It assumes that waste management is exclusively a technical problem; this is not the case. Resource usage, waste production and valuation are essentially human issues. Another problem with this definition is that it begins with waste collection and sorting, not with the design of the product or waste production. This limits the applicability of the principle of prevention.

A more holistic definition of IWM is provided by Maclaren 2005:

Integrated waste management involves three different types of integration: (1) integration of different waste management strategies (2) integration of social, economic, legal, political, institutional, environmental and technological aspects of waste management (3) integration of stakeholders views, priorities and service delivery capability (Maclaren 2005)

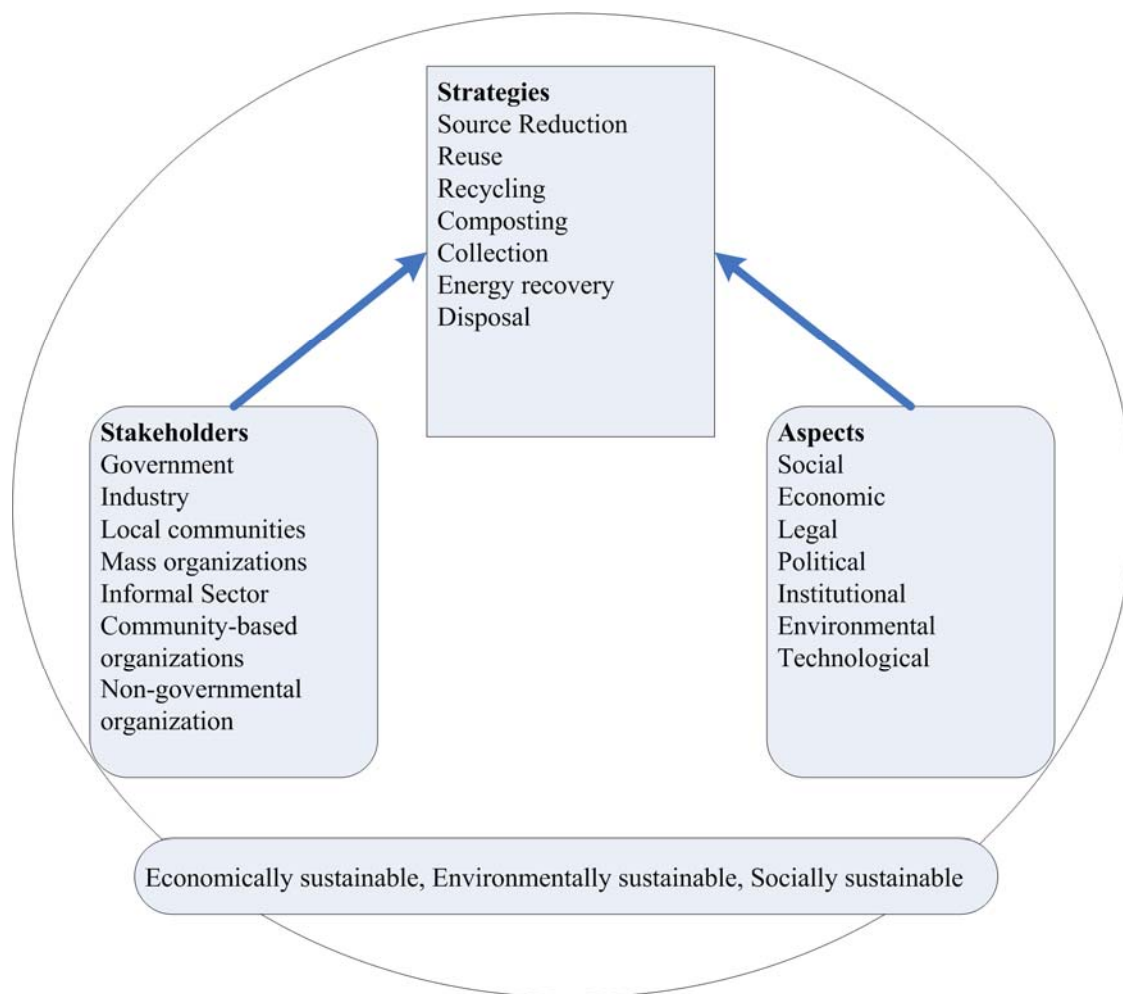


Figure 2.5: Theoretical overview of integrated waste management

Maclaren 2005

This definition of IWM incorporates more than planning strategies, considering the human, technological needs, and community desires, participation and feasibility. Factors beyond integration of waste management strategies may be decidedly influential in implementing MSWM strategies, particularly economics and political issues. To reconcile these two perspectives, IWM can be viewed as a process within a process, or a series of nested hierarchies.

Hainan province has developed an integrated waste management plan that it hopes to implement by 2020 (*Hua Zhong University of Science and Technology of Environmental Science and Engineering*,

2005). This plan entails the use of multiple waste management strategies. Prior to this project Hainan province attempted to apply an integrated waste management system in Sanya, however due to inappropriate technology this has not been successful. Hainan province is attempting to develop Baisha Township as a model case of integrated waste management. Currently there is an attempt to develop a landfill, and to integrate composting of the market waste, and the commercial and residential waste.

The Hainan department of Land, Environment and Resources are attempting to apply integrated waste management is currently Baisha Hainan and extend it to other areas (field notes 2006).

This case informs the application of integrated waste management in a specific context. It focuses exclusively on composting. Composting is often a feature of integrated waste management system depending on the feasibility of applying composting. This specific case study examines the challenges and potential of implementing composting as part of an integrated waste management strategy.

2.3 Characteristics of waste management in developing countries

A meta-analysis (N=30¹¹) of the some of the literature on waste management systems in developing countries indicates that waste management systems in developing countries share a cluster of unique characteristics. Waste management systems differ depending on the specific location (country, province, city, and neighborhood); at the same time there are significant differences between waste management systems in developed and developing countries (ISWA & UNEP 2002). In some developing countries waste management systems may be virtually non-existent or may be

¹¹ Agunwamba 1998, Beede et al.. 1995, Breslin 2002, Campbell 1999, Cointreau 2005, Da Silva et al. 2005, Forsyth 2005, Hoornweg et al. 1999, Hui 2006, ISWA 2002, Kgathi and Bolaane 2001, Kinnamen 1999, Maclaren 2005, Mbuligwa 2002, Nguyen 2005, Paquin and Sbert 2004, Raninger et al. 2006, Rushbrook and Finnecey 1988, Scheinberg 1999, Schubeler 1996, Sudhir et al. 1997, Suocheng et al. 2001, Taylor 1999, Wang and Nie 2001, Wang and Nie 2001, Wei et al. 1997, Wei et al. 2000, World Bank 2005, Zurbrugg 2002

environmentally hazardous to the environment and people. The prevailing conditions of waste management in developing countries listed in Table 2.1 are organized along the lines of culture and gender, waste planning and operations, institutional, occupational and economic and industrializing issues. These specific topics as well as the interaction between these topics are useful to consider in improving waste management systems in developing countries.

Table 2.1: Distinguishing features of waste management systems in developing countries culture and gender

Culture and gender	
Attitude towards waste	<ul style="list-style-type: none"> • Lack of responsibility towards the production of waste • View waste as dirty • Apathetic towards waste management
Gender and waste	<ul style="list-style-type: none"> • Women and men have different roles in the waste sector • Women are more prevalent in waste working • Men and women are subject to different impacts
Waste planning and operations	
Collection problems	<ul style="list-style-type: none"> • Inadequate waste collection due to insufficient funding, those who pay receive waste collection, those who do not pay do not receive waste collection • Inefficient waste collection, waste may be collected several times per days in some areas and not at all in other areas • Only 50-70% of waste generated is collected
Final disposal problems	<ul style="list-style-type: none"> • Adverse health and safety impacts • Adverse impact on essential infrastructure and water quality • Adverse impacts on air, soil, water, agriculture
Technology problems	<ul style="list-style-type: none"> • Poor equipment • Lack of training in solid waste management practices
Financial problems	<ul style="list-style-type: none"> • Lack of financial resources • Higher relative cost in developing countries than developed countries, cost 20-50% of local government revenues
Institutional	
Institutional framework	<ul style="list-style-type: none"> • Differences in institutional framework. Possible complications and problems, overlap of agencies responsible • Lack of discourse and cooperation between agencies responsible • Inadequate waste management policy and enforcement • Adequate waste management policy but lack of enforcement
Occupational	
Workers are exposed to a greater number of occupational hazards	<ul style="list-style-type: none"> • Protective measures are rarely implemented in developing countries • Increased risk of infectious diseases, allergic pulmonary and non allergic pulmonary diseases, chronic bronchitis, hepatitis, parasites, acute diarrhea, coronary diseases, injuries, accidents, musculoskeletal problems • Informal sector rarely wears protective clothing • Informal sector walks long distances with heavy carts

	<ul style="list-style-type: none"> • Informal sector heavy lifting • Informal sector Frequent repetitive movements • Exposure to chemical hazard: batteries (car and normal), oils and greases, insecticides and herbicides, solvents, paints, cleaning products, cosmetics, drugs and aerosol containers under pressure • Exposed to biological hazards: bandages disposable diapers, toilet paper, sanitary napkins disposable needles or syringes and condoms • Safety hazards • Psychosocial hazards • Informal population tends to have pregnant women and children
Labor intensive	<ul style="list-style-type: none"> • Labor intensive • Workers come into more direct contact with the waste
Economic and industrializing	
Industrializing countries larger amount and more diversity of materials.	
More income; more waste	<ul style="list-style-type: none"> • Income affects amount of waste generated
Type of waste, change in waste stream, high organic content	<ul style="list-style-type: none"> • High organic content in developing countries
Informal sector, plays a critical role	<ul style="list-style-type: none"> • High unemployment rate and large sums of uncollected waste which can translate into opportunity • Growing global market for recyclables • Handle large section of recyclable materials • Informal sector can interfere with formal collection systems
Resource recovery	<ul style="list-style-type: none"> • Local industries often dependent of secondary processed materials • Methods of resource recovery are inefficient and hazardous to occupational health • Informal sector plays a key role

2.3.1 Culture and gender

The literature reveals that developing countries and developed countries differ in terms of cultural attitudes towards waste. In some developing countries, waste is viewed as something dirty that people do not want to handle, there is also a lack of a sense of responsibility towards the production and disposal of waste (Agunwamba 1998). This contributes to an apathetic or indifferent attitude towards waste management (ibid.). This attitude effects disposal of waste, as well as willingness to separate waste. Collection of waste is often viewed as the responsibility of waste workers and the household

may be reluctant to separate waste (ibid). Cultural attitudes are place specific and can be significant barriers or divers to implementing composting (Schubler 1996, Hoornweg et al. 1999)

Gender analysis argues that often men and women have different roles in society, and experiences by men and women are radically different. Gender plays a unique role in waste management in developing countries both in terms of the function that each gender holds in the waste management system and in terms of their experience (Scheinberg 1999). Women are often responsible for household sanitation, and thus play an important role in managing household waste (Nguyen, 2005). In terms of the waste management sector, women are often overrepresented in both the formal and informal sector of waste management and underrepresented in administration and management. (ibid) Thus, the experience of a women waste worker is different than a male waste worker. This is true in terms of psychosocial and sociological factors as well as health (Nguyen 2005, Scheinberg 1999).

2.3.2 Planning logistics and operations

Challenges in waste planning and operations that prevail in developing countries include: collection problems, final disposal problems, technological problems, and financial problems. With respect to collection, most of the literature reviewed concurs that collection is inadequate (Schubeler 1996, World Bank 2005, Zurbrugg 2002). Collection is often inefficient, with spatial discrepancies in the frequency of collections; some areas may receive collection twice a day while others may never receive collection. Final disposal practices in developing countries include open pit burning and dumping, these have negative impacts on both environmental health as well as human health. In terms of environmental health final disposal practices have impacts on air quality, soil, ground and surface water as well as vegetation in the area. Direct human health impacts include respiration problems, toxicity, and the attraction of vectors which spread diseases (Cointreau 2005). Technological problems include a lack of appropriate technology, a lack of capacity in operating technology, a lack

of solid waste management training, and the difficulty and expense of repairing technology, especially if parts are not available (Schubeler 1996). Cost is an important issue as countries may already be experiencing financial difficulties even in implementing basic collection services. Developing countries face a higher relative cost than developed countries. In many developing countries waste management comprises about 20%-50% of the local government's revenues (Cointreau 2005). Methods that are chosen must be financially appropriate. There is consensus in the literature that the most expensive waste disposal method when taking into consideration capital and operating expenses is incineration, followed by composting, followed by sanitary landfilling (recycling can be used to compliment any of the above systems) (Cointreau 2005).

2.3.3 Institutional

Some developing countries face institutional problems that hamper the development of waste management policy as well as implementation of the policy. In some developing countries, due to lack of effective institutional framework, overlap of agency responsibilities may occur (Campbell 1999). While having multiple agencies working on one issue is not inherently negative, since it may lead to more resource availability, this may be problematic in cases where responsibility and authority are not clearly defined or when government agencies are not willing to cooperate (World Bank 2005). Many developing countries do not have adequate waste management policy (ISWA & UNEP 2002). Other developing countries may have adequate policy and standards but implementation and enforcement is lacking (Paquin and Sbert 2004).

2.3.4 Occupational

Occupational hazards for waste workers exist in both formal and informal waste management settings. Protective clothing is often not worn by workers in either formal or informal settings; this is especially true in the informal settings. Waste workers are often exposed to biological and chemical

hazards that coupled with the lack of protective measures results in increased health risks. Biological hazards include direct or indirect contact with, bandages, disposable diapers, toilet paper, sanitary napkins, disposable needles or syringes, and condoms (Da Silva 2005, Cointreau 2005). Chemical hazards include batteries, oils and greases, insecticides and herbicides, solvents, paints, cleaning products, cosmetics, drugs and aerosol containers under pressure (Da Silva 2005). This contributes to increased risk of infectious diseases, allergic and non-allergic pulmonary diseases, chronic bronchitis, hepatitis, parasitic infection, acute diarrhea, and coronary diseases (Cointreau 2005, Da Silva 2005). Safety hazards such as walking along traffic-congested streets and the physical demands of this work lead to increases in injuries, accidents, and musculoskeletal problems. Furthermore, children, women and pregnant women are often over-represented within the informal waste sector. It should be noted that these demographic populations may handle exposures to biological, chemical and safety hazards in ways which make them more vulnerable than an adult male.

2.3.5 Economic and industrializing

Wealth is arguably one of the distinguishing feature between developed countries and developing countries. In terms of waste management, this results in a number of implications ranging from the waste volume produced to the relative financing available for MSWM systems. The relationship between waste generation and income level is well documented, with higher income leading to an increased waste production (Kinnamen 1999, Cointreau 2005, Da Silva et al. 2005). Developing countries are often undergoing processes of industrialization, leading to changes in waste stream composition. Developing countries tend to have high organic content in waste streams¹² (Mbuligwe 2002, Hoornweg 2000). While increases in income correlates with increases in waste, many

¹² This is significant because it speaks to the urgent need of organic waste management in developing countries.

developing countries have high populations thus, developing countries often produce higher absolute amounts of waste that contain a more diverse type of material (ISWA & UNEP 2002).

Waste planners should be considerate of future changes in waste stream composition. Currently, developing countries have high organic content. However, the implications of changes in the waste stream due to industrialization should be considered. Changes in waste stream composition because of consumption as well as seasonal changes are important to take into account for waste management planning purposes.

Resource recovery by the informal sector plays a critical role in the local economic development of developing countries. High unemployment rates and large sums of uncollected waste can translate into opportunity for those who cannot find employment in other sectors (Da Silva 2005). The informal economy often handles large section of recyclable materials (Da Silva 2005). There is a growing global market for recyclables both domestic and global that local economies partake in (Da Silva 2005). Also, local industries are often dependent on secondary processed materials (ISWA & UNEP 2002). Drawbacks include that methods of resource recovery are inefficient and hazardous to occupational health (ISWA & UNEP 2002). Moreover, informal sector can interfere with formal waste management systems- specifically the process of waste collection (ISWA & UNEP 2002).

2.3.6 Place-specific factors

These issues exist in different developing countries and they are often mutually reinforcing. Some countries or specific regions of certain developing countries may not share all of these characteristics. These issues do not exist in isolation but that reinforce each other. For instance, institutional problems may hinder proper operations and planning. Lack of proper operations and planning may make the informal sector more viable.

2.4 Composting: potential, process and challenges in developing countries

Composting is part of the waste management hierarchy and in the IWM method of waste management is often the recommended method of handling organic waste. Although composting is currently implemented in some developed countries such as parts of Canada, The United States and throughout the European Union, composting has not reached its potential in these countries (Briton 2000). The application of composting in both developed and developing countries faces great potential as well as many challenges. Composting organic waste is an effective method of waste recovery and waste reduction. Compost can be beneficial to agriculture and has unique benefits within the Chinese context, for agricultural uses and mine rehabilitation and desertification.

2.4.1 Potential uses of compost

Compost is a soil conditioner composed of organic matter that improves soil structure and can reduce the amount of chemical fertilizer required for agricultural practice (Haight and Taylor 2000). The use of compost leads to less erosion and better moisture retention resulting in a reduction in the need for irrigation (Word Bank 2005). It promotes seed germination and plant growth with stronger roots, and possesses diseases suppressing qualities (World Bank 2005). Modern agricultural practice tends to consume organic matter and over time reduce soil fertility (Haight and Taylor 2000). Soil that lacks sufficient organic matter requires larger application of chemical fertilizer (Haight and Taylor 2000). Compost increases the efficiency of fertilizer by reducing runoff and making fertilizer available to plants for a longer period of time (World Bank 2005). Depleted soil contains 1-3% organic matter, compost contains about 30-40%, and thus a small quantity of compost can increase the organic matter to about 10-15% (Haight and Taylor 2000). Therefore, compost can to some extent act as a substitute in reducing the amount of fertilizer needed.

In China, the potential uses for compost in agriculture are vast. Currently close to 60% of the Chinese population is agriculturally based (Shen 1998). Modern agricultural practices in China have resulted in both the depletion of organic matter in the soil as well as the overuse of chemical fertilizer (Muldavin 2000, Zhu 2002). For an estimated 5000-7000 years Chinese farmers practiced a sustainable form of agriculture which incorporated household composting and the return of organic matter to the earth (Da Zhong and Pimentel, 1986). This type of agriculture was a closed loop system with organic matter and nutrients returning to the soil. With the introduction of modernized agricultural practices that entail mechanization and addition of chemical fertilizers, many farmers no longer return organic waste to the earth (Zhu and Chen 2002) because chemical fertilizers are viewed as a cheap substitute (Ichim 2006). Thus, the closed loop that existed prior to the modernization of agriculture was opened and organic matter began to be drawn out without being returned to the earth. Currently, the organic matter content of soil in China is a matter of significant concern (Wu et al. 2003). The overuse of chemical fertilizers in China in the past 20 years has become another serious problem¹³ (Zhu and Chen 2002). The over usage of chemical fertilizer is partially responsible for soil degradation, a loss of soil structure, a decline in overall soil quality and a decrease in soil's nutrient availability (Muldavin 2000). Moreover, due to a lack of knowledge unbalanced practices of fertilizer usage have developed¹⁴ (Ji 1998). The use of compost could aid in mitigating the depletion of organic matter in agricultural land as well as reducing the amount of fertilizer used by increasing the productivity of fertilizer and making the fertilizer more bio-available (Haight and Taylor 2001).

Mine rehabilitation and desertification are other major concerns in China that can be potentially mitigated by use of compost. The benefit of compost usage in these situations is that the quality of compost does not have to be on par with the quality of compost used for agricultural purposes.

¹³ Increased nitrogen concentration in surface and ground water has resulted in “algae booms in lakes” and increased emissions of N_2O (Nitrous Oxide) and NH_3 (Ammonia) in agricultural areas (Zhu and Chen 2002)

Currently mine rehabilitation is a major issue for China, with a total of 0.3 million hectares affected, and 20 000 hectares affected annually (Zheng fu 2001). Compost has been shown to have potential in rehabilitating mining sites (Kelly 2006). This is important since China produces the greatest output of coal globally (Zheng fu 2001). Desertification in China is another major issue that compost has potential to remedy. Desertification is caused by natural factors including climate change, winds, and low precipitation, as well as human factors such as overgrazing, misuses of water and land use mismanagement (Kim et al. 2006). In China an estimated 150 km² is lost to desertification each year (ibid). Many areas in China are affected by desertification (Ding et al. 1998, Kim et al. 2006, Li 2007) include Western Hainan province (Li 2007). Applying compost to desertified land has the potential to rehabilitate this land (Grassi 2004). However, further research is needed and compost specific considerations need to be taken into account when applying compost which is derived from MSW¹⁵.

2.4.2 Composting process

Composting is the regulated decomposition of organic matter to produce a final product called compost; it is used in waste management as a method to recover organic waste (Haight 2006). The composting process entails managing and accelerating the biological and oxygen demanding process as a mixture of organic materials pass through a series of stages that are characterized by increases in temperature and bacterial types leading to a stable organic material called compost (Haight and Taylor 2000). Composting of organic waste is recognized as an effective method to manage this waste type as it aims to recover organic waste in the waste stream and produces a useful end-product (Hoornweg 2000).

¹⁴ An over usage of Nitrogen based fertilizer, in adequate potassium and in adequate phosphorus (Ji 1998)

¹⁵ Although it must be recognized that there are risks of applying surplus nutrients, creating an imbalance in nutrient input, and importing heavy metal and organic pollutants (Vetterlein and Huttli 1999).

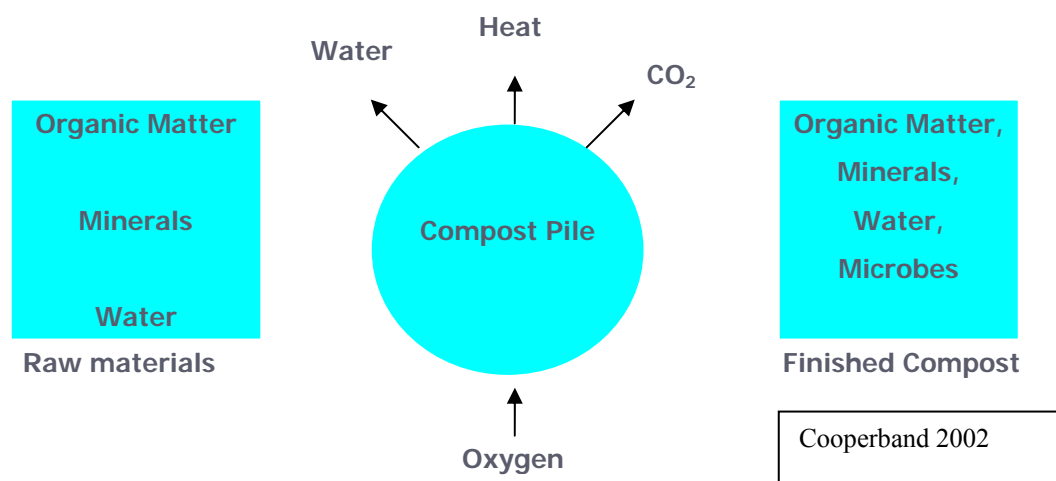


Figure 2.6 : The composting process

Composting mimics the natural process of decay (Haight and Taylor 2001) in an accelerated form. The composting process, shown above, requires the input of organic matter (organic waste products), minerals, water and microorganism. Organic waste is processed in a pile or windrows and releases heat, water, and CO₂, in an oxygen dependant fashion. During composting waste undergoes a decomposition process. The stages of decomposition are characterized by increases and decreases in temperature. Initially organic matter is decomposed by mesospheric bacteria (around 37°C), then thermopiles (over 45°F), and then again by mesospheric bacteria. The initial phase, within 24-72 hours of forming the pile, is where the temperature increases and remains between 55°C to 65°C or the “active phase”. This phase usually takes several weeks¹⁶. The next phase is the curing phase, in which the temperature declines to approximately 37°C. Once the compost is cured it is biologically stable and relatively free of pathogenic material (Cooperband 2002, Haight and Taylor 2000, Haight 2006).

¹⁶ Temperature must be maintained below 70° C because once the temperature increases past 70°C theomorphic bacteria die. Temperature can be reduced in windrow composting by turning the waste (Cooperband 2002, Haight and Taylor 2000, Haight 2006).

2.4.3 Challenges to implementing composting

Developing countries face three types of challenges with respect to composting: human challenges, technological/ process challenges and place specific challenges. Human challenges include policy and institutional, human acceptance, finances, markets and final end use, and capacity in terms of a lack of technical expertise. Process issues include choosing an appropriate method, choosing a location, creating and managing the compost pile, heavy metal content, and maturity of compost. Finally, place specific characteristics may pertain to both human and process issues; these include management, community response, capacity, local weather patterns, and waste characteristics.

A review of 25¹⁷ key sources revealed some of the key composting challenges, including human challenges, process challenges and place-specific challenges.

Table 1.2: Challenges to composting

Human challenges:	
1. Policy/ institution	<ul style="list-style-type: none">• Political will• Government support, stakeholder support
2. Human acceptance (source separation and site situation)	<ul style="list-style-type: none">• Accept the idea• Accept separation waste• Accept site situation
3. Finances	<ul style="list-style-type: none">• Costs need to be manageable• Governments will to pay
4. Markets and final end use	<ul style="list-style-type: none">• While end uses are vast in principle, tangibly what are the markets• Willingness to pay• Creative options: compost fertilizer mixes, mine rehabilitation
5. Capacity: technical and human	<ul style="list-style-type: none">• The local ability to implement composting• Labor• Infrastructure for collection• Equipment required (temperature and grinder)
Process challenges:	
1. Choosing an appropriate method	<ul style="list-style-type: none">• Pile, windrow, anaerobic digestion, household or centralized• Which type of method; high technology, low technology• Sources separation or mixed waste

¹⁷ Bardos 2004, Breslin 2002, Brinton 2000, Cooperband 2002, Feguson 1995, Forsyth 2005, Furedy 2002, Haight and Taylor 2000, Haight 2006, Haug 1993, Hoornweg 1999, Hui 2006, Kgathi and Bolaane 2001, Kreith and Tchobanoglos 2002, Lynn 1962, Maclaren 2005, Mcdougall 2005, Wang and Nei 2001, Wang and Nei 2001, Wei 2007, White et al. 1999, Troi 2001, World Bank 2005, Petts 1995, Zurbrugg 2002.

2. Choosing a location	<ul style="list-style-type: none"> • Flat land • Consider storm water runoff and compost runoff
3. Creating and managing the composting pile or windrow ¹⁸	<ul style="list-style-type: none"> • The chemical makeup of the feedstock: Carbon to Nitrogen Ratio • Oxygen availability: facilitate oxygen availability • The physical properties of the feedstock and pile: size of feedstock and porosity is important to consider may need to grind large pieces • The moisture content of the pile: Pile can neither be too moist or too dry 45%-65% • Height of pile: if it is too small it may not maintain heat, if it is too big oxygen availability may become problematic 1m- 1.5m • Temperature: ideal temperature 40°C – 65°C must be maintained to promote the desired bacteria. If temperature is too low process is slowed if temperature is too high important microorganisms will die.
4. Foreign particles	<ul style="list-style-type: none"> • Different standards exist regarding the size, amount and type of foreign particles that are acceptable in compost.
5. Heavy metal content	<ul style="list-style-type: none"> • Different countries have different heavy metal standard
6. Stability: temperature testing	<ul style="list-style-type: none"> • Temperature can be used as an indicator to assess if the composting process has been complete and is stable; compost should be near ambient temperature and not reheat. • The compost should have achieved sufficient heat to kill bacteria: turning while the temperature is high to ensure that all bacteria were killed.
7. Other testing	<ul style="list-style-type: none"> • pH can also be an indicator for stability acceptable pH for stable compost is 6-8 • Electro-conductivity tests • Water solubility • Oxygen consumption • Plant growth
Place specific challenges	
1. Management	<ul style="list-style-type: none"> • Local management
2. NIMBY – not in my backyard Community response	<ul style="list-style-type: none"> • How is the local community responding
3. Capacity	<ul style="list-style-type: none"> • Is the necessary human and technological infrastructure and capacity in place
4. Local weather patterns	<ul style="list-style-type: none"> • Precipitation and typhoons are potential local factors which effect implementing composting in Hainan project
5. Waste characteristics	<ul style="list-style-type: none"> • Amount of waste • Type of waste • Changes in waste; Seasonal and structural

¹⁸ This applies to the windrow method

2.4.4 Human factors

Human factors are the determining factors in deciding whether composting is adopted as part of a waste management plan. Political will¹⁹ must exist to formulate and implement policy promoting composting. Participation in terms of household waste separation is necessary if source separated composting is to be viable. Not in my backyard (NIMBY) can present a problem both in developed and developing countries when selecting waste management sites (Petts 1995).

Economic concerns such as financing, markets, and end use may influence implementation but they should not be the overarching factors in determining whether composting should be implemented or not. Composting can be viewed as a social good, where the net benefit to society²⁰ is greater than the economic value of the end-product. Thus, economics alone should not be a determining factor in deciding if composting ought to be pursued.

Capacity in terms both technology capacity and human expertise should be considered in the implementation of composting as part of a MSWM system. If source separation is to be implemented, necessary infrastructure should be available. Separate garbage receptacles should be provided, and separate collection of waste should be organized. Waste workers should be trained in the collection, separation and composting process. Residents should also be provided with knowledge regarding what is compostable and what is not.

2.4.5 Process challenges

Choosing an appropriate method of composting and an appropriate compost site is an important factor in the composting process. Technological factors to consider include which type of composting is to be implemented, pile, windrow, anaerobic digestion as well as what scale: household scale or

¹⁹ Political will may come from government, community members or international pressure.

centralized is to be employed. Will the method be highly technical or minimally technical? At what point during the waste generation process will separation occur? Will the compost be source separated or mixed waste? Siting: topography and human acceptance should be factors to consider. Other factors can include capital versus labor costs, technical expertise, waste stream composition, land availability, topography, and citizen acceptance.

Issues to consider in managing the composting process when using a windrow or pile method are the chemical makeup of the feedstock, oxygen availability, the physical properties of the feedstock and pile, the moisture content of the pile, and temperature. In terms of the chemical makeup of feedstock it is important to maintain a proper carbon to nitrogen ratio of about 3:1 (Cooperband 2002). If the feedstock does not have this carbon to nitrogen ratio than substitute material must be acquired. As aerobic composting is an oxygen demanding process, oxygen availability must be facilitated. This can be done in several ways; by being attentive to the porosity of the feedstock, by inserting pipes into the pile, by inserting a wooden pyramid into the center of the compost or by turning the pile regularly (Haug 1993). The physical properties of the pile and the feedstock should also be considered (Cooperband 2002). The height of the pile should be between 1 meter and 1.5 meters. If it is too small it will not maintain heat, if it is too big it will be difficult to turn (Haight 2006). The size of the feedstock and the porosity of the feedstock should be considered. If feedstock is too big it should be chopped up into smaller pieces, which may require a grinder. The feedstock should consist of different sizes and shapes so that it is porous and allows oxygen to reside inside of the pile (Cooperband 2002). The moisture content of the pile should be 45% to 60%, thus more water may be added if the compost is excessively dry or more carbonous material may be added if the compost is excessively moist (Haight and Taylor 2006).

²⁰ Net benefits to society includes less landfill waste, mitigation of methane, returning organic matter to the

The ideal temperature during the active phase of composting is between 40°C and 65°C. If the temperature is under 40°C it will require an excessively long time for the compost to decompose whereas if the temperature is above 70°C it will kill the bacteria necessary for the composting process and will release a foul odor (Haight and Taylor 2000).

High temperature can be used to ensure the destruction of pathogens. If the compost is exposed to high temperature for extended periods of time harmful pathogens will be destroyed (Haight and Taylor 2000). Canadian Council of Ministries of the Environment (CCME) standards indicate that the compost must reach an internal temperature of 55⁰ C or greater for 15 days and be turned 5 times if a windrow composting method is used, or if it is an aerated static pile composting method, temperature must reach an internal temperature of 55⁰ C for a minimum of three days (Troi 2001).

2.4.6 Standards: heavy metals and compost maturity

Quality composting requires that compost complies with set standards. In Canada these standards pertain to pH, electrical conductivity (soluble salts), nutrient content, moisture content, organic carbon, organic matter content, maturity, stability and particle size (Troi 2001). Heavy metals and compost maturity will be discussed in this section. While the other parameters are also important, heavy metals standards were chosen for elaboration because of the potential threat of heavy metals to humans, and maturity was chosen because of the pragmatic relevance of maturity to the composting pilot project.

The heavy metals²¹ commonly regulated are arsenic, cadmium, chromium, copper, lead, nickel, mercury and zinc²². Heavy metals content is a subject of concern for agricultural usage of compost,

earth is beneficial for improving soil structure, reducing flooding (Haight and Taylor 2000, World Bank 2005, Haug 1993, Hoornweg 1999, Zurbugg 2002).

²¹ Humans require trace elements of some heavy metals, however if more than an acceptable level of certain metals are consumed by humans there may be negative consequences to human health

particularly the bioavailability of heavy metals in soils over long-term usage (Zheljazkov and Warman, 2004). Standards differ greatly on particular metals between China, the United States, Canada²³ and Europe.

Table 2.2: International heavy metal standards

Metal	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Country	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
China 1987 standards (China Environment Protection Bureau 1987)	30	3	300	-	100	5	-	-
World Bank Proposed Standards for Developing Countries (Hoorweg 1999)	10	3	50	80	150	1	50	300
USA (Hoorweg 1999)	41	39	1200	1500	300	17	420	2800
EU Range (Brinton 2000)	-	.7-10	70-200	70-600	70-1000	.7-10	20-200	210-4000
Ontario Agricultural application High range AA-A Low range B (Trois 2001)	13-75	3-20	210-1060	100-757	150-500	.8-5	62-180	500-1850

Milligrams Kilo Dried Matter

Sources: This Table is Derived From, China Environment Protection Bureau- Control Standards For Urban Waste For Agricultural Use 1987, Brinton 2000, Hoorweg 1999, Trois 2001.

Upon evaluation of China's 1987 standards on the amount of heavy metals allowable in compost used on agricultural land, China's standards are more stringent for some of the heavy metals but overall are on par with North American and European Union Standards. China only regulates five of the eight heavy metals regulated by North America and the European Union: arsenic, cadmium, chromium, lead, and mercury. In China, copper, nickel, and zinc are not regulated.

²² These eight heavy metals were chosen because they are the most commonly heavy metals regulated by the EU, USA and Canada. In addition the fact that the world bank prescribes recommended standards.

²³ Canada actually regulates the eight metals listed as well as Mo (Molybdenum) and Se (Selenium) (Canadian Council of Ministries of the Environment 1996)

China's arsenic (30mg/kg) and cadmium (3mg/kg) standards are more stringent than the United States' standards, and fall within the Canadian and European Union Standards. China's chromium (300 mg/kg) standards are lower than the European Union (70-200mg/kg), within the acceptable range of Canada (210- 1060mg/kg) and higher than the United States (1200mg/kg). China has more stringent standards for lead (100mg/kg) than the lead standards in Canada (150-500mg/kg) and the United States (300mg/kg) as well as the standards recommended by the World Bank. Furthermore, China's lead standards fall on the lower end of the European Union standards (70-1000mg/kg). Finally, China's mercury standards (5mg/kg) are within the acceptable range for the European Union (0.7-10mg/kg) and Canada (0.8-5mg/kg); it is more stringent than the World Bank proposed standard and more stringent the United States standards (17mg/kg).

Measuring maturity of compost is important for determining if the compost is biologically stable. Currently, there are several methods which can be used individually or in combination these tests include: pH, water soluble nutrients, self heating (Dewar self heating test), oxygen uptake and plant growth (Briton 2000). International standards usually employ one or more of these tests to indicate stability (Ibid). The viability of applying these tests in developing countries depends upon, technological expertise and availability. However, temperature and time generally are accessible tests that can be implemented in developing countries. Canadian standards recommend that if no other test can be used to measure maturity, the compost should be cured for six month (Troi 2001).

2.4.7 Place-specific challenges

Place-specific challenges can also affect implementation of composting as part of a waste management system. Local human factors such as management, capacity, and community response are essential factors to the successful implementation of composting as part of a waste management

system: local concerns that affect the operations and technical aspects include local weather patterns and waste characteristics.

Management of composting operations is not exclusively about the management process but also the institutionalization of management (Hoornweg 1999). Specifically, concerns such as whether the process is private or public, and whether coordination and integration of necessary stakeholders is in place are significant issues. Technical and human capacities are aspects that need to be considered, if management and capacity is lacking than this could affect the implementation of composting.

Community response and NIMBY attitudes often pose substantial challenges regarding siting of potential composting sites. Education and addressing concerns of the stakeholders' involvement should be considered as part of the implementation process (Petts 1995).

Weather patterns and waste characteristics can have a substantial affect on the success of the windrow composting process if the compost pile is located outdoors (Hoornweg 1999). Weather considerations should be integrated into initial planning of the composting facility and method. Weather patterns are significant in Hainan because Hainan is situated in a tropical location with high temperatures²⁴ and because monsoonal patterns affect precipitation²⁵, and winds. Because monsoons are annual events, planning should consider not only precipitation and winds but also the distribution of the precipitation.

Waste characteristics, such as proportions of organics and absolute amounts of organics affect the ability to implement composting. Waste characteristics such as the amount of waste and the proportion of organics in the waste changes in response to industrialization (Wang and Nie 2001).

²⁴ Average annual temperature is 24.6°C, With highs in May 28 °C, June 29°C, July 29°C, August 28.2 °C, and lows in December 19.7 °C, January 18.4 °C, February 19.1 °C, March 21.9 °C (Li 2007).

²⁵ On average the total annual precipitation Hainan receives is 993.3mm. With the majority occurring in June (153.0mm), July (141.7mm), August (224.6mm), and September (193.1mm) (Li 2007).

Thus, planning for the future composition of waste should consider possible changes in waste characteristics.

2.5 Summary

This chapter discussed literature that was used to form the conceptual and empirical grounding for the composting pilot project. The literature on four themes were discussed; the first theme is the relationship between waste and resources; the second is waste management theory; the third is distinguishing features pertaining to waste management in developing countries; the fourth is the composting: process and challenges in developing countries.

Chapter 3

Research methods: action research

This chapter discusses the epistemological underpinnings of the research, the methodological framework, the research objectives and the methods employed. The theoretical and epistemological underpinnings that inform the methodological approach underlying this research are discussed. A methodological framework for this research is provided. The objectives of the research and methods employed to answer the research question are described.

The research methodology employed is participatory action research. A multiple method approach was used that entailed a review of the relevant literature, a review of government data, implementation of a composting pilot project, participatory observation, key informant interviews, waste mapping, and transect walks. Multiple methods were employed for triangularization purposes (Flowerdew and Martin, 2005). The research, which aims to understand both technological and social factors that effect the adoption of composting as part of a MSWM strategy, employed both quantitative and qualitative research methods as well as deductive and inductive reasoning.

3.1 Epistemological underpinnings of the methodology

Epistemological assumptions shape the methodological approach. That is, beliefs about how knowledge is formed and what knowledge is valuable shape the type of knowledge being sought and the specific research objectives. Knowledge is created both through deductive and inductive reasoning. This thesis employs both deductive reasoning and inductive reasoning. The composting method and process employed in the pilot project are based on the application of deductive scientific knowledge. The challenges for humans are identified through empirical data collection and inductive

reasoning. The implementation and place-specific knowledge are based on both deductive theories and inductive observation.

Aristotle proposed that there are three types of knowledge: *theoria*, knowledge in search of the truth; *poiesis*, knowledge that contributes to production; and *praxis*, knowledge that contributes to action (Aristotle 1998). For implementation studies and feasibility studies the synthesis of these three types of knowledge is required. Prudent choices regarding implementation (*praxis*) require a grasp of *theoria* and *poiesis* (*ibid*).

The action research model uses *praxis* to identify and implement valid and relevant *theoria* and *poiesis* in a specific time-place context, and combines theory and practice through change and reflection (Rapoport 1970). Lau describes participatory action research as a collaborative process that occurs in a mutually acceptable framework and aims to expand scientific knowledge enhance actors' competency at a specific task in a specific situation, increase understanding of a specific social situation in order to increase understanding of change processes (Lau 1999). More simply action research can be viewed as an experiment that occurs in real-time, with both human and technical dimensions, allowing for learning to occur throughout the experimental process.

Action research can potentially bridge positivist and post-positivist methods (Phelps and Hase 2002) and provide understanding of real life problems. Action research can be structured in a way that can integrate a positivist as well as post-positivist approach (*ibid*). By using both positivist and post-positivist methods, action research can overcome the tendency for reductionism and oversimplification that may be a limitation of positivist research. Action research is able to look at complexity and systems in real life as the variables interact with each other (*ibid*). Action research deals with place-specific problems in a real-life context with multiple factors and interaction

occurring. It enables a more holistic understanding of the problem and recommendation of practicable solutions.

Both quantitative and qualitative data were analyzed in this research project because both human and technical aspects are essential to the research objectives. Qualitative data was collected to analyze the human dimensions of this project since it enabled a holistic understanding of human factors. Quantitative data were collected to analyze the technical aspects of this research, such as the composting process that required maintenance of specific temperatures, adherence to heavy metal standards and time requirements.

3.2 Methodological framework

The objective of this research is to identify the challenges and potential of implementing composting as part of a waste management strategy in Baisha, Hainan. The researcher sought to assess the practicability on multiple dimensions: human, technical, and context specific. The action research framework below explains the process:

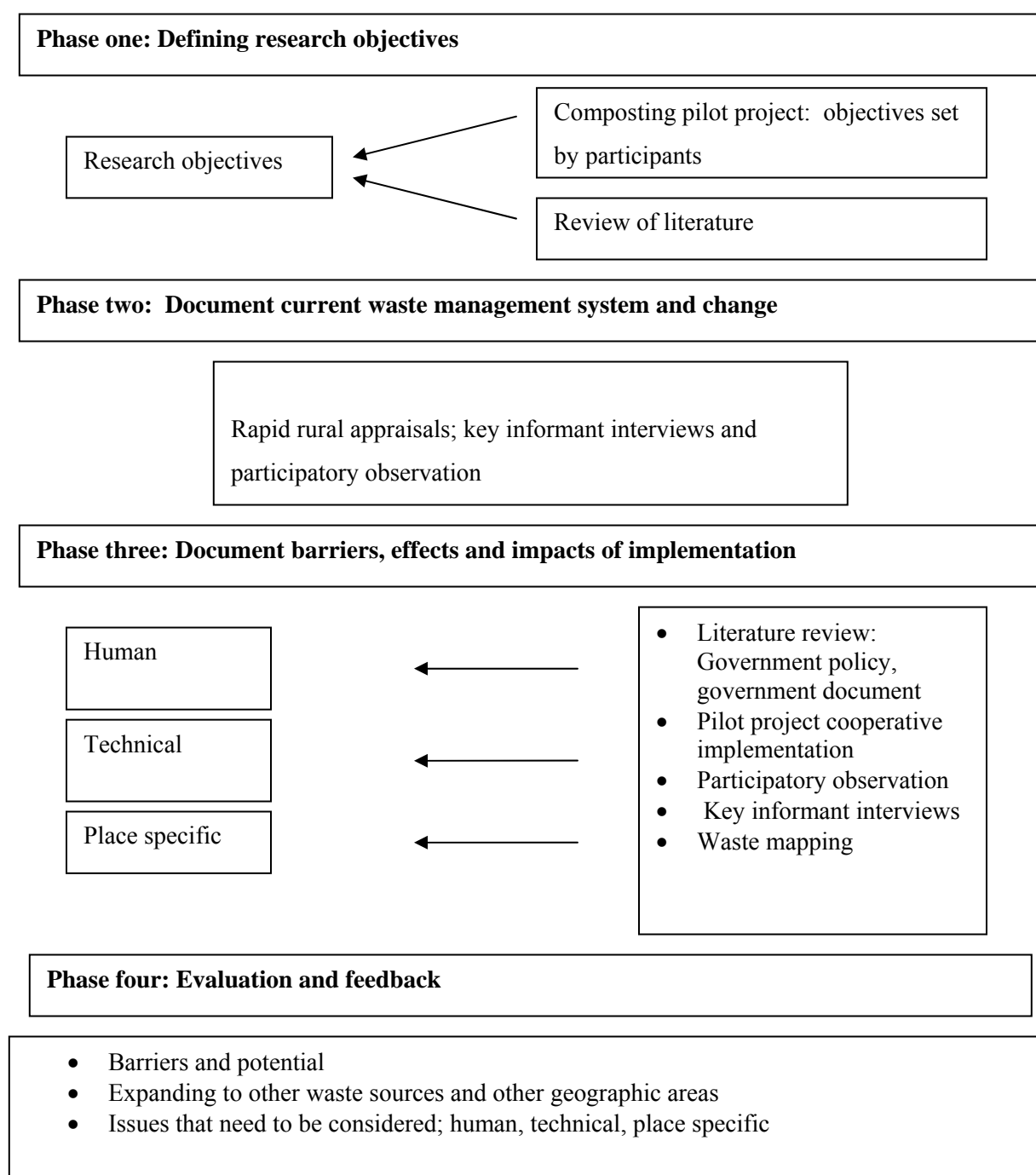


Figure 3.1 : Methodological framework

This action research framework uses a problem-based approach. The problem was how to incorporate composting into Baisha's waste management system, dealing with the feasibility of implementation,

and the potential for expansion of composting as a means of waste management into other areas of China. This research was based on a one time case study²⁶. It used a participatory approach by incorporating the concerns of the specific actors and stakeholders in establishing the research objectives. Research objectives were established inductively through consultation with the stakeholders and through a review of relevant literature. The concerns identified in the literature review were incorporated in the research process in order to provide academic rigor. This framework was iterative in order to build a better understanding of the problem and solution. A multiple method approach was used to assess multiple dimensions of implementing composting (Flowerdew and Martin 2005). Multiple methods were also used for triangularization purposes, to cross check data acquired from one source in order to get a fuller understanding of the problem and of causality (ibid). There were four phases of research in the research framework: the first phase entailed defining research objectives. The first phase is a normative phase when the initial research objectives were defined. The objectives were identified in two ways, first by considering the objectives of the stakeholders, and second through a review of the literature. The research objectives were initially defined as follows:

- To document and understand the current waste management system in Baisha
- To outline the potential for composting to contribute to the current waste management system.
- To understand the barriers to implementation
- To understand the implications: impacts, barriers and potential to adopting composting
- Make recommendations regarding the barriers and potential.

The second phase entailed understanding the current waste management system in Baisha Hainan.

The methods employed to gain this understanding are a linked suit called rapid rural appraisals. Rapid

²⁶ Drawbacks of using action research based on one case study include, problems making controlled observations, making controlled deductions, replicability and generalizability (Lee 1989).

rural appraisals include key informant interviews, waste mapping, and participant observation. This second phase entailed understanding the specific details of the waste management systems in Baisha, documenting types and amounts of waste produced in Baisha, and detailed mapping of the market in Baisha. Key informant interviews with market vendors were employed to understand what types of waste they produced, whether they were producers of their products or were secondary distributors, whether seasonal variation existed, whether material was reused, whether vendors had heard of waste composting, whether they were concerned about their waste, and whether they were willing to separate their waste.

The third phase entailed documenting impacts, barriers, and the potential for implementation. This phase built upon knowledge generated in the first and second phases and was employed as an iterative process. It entailed a more refined search and analysis of the objectives set out in the first phase. The aim is to understand the barriers, impacts and potential of implementation by examining specific human, technical, and place-specific challenges that were identified. Human, technical and place specific concerns were identified through both inductive and deductive methods: examining both the theory and relevant methods employed for this phase were a review of the relevant literature, a review of government policy, a review of government data, implementation of a composting pilot project, participatory observation, key informant interviews, waste mapping, and transect walks.

The human concerns regarding implementing composting were identified through a literature review, participatory observation and the expressed concerns of the participants. Process or technological concerns were identified through the review of the literature, key informant interviews, the implementation of the composting case, and waste mapping. Place-specific challenges were identified through a review of the relevant literature, a review of government policy, a review of government data, implementation of a composting pilot project, participatory observation, key informant interviews, waste mapping, rapid rural waste assessment, and transect walks.

The fourth phase is a normative iterative phase where the issues and challenges identified in the previous phases are assessed. Recommendations about how to overcome the barriers were provided. The potential of applying composting in the market waste and expanding the composting to other waste sources as well as other geographic areas is discussed. Issues that affect the feasibility and the potential of composting as a means of waste management are discussed.

3.3 Methods

Multiple methods were employed to solve the research objectives. The methods employed include; a review of literature, implementation of a compost pilot project using market waste, participatory observation, Rapid Rural Appraisal (RRA), and key informant interviews.

Review of relevant literature included published and unpublished academic papers, working papers, transnational papers, and technical reports. The government documents reviewed included the Chinese national policy that informs the process, Hainan's eco-province policy, and local Baisha sanitation reports on cost of operations, collection fees, and labor costs of operations.

A composting "pilot project" using market waste was implemented in Baisha Township, Hainan Province. The composting pilot project was implemented by multiple levels of actors: international development actors (Canadian International Development Agency, C.I.D.A.), international academic actors (University of Waterloo), and Provincial Chinese Actors (Department of Land Environment and Resource). In addition, the project received strong support and cooperation from the local Baisha township government and cooperation from multiple local actors (The Environment Protection Bureau, The Department of Land, and The Department of Sanitation). Funding was provided by CIDA through Eco Plan China²⁷. The University of Waterloo provided the technical expertise. The

²⁷ Eco-plan China is a tier one CIDA funded research program between the University of Waterloo and Dalian Technical University, Nanjing University and The Hainan Department of Land Environment and Resources.

province provided the authority and the central planning. The local government made a commitment to give local land, labor, technical support, and waste. My role was to help implement the composting pilot project: this entailed managing the process in cooperation with the local waste workers. It also required coordination with the Department of Sanitation who provided waste workers to participate and learn the process of composting.

The participatory observation elements entailed living in Hainan province for three months. The first month, during which time planning for the project occurred, was spent in Haikou. Planning entailed finding suitable contractors to build the composting site, looking for grinding equipment, and traveling to Baisha with the provincial Department of Land Environment and Resource to discuss and negotiate the various aspects of the project. The first visit to Baisha served to help identify some of the key issues that shaped the research objectives and develop questions to be asked during the interview process. This time in Haikou also entailed doing basic research on China's policy regarding heavy metal standards in composts, as well as procuring government policy and documents.

After one month in the field, Dr. Murray Haight arrived in Haikou and spent several days in Baisha to establish the composting pilot project. Dr. Haight provided a brief composting training program for the waste workers and we initiated the first batch of compost. The researcher spent the following two months in Baisha working with the local waste workers in monitoring the composting pilot project, coordinating with the provincial level that came to Baisha several times. The researcher also spent time developing an understanding of the waste management system and the market. Upon the completion of the composting project a televised ceremony was carried out with local, provincial, and national officials and friendship trees were planted. This ceremony aired on Hainan provincial T.V. and helped raise the profile of composting provincially. At the end of the pilot project the researcher was asked to provide a workshop to the provincial Department of Land Environment and Resource about composting and the pilot that we had implemented.

Rapid rural appraisals (RRA) were also used. RRA's are a linked suite of methods developed by Chambers which are linked by the idea that it is better to be generally right rather than precisely wrong (Chambers 1994). These methods include, participant observation in the form of calculated observation, transect walks, waste mapping and key informant interviews. These methods entail gaining some basic information in rapid ways without becoming caught up in details. Rapid rural appraisals were used to estimate the amount of total waste as well as the composition of waste. The researcher observed and spoke to the waste workers about how many waste baskets existed, the researcher measured the size of these baskets and multiplied the number of baskets by the size of the basket, by the number of times they were collected. The type of waste that was produced in the market was assessed through observation and interview. Transect walks were also employed to find areas in the township where waste was not collected.

Next 122 semi-structured interviews were conducted with randomly chosen key informants. Interviews were conducted with market sellers (n=53)²⁸, formal waste workers (n=4), informal waste workers (n=6), people affected by dump sites (n=9), local government officials (Departments of Planning, Land and Sanitation) (n=7), villages throughout Baisha county (n=13), businesses (n=20) and residents of Baisha township (n=10). The length of these interviews ranged from 10 minutes to three hours (with officials from the Department of Sanitation). The average length was 20 minutes. Questions were semi-structured and were left open-ended in order to allow for elaboration of any element the informant believed to be significant. Market sellers were selected because the initial composting pilot project focused on market level waste, thus understanding the dynamics in the market was important.

²⁸ Vegetable Vendors (15), Meat Vendor (6), Clothing shop/ booth (5), Live Stock (5), Fruit vendor (4), Fruit booth (4), Fish Vendors (fresh fish) and Booths (4), Small and large restaurants (2), Hospital (1), Household Appliances (1), , Pharmacy (1), Egg Vendor (1), Convenience Shop/ Convenience Store (1), Assorted Product Shop/ Booth (1), Fish vendor (dried fish) (1), Tofu Vendor (1).

3.4 Sampling method and survey questions

A representative sample was chosen of formal and informal waste workers, people affected by dump sites, local government officials, villagers throughout Baisha, businesses and residents. Interviews with the market sellers were selected after the market was mapped in order to select a proportionate number of vendors. The market has over 500 vendors of assorted products including fruit, vegetables, meat, convenient stores, clothing stores, restaurants, livestock, fish, a medical center and a pharmacy. Semi-structured interviews with about 10% of the market sellers were conducted roughly (Appendix A).

The interviews were conducted during the second month of the field study. The questions were constructed based on issues identified in the literature review, participant observation and the objectives of the research questions. Interviews with market vendors, commercial and residential waste producers were semi-structured and left open ended in order to generate quantitative data (Appendix B). The reason for the questions is provided in Appendix C. The other interviews were asked less structured question. The questions were open ended questions which sought to address the research objectives outlined in Appendix A. The objective of these interviews were to provide qualitative exploratory data about human issues.

Chapter 4

Introduction to case study

4.1 Introduction to Hainan province

Geographically, Hainan province is a unique province in China (Figure 4.1). Hainan is the most southern province of China and the only tropical island in China (Yuping 2003). Hainan province is located at latitude between 18°-20° N (Hsieh 1990). Hainan's northern borders face the Lei zhou peninsular and Guangdong province China, the western borders face Vietnam, the south east faces Malaysia and the eastern borders face the Philippines (ibid).

Demographically, Hainan Island is sparsely populated relative to most other provinces in China, with a population density of 232 people per square km (UNESCAP 2000). Hainan province has a surface area of 34, 000² km (Yuping 2003). In 2000 Hainan Island had a population of 7.87 million people (UNESCAP 2000).

Hainan Island aspires to be an environmental leader in China. The government of Hainan expressed a commitment to ecological sustainability and economic development (An Outline Program for Building Hainan into an Ecological Province, Revised 2005). Hainan aims to become an “eco-province” (*shen tai sheng*) (Hainan statistical yearbook 2001). This is to say that, Hainan Province aspires to continue its economic development yet minimize its impact on the environment and serve as a conceptual model for the rest of China (An Outline Program for Building Hainan into an Ecological Province, Revised 2005).

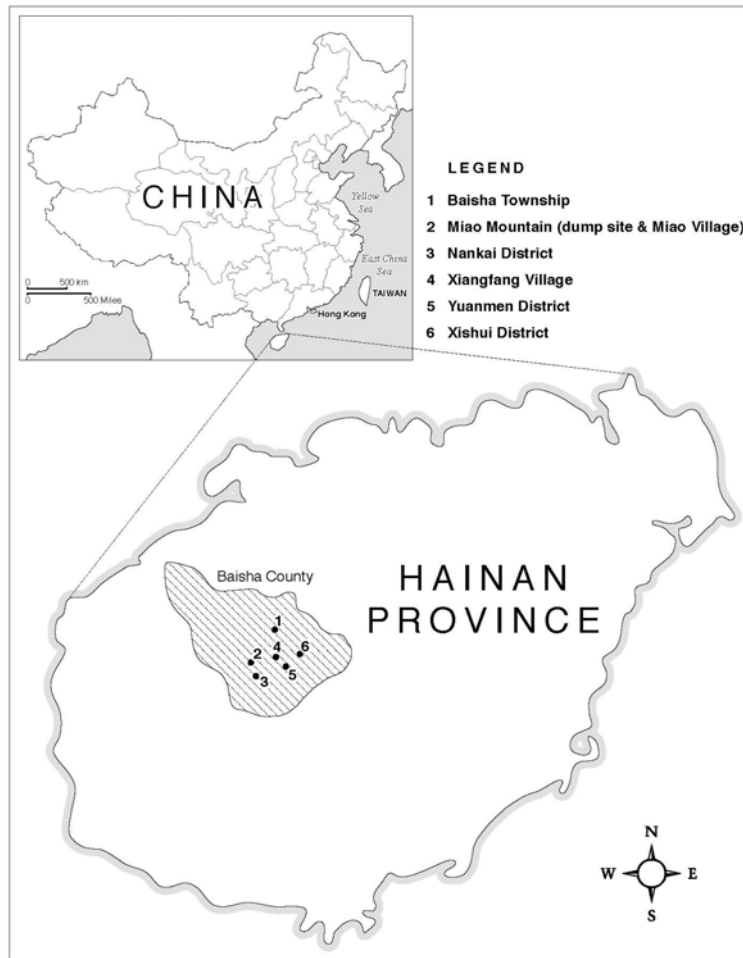


Figure 4.1: Map of Baisha and surrounding villages in context

4.2 Hainan's composting goals

The Hainan City Environment and Sanitary Association, in association with *Hua Zhong* University of Science and Technology of Environmental Science and Engineering, have developed an integrated waste management (IWM) plan. This plan is accepted as the blue print for developing waste management systems from 2005-2020. This IWM plan entails the usage of landfills, incineration and composting. It does not entail any recycling initiatives *per se* as recycling at the informal and semiformal level is run by the private sector using market based incentives. This plan deals with the

MSW according to the specific demands of each city and municipality with regards to composition, and amount of waste produced. According to this report, Hainan province produces an estimated 5096 metric tons of MSW per day. Of this waste, an estimated 50%- 60% of the waste is organic or between 2548 – 3057 metric tons of organics per day (Hainan Province Municipal Waste Management Regulation Plan, 2005- 2020. *Hua Zhong* University of Science and Technology of Environmental Science and Engineering & Hainan City Environment and Sanitary Association. March 2005).

The fifteen year plan is very ambitious and aims to incorporate composting in a comprehensive way throughout Hainan Province. According to the provincial plan, organic waste will be composted using a high temperature approach. Four large composting facilities will be created in the north (service Haikou and suburbs)²⁹, south (service Sanya and suburbs), midwest (service Yang Pu economic development zone as well as Shan Zhou and the surrounding suburban are) and South East (service Wan Ning and Suburban areas). The processing capacity for the large composting facilities will be between 100-200 m/t/ per day. In addition, eight medium size composting facilities will be created in Wen Chang, Bai Sha, Yang Pu, Le Dong, Bao Ting/ Ling Shui, Wu Zi Shan, Qiong Zhong, and Tun Chong, the processing capacity of each site between 20-50 m/t per day. There will also be an undetermined number of small sites which are also significant due to the relatively large number of people living in rural setting in China with a cumulative total processing capacity of 800m/t per day in the small villages (ibid).

The first integrated waste management facility with composting was developed in Sanya Hainan. This facility is a capital intensive project that draws criticism and faces challenges as it is heavily government subsidized. Even through this facility has been operating for several years the

²⁹ Suburban area in this context is akin to peri-urban area, rather than the North American concept of suburb

composting aspect has been heavily criticized by local government official and provincial officials. It faces problems due to improper sources separation, technological problems and a lack of developed of composting market. The challenges that were presented in Sanya indicate that there are many aspects which need to be considered when incorporating composting as a part of a MSWM plan (field notes 2006). Thus there is a need for appropriate preliminary studies and attention paid to feasible technology.

4.3 Overview of Baisha County

Baisha County is located in Central Western Hainan province. The Songtao water reservoir is the biggest reservoir in Hainan province and is located in Baisha County. Baisha County had a population of 170 000 people. Baisha Township has both rural and urban residents with a population of 30 000 (Baisha Hainan Government). There are a total of 10 000 urban residents and a total of 20 000 urban residents (Baisha Hainan Government). Thus, approximately 66% Baisha Township's population engages in agricultural activities, it has a fairly close representation of rural/urban distribution as the rest of China (59.47% (Chinese Statistical Yearbook 2004).

Economically, Baisha Autonomous Li County which surrounds Baisha Township is predominantly agricultural with 528 million RMB (\$ 74 million CAD) coming from agriculture, 182 million RMB (\$ 25 million CAN) from industry and 82.9 million RMB (\$11.5 Million CAN) from forestry (Hainan Statistical Yearbook 2001). This type of economic activity is significant because it indicates that the waste produced is expected to have a high organic content.

In Baisha Township commercial activities are centralized and the market place plays a major role in the commercial life. Commercial activities occur in five major streets in the township. With many commercial activities occurring in one centralized market place. The market place has over 50 types

of commercial activities, over 500 booths/ vendors or commercial establishments and over 700 individuals working in the market³⁰ (field notes 2006).

4.4 The pilot composting project

The pilot composting project was an action research project established through Eco-Plan China³¹. This pilot project involved cooperation between University of Waterloo (a Canadian Academic Institution) and provincial (The Department of Land Environment and Resources) and municipal (Land Bureau, Environment Protection Bureau and Sanitation Bureau) Chinese government authorities.

The pilot project involved establishing a composting pilot project using market waste from the central market in Baisha Township. The market place was chosen for two reasons: first it produced a significant yet manageable amount of waste for one pilot project- about 12% of the total MSW, and; second it was believed³² that some degree of natural source separation occurs there.

The objective of the pilot project was to set up a test case which could identify some of the variables which would affect the implementation of MSW composting. These variables include process issues, human issues, and place specific issues. It was also hoped that by working together with the Chinese counterparts some technology transfer would occur. Based on the experiences of the pilot project, a permanent facility would be build. This permanent facility would serve as a model that the province could promote as the ideal model for medium size composting facilities as outlined in their plans.

³⁰ Some vendors employed two individuals.

³¹ Eco-Plan China is a Tier One cooperation agreement between the University of Waterloo, Hainan Department of Land Environment and Resources and Dalian Institute of Science and Technology and Nanjing University funded by Canadian International Development Agency (C.I.D.A).

³² The Canadians, Provincial and Municipal Partners held the belief that natural source separation occurred at the market place.

Chapter 5

Results

This chapter reports on generated data regarding the current waste management system; self reported attitudes and practices of waste generators, and the proposed change in the waste management system which entails describing factors which are significant for implementing composting in the current waste management system. The section on the current waste management system entails a description of the amount, composition and the logistics of the current waste management system, the informal waste sector in Baisha Township, as well as the impact of the current waste management system on humans and the environment. Finally the waste management practices in smaller villages³³ throughout Baisha County are briefly described. A description of the commercial activities that occur in the market is presented, in order to gain understanding of the type of waste that is generated. Self reported attitudes and practices of waste generators are depicted through survey results from market vendors, commercial vendors outside of the market, and residents of Baisha Township.

The proposed change in the system is described in terms of technical aspects of composting, human resource and training aspects which should be considered, as well as place specific issues that are significant. Technical aspects of the composting pilot project which are discussed are: separation of waste, the composting method employed, porosity and oxygen availability, carbon to nitrogen ratio, time and temperature, turning the compost, time-labour requirements, and space requirements in terms of land required. The issue of training is discussed. Finally place specific issues are discussed, these issues include: the central planning and market integration of compost, unique potential markets, community response: not in my backyard (NIMBY), as well as climatic issues.

³³ The smaller villages were in three districts of Baisha county, Nan Kai (Nan Lan and Nan Mei Village), Yuan Men (Nan Xun Village), Xi Shui (Fanglun Village)

5.1 The current waste management system:

5.1.1 The amount of waste generated

The amount of waste currently collected ³⁴ by the formal waste management system in Baisha Township is 26m³ per day (Table 5.1). This figure includes market waste (3m³), and residential and commercial waste (23 m³)³⁵. The amount of market waste, and residential and commercial waste was established by measuring the size of the waste basket and multiplying it by the number of baskets and the number of times per day that the baskets were collected.

Table 5.1: Amount of waste collected

Market waste
Market waste was collected in baskets which measure 47cm x 40cm x 60cm three times per day:
9:00 am – 4 baskets (47cm x 40cm x 60cm) = 0.4512m ³
3:00 pm-10 basket (47cm x 40cm x 60cm) = 1.128m ³
9:30 pm – 15 baskets (47cm x 40cm x 60cm) = 1.692m ³
= 3.2712m ³
If it is assumed that 50% of the waste stream that is collected is organic than the total amount of organic waste collected in the market is 1.635m ³
Residential and commercial waste
Residential and commercial waste is collected twice a day in 25 carts which measure 102 cm x 75 cm x 62 cm:
8 am- 25 (102 cm x 75 cm x 62 cm (0.47m ³)) = 11.86m ³
4 pm- 25 (102 cm x 75 cm x 62 cm (0.47m ³)) = 11.86m ³
= 22.72 m ³
If 50% of the waste is organic than the total amount of organic waste for the residential and commercial waste is 11.86m ³
The total amount MSW collected from the market waste and the residential and commercial waste is 26.99m ³ . The total amount of organic waste collected is 13.49m ³

³⁴ It is important to note a distinction between waste that is collected by the formal waste management system and waste that is produced. All waste produced is not necessarily collected: this could be due to some failure in the waste management system or due to resource re usage or informal recycling.

³⁵ It does not include waste produced on Baisha/Yatcha Farm.

If it is assumed that 50% of this waste stream is organic, then the total amount of organic waste per day is equal to 13.49m³. Based on the total amount of waste collected it should be noted that market waste accounts for approximately 12% of the total waste collected in Baisha Township.

Interviews with waste collectors revealed that significant fluctuation in waste collection do not occur on a seasonal or daily basis. This, however, does not concur with information collected from market vendors who described seasonal fluctuation in the type of waste produced, most notably an increase in waste production occurred during the spring festival that takes place annually from mid-January to mid-February (Chinese New Year)³⁶. Thus it is expected that some fluctuations in waste production does occur, however the precise nature of these fluctuations are not known at present. Moreover, these fluctuations are most likely not of great significance because they are not observed by the waste collectors.

5.1.2 Composition of waste in Baisha Township

In Baisha Township, “kitchen waste” (organic) represents 47% of the waste stream. The fact that there is no wood or bamboo waste is significant as it indicates that the waste is most likely highly nitrogenous, therefore supplementary carbon sources may be necessary to achieve a suitable carbon to nitrogen ratio for composting. The “other” category, which represents 20% of the waste stream, is significant as it is likely partially comprised of coal ash that is used as a source of energy. For the purpose of this thesis it is assumed that organic waste represents 50% of the waste stream since a portion of the waste classified as being in the “other category” might be organic even though it is not “kitchen waste” *per se*.

³⁶ Vegetable vendors, clothes vendors, fruit vendors, fish vendors, meat vendors, restaurants, live stock, egg vendors and tofu vendors all note that fluctuation occur in the amount of waste they produce on a seasonal basis.

The breakdown presented below is the composition of Baisha Township residential and commercial waste (Table 5.2). Market waste is expected to resemble this composition to some degree³⁷, yet visual appraisal of the market waste indicates a higher plastic content than the residential and commercial waste (Ichim field notes 2006, Wen and Jiao 2006). The higher plastic content is most likely attributed to the plastic wrapping used in the market.

Table 3.2: Composition of MSW in Baisha Township residential and commercial waste

Component of MSW Baisha Township	Percentage
Plastics	10%
Rubber	2%
Glass	3%
Bricks and Stones	7%
Metal	2%
Paper	6%
Fibre	2%
Wood and Bamboo	0
Kitchen Waste	47%
Other	20%

Source: Wen and Jiao-2006- Baisha Township

The heavy metal content in Baisha Township's commercial and residential waste is expected to be representative to an extent of the heavy metal content in the market waste because of the type of commercial activities which take place in the market as well as because of similar geographic location (Table 5.3).

Table 5.3: Heavy metal content of commercial and residential waste in Baisha Township

Element	Cd Cadmium	Pb Lead	As Arsenic	Hg Mercury	Cr Chromium
Mg/ Kg Dried matter	4.93	108	10.3	0.040	33

Source: Wen and Jiao – 2006 – Baisha Township

³⁷ While it may seem unreasonable to expect market waste to resemble commercial and residential waste the type of the commercial activities which take place in the market resemble the type of commercial activities which take place in the commercial sector of Baisha Township. While the residential sector may not be represented in the market this is recognized as a limitation.

Since these figures are derived from un-separated waste, not from finished composts, they provide only an approximation of what the heavy metal concentration might be in completed compost. However, it is expected that final composts would have lower concentrations of heavy metals due to source separation or mechanical separation of waste.

These concentrations of heavy metal are below the Chinese National Standard for Applying to Agricultural land for arsenic (30mg/kg), mercury (5mg/kg) and chromium (300mg/kg). They are however slightly higher for lead (Standard 100mg/kg versus Baisha MSW 108 mg/kg) and cadmium (Standard 3mg/kg versus Baisha MSW 4.93mg/kg). The concentrations of heavy metals in this MSW falls within an acceptable heavy metal range according to European standards, Canadian (Ontario) standards and The United States' standards ³⁸. The MSW has higher levels of lead (8mg/kg) and cadmium (1.93 mg/kg) than acceptable by Chinese standard. It should be recognized that the levels of heavy metals are expected to be lower after source separation or mechanical separation of waste.

5.1.3 Logistics of the current waste management system

Based on the researcher's observation, the system of waste management in Baisha is comprehensive in terms of the collection of waste and competent in terms of the transportation of waste, however its final disposal system is in need of improvement (field notes 2006). The reuse of waste and symbiotic informal waste-resource exchange occurs at the market level, village level, and residential and commercial levels³⁹.

³⁸ Concentrations of, copper, nickel and zinc are unknown and China does not have regulation on these elements, this may potentially be an area of concern.

³⁹ An account of symbiotic activity at the market level will be provided in the responses from the market surveys.

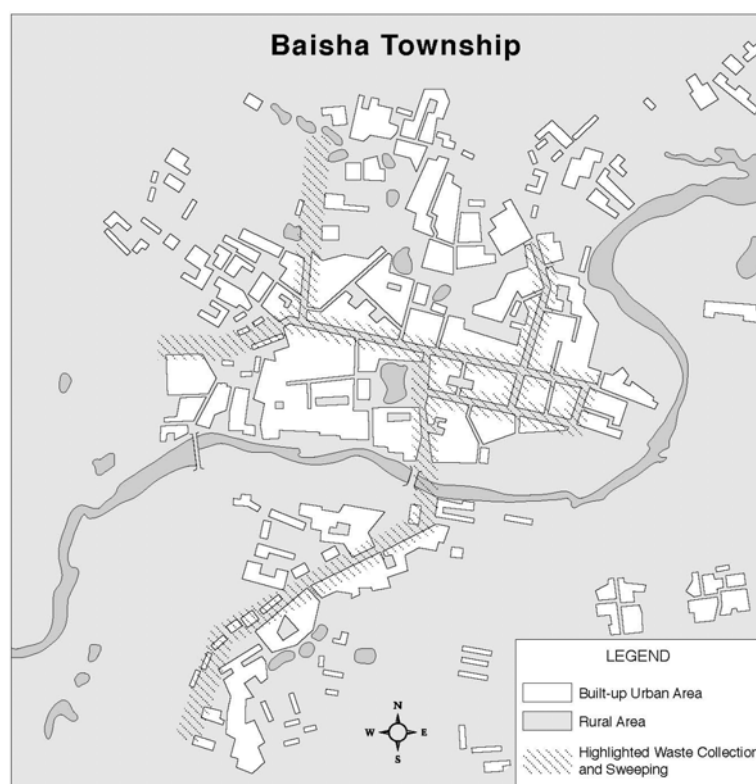


Figure 5.1: Waste collection in Baisha

Responsibility for waste management in Baisha Township is divided between three parties. The local Sanitation Bureau is responsible for all residential and commercial waste, with the exception of medical waste ⁴⁰, the Qing Zhuang company is responsible for market waste, and Yatcha farm is responsible for its own waste ⁴¹.

The Qing Zhuang company owns and operates the market. It employs independent sanitary workers for its waste management operations. The Qing Zhuang company charges market vendors money to allow them to sell their goods in the market place. There is no separate waste fee collection because

⁴⁰ Medical waste is collected by the local “people’s hospital” and then it is incinerated in Sanya. All medical facilities are charged a disposal fee. Market waste is disposed of by a private company called Qing Zhuang and waste is collected 3 times a day a total of 3.3 m2 of waste is produced.

the waste collection fee is included in the operation fee. Waste is collected three times per day. Market waste is disposed of in the same area that the residential and commercial waste is disposed of, Miao Ling Mountain.

The Sanitation Bureau is responsible for the residential and commercial waste throughout Baisha Township. Most residential dwellings do not pay waste disposal fees (key informant 106). Many commercial establishments (over 200-according to the Sanitation Bureau) pay a waste disposal fee between 5-50 RMB (\$0.70 - \$7CAD). The Sanitation Bureau collects waste over a total area of 150 000 m². There are 25 dumpsters placed on 12 streets. These 12 streets are swept and waste is collected two times per day. These dumpsters are located in populated areas, typically sited in the vicinity of multi residential complexes or commercial establishments. Geographically, waste collection occurs in all of the main streets in Baisha Township and dumpsters are readily accessible to most of the population; however several isolated cases of open dumping were documented (Photo 5.1 and 5.2). Notwithstanding these cases dumpsters are accessible to most residential areas in Baisha Township.



Photo 5.1, 5.2 : Improper waste disposal around Baisha Township

⁴¹ Yatcha farm was not fully investigate because they do not dispose of their waste in the dump on Miao Ling mountain. They are self sufficient and independent. Moreover we were not fully aware of the amount of waste they produced until later in our field work.

After waste is collected in Baisha Township from the small dumpsters, a garbage truck transports and discards the waste on to Miao Ling Mountain. After the waste is dumped, it is set on fire by waste workers and whatever remains is bulldozed off the mountain (Photo 5.3). Miao Ling Mountain is located about 10 km outside of Baisha Township.

The current method of final disposal is in need of improvement because it is environmentally hazardous, and poses risks to humans. Local government officials claim that this waste disposal method does not pose a hazard to the health of the people in Baisha Township. However, local residents in Miao Cun village, a village close to the waste dump site, have reported that they experience air quality issues, and have experienced negative health impacts. Local government officials of Fang Xiang, a village at the bottom of Miao Mountain, attribute water quality issues to leachate runoff from the dump (key informant 90, 91, 92). They reported changing their drinking water sources due to pollution caused by the leachate runoff (key informant 90, 91).

Nevertheless, it should be recognized that this method of waste disposal is an improvement over previous methods of waste disposal. Prior to the year 2000, waste that was collected was discarded behind one of the local middle schools and also dumped in several tributaries of the Song Tao Reservoir (key informant 19, 80, 108, 109). This method of waste disposal had an impact on a larger population and a direct impact on water quality as waste was disposed of directly in rivers. Thus, even though the current method of waste management is environmentally hazardous, it is a modest improvement over prior methods of waste management.



Photo 5.3: Currently Baisha’s MSW is disposed of on top of Miao Ling Mountain

5.1.4 The informal waste management sector

The informal recycling sector in Baisha Township plays an important role in waste management. A total of six informal waste workers ⁴² were interviewed to gain a better understanding of the role of the informal sectors in waste management. In Baisha Township there are a total of six recycling centers. These recycling centers purchase recyclables from informal waste pickers. According to the informal waste pickers the total number of waste pickers in Baisha Township is between 50-100 people (115, 117, 118, 119).

The informal sector typically recycles water bottles, cans, waste paper, iron, plastic shoes, rubber, and beer bottles. Below is a list of the material and the price at which the recycling centers purchases waste (Table 5.4).

⁴² Of the six waste workers who were interviewed two of the waste workers collected waste by bicycle and four by foot, five out of the six were women and only one was a man. All of the waste pickers were not local Baisha people “*ben di*” but from mainland China “*da lou*”, four of the waste pickers were from Dangzhou, where they previously owned land but could not make the land agriculturally productive, the two waste pickers who rode bicycles were from Henan a province in northern China.

Table 5.4 : Buying price of recycled materials

Beer bottles: 0.1 RMB per can (\$.01 CAN)
1 kilo of cardboard: 0.6 RMB (\$.8 CAN)
1 kilo of plastic bottles 4 RMB (\$.56 CAN)
1 kilo metal cans 1.6 RMB (\$.22 CAN)
1 kilo bicycle metal 1.6 RMB (\$.22 CAN)
1 kilo rubber (from shoe soles) 1.6 RMB (\$.22 CAN)
1 kilo newspaper 1RMB (\$.14 CAN)
1 kilo book paper (lower quality than newspaper) 0.8 RMB (\$.11 CAN)

Source: Ichim field notes 2006

Local recycling stations sell this waste to the waste development district in Haikou. There are two general categories of waste pickers: the type who ride a bicycle and the type that pick waste on foot (Photo 5.4, 5.5). The waste pickers who ride bicycles purchase waste from commercial establishments and resident at one third of the price at which they sell the waste to the recycling station. The waste pickers who walk tend to search through dumpsters and do not purchase waste from residents. While the waste pickers that ride bicycles refused to disclose how much they earned per day, the ones who pick waste directly from dumpsters earned between 2 - 12 RMB (\$.28- \$ 1.68) per day. Many of the waste pickers that do not ride bicycles have informal contracts with recycling stations whereby the recycling station provides housing to the waste pickers in exchange for having the rights to purchase the waste that they collect. It is difficult to estimate how many waste pickers were on bicycle vs. foot.



5.4



5.5

Photo 5.4, 5.5 : Informal waste workers in Baisha Township

Some waste pickers as well as local residents who are not actually waste collectors were spotted collecting organics from the waste dumpsters (Photo 5.6). These people usually collected greens and leaves from the dumpsters, most probably to feed livestock. The author was unable to interview any of these people because whenever they were approached they generally smiled and ran away. These organic waste collectors were seen infrequently within a two month period: an estimated seven people were seen collecting organics from dumpster.



Photo 5.6: An informal waste collector separates organic waste from in organic waste

Judging the overall effectiveness of the informal sector was beyond the scope of this thesis however the waste composition analysis indicates that there is high proportion of plastics (10%) and paper (6%) being discarded into landfill sites; this would indicate that plastics and paper are most likely not being recycled at optimal levels. The informal sector seems to be fairly effective at recovering rubber (2%), glass (3%) and metals (3%).

The workers in the informal sector are subject to occupational hazards as a result of their work. Visual appraisals indicated that many informal workers do not wear protective clothing such as masks and gloves. This is particularly hazardous for those waste workers who scavenge through dumpsters. One reason given for not wearing protective clothing is due to economic constraints. Some informal workers make as little as 2 RMB (\$.28 CAN) per day thus barely covering the cost of food (key informant 116, 117).

5.1.5 Impacts of the current waste disposal system on people and the environment

The current method of waste disposal may not pose an immediate and direct hazard to the health of the people of Baisha Township since the final disposal site is located 10km away; however the current disposal practices have potential indirect impacts on Baisha residents. It also has direct

impacts on the health of the people living in Miao Cun, a small village located close to Miao Ling Mountain. This type of waste disposal results in air pollution, which lowers the air quality, and leachate pollution, which potentially effects water quality (El- Fadel 1997). This current method of waste disposal contributes to air pollution since waste is constantly burned at low temperatures and in incomplete manner, this causes the release of dioxin when plastics are burn (Cointreau 2005). While leachate pollution may not seep directly into the Song Tao tributaries, it is possible that it will seep into some of the groundwater sources at the foot of the mountain.

Key informant interviews with surrounding residents of Miao Cun and Fang Xiang revealed allegations of air quality impacts, water quality issues and health impacts on the citizens of Miao Cun. All of the key informants from Miao Cun interviewed (n=6) complained about the air quality citing foul odor and smoke. This method of waste management effects the residents of Miao Cun in several respects: when waste is trucked to the landfill, the residents are exposed to waste fumes, and when the waste is burned these residents are exposed to resulting air pollution. Finally, when residents are required to tend to agricultural land which is in close proximity to the dumpsite they are exposed to garbage fumes and to disease vectors. Two residents of Miao Cun blamed the landfill for bringing in disease vectors such as mosquitoes (key informant 85, 89). One resident stated that he often felt ill after going to tend to his land near the dump (key informant 89).

According to government spokespersons from Fang Xiang village, the leachate from the landfill has polluted Fang Xiang's historic water source (key informant 90, 91). In 2003 there were reports of dead fish in this water supply which the local government attributed to leachate pollution (key informant 90, 91). Thus, residents of Fang Xiang currently have had to redirect their drinking water

supply from their historical source to wells that they have dug themselves, and to the nearby town of Dong Feng Village⁴³.

5.1.6 Methods of waste disposal in villages in Baisha County

In order to assess the potential for expanding composting to the village level twelve farmers were interviewed in different villages within Baisha County (Nan Kai district Nan Lan and Nan Mei village, Yuan Men district Nan Xun village and Xi Shui district Fang Lun village). These interviews were conducted in order to assess the current practices of waste management, as well as to determine how widespread the use of fertilizer is, and provide some indication of the market potential of compost fertilizer.

The use of biogas reactors, to convert human and animal fecal matter into energy is fairly wide spread throughout Hainan province, due to the recent governmental initiatives (An Outline Program for Building Hainan into an Ecological Province, 2005). Promoting the use of biogas reactors at the village level is one of the major tenets of the Hainan province's agenda to become an "ecological province" (ibid). The use of biogas reactors at the household level is heavily promoted and government subsidized (key informant 102). While financing options may differ in different villages in Fanglun village, in Xi Shui district the citizen is required to pay 20% of the total cost of installing biogas reactors and the government is responsible for paying 80% of the cost (key informant 102). Of the villagers that were interviewed 33% (n=4/12) had installed biogas reactors.

The use of biogas as a method for the disposal of fecal waste implies that some organics are being used as energy sources instead of being returned to the soil as in traditional Chinese composting methods. Traditional Chinese composting is documented in Nan Mei, Nan Xun and Nan Lan villages.

⁴³ Initially there were reports made the government officials of Fang Xiang of water pollution of Dong Feng's water source, however local officials from Dong Feng deny these reports.

This method of composting entails the mixture of organic matter with nitrogenous (animal and human fecal matter, weeds, *fei ji* grass) and carbonous (dried leaves, twigs, ash and rice husks) waste composition⁴⁴. The final compost is produced between one to three times per year. In the villages 25% (3/12) of people interviewed conducted a local household level type of composting. When asked about the method of organic waste disposal used by parents and grandparents 58% (7/12) state that the waste was composted and applied to plants while 25% (3/12) did not remember.

Those whose parents and grandparents practiced composting but who currently do not practice composting cited three reasons: First, the use of human and animal fecal matter is now used as an input into biogas reactors thus limiting the availability of this input into the compost; secondly the practice of composting is tiresome, requiring both time and effort; thirdly, chemical fertilizers are available at reasonable costs and result in greater yield.

Currently, 91% (11/12) of farmers interviewed use chemical fertilizers. The cost of fertilizer per year per farmer is between 200- 2000 RMB (\$28-\$280 CAN), with an average of 590 RMB (\$82 CAN). This indicates that the use of chemical fertilizer is widespread in Hainan Province. It also indicates that the fertilizer market is quite large.

The remaining waste that is not composted or disposed of in biogas reactors is either recycled or dumped. The informal recycling sector collects recyclables in villages. Several times per week a truck comes to these villages and purchases recyclables from villagers (key informants 93, 94 99, 103, 105). Other waste is dumped in central waste disposal areas. For example, key informant interviews revealed that 81% (9/11) people dispose of waste in central waste disposal areas, which are usually openly burnt on a weekly basis. Others dump waste at the roadsides, and river tributaries. Some

⁴⁴ The preferred usage for leftover food is to feed it to animals 66% (8/12) of those interviewed stated that they gave leftover food to animals. Alternatively some 33% (4/12) mix leftover food with rice husks and feed it to pigs, dogs and chickens.

farmers mentioned collecting the ash from the central dumpsite and applying it on agricultural products.

5.2 The central market in Baisha Township

The market consists of 535 vendors this includes booths and stores. There are an estimated 702 individuals selling goods⁴⁵. There are 45 different types of commercial activities: broadly speaking the commercial activities which occur in this market includes fruits/vegetable vendors, livestock vendors, restaurants, cloth vendors, as well as pharmacies and one hospital. A precise breakdown of the exact composition of the market is found in Appendix D. Below is a chart with the vendors whose commercial activities generate organic waste⁴⁶ (Table 5.5). A total of 301 vendors out of 535 vendors (56%) engage in commercial activities that generate organic waste.

⁴⁵ Some vendors employed two individuals.

⁴⁶ It should also be noted that the other vendors may also generate organic waste through personal consumption of food.

Table 5.5 : Market vendors that produce organic waste

Type of Commercial Activity	Number of booths or vendors (not individual people)	Type of Products Sold	Type of Waste Produced
1. Fruit vendors (fruit booths and fruit vendors)	50	Longyan fruit, Jackfruit, peanut, watermelon, banana, guava	Leaves, twigs, longyan peels and seeds, fruit peels.
2. Clam vendor	5	Clams and water snail	Shells
3. Fish vendor & booth	32	Fish (Most of the fish is initially alive then they are killed gutted and sold)	Fish insides, fish scales, fish fecal matter, plastic bags
4. Convenience Shop/ convenience store	31	detergent, lighters, magazines, snacks, cigarettes, soft drinks, cooking oil, towels, shampoo, dried noodles, garlic, ginger No Fruits or Vegetables	Boxes, Cardboard, Bags, plastic wrapping, food waste
5. Meat Vendor	21	Pork, chicken, ham, dumplings	Pigs hair, fecal matter inside pigs body, useless things inside of the pig, paper napkin, plastic bags
6. Seed booth	2	Assorted seeds, lighters, tobacco, soft drink, spring water, ice cream, longyan fruit	Lighters, cans, spring water bottles, twigs and longyan peels
7. Roasted meat	2	Roast meat	Bottles, bones, skin
8. Livestock	17	Live chicken, live duck, live pig, jinzhu chicken, rabbit, pigeon, Anchun birds	Fecal matter of animals, excess feathers and hair
9. Small restaurant& Restaurant	17	Bread, steamed bun, soft drinks, ice cream, noodles, fast Chinese food, rice, roast meat, fish	Fish bones, pig bone, rice, beer bottles assorted foods, pop can, wrapping, cardboard, plastic bags
10. Vegetable vendor	121	Assorted vegetables both imported from the mainland and domestically grown	Vegetable leaves and plastic bags Some clean the vegetables at home so they do not produce waste at the market.
11. KTV	1	Entertainment facility	Beer and baijiu bottles, spring water bottles, cans, fruit skins
12. Peanut Vendor	1	Roast peanuts	Peanut shells
13. Rice and vegetable vendors	1	Rice and assorted vegetables	Bags, vegetable stems

Source: Field notes 2006

After the market was mapped, surveys were conducted to gather information on specific questions which could potentially influence the implementation of the composting. The questions are based on human factors which were identified in the literature review as influencing the implementation of composting. Each question is described below and the interviewees' responses are discussed.

A cross section sample of the entire market was chosen to be interviewed ⁴⁷ however organic waste producers were intentionally overrepresented. Only 56% of the market vendors produced organic waste however organic waste producers were overrepresented in the population sample interviews. Sixty-nine percent (37/53) of those interviewed engaged in commercial activities that produced organic waste. Those who produced significant quantities or types of organic waste such as vegetable vendors (15/121), meat vendors (6/21) and livestock vendors (5/17) were also over represented. A smaller number of vendors whose commercial activities did not produce organic waste were interviewed for two reasons. Even if commercial activities do not generate organic waste- the individual employed may generate organic waste while in the market. Secondly, understanding both the organic and inorganic components of market waste is significant to the waste management system within the market.

⁴⁷ Vegetable Vendors (15), Meat Vendor (6), Clothing shop/ booth (5), Live Stock (5), Fruit vendor (4), Fruit booth (4), Fish Vendors (fresh fish) and Booths (4), Small and large restaurants (2), Hospital (1), Household Appliances (1), , Pharmacy (1), Egg Vendor (1), Convenience Shop/ Convenience Store (1), Assorted Product Shop/ Booth (1), Fish vendor (dried fish) (1), Tofu Vendor (1).

5.3 Results of the oral interviews/survey:

5.3.1 Market vendors:

5.3.1.1 Do you produce the products you sell or do you act as a secondary distributor?

The vendors were asked whether they produced the products that they sold or whether they bought and sold (act as a secondary distributor). This question was asked to assess whether loop closing was possible. Initially it was believed (by the local government, the provincial actors and the Canadian partners) that the market was a closed system in the sense that vendors were also producers of the goods they sold. In this case, loop closing would have been possible in the sense that organic waste that was composted could be sold or given to the producers of agricultural products, thus forming a closed loop.

Results revealed that the market was overwhelmingly an open system tied into national supply chains (Table 5.6). The market consisted overwhelmingly of secondary distributors who bought from producers and re-sold the goods. Over 84% of vendors were buyers and vendors as opposed to producers and vendors. In terms of those producing organic waste, only a small proportion of meat vendors (1/6; 16%) and vegetable vendors (9/15; 40%) produced the products they sold. While it may have been expected that fruit booths which sold apples, watermelons and other luxury fruit would not produce their own fruits, the research revealed that fruit vendors (small vendors who sell longyan fruit on the ground also) did not produce their own fruit but purchased the fruit from local producers.

Table 5.6: Do you produce the products that you sell or do you act as a secondary distributor?

Do you produce the products that you sell or do you act as a secondary distributor?					
Type of Vendor	# Interviewed	Produce and Sell	%	Secondary distributor	%
Vegetable Vendors	15	6	40%	9	60%
Clothes Vendors	6	0	0%	6	100%
Fruit Vendors	4	0	0%	4	100%
Fish Vendors	4	0	0%	4	100%
Convenience Stores	1	0	0%	1	100%
Meat Vendors	6	1	17%	5	83%
Assorted Products	1	0	0%	1	100%
Dried Fish	1	0	0%	1	100%
Restaurant	2	0	0%	2	100%
Tofu	1	1	100%	0	0%
Livestock	5	0	0%	5	100%
Fruit Booths	3	0	0%	3	100%
Egg	1	0	0%	1	100%
Hospital	N/A	0	0%	0	0%
Household Appliances	1	0	0%	1	100%
Pharmacy	1	0	0%	1	100%
Totals	52	8		44	
Average Percentages			15%		85%

The research revealed that the segment of the vendor population that has the greatest ability for loop closing are vegetable vendors as they might be the potential consumers of composts. The results indicate that 40% of vegetable vendors also grow vegetables. This number should be contextualized since all of the vegetable vendors that reported growing vegetables were also small vendors. The vendors who reported producing their own vegetables were the vendors who sold between one to three products and tended to be smaller scale. Furthermore, these vendors tended to sell “on the floor” rather than in booths or stores. By contrast, larger vendors that tended to sell diverse types and generate large quantities of waste did not produce their own vegetables. Thus although there may be potential for loop closing at the vegetable vendor level, this potential only applies to smaller vendors and not to larger vendors.

5.3.1.2 Have you heard of waste composting?

In order to assess the vendor's knowledge of waste composting, vendors were asked if they had ever heard of waste composting⁴⁸. Sixty-nine percent of the respondents had not heard of composting (Table 5.7). Those who had heard of composting had heard about it from television, newspapers or associated it with historical Chinese practices. Those who produced organic waste had a lower rate of knowledge about composting than those who did not produce organic waste. Vegetable vendors had a below average level of knowledge about composting, only 20% stating that they had heard of composting. Similarly only 25% of fruit vendors said that they had heard of composting. This is not unexpected since most of the vendors do not produce their own products. Most vendors who produce their own products, view waste- as waste not as organics with recovery potential (key informant 2, 4, 7, 13). Key informant interviews suggest that, those who produce their own vegetables view the waste that they produce in their farms as different from the waste that is produced at the market. Those who had not heard of composting often expressed surprise and disbelief at the notion that waste could be turned into an agriculturally beneficial product (key informant 2, 8, 9, 12, 13, 54).

⁴⁸ Historically Chinese farmers used a composting practice called *ou fei*, however the composting practice that is employed for municipal solid waste is referred to as *dui fei*. Composting *ou fei* and *dui fei* is not always recognized by urban or rural residents.

Table 5.7: Have you heard of waste composting?

Have you heard of waste composting? (Yes/No)					
Type of Vendor	# Interviewed	"Yes"	%	"No"	%
Vegetable Vendors	15	3	20%	12	80%
Clothes Vendors	6	2	33%	4	67%
Fruit Vendors	4	1	25%	3	75%
Fish Vendors	4	0	0%	4	100%
Convenience Stores	1	0	0%	1	100%
Meat Vendors	6	3	50%	3	50%
Assorted Products	1	1	100%	0	0%
Dried Fish	1	0	0%	1	100%
Restaurant	2	2	100%	0	0%
Tofu	1	0	0%	1	100%
Livestock	5	3	60%	2	40%
Fruit Booths	3	0	0%	3	100%
Egg	1	0	0%	1	100%
Hospital	N/A	0	0%	0	0%
Household Appliances	1	1	100%	0	0%
Pharmacy	1	0	0%	1	100%
Totals	52	16		36	
Average Percentages			31%		69%

5.3.1.3 Is there fluctuation (daily or seasonal) in the amount of waste you produce?

Interviews with waste producers indicate that there are fluctuations in the individual amount of waste produced however the implications on the total amount of waste produced are difficult to decipher (Table 5.9). Slightly under half of the vendors (46%) indicate that there are no fluctuations in waste production. Fluctuations are reported by 40% of the vendors, while small fluctuations are reported by 13% of vendors. These fluctuations occur according to the spring festival for clothes vendors, fruit, fish vendors, meat vendors, and restaurants, with more waste being produced in January and February.

Interviews with waste collectors did not concur with these results. Waste collectors hold the view that there is no fluctuation in the amount of waste (key informant 120, 121, 122).

Table 5.8: Are there fluctuations in the amount of waste you produce?

Are there fluctuations in the amount of waste you produce? (yes/no/small)							
Type of Vendor	# Interviewed	"Yes"	"Yes" %	"No"	"No" %	"Small"	"Small" %
Vegetable Vendors	15	5	33.33%	7	46.66%	3	20%
Clothes Vendors	6	6	100%	0	0%	0	0%
Fruit Vendors	4	1	25%	2	50%	1	25%
Fish Vendors	4	2	50%	1	25%	1	25%
Convenience Stores	1	0	0%	1	100%	0	0%
Meat Vendors	6	1	17%	4	67%	1	17%
Assorted Products	1	0	0%	1	100%	0	0%
Dried Fish	1	0	0%	1	100%	0	0%
Restaurant	2	2	100%	0	0%	0	0%
Tofu	1	0	0%	0	0%	1	100%
Livestock	5	1	20%	4	80%	0	0%
Fruit Booths	3	2	0%	1	100%	0	0%
Egg	1	1	100%	0	0%	0	0%
Hospital	N/A	0	0%	0	0%	0	0%
Household Appliances	1	0	0%	1	100%	0	0%
Pharmacy	1	0	0%	1	100%	0	0%
Totals	52	21		24		7	
Average Percentages			40%		46%		13%

5.3.1.4 Do you reuse any of your waste?

This question was asked to gain insight about the current resource flow of waste with a specific interest in the reuse of organic waste. The results indicate that there is a rich flow of resource reuse that occurs at the inter-vendor level in the market place (Table 5.9).

Table 5.9: Do you reuse any of your waste?

Do you reuse any of your waste? (yes/no/give it away)							
Type of Vendor	# Interviewed	"Yes"	%	"No"	%	"Give it Away"	%
Vegetable Vendors	15	0	0%	11	73%	4	27%
Clothes Vendors	6	4	67%	2	33%	0	0%
Fruit Vendors	4	0	0%	2	50%	2	50%
Fish Vendors	4	1	25%	0	0%	3	75%
Convenience Stores	1	0	0%	1	100%	0	0%
Meat Vendors	6	3	50%	1	17%	2	33%
Assorted Products	1	0	0%	1	100%	0	0%
Dried Fish	1	0	0%	1	100%	0	0%
Restaurant	2	0	0%	1	50%	1	50%
Tofu	1	1	100%	0	0%	0	0%
Livestock	5	0	0%	2	40%	3	60%
Fruit Booths	3	0	0%	3	100%	0	0%
Egg	1	0	0%	0	0%	1	100%
Hospital	N/A	0	0%	0	0%	0	0%
Household Appliances	1	0	0%	1	100%	0	0%
Pharmacy	1	0	0%	1	100%	0	0%
Totals	52	9		27		16	
Average Percentages			17%		52%		31%

Just over half of the vendors do not reuse their waste (52%). A rapid overview of those sectors where 100% of vendors do not reuse or give away waste ⁴⁹ revealed that waste produced includes a large amount of wrappers, plastic and cardboard. Some of these vendors may be able to participate in the symbiotic relationships described below, promoting reuse at this level may increase recovery of resources. The fact that 73% of vegetable vendors dispose of their organic waste is significant for composting as this indicates that most of the organic waste generated in the market is disposed of and not reused. This confirms that the market does contribute a significant source of organic waste.

The other half of the market engages in market level symbiosis that is worthy of documentation. Of the 17% that reuse their waste: 67% of clothes vendors reuse boxes, wrappers and clothes; 25% of fish vendors use the fish insides and waste as fish food for the other fish; 50% of the meat vendors reuse their waste to feed live stock (two of them feed dogs and one feeds pigs); and the tofu (n=1,

⁴⁹ Convenient stores, assorted products, dried fish, fruit booths, house hold appliances, hospitals and pharmacy

100%) vendor reuses all of the waste that was produced, including organic waste produced from personal consumption, and plastic bags.

Of all the market vendors, 24% give the waste away, and the way in which these materials are reused and reassigned of value is note worthy, revealing a case of market level symbiosis. The waste of one vendor is considered a resource by other vendors. It was noted that the type of waste that is being given away is organic waste that is used as an agricultural or livestock input. Thus, there is some loop closing currently occurring at the market level.

Of the vegetable vendors 26% give waste away. This waste is given to those who own livestock such as pigs or chickens, either to other vendors in the market or to friends and neighbors. Fifty percent of fruit vendors (not fruit booths) give part of their waste leaves away to those who feed livestock. Seventy- five percent of fish vendors give away their waste (fish fecal matter and fish remains, scales, and inner parts). This waste is usually given to agricultural producers of vegetables; it is generally used to improve the quality of the soil. Restaurants (50%) and meat vendors (33%) give their remains to agricultural producers to use as pig feed or dog feed. Over half (60%) of those who sell livestock reported giving away the animal's fecal matter. Those who sell birds reported giving away avian fecal matter to fish vendors who then use it as fish feed⁵⁰. This symbiotic relationship is promoted (intentionally or unintentionally) by the close geographic proximity of fish vendors and livestock vendors.

Although some vendors reported selling their waste informally, the specific number was difficult to assess⁵¹. These waste types include, paper, plastic, metal, rubber, beer bottles, water bottles, soda

⁵⁰ This practice needs to be examined by public health workers due to possible concerns about spreading Avian flu.

⁵¹ This was discovered half way through the interviews. The reason that this fact was not noticed earlier was because people who sell their waste do not consider the waste as waste per se, rather as an intrinsic method of cost recovery.

cans, cardboard, heavy duty plastic bags. While paper, plastic, metal, rubber, beer bottles, water bottles, soda cans and cardboard are to a large extent typical products recycled by the informal sector (and will be discussed later), cardboard and heavy duty plastic bags, such as, fertilizer bags, and rice bags are used in unique ways in this market place.

Waste cardboard produced as a by-product of many commercial activities such as clothes vendors, convenience stores, assorted product stores, restaurants, pharmacies and hospitals are often sold to vegetable vendors, fruit vendors, meat vendors, dried fish, tofu stands and fruit booths. Those who buy cardboard use the cardboard to display their products. A rapid visual assessment revealed that most of those who sell vegetables, fruits, meat, dried fish and tofu use pre-used cardboard to display their products. There are over 200 vendors who regularly produce cardboard as part of their waste stream and similarly there are over 200 vendors who purchase this waste cardboard to display products. According to key informant interviews with vegetable vendors and fruit vendors (key informant 12, 14, 24, 25) the price of cardboard is 0.6 RMB (\$.8 CAN) per kilogram.

Used heavy duty plastic bags and fertilizer bags are often sold to fruit vendors (the vendors who sell fruit on the ground n=50) who use these plastic bags to display fruit. These bags are sometimes given to people and sometimes sold to people; if they are sold the current price is 0.8 RMB (\$.11 CAN). Site visits to the small hospital inside of the market indicates that the hospital uses fertilizer bags to store the medical waste produced in the hospital. The hospital representative states that after usage the hospital disposes of the bags.

5.3.1.5 Are you concerned about your waste?

Table 5.10: Are you concerned about your waste?

Are you concerned about your waste? (yes/no/refuse to answer)							
Type of Vendor	# Interviewed	"Yes"	%	"No"	%	"Refuse to Answer"	"Refuse to Answer"
Vegetable Vendors	15	9	60%	5	33%	1	7%
Clothes Vendors	6	3	50%	3	50%	0	0%
Fruit Vendors	4	2	50%	2	50%	0	0%
Fish Vendors	4	3	75%	1	25%	0	0%
Convenience Stores	1	1	100%	0	0%	0	0%
Meat Vendors	6	6	100%	0	0%	0	0%
Assorted Products	1	1	100%	0	0%	0	0%
Dried Fish	1	1	100%	0	0%	0	0%
Restaurant	2	2	100%	0	0%	0	0%
Tofu	1	1	100%	0	0%	0	0%
Livestock	5	4	80%	1	20%	0	0%
Fruit Booths	3	2	0%	1	100%	0	0%
Egg	1	0	0%	1	100%	0	0%
Hospital	N/A	0	0%	0	0%	0	0%
Household Appliances	1	1	100%	0	0%	0	0%
Pharmacy	1	0	0%	1	100%	0	0%
Totals	52	36		15		1	
Percentage			69%		29%		2%

This question “are you concerned about your waste” was asked in order to assess self reported attitudes towards waste. The current waste management practices of open dumping and burning of waste were described to the vendors and then they were asked if it was a cause for concern. Most people (69%) answered that they were concerned about their waste (Table 5.10). Some expressed deep concern about burning plastics, plastic bags and the disposal of batteries, yet stated that there is a lack of viable alternatives for waste disposal. Close to one third (28%) of people answered that they are not concerned about their waste. This was accompanied by statements that waste management was none of their business: it is the job of the government and the waste workers.

5.3.1.6 Are you willing to separate your waste?

To assess the degree to which vendors would be willing to separate their waste the question was asked “if the government asked you to separate your waste would you be willing to separate it”. The separation of waste is very important for implementing source separated composting, in order to insure organic waste is isolated from non organic waste. The question was asked in the form presented above with reference to the government because in China the institutional framework is significant for compliance. Since the waste management system is operated by the government the regulations governing waste collection must also be decreed by the government. If composting is established as part of the MSWM strategy then the local government is responsible for source separation and the government may pursue the option of issuing regulations to promote source separation.

Most people (92%) said they would be willing to separate their waste (Table 5.11). Few people 6% said they would not be willing to separate their waste and 2% said maybe. The few who said “no” cited the following reason: lack of time, lack of space, they feel that they produce insignificant quantities of waste (key informant 32) and also that they did not want to listen to the government (key informant 25). Others insisted that if source separation was required than the separation is not their job but the job of the waste workers (key informant 52).

All vegetable vendors stated that they would be willing to separate waste. This is significant because vegetable vendors likely produce the largest proportion of organic waste. One fruit vendor said that they refused to separate the waste. This is significant as the fruit vendors likely produce the most significant amounts of plastics. One meat vendor also said that he would refuse to separate waste, because he did not think that he produced a significant amount of waste.

Table 5.11: Are you willing to separate your waste?

Are you willing to separate your waste? (yes/no/maybe)							
Type of Vendor	# Interviewed	"Yes"	%	"No"	%	"Maybe"	%
Vegetable Vendors	15	15	100%	0	0%	0	0%
Clothes Vendors	6	6	100%	0	0%	0	0%
Fruit Vendors	4	2	50%	1	25%	1	25%
Fish Vendors	4	4	100%	0	0%	0	0%
Convenience Stores	1	1	100%	0	0%	0	0%
Meat Vendors	6	5	83%	1	17%	0	0%
Assorted Products	1	1	100%	0	0%	0	0%
Dried Fish	1	1	100%	0	0%	0	0%
Restaurant	2	2	100%	0	0%	0	0%
Tofu	1	1	100%	0	0%	0	0%
Livestock	5	5	100%	0	0%	0	0%
Fruit Booths	3	3	100%	0	0%	0	0%
Egg	1	1	100%	0	0%	0	0%
Hospital	N/A	0	0%	0	0%	0	0%
Household Appliances	1	1	100%	0	0%	0	0%
Pharmacy	1	0	0%	1	100%	0	0%
Totals	52	48		3		1	
Average Percentages			92%		6%		2%

5.3.1.7 Interviews with commercial and residential waste producers

Since participant observation reveals that the local government intends to expand waste composting beyond the market level to the residential and commercial waste (108, 110), this section provides data which could be used to assess the potential of expanding composting into these streams of waste.

First, interviews with commercial waste producers ⁵² (Table 5.12; n=20) are presented then interviews with residential waste producers (Table 5.13; n=10).

5.3.1.8 Interviews with commercial waste producers

Table 5.12: Interviews with commercial waste producers

Commercial waste producers						
Question	# Interviewed	"Yes"	"Yes" %	"No"	"No" %	refused
Do you recycle?	20	15	75%	5	25%	
Do you pay waste fees?	20	18	90%	2	10%	
Is the waste fee too high?	20	3	15.79%	16	84.21%	1
Would you be against raising the fees?	20	15	83.33%	3	16.66%	2
Are you concerned about waste?	20	19	95%	1	5%	
Are you willing to separate waste?	20	17	85%	3	15%	
Are you opposed to collecting waste once a day?	20	17	85%	3	15%	
Did you hear about waste composting?	20	8	40%	12	60	

Question	# Interviewed	"Once a day"	"More than once a day"
How often do you dump your waste?	20	13	7
		65%	35%

Question	# Interviewed	"I have none"	"Sell it"	"Throw it away"	"Give it to people to feed animals"
What do you do with your left over food?	20	7	3	6	4
Average		35%	15%	30%	20%

⁵² The composition of those commercial establishments are as follows: 6 restaurants, 2 tea houses, 1 coffee house, 1 clothing store, 1 convenience store, 1 rice shop, 1 supermarket, 1 barber shop, 1 snack shop, 1 KTV (karaoke television), 1 hotel, 1 fertilizer shop, 1 paint shop, 1 veterinary hospital.

With respect to the first question “do you recycle?”, 75% of the commercial establishments interviewed stated that they did recycle. They participated in recycling by either directly selling their waste to the recycling stations or by selling their waste to informal workers who then sold the waste to recycling stations. While the waste recycled usually consisted of metals, plastic, paper and bottles, organic wastes were also recycled. Three of the restaurants (50%=3 /6) interviewed recycled their organic waste by selling their organic waste to pig farmers to be used as animal feed. The three restaurants that did this were also the biggest restaurants in Baisha.

Most commercial establishments are required to pay waste collection fees to the Sanitation Bureau. Ninety percent of those interviewed pay waste collection fees. These fees range from 5 to 50 RMB (\$0.70-\$7CAD). Only 15% (n=3/20) of those interviewed said the fee was too high; those who said it was too high were not satisfied with the services provided by the Sanitation Bureau. The most common complaint cited was that waste was not swept from their storefront. In regards to increasing the fees, 75% said they would oppose an increase in the fee. A few (16%, n=3/18) stated that if the service was improved or if there were changes made to the waste management system then they would be willing to pay a higher fee.

A higher proportion of commercial vendors (95%) than market vendors expressed a concern about their waste. The main concerns of the commercial residents were concerns about source water pollution, air pollution and basic hygiene. Those who were not concerned stated that no other option exists except the burning of waste, and if a better method were possible then that would be acceptable. However, until a better method is found, water pollution and air pollution seen by commercial vendors to be just part of the cost of living.

Most commercial establishments (85%) said that they would be willing to separate their waste. While 15% (n=3/20) stated that they were unwilling to separate their waste, time requirements and space

requirements were cited as the major reasons for not wanting to separate waste. The three commercial establishments which were unwilling to separate their waste included of two restaurants and one hotel. Since hotels and restaurants produce significant amounts of organic waste it is important to attempt to persuade these types of businesses to separate their waste. Thus, even though most commercial establishments indicate that they are willing to separate their waste, the minority who respond negatively provide indication that can enable the government to foresee future problems and take preemptive measures to mitigate these problems.

The awareness of composting is slightly higher among commercial waste producers than market vendors. Less than half of the commercial establishments interviewed (40%) have heard of waste composting and slightly more than half have not heard of waste composting (60%). When compared to the market vendors, a 10% higher proportion of commercial vendors are aware of composting.

Currently waste is collected twice daily in Baisha Township and research tested the possibility that, this frequency may be too often. To test this hypothesis, the commercial vendors were asked if they would be opposed to having waste collected once a day. The response was overwhelmingly against collections occurring once a day, with 85% of the respondents saying that they would be opposed. The reasons cited were that the waste would smell, the streets would be unclean--which would lead to negative impacts on their business, there would also be a negative impact on public hygiene. Fifteen percent said that they would not have a problem with waste collection if it occurred only once per day. Those who were not opposed to collection occurring once every day stated that as long as it did not affect them they were indifferent to the number of times collection occurred.

While 85% of people were opposed to waste collection occurring once a day, 65% of respondents stated that they only dump their waste out one time per day, with only 35% saying that they dumped their waste out more than once per day. This means that even though many people only dispose of

their waste daily they still demand waste collection at least two times a day. When asked to explain this apparent inconsistency the waste producers cited that they are concerned about littering. Another problem is limited on site storage capacity and the fact that the waste collection units are too small.

The current pattern of organic waste usage by commercial vendors has positive implications on the potential for implementing composting in Baisha Township. The majority of commercial establishments interviewed (35%) claim that they do not produce organic waste. Currently organics are either, disposed of (30%), sold (15%) or given away to feed animals (20%). Thus 35% of the organic waste current generated in the commercial sector is being reused and only 30% is being disposed of.

5.3.1.9 Residential waste producers

Table 5.13: Questions asked of residential waste producers

Residential waste producers						
Question	# Interviewed	"Yes"	"Yes"	"No"	"No"	refused to answer
Do you recycle?	9	3	33.33	6	66.66	
Do you pay waste fees?	9	2	22.22	7	77.77%	
Is the waste fee too high?	9	2	100%	0	0%	7
Would you be against raising the fees?	9	2	100%	0	0%	7
Are you concerned about waste?	9	8	88.88	1	11.11%	
Are you willing to separate waste?	9	9	100	0	0%	
Did you hear about waste composting?	9	3	33.33	6	66.66%	

Question	# Interviewed	"I have none"	"Throw it away"	"Give it to people to feed animals"
What do you do with your left over food?	9	2 (22%)	2 (22%)	5 (22%)

Of the resident population 67% (Table 5.13) stated that they did not recycle, with only 33% claiming that they did recycle. This indicates that residents recycle far less than commercial vendors: the residential rate of recycling is 33% while the commercial rate of recycling is 75%. This low rate of

recycling might be partially attributed to the possibility that some residents may believe that they do not produce a significant amount of recyclable waste, hence there is no need to recycle. In any case, the fact that the rate of recycling is so low allows for job creation in the informal sector who pick through the waste.

Waste disposal fees were paid by 22% of the resident respondents (n=2/9), both of whom dwelled in multi-residential apartment complexes. They both stated that the waste fees were too high and that they would not be willing to pay more if the waste fee was increased. Only 22% of residents stated that they pay waste fees, this provides some reason to believe that most of the residents in Baisha Township are currently not paying waste disposal fees. Interviews with government officials from the sanitation bureau confirmed that most residential areas do not pay waste collection fees (key informant 106). Furthermore, the fact that both of these residents stated that the waste disposal fees they were paying was too high indicates that these residents are more sensitive to the cost of the waste disposal fees than commercial establishments are.

Residential respondent had a high level of concern about their waste (88%) which was similar to the commercial vendors (95%). Also similar to the commercial vendors, residents stated that they were concerned about air, soil and water quality. There was also a feeling of frustration with the lack of alternatives to burning waste with regards to waste management options (key informant 77, 78).

All of the residents (100%) asked whether they were willing to separate their waste stated that they were willing to do so. Although some (n=2/9) were initially hesitant, they stated that if there was a reason for them to separate their waste they would be willing to do so. One resident expressed enthusiasm at the prospect of separating their waste by citing the old Maoist slogan “*wei ren min fu*” (work for the people).

The level of residential awareness regarding composting is relatively low, with only 33% of the residents questioned having heard about waste composting. Similar to the market vendors some of the residents expressed surprise at the fact that organic waste can be turned into an agriculturally beneficial product (key informant 75, 77).

Regarding the current usage of organic waste, 22% of respondents stated that they have none, 22% disposed of their organics and 55% gave their organics away to people who feed animals: pig, chicken, dogs. The fact that 55% of people stated that they give their organics to other people needs to be viewed with some skepticism. This could mean that they sometimes give their organics away or perhaps they are giving the “socially desirable” answer.

5.4 Proposed change to the current waste management system: composting

5.4.1 Technical aspects of the pilot composting project:

This section summarizes the technical aspects of the pilot project, separation of waste, the process: porosity, carbon to nitrogen ratio, the time required, temperature and turning as well as moisture content.

5.4.1.1 Separation of Waste

Market waste was used as the source of waste for this pilot project because it was believed ⁵³ that some degree of natural source separation occurred. Since the market was organized in sections according to the type of product that was sold, a type of natural source separation would occur according to the type of commercial activity that occurred. In addition, it was believed that there would be higher organic content in market waste, and thus, that no additional source separation would

⁵³ Believed by the partners: Canadians, provincial environment and resources bureau and the local governments.

be required. However, in fact the waste required separation, and this was carried out upon arrival at the composting facility.

Due to limited resources precise tests were not carried out to determine the composition of the waste, however, visual appraisals were used to try to understand the composition of the waste. Observation indicated that the waste contained a higher proportion of organic and plastic content compared to the commercial and residential waste. The organic content could be attributed to organic market waste from vegetable vendors, while the plastic content could be attributed to plastic wrapping.

For the pilot composting project, six waste workers separated waste for one hour and a half (Photo 5.7). There was a large quantity of non organic waste removed. An estimated three buckets of plastic were removed throughout the composting process. In the final screening process one additional bucket of plastic was removed.



Photo 5.7 : Waste workers separating waste for the pilot project

Non organic waste included plastic as well as several other types of contaminants which could potentially compromise the quality of the final compost or pose occupational hazards to waste workers (Photo 5.8 and 5.9). These contaminants included: a used syringe and needle, a vial of pig

vaccine, packs of cigarettes, cigarettes, assorted medication, batteries, used feminine hygiene products, and razors.



5.8



5.9

Photo 5.8, 5.9: Contaminants which pose hazards to occupational workers and compost quality

5.4.1.2 The composting method employed

Windrow composting was employed (Photo 5.10). This method was chosen because it was believed⁵⁴ to be the most suitable method in terms of minimal capital investment, economic feasibility, and the ease with which it could be applied and operate manually. This method required minimal capital investment because that it does not require highly specialized machinery or capital intensive infrastructure and relies primarily on human labour. It is economical in the sense that the operation costs might be higher than landfilling but not much higher⁵⁵. It does not require a high degree of specialized labour since it only requires monitoring of a few key variables: oxygen availability, the carbon to nitrogen ratio, moisture, temperature and unexpected problems (Haight and Taylor 2000)⁵⁶.

⁵⁴ It was believed by the Canadian Partners.

⁵⁵ This thesis calculates time labor requirements, however if the total cost is to be calculated then the labor costs must be established by the Sanitation Bureau.

⁵⁶ Unexpected problems include, odor, pests and other unexpected operational problems.

This method entails piling waste on top of a hollow pyramid and managing it by turning it when the temperature increases above 65° Celsius. A bamboo prism was used to enable oxygen penetration. The pilot project pile was .9 m high x 3.8 m long x 2.3m wide.



Photo 5.10: Windrow composting method: a composting pile was constructed on top of this bamboo prism

5.4.1.3 Porosity of feedstock

Even though windrows with bamboo prisms inside were used to facilitate oxygen availability, this on its own was not sufficient; attention also had to be paid to the porosity of the feedstock. A wide variety in the type of feedstock used, specifically with respect to the sizes, should be added in order to enable oxygen penetration. Literature on composting suggests that a grinder should be employed to chop up large pieces of carbonous material. Even though ideally a grinder should be used, there is still a need for diversity in the size of waste, in order to ensure that there is sufficient porosity to enable oxygen penetration. We were unable to procure a grinder, so a grinder was not used for this pilot project.

5.4.1.4 Carbon to nitrogen ratio of feedstock

The ideal ratio of carbon to nitrogen in the composting feedstock is 3:1 (Cooperband, 2002), however since the composition of the feedstock from the market was highly nitrogenous, we were forced to find additional carbonous material. We supplemented the market waste with rice husks, in order to achieve a proper mix. After the screening of the compost we had surplus carbonous material that had not yet broken down. In future processes this excessive material can be used to supplement and initiate the next batch of compost.

We had 0.76m^3 ⁵⁷ amount of organic waste left over. While it is expected that carbonous material breaks down slower than nitrogenous, this amount of residual organic waste is quite high. This residual material was comprised mainly of three types of organics: Woody material (chopsticks, twigs, and branches), leaves, and the seeds of longyan fruit (Photo 5.11). This large amount of organic waste can be partially attributed to the fact that the carbonous material was not chopped into smaller pieces when the compost pile was established. In ideal operational conditions large pieces of carbon would be reduced in size. Nevertheless, this carbonous material can be reused in the next batch of compost and thus make up for the lack of carbonous material in the feed stock.



⁵⁷ Organic pile 106cm across, 134 cm long, height 54 cm volume= $1.06 \times 1.34 \times 54 / 3 = .76\text{m}^3$

Photo 5.11: Residual organic waste

5.4.1.5 Time and temperature required for the composting pilot project

The literature reveals that the aerobic decomposition of organic waste undergoes a process of decomposition which can be determined through the type of bacteria present; the type of bacteria present in turn can be determined by the temperature of the compost (Cooperband 2002, Haight 2006, Haight and Taylor 2000). Since organic waste decomposes in a predictable way, time and temperature can be employed as indicators. The literature reveals that the decomposition of organic waste proceeds through two phases. The first phase is an active phase where waste is decomposing while, the second phase is a curing phase where the compost is stabilizing (ibid).

Our composting process matched the typical relationship between temperature and time that is present in typical compost (Cooperband 2002). There is an initial peak in the temperature: this is the active phase. Next, there is a reduction of temperature to about 10 degrees above ambient temperature. Then from day 35 to day 45 there is a small increase in temperature. For the active phase to be considered complete there must not be a peak in the temperature above 20 degrees Celsius from ambient temperature. Figure 5.2 shows that the active phase of the compost was complete after 35 days.

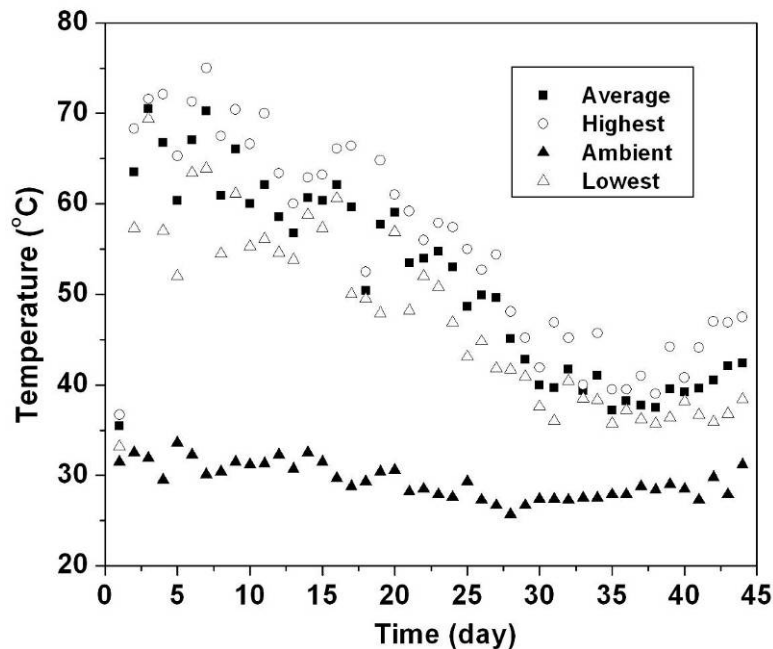


Figure 5.2: Composting temperature

5.4.1.6 Turning the compost

Turning is required for several reasons: to ensure that all of the compost is exposed to sufficiently high temperature so as to kill pathogens such as *E. coli.*, to mix up the content, as well as to control odour and to reduce temperature (to maintain the temperature under 70°C) (Haight 2006). This pile was turned a total of six times when temperature exceeded 68°C. Most of the turning occurred during the first two weeks⁵⁸.

5.4.1.7 Moisture of compost

In order for waste to breakdown, proper moisture content must be achieved. The ideal water content is between 45 to 60% (Cooperband 2002). As precise measurements were difficult to obtain, a rapid

⁵⁸ The number of times that turning is required will depend upon the specific pile of compost. Canadian standards state that an internal temperature of 55°C should be achieved for 15 days. The pile should be turned at least 5 times while the temperature is over 55°C Troi et. al. 2001.

method to assess this is to assess moisture content through feel. Literature revealed that water content is roughly 45-60% if the compost is moist though not excessively wet, and water should not drip nor should there be any dry areas (Cooperband 2002 and Haight 2006, Haight and Taylor 2000). We added about two to four buckets of water seven times, usually by sprinkling in as the compost was turned or poured on top.

5.4.2 Labor requirements for composting the market waste and the residential and commercial waste

Based on the labor inputs that were required for the composting pilot project, the researcher calculated that a total of 17 workers working 8 hour per day, 7 days a week will be needed to compost all of the Baisha residential and commercial waste, and 2.5 workers working 8 hours per day, 7 days a week will be required to compost the market waste. These numbers are based on the pilot project which was not an optimized experiment, and changes in process and technology could potentially reduce the amount of time or workers required. The calculations are found in Appendix F.

5.4.3 Space requirements for composting the market waste and the residential and commercial waste

The table below indicates the space required for composting of market, residential and commercial waste both during the active⁵⁹ and curing phases of composting (Table 5.14)⁶⁰. The waste in the active phase of composting is formed into a prism which requires a height of 1.5 m so as to facilitate the turning of the compost. The waste in the curing phase has the shape of a cone, which is 2 m high because it is constrained by the human inability to pile the waste higher than 2 m. The calculations are found in Appendix F.

⁵⁹ which according to the pilot project is 35 days

Table 5.14: Composting space requirements for market and residential and commercial waste

Type of Waste Phase of Composting	Residential and commercial	Market
Active Phase- 35 Days		
Total Volume	397.60m ³	57.25m ³
Width	2m	2m
Length	265.07m	38.15m
Height	1.5m	1.5m
Total Surface Area	530.14 m ²	76.3 m ²
Curing Phase- 30 days		
Height	2m	2m
Total Volume	340.80m ³	49.05m ³
Diameter	25.52m	9.68m
Total Surface Area	511.16m ²	73.57m ²

5.5 Human resources and training

Informal discussion with waste workers and provincial government officials indicates that more training is required. An information package was requested by both the provincial level and the local levels of government, and one first step in capacity building for composting would be working together and establishing such a package⁶¹. According to the local and provincial government, a longer and more detailed and specific training program or courses for waste worker should be established. Because the provincial government would like to expand composting to other areas in Hainan, they requested a detailed information package or course which could be used to train waste workers in other municipalities, if the provincial government expands composting to other areas. Information gathered through participant observation methods revealed that the training program should consider the accessibility of the information as well as language considerations.

⁶⁰ Furthermore shrinkage and removal of non organics and non decomposed carbonous materials are significant but are not factored into the space requirements.

⁶¹ “A Manual for Composting in Hotels” was translated roughly and given to the Hainan department of environment and resources. This may not be sufficient and more precise guidance and training may be required.

5.5.1 There is a demand to explain basic concepts and how they apply to composting

Basic concepts underlying composting were found to be lacking and there should be some assessment methods to ensure that the basic concepts are understood. The concepts include: what is organic; carbon to nitrogen ratio; the composting process; why water needs to be added; when to turn the pile and why.

Questions that I was asked by waste workers and provincial representatives which indicate that there is a lack of understanding of how to apply these issues in composting: include “can cigarette packages be composted?”, “exactly how much rice husks do we need to add next time?”, “do we add water to the compost in order to lower the temperature?”, “exactly how many times do we turn the compost”.

5.5.2 There is a need to establish best practices

There is a need to establish best practices. The author was repeatedly asked to provide a "recipe" for the composting procedure, which detailed precise knowledge about how much rice husks to add, how much water to add and how many times to turn the compost. While the author attempted to convey the idea of adaptability, flexibility and the importance of the concepts and how they interact with each other the Chinese counterparts insisted on knowing the precise details. Thus it is important to convey how the ideas interact with each other for instance regarding turning: the number of times that the compost must be turned depends on the temperature, but it should be turned a minimum of 5 times at a temperature over 55°C in order to ensure the elimination of pathogens. Some kind of flexible guidelines were repeatedly requested in order to allow for the smooth adaptation of composting as part of a MSWM strategy in Baisha as well as in other municipalities.

5.5.3 Language consideration

Several key informants (106, 119, 122) indicated that waste workers may not have the same level of proficiency in Mandarin as government workers. Formal waste worker often speak other first languages such as *Hainan hua* (the local Hainan language) or *Li hua* (the *Li* language) and often lack competent proficiency of Mandarin. These language considerations are significant for training purposes.

5.5.4 China-specific demands

Due to a lack of knowledge about composting, initial surprise was expressed by market vendors, waste workers and government officials alike that waste can be turned into compost, when asked if composting is used in China (key informants 121, 111, 2, 8, 9, 12, 13, 54). When information from other countries is presented, there appears to be a common feeling that such information might lack relevance for the Chinese context. The government officials and waste workers often insist on hearing if this method is employed in China. Thus, training materials should discuss Chinese cases and draw upon the Chinese experience. This can be done by discussing pilot projects such as this one. Alternatively using traditional knowledge in a functional way by referring to ancient Chinese composting practices or “*ou fei*” currently practiced in the country side may have some resonance with the public and government officials.

5.6 Place-specific issues

Place-specific issues that are significant include, the unique characteristics of central planning, community response management, weather, and unique potential markets.

5.6.1 Central planning and market integration

If composting is integrated into the MSWM system in Hainan, it is important to consider the unique characteristics of working within China. Within the Chinese context, two factors are of critical importance: the political system and the move from a centrally planned economic system to a more *laissez faire* economic system. Central planning continues to play a significant role in providing public services such as waste management at the municipal level. Currently, the Sanitation Bureau at the township level in Baisha is operated by the local government and is heavily subsidised by the local and national government. Key informant interviews (key informant 106) reveal that tipping fees only cover 20% of the local cost of the current waste management system. Thus the local government must play an active leadership role in implementing composting if it is to be implemented. After the 1978 open door policy was adopted in China, there has been a steady increase in *laissez faire* economics and privatization of public service which has been extending towards privatizing waste management service providers. While the township level is still publicly run, currently there are two private companies which provide waste management services in Hainan province, they operate in close cooperation with the government and receive government subsidies (field notes 2006).

5.6.2 Unique potential markets

According to the literature one of the major reasons for the failure to integrate composting as part of MSW is the lack of attention paid to marketing of the final product (Hoornweg et al. 1999, World Bank 2005, Zurbrugg 2002). Thus, identifying unique market potential is important to ensure success. China has great domestic market potential for compost due to the fact that 60% of China's population is agrarian (Shen 1998). Hainan province particularly has a thriving rubber tree industry, this also provides a unique market potential (key informant 107, 108). This is significant because rubber trees could be a potential market for lower quality compost. Lower quality compost can be used on rubber tree land, rather than agricultural land because rubber trees are not ingested by humans thus there is

not the same level of concern about the impact of heavy metals of human ingestion. Interviews with farmers in the villages reveal that 91% (11/12) of farmers currently purchase fertilizer and spend between 200- 2000 RMB (\$27.00- \$270.00 CAN) per year. If compost can be promoted to take part of this market share there is a significant marketing potential.

5.6.3 Not in my back yard: NIMBY

Community response management is an important factor in promoting source separation of waste and responding to *not in my backyard* (NIMBY) movements which often result from the siting of waste management facilities (Petts 1995). The results indicated that many of the people would be willing to separate their waste if the government asked them to (92% of market vendors, 100% of residents, 85% of commercial residents). If source separation is to be successful the government must take the initiative to promote source separation.

In regards to NIMBY community response management is important. Concerns were expressed by residents in Baisha about siting the facility. Residents of Baisha expressed concern about government land expropriation as well as about the environmental impact of siting the composting facilities in proximity to residential areas (Ichim field notes 2006). Three major concerns related to water pollution, air pollution and odour (ibid).

5.6.4 Climatic concerns

Climatic concerns such as temperature, precipitation patterns and monsoons can potentially affect composting implementation. Hainan is a tropical province with an annual temperature range between 18°C – 29°C (Li et al 2006). This temperature is conducive to composting as it provides a warm environment which aids the decomposition of organic matter although Baisha is slightly cooler and less humid than the rest of Hainan because it is located in the mountains.

Total precipitation and the distribution of the precipitation are also important to consider when constructing the composting facility. The figure below shows the average annual precipitation for Baisha and for Hainan Province (Figure 5.3). As indicated below Baisha receives an above average amount of precipitation. As seen in this figure, during the highest period of monthly precipitation Baisha receives from 225 mm to 350 mm during August to October (Li et al. 2007). The average yearly precipitation for Baisha, is 1706.5mm (ibid).

This high amount of precipitation has implications for composting. One of the positive aspects of the large amount of rainfall is that additional water may not be required during the months with heavy rainfall. One negative aspect is that there may be a need for more shelter for the compost windrows during the months with heavy rainfall.

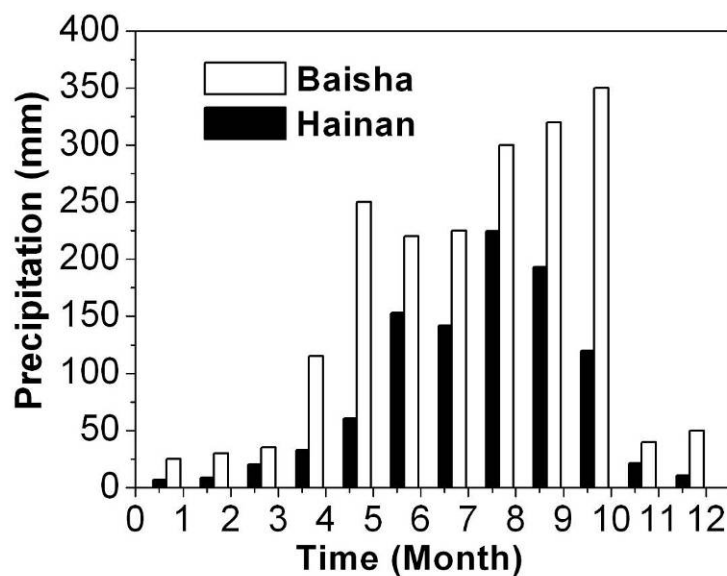


Figure 5.3: Precipitation in Hainan, Baisha in the Hainan context

Figure adapted from Wang et al. 2006 and Li et al. 2007

The monsoon is another significant climatic variable which may impact implementation of composting. During the authors' time in Hainan there was one monsoon scare during the implementation of the composting pilot project. The local government officials warned us that impending rainfall may wash away the composting pile or that high winds may move parts of the pile away. In response to this, we purchased a large plastic tarp and covered it with rocks so that it could not be blown away (Photo 5.12). The compost pile was not blown away, however the roof of the bamboo structure overhead broke and we had to arrange for it to be fixed. Thus, the monsoonal weather should be considered when building and planning for the composting facility.

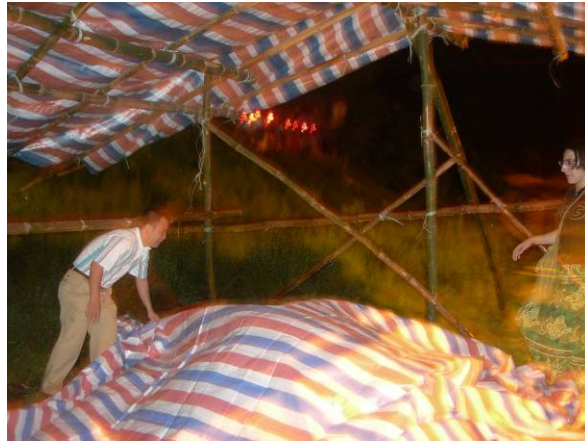


Photo 5.12: Covering compost to protect it from the monsoon

Chapter 6

Discussion: impacts, barriers, and potential

This chapter examines the impact, barriers, and the potential for integration of composting as a part of a MSWM strategy in Baisha, Hainan. The impacts are categorized as positive, negative and new aspects. Potential barriers are identified and possible ways of responding to them are proposed. Finally, the potential of implementing composting at the market level, and residential and commercial level will be discussed.

6.1 Positive impacts:

The positive impacts of adopting composting as part of a MSWM strategy in Baisha include creation of a new resource, job opportunities, less atmospheric methane, and enhancement of other waste management options.

Integrating composting as part of a MSWM strategy enables the creation of compost, which is a renewable resource, as well as the generation of employment. This resource has many practical applications if marketed as soil conditioner or mixed with fertilizer and marketed as semi- organic fertilizer. Semi-skilled job opportunities will also be created. Using the current labour-intensive method almost 20 full time permanent (19.5) semi- skilled positions will be required to turn Baisha's market waste and the residential and commercial waste into compost⁶².

If source separation is integrated into the waste management system then there could be positive effects in terms of increased environmental awareness of citizens. Requesting citizens to separate their waste may cause the citizens to actively engage in environmental stewardship thus making

⁶² This number is based on the usage of un separated, market waste. If source separation is applied less workers will be required to separate the waste, however depending on the type of source separation that is employed, waste collectors may be required to do some separation on site thus more workers may be required.

citizens aware of waste as part of their daily lives. This source separation also provides an opportunity for the government to promote other waste reduction initiatives as well.

Adopting composting will enhance other waste management options. Less organics in the waste stream will make resource recovery of other recyclables more efficient. The reduction of organics in dumps/landfills reduces the number of disease vectors attracted to the dump/landfill, since these vectors are usually attracted to organics. In addition, the reduction of organics in landfills⁶³ will result in greater physical stability of the landfill since there will be less shrinkage of organics (Fadel *et al*).

Using composting as a method of handling organic waste will reduce the amount of atmospheric methane. Decomposition of organic matter in landfills releases methane gas, however, when organic waste is processed by composting it releases carbon dioxide instead. Carbon dioxide is considered neutral because plants consume carbon dioxide as a part of respiration. Therefore, if waste is composted it reduces the amount of methane that is released into the atmosphere when it becomes a significant source of anthropogenic green house gas (World Bank 2005).

6.2 Negative impacts

Potential negative impacts include increased cost, more work for waste workers, as well as changes to the current uses of organics.

There will likely be an increase in the operation cost in the waste management sector as well as a potential increase in the workload of waste collectors. While the precise increase in operational cost is difficult to assess, the fact that almost 20 more workers will be required indicates that there will be an increase in operational costs of waste management. This increase in cost could potentially be offset by revenues generated through the sale of compost. In addition to the 20 workers that will be required for composting of the waste, there may be an increased workload on the waste workers due to

improper source separation. However, it should be noted that if source separation occurs at the collection phase fewer workers will be required for the sorting phase.

The integration of composting will likely have effects on the preferred uses of organics. If vendors are required to separate their waste those who produce large quantities of organic waste may be inclined to sell their organics rather than contribute them to composting. In addition, the formal usage of organics may negatively influence the informal actors who collect organics. Alternatively, it might make it more lucrative for the informal actors to collect organics.

6.3 New aspects than need to be considered:

Two new aspects that need to be considered are that new infrastructure may need to be adopted and that a market will need to be developed for compost. If source separation is to be applied, new infrastructure will be required in order to make source separation feasible. The new infrastructure may include segregated collection vehicles and segregated waste bins.

Markets for compost will need to be developed. Attention should be paid to identifying and implementing a suitable method to integrating the sale of compost into the private sector. Market integration may occur in several ways, for instance the Sanitation Bureau may take full responsibility for marketing the product. Alternatively, the Sanitation Bureau may cooperate with private fertilizer companies to produce the compost and sell it as an organic soil conditioner or as a compost/ fertilizer combination.

6.4 Potential barriers

Some potential barriers have been identified through participant observation, key informant interviews different actors and stakeholders, as well as through the application of the composting pilot

⁶³ Currently Baisha Township is planning on building a landfill.

project. Some potential barriers which may arise and suggestions regarding how to overcome them are discussed below. The potential barriers are divided into two types, potential *process* barriers and potential *human* barriers.

6.4.1 Potential process barriers

6.4.1.1 Insufficient carbonous material in feedstock to maintain a proper carbon to nitrogen ratio

Rapid visual assessment of the composition of the organics in the market waste and the commercial and residential waste indicate that the waste has high nitrogen content. The ideal carbon: nitrogen ratio is three to one, whereas the waste stream (market, commercial and residential) has a carbon content that is significantly below this threshold. While it is difficult to determine the exact carbon to nitrogen ratio, it is likely that extra carbon will be needed.

Initially, extra carbon may need to be purchased. However after several composting batches are conducted it is expected that carbon from previous composting piles could be reused. The pilot composting project resulted in a significant amount of residual carbonous material 0.76m^3 out of 2.71m^3 ⁶⁴. This means that residual carbonous materials will be produced and can be reused in future compost piles.

6.4.1.2 Extra water is needed for the process

It should be noted that the composting pile will not retain moisture on its own and will require extra water. This potential barrier can be solved by uncovering piles during the rainy season, collecting rainwater or having a water source near by.

⁶⁴ It should be noted that future composting piles may not produce such a large amount of carbonous material. This is due to the fact that we did not chop large pieces of carbonous material in the composting process which was employed in the pilot case, this was because we did not have a grinder available.

6.4.1.3 Space and labour intensive

According to the time and space requirements that were derived from the pilot project, a significant amount of space⁶⁵ will be needed as well as a large number of workers⁶⁶ required⁶⁷. The space requirement and labour requirement may act as a barrier in implementing composting.

The current time and space requirements should be considered as a starting point until the system can be optimized. The fact that it was the first time that the process was carried out enables us to identify areas in which this practical experiment can be improved. If some process, technological and human changes are made, time and space requirements could be minimized.

According to the data presented in the pilot case the sorting process took 9 hours for a pile of 2.71m³ volume, this is 27% of the total time required. It is worth mentioning that these statistics are derived from workers who were presented with the task of sorting waste for the first time and, it is likely that workers will become more efficient and less time will be required with specialization. Furthermore, waste was collected from the market without any source separation being implemented. If some source separation were to be implemented then the waste sorting process will require less time.

Improved technology can minimize time and space requirements. The time required to sort waste could be minimized if an elevated platform with a rotating band that moves waste is used to separate waste as it is delivered. At the market level this may not be necessary but if residential and commercial waste is also composted this could be a worthwhile investment. Currently, turning the

⁶⁵ If the compost pile is 1.5m high x 2 meters wide the total space required is 76.3m² for the active phase of the market waste, 530.14 m² for the active phase of the commercial and residential waste. If the curing pile is 2 meters high a total amount of 9.68 m² will be required to cure one months worth of market compost, 511.16m² will be required to cure one months worth of market compost.

⁶⁶ If workers work eight hours per day seven days per week, 2.5 workers are required for the market waste, 17 workers are required for the residential and commercial waste. Thus a total of 19.5 workers are required.

⁶⁷ Precise amount of time and space required depends on the operational choices.

composting pile requires 54% of the total time required (18 hours), using pitchforks and shovels. The time required could be reduced if better shovels were used to turn the piles.

The required curing space could be reduced if larger curing piles were constructed. While the active phase of composting must operate within certain parameters in order to make turning feasible, the curing phase has more flexible parameters. Once the curing piles are established they do not need to be turned, and their size could be increased. The current space requirement is 9.68m² for the market waste and 511.16m² for the residential and commercial waste. The reason for this large spatial requirement is due to the height constraint of 2m. This height constraint is a practical physical constraint because it is unlikely that workers could construct a pile which is higher than 2m. These physical constraints could be overcome if an excavator was used, to pile the compost higher

6.4.1.4 Precipitation and typhoon

Large amounts of precipitation and typhoon weather patterns may serve as a potential barrier to the successful implementation of composting, since typhoons may cause flooding and increased winds might scatter the compost. This barrier could be overcome by considering the weather patterns and building in response to those patterns. Also, tarps could be used to cover the compost when a typhoon is anticipated.

6.4.2 Potential human barriers

6.4.2.1 Not in my back yard (NIMBY)

There was some indication of NIMBY type opposition to constructing a permanent waste composting facility in some areas of Baisha Township. Thus, there may potentially be some citizen concern regarding the establishment of a composting facility in Baisha. These concerns could potentially be addressed through consultation with the community and by conducting an environment impact

assessment (EIA)⁶⁸ that would lend credibility when addressing citizens' concerns. The citizens were concerned that waste would cause odour, as well as air and water pollution. The hesitation in accepting composting as part of a MSWM plan is understandable given that the current status of knowledge about composting is very low (69% of market vendors, 60% of commercial vendors, 66% of residents do not know what composting is). Field observation revealed that citizens argued that no EIA was conducted, thus they could not know the potential impacts of the composting facility on the environment.

Due to the potential opposition, precautions might be taken in order to facilitate public acceptance of composting. Some suggestions that may facilitate community acceptance are as follows:

- The local government in cooperation with the provincial Department of Land, Environment and Resources should carry out Environment Impact Assessment regardless of whether or not the law requires it. This will help to ensure there are no significant environmental impacts and will build credibility in the eyes of the community.
- The local government in cooperation with the provincial Department of Land, Environment and Resources, should hold community forums, open to the public, where composting can be explained and where citizens can voice their opinions and concerns.
- The Canadian partners should help the local government to explain what composting is and the benefits that composting brings to the community, the waste management system and the atmosphere. Involving the Canadians in this will build credibility as the Canadians are viewed as “foreign experts”.

⁶⁸ Hainan province requires Environment Impact Assessments to be carried in certain cases.

- The local people should form sub-committees within the current political establishment to work with the Sanitation Bureau and discuss public concerns and solutions to those concerns.
- Samples of the compost can be given out to the citizens of Baisha Township.
- The pilot project that was completed can be used as a proof of the principle that composting has no major negative consequences to the community.

6.4.2.2 Source separation

Due to the diverse composition of waste, composting will require separation of organic from non-organic waste. The composting pilot project indicates that conducting at-site separation of mixed waste is time consuming and if carried out at a municipal level would be labour intensive. Furthermore, some of the contaminants present in the waste⁶⁹ are not conducive to the production of high quality compost. Thus, in order to ensure that quality compost is produced some degree of source separation is required.

Much literature on the implementation of source separation in developing countries indicates that this is a major challenge, however due to the unique characteristics of China's political structure the implementation of source separation may be feasible. It is important to recognize the unique feature of Chinese history, in contrast to many developing countries; China has a history of central planning which means that regulatory policy in China carries with it a degree of legitimacy and demands compliance. Thus, the potential barrier of not acquiring source separation can be overcome in Baisha by working with the local and provincial government to decree regulations that promote source separation. These regulations can take the form of provincial policy that is backed up by local by-laws. Alternatively, these regulations can be established through the initiative of the Sanitation

⁶⁹ Razors, batteries, medicine, glass, pig vaccines

Bureau in cooperation with the local government and/or with the local business regulation committee. Local government officials (key informants 108, 110) suggested that one method to establish source separation is by working with the local business regulation committees to persuade the market vendors and the commercial vendors to separate waste. Given that the local business regulation committee establishes the rules of operation for businesses in Baisha, if they decree that waste must be separated than businesses are likely to comply. At the market level, enforcement of source separation must consider working with The Qing Zhuang Company that currently owns and operates the market. The fact that the market is owned by one company may either work to the advantage or disadvantage of source separation.

If regulations are established by the local or provincial government then the outlook for source separation appears promising. The self reported attitudes of waste producers seem to be that there is a willingness to separate waste. Most market vendors (92%), commercial vendors (85%) and residents (100%)⁷⁰ interviewed stated that they would be willing to separate their waste.

6.4.2.3 Markets for end use product and market integration

The literature revealed that often attempts to integrate composting as part of MSWM systems fail because insufficient attention is paid to the markets for the end-product (Hoornweg et al 1999, World Bank 2005, Zurbrugg 2002). While the theoretical demand for compost is immense, the pragmatic question of how compost will be integrated into the market system must be addressed. Questions such as who (Sanitation Bureau, private sector, or some other actor) will be responsible for marketing the final product, and how the product will be integrated in the market system should be addressed from the onset.

⁷⁰ It should be recognized that the populations samples were not random samples thus it may be difficult to generalize based on these samples.

6.4.2.4 Lack of awareness about composting

Currently, the degree of awareness regarding composting seems to be low. This lack of knowledge is a barrier because it prevents people from understanding the benefits of composting. Tangibly, it may translate into apathy towards source separation. Less than 40% of waste producers interviewed know what composting is: 69% of the market sellers interviewed, 60% of commercial vendors interviewed, 66% of residents interviewed have not heard of composting. It is important to raise the profile of composting so as to promote a general understanding of the significance of proper waste disposal. It is also likely that knowledge of composting may make citizens more inclined to separate their waste.

6.4.2.5 Finances

Since adopting composting as part of a MSWM strategy requires increased expenditure it is important to consider which sources of financing are available. According to the local sanitation bureau tipping fees only cover about 20% of the total cost of the current waste management system. Since the current waste management system is heavily subsidized by the government, it is not unreasonable to request the government to subsidize composting as part of the waste management system.

Another option would be to increase waste disposal fees. This could be done at the market level by simply charging Qing Zhuang Company more money. However, since the waste disposal fees currently provide for only 20% of the cost it is unlikely that increasing waste disposal fees will be sufficient to cover the cost of composting. Currently, few residents pay waste disposal fees (22%, n=2/9)⁷¹. Of the residents interviewed those who pay waste disposal fees feel that the waste disposal fees are too high and would not be willing to pay more. Of the commercial vendors interviewed 84% feel that the current waste disposal fees are not too high. However, 83% of the vendors interviewed

⁷¹ This is based on a non representative interview sample corroborated by interviews with government officials in the Sanitation Bureau.

are against increasing the waste fees. The remaining 16% stated that they would not be against increases in waste fees if improvements were made to the current waste management system⁷².

One reason to increase waste fees may be to raise awareness and promote responsibility among citizens in order to pursue them to be more vigilant in source separation. If source separation and increased fees are implemented together than it may promote greater responsibility with regards to source separation. Since composting may be promoted as a service being provided to the whole community.

Other possible sources of financing include international funding, through “carbon financing”. Carbon financing is provided by the Clean Development Mechanism established by the Kyoto protocol to programs that aim to reduce greenhouse gases. The unregulated decomposition of organic waste in landfills leads to the release of methane into the atmosphere. Methane is a greenhouse gas 21 fold more potent at warming the atmosphere than carbon dioxide. Currently the Clean Development Mechanism provides funding for programs that aim to reduce the amount of greenhouse gases released into the atmosphere. In addition through this Clean Development Mechanism developing countries can sell carbon credits to developed countries. The World Bank estimates that the MSW sector in Chinese cities could produce an estimated \$1 Billion USD per year through the prevention of carbon emissions (World Bank, 2005).

Financing is a major concern of local government officials who have been interviewed. This is a legitimate concern as composting will increase the operation costs of the waste management system. Diversification of financial sources should be pursued. National and provincial governmental funding will most likely be required. While there may be some opposition to increasing waste fees, if this is

⁷² It should be recognized that a non random sample of commercial vendors were interviewed thus one must be reluctant to make generalization to the whole population.

implemented in combination with a request to source separate people may be inclined to take more responsibility for source separation. Finally, carbon financing possibilities should be pursued.

6.4.3 Potential: based on positive aspects, negative aspects and barriers is there a potential for composting?

The case study in Baisha revealed that applying composting as part of an integrated waste management strategy in Baisha, while promising may have some negative unforeseen impacts. There is a need to consider human, technological and place specific factors in an integrated way. It should be noted that the implementation of composting of all organic waste could have unintended consequences on the current use of organic waste: for instance those restaurants that sell organic waste to pig farmers and those organic waste collectors.

Overall there are some positive indicators that applying composting in as part of an integrated waste management strategy in Baisha Township at the market level and the residential and commercial level will be successful. These indicators include the fact that currently there is a fully functioning waste collection system and with waste collection fees in place there is a concern about waste and a willingness to separate waste, the MSW in Baisha meets most of China's heavy metal standards. While market waste is an ideal place to start, the government's ambition to expand composting to the commercial and residential waste must be considered when proposing appropriate composting methods. Composting in villages should be encouraged at the household level due to the current usage pattern of organic waste. Finally, traditional Chinese composting documented at the village level (*ou fei*) can be used to promote composting of MSW (*dui fei*).

Currently the market and the commercial and residential areas have a fully functioning waste collection system, which means that some of the necessary structure is already in place to enable the

collection of organics. The current waste management system collects waste often⁷³ and thoroughly⁷⁴. Furthermore, a waste disposal fee collection system is also already in place which means that if fees are raised then a new system does not need to be established. While some new infrastructure may be required for source separation the current system is a good starting point for expansion.

A significant number of market vendors and commercial and residential waste producers indicate that they are concerned about their waste. This is a positive indicator for the feasibility of implementing composting as a means of MSWM. Currently 69% of market vendors, 95% of commercial vendors and 88% of residents expressed concern about their waste. Some interviewees felt that they lack a choice regarding alternative methods of disposal to dumping and burning waste. Thus, it would be reasonable to assume that if an alternate method of waste management was provided many people would be supportive and cooperative.

The fact that most people stated that they would be willing to separate their waste if the government requested them to indicate that source separation has potential at the market level, as well as at the commercial and residential level. Most waste producers, 92% of market vendors, 85% of commercial vendors, and 100% of residents interviewed stated that if the government asked them to separate their waste they would be willing to do so. This willingness to separate waste indicates that the potential for source separation is positive.

The current level of most heavy metals in Baisha's MSW is below China's National Standards for most heavy metals; if source separation of waste is applied the heavy metal concentration will most likely be even lower. Currently, Baisha's MSW falls below the Chinese National Standards for Arsenic, Mercury and Chromium. Baisha exceeds China's National Standard for Lead (standard

⁷³ three times per day for the market and twice per day for the residential and commercial waste

⁷⁴ In the market, all of the waste is removed and in Baisha Township all of the waste is removed in most residential and commercial areas.

100mg/kg, Baisha MSW 108mg/kg) and Cadmium (standard 3mg/kg Baisha MSW 4.93 mg/ kg). The concentrations of heavy metals in this MSW fall into an acceptable heavy metal range according to: European standards, Canadian (Ontario) standards and The United States' standards. Nevertheless if waste is separated and attention is paid to the type of waste that is composted then the concentration of Lead and Cadmium will likely decrease.

The current pilot project used market waste. Market waste was selected since market waste constitutes 12% of the total MSW. However, the fact that the government plans to expand composting beyond the market level must be considered when determining the potential of adopting composting as part of a MSWM strategy. Beginning with market waste is a good first step towards establishing a program that will compost residential and commercial waste. However to maximize the potential of residential and commercial waste composting system optimization should be considered.

Due to the current waste flow of organic waste, at the village level, household or neighbourhood level composting may be the most promising option of composting. Currently much of the organic waste produced at the village level is reused, as there is a demand within the agricultural system for the organic waste produced. A combination of three methods are currently employed to dispose of organics, 72% of people feed organics to animals, 44% of people dispose of some organics in biogas reactors and 27% practice traditional Chinese composting "*ou fei*". Given this current situation, and the governments push in promoting biogas reactors, perhaps there is some potential for composting at the household level. However, key informant interviews reveal that some people have ceased to practice traditional composting because it is viewed as time and labour intensive and chemical fertilizers are viewed as reasonably priced and effective alternatives.

The fact that historically Chinese farmers employed composting as a method of organic waste management can be used in to promote source separation and awareness about composting. While the

current level of knowledge regarding composting is quite low in Baisha Township, China has many historical examples of composting, as well as contemporary examples of composting being applied in China. Thus the government can take advantage of this traditional knowledge in promoting composting as a historical Chinese practice. This will enable people to relate to the current composting practices within their own historical backdrop.

Chapter 7

Recommendations and conclusion

This chapter begins by presenting several recommendations on how to implement composting and how to improve the overall waste management system in Baisha, Hainan. It rates these suggestions in terms of primary and secondary importance. An overview of the contribution that this research has made is discussed. Waste Management in Baisha is compared to other developing countries. Suggestions for future research are provided. Finally the concluding comments summarises the seven necessary factors for the successful implementation of composting in Baisha Hainan.

7.1 Recommendations on how to implement composting

7.1.1 Scale

The scale of composting should be established and decisions should be based upon the ultimate goals of the local and provincial government. The scale of composting has implication on the construction of the composting facility, and potentially on the type of composting process and technology required. Thus, the scale of composting (the type of waste source: market or market and residential and commercial) at the next phase should be agreed upon from the beginning by the local government, the provincial government and the Canadian actors (primary).

7.1.2 Source separation

If source separation is to be pursued then source separation should initially occur at all levels, also regulation should be enacted, and awareness of composting should be increased and specific populations should be targeted. If source separation is to be pursued than waste separation should occur at all levels: producers, collector, composting facility, as well as throughout the composting process (primary). This is due to the high plastic content and to ensure that organics are separated

from other waste. In order for source separation to be effective the local government should enact regulation to promote source separation, awareness of composting should be increased and specific populations should be targeted. Currently, overall awareness about composting is low in the population samples interviewed. As suggested in the discussion, source separation should be viewed as an opportunity to increase awareness about waste issues generally and composting specifically. In order to increase the effectiveness of source separation targeting specific producers of waste should be considered-- for instance, targeting those who produce organic waste such as vegetable vendors in the market.

7.1.3 Best practices

Best practices for the composting method should be established. Standards for several indicators in the composting process⁷⁵ should be established by the Hainan Department of Land Environment and Resources in cooperation with the Canadian actors (primary). Establishing standards will allow the provincial government to replicate the composting method in other townships. The windrow type of composting can be employed initially and later switched to an optimized system if space and labour requirements act as limiting constraints (secondary).

7.1.4 Technological improvements

Adopting a minimal amount of technology could aid in reducing the amount of space required for composting and can help in the separation of organic from non-organic waste. To save space, curing piles can be constructed higher than 2 meters but some kind of technology, such as an excavator, would have to be employed to make this feasible (secondary). In order to improve the separation of waste at the composting facility an elevated platform with a conveyor band can be employed (secondary).

7.1.5 Ensuring quality compost

Precautions can be taken to attempt to ensure the quality of compost. Heavy metal testing facilities should be made available in Hainan province⁷⁶ (secondary). Even though heavy metal content in MSW in Baisha is reasonably low, if other municipalities adopt composting then each municipality should have heavy metal tests conducted (secondary). Waste producers should be aware of waste that could compromise the quality of the compost. Examples of such waste include batteries, needles, glass, and medicine. To deal with this problem alternative disposal options should be provided (primary).

7.1.6 Hainan specific characteristics

Characteristics specific to Hainan should be considered when applying composting. When building the compost facility climatic considerations and the monsoonal season in Hainan province should be considered (primary). It might also be possible to take advantage of place specific comparative advantage in marketing composting, such as Hainan's forestry agricultural specialization (secondary).

7.2 Recommendation for improving the overall waste management system

7.2.1 Reducing environmental and human hazards

The method of final disposal of waste should be improved and special attention should be paid to household hazards and veterinary waste. Currently, the method of final disposal of waste poses hazards to humans and the environment. Thus, improvements in the final method of disposal are recommended (primary). Currently, the local government is working to establish an engineered landfill before 2010. Awareness of household hazardous waste should be raised in Baisha and safer

⁷⁵ Indicators potentially include: Time, Temperature, Turning, Carbon to Nitrogen and Maturity.

⁷⁶ Currently the Hainan department of land resource and environmental protection does not have in house capacity and sends samples to Qiong Qing University in mainland China.

methods of disposing of that waste should be promoted. Furthermore, veterinary waste should not be disposed of in the same manner as other MSW (primary).

7.2.2 Waste reuse and clean production

The government should promote better “white waste” management, encourage reuse, and promote cleaner production. Currently, there is a high content of “white waste.” This waste can be diverted from dumping or landfilling by reducing it or promoting better recycling habits and producer responsibility and stewardship (secondary). One method of promoting better “white waste” habits is to take advantage of symbiotic activity. Currently, market level symbiosis occurs in which waste is actively reused. Thus, market level symbiosis should be encouraged in order to promote reuse of waste that has value to other vendors. Examples of such waste are cardboard, and heavy duty plastic bags. Cleaner production should be promoted by the government; this would enable the reduction of unnecessary wrapping and packaging. Cleaner production can also potentially reduce the level of heavy metal content in the waste (secondary).

7.2.3 Increasing efficiency of the current waste management system

Increasing efficiency of the current waste management system can be achieved by increasing the size of waste bins and reducing the frequency of collection to either once a day or once every two days. This should be accompanied by greater storage capacity of waste at the firm level and individuals should be encouraged to dispose of waste in waste bins and not on the street. Even though most people interviewed opposed a reduction in collection, a reduction in collection to daily or every two days will not likely result in the release of foul odours or have negative sanitary impacts. Moreover, most people interviewed dispose of waste once a day anyway, so if people were encouraged to dispose of their waste at one specific time, this would decrease negative reactions. Collection of waste

every two days may be sufficient to compensate for the climatic factors. Furthermore having less collection will make people more conscientious of waste disposal (secondary).

7.2.4 Improving occupational conditions for informal waste workers

Occupational conditions of waste workers should be improved. The informal waste recovery sector makes an important contribution to the waste management system, thus, their services should be valued by the government. The informal sector should be encouraged to continue its role, while government should attempt to provide occupational assistance by providing masks and gloves, and establishing social assistance (primary).

7.3 Contribution of this study

This study made empirical, practical and applied, as well as methodological contributions. Empirically, this is the first pilot composting project in Hainan province. Practically, this pilot project will be used as a model for the next phase of composting in Baisha Township. Another practical contribution that this research made was knowledge transfer. Finally, methodologically, a new form of action research where there was cooperation between the government, international actors and universities was employed.

This project contributes to the current state of research by documenting several unique features of waste management in China. These features include: that knowledge about composting was lost as people moved from rural to urban dwellings; that practical examples of loop closing through symbiotic activities occur at the market level; that the waste management system in Baisha is comparable to the waste management systems in other developing countries. Furthermore, the high organic content in the waste of developing countries was confirmed and a high nitrogenous content was also observed in Baisha's waste. Finally, this project was able to provide insight into unique marketing potentials for compost in Hainan.

The results indicate that knowledge about composting may have been lost as people moved from the countryside to the city⁷⁷. In rural areas 25% of people interviewed stated that they practiced “*ou fei*,” traditional Chinese composting and 58% stated that their parents and grandparents practiced “*ou fei*”. Thus, a type of composting is currently being practiced in rural areas and many people are familiar with this type of composting since 58% of people remember their parents and grandparents practicing waste composting. In urban areas over 60% of the people have not heard of waste composting (60% of commercial vendors, 66% of residents, and 69% of markets sellers). Thus, it appears that as some people migrated from rural areas to urban areas knowledge about composting was lost.

Practical examples of loop closing and symbiotic activity in the market place were documented. Thus, practical examples of the waste to resource continuum were identified. As an object lost value to one vendor if it had the potential of being valuable to another vendor it was sold or given to that other vendor. Thus, value was reassigned to objects that would have been waste -- which *de facto* made some waste into a resource.

This project entailed documenting the waste management system in Baisha, by documenting this waste management system it can be compared to waste management systems in other developing countries. Thus, Baisha’s waste management system can be compared and contrasted to waste management systems in other parts of China and other developing countries. While Baisha has substantial problems with the final disposal of waste, other aspects of the waste management system are ideal for a developing country, such as collections that occur throughout the urban area.

⁷⁷ Notwithstanding the fact that the survey was conducted on a small non random sample of the population this finding is significant, yet in order to confirm these preliminary results bigger samples and a random selection is required.

This research confirmed previous observations that developing countries have high organic content in their waste. Baisha's residential and commercial waste had approximately 50% organic content. This corroborates previous reports in the literature (World Bank 2005, Hoornweg 1999, Hui 1999).

A unique observation was the high nitrogen content in the market waste and in the commercial and residential waste. The method of handling this problem is also a unique contribution. Initial supplementary carbonous material may be purchased or obtained from outside of the waste stream, the fact that about 0.70m³ of carbonous material had remained indicates that if carbon content is managed appropriately then residual carbon can be reused. Thus, while initially it may be necessary to purchase carbonous material, after some time residual carbon may be sufficient to achieve a proper carbon to nitrogen ratio.

The literature suggests that one of the biggest problems for implementing composting is a lack of attention to markets for the final product (Hoornweg et al 1999, World Bank 2005, Zurbrugg 2002). This study suggests some ways to overcome these marketing challenges. Specifically by marketing it to the forestry industry in Hainan and by combining compost with fertilizer and marketing it as more efficient fertilizer.

It is empirically significant that this is the first "appropriate- technology" composting pilot case in Hainan, China. While there was another composting facility established in Sanya that receives much criticism, this is the first township-scale pilot project in Hainan province using labor intensive windrow composting. According to government officials, this pilot project is intended to serve as a model for other facilities that will be constructed in accordance with the province's plans for implementing composting throughout the province.

This work is of practical and applied significance since the pilot project and the composting site that will be constructed in the next phase will serve as a model for Baisha's composting facility as well as

for other facilities in Hainan. The implementation of this pilot project provides data that can be used to inform the next step. This data includes: information about the current waste management system, information about the human dimension of implementing composting, as well as process information. Knowledge transfer about composting occurred in several ways. Practical process knowledge was transferred to the waste workers as well as the student intern⁷⁸ through our daily work. By communicating with the provincial officials, and providing a lecture about composting and briefing of our pilot project to the Hainan Department of Resource and Land some theoretical as well as practical knowledge was transferred.

The action research method is unique since it took place in China and involved direct cooperation within the government structure. The institutional structure of this pilot project is unique because the institutions involved have the ability to institutionalize and implement composting as part of the MSWM strategy. The institutional structure involved the cooperation of local government agencies, provincial levels of government, academic institutions and international funding⁷⁹. This institutional structure provides a unique opportunity in terms of integrating the concerns of the government into the research objectives. Moreover, this structure of action research provides direct access to decision makers thus enabling the concerns to be recognized by those who will implement composting.

7.4 Baisha in Context of Developing Countries

When examining the waste management system in Baisha in the context, of waste management systems in other developing countries similar and differences can be observed. Table 7.1 compares

⁷⁸ A student intern from Qiong Qing was employed by the Hainan Department of Resource and Land.

⁷⁹ Local government agencies involvement huan bao ju (environment protection bureau) which provided technical support, wei shen ju (sanitation bureau) which provided labour, and hou tu ju (land bureau) which will provide land for the permanent site. On the provincial level the hai nan sheng guo tu huan jing zi yuan ting (department of land, environment and resource of Hainan Province) was the Chinese agency responsible for initiating the pilot demonstration case, the University of Waterloo provided technical expertise and C.I.D.A provided funding.

and contrasts Baisha's waste management system in the context of the waste management systems in other developing countries.

Table 7.1: Waste Management in Baisha compared to developing countries

Culture and gender	Developing Countries	Baisha Hainan China
Attitude towards waste	<ul style="list-style-type: none"> • Lack of responsibility towards the production of waste • View waste as dirty • Apathetic towards waste management 	<ul style="list-style-type: none"> • There was a concern about waste, expressed by market vendors (69% of interviewees), commercial vendors (95% of interviewees), residential (88%). • Some key informants expressed apathy toward waste- "waste is none of my business". • Formal waste workers indicated that many people view waste as dirty
Gender and waste	<ul style="list-style-type: none"> • Women and men have different roles in the waste sector • Women are more prevalent in waste working • Men and women are subject to different impacts 	<ul style="list-style-type: none"> • Informal waste management sector is predominantly women • Data on formal waste management sector was not gathered

Waste planning and operations

Collection problems	<ul style="list-style-type: none"> • Inadequate waste collection due to insufficient funding, those who pay receive waste collection, those who do not pay do not receive waste collection • Inefficient waste collection, waste may be collected several times per days in some areas and not at all in other areas • Only 50-70% of waste generated is collected 	<ul style="list-style-type: none"> • Waste collection system is through • Waste collection is collected several times a day. • Villages lack waste collection systems.
Final disposal problems	<ul style="list-style-type: none"> • Adverse health and safety impacts • Adverse impact on essential infrastructure and water quality • Adverse impacts on air, soil, water, agriculture 	<ul style="list-style-type: none"> • Adverse health impacts on population surrounding landfill • Adverse impact on water quality • Adverse impacts on air, soil, water, agriculture
Technology problems	<ul style="list-style-type: none"> • Poor equipment 	<ul style="list-style-type: none"> • Poor equipment

	<ul style="list-style-type: none"> • Lack of training in solid waste management practices 	Lack of training in solid waste management practices
Financial problems	<ul style="list-style-type: none"> • Lack of financial resources • Higher relative cost in developing countries than developed countries, cost 20-50% of local government revenues 	<ul style="list-style-type: none"> • Revenues generated by collection fees account for 20% of total cost • Municipal government receives subsidies from national government • Finances are of concern to sanitation bureau

Institutional

Institutional framework	<ul style="list-style-type: none"> • Differences in institutional framework. Possible complications and problems, overlap of agencies responsible • Lack of discourse and cooperation between agencies responsible • Inadequate waste management policy and enforcement • Adequate waste management policy but lack of enforcement 	<ul style="list-style-type: none"> • There are separate environment bureau, sanitation bureau, and land and planning bureau. Cooperation was observed. • Waste management policy is being improved
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Occupational

Workers are exposed to a greater number of occupational hazards	<ul style="list-style-type: none"> • Protective measures are rarely implemented in developing countries • Increased risk of infectious diseases, allergic pulmonary and non allergic pulmonary diseases, chronic bronchitis, hepatitis, parasites, acute diarrhea, coronary diseases, injuries, accidents, musculoskeletal problems • Informal sector rarely wears protective clothing • Informal sector walks long distances with heavy carts • Informal sector heavy lifting • Informal sector Frequent repetitive movements • Exposure to chemical hazard: batteries (car and normal), oils and greases, insecticides and herbicides, solvents, paints, cleaning products, cosmetics, drugs and aerosol containers 	<ul style="list-style-type: none"> • Informal sector often do not wear protective clothing. • There were some complaints among informal workers about health concerns • Both informal and formal sector are exposed to chemical, biological, safety and psychosocial hazards. • Pregnant women and children were not noticed in the informal waste management sector
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	under pressure <ul style="list-style-type: none"> Exposed to biological hazards: bandages disposable diapers, toilet paper, sanitary napkins disposable needles or syringes and condoms Safety hazards Psychosocial hazards Informal population tends to have pregnant women and children 	
Labor intensive	<ul style="list-style-type: none"> Labor intensive Workers come into more direct contact with the waste 	<ul style="list-style-type: none"> Waste collection and sweeping is more labor intensive There is direct contact with waste

Economic and industrializing

Industrializing countries larger amount and more diversity of materials.		
More income; more waste	<ul style="list-style-type: none"> Income affects amount of waste generated 	
Type of waste, change in waste stream, high organic content	<ul style="list-style-type: none"> High organic content in developing countries 	<ul style="list-style-type: none"> Baisha has a high organic content
Informal sector, plays a critical role	<ul style="list-style-type: none"> High unemployment rate and large sums of uncollected waste which can translate into opportunity Growing global market for recyclables Handle large section of recyclable materials Informal sector can interfere with formal collection systems 	<ul style="list-style-type: none"> Informal sector conducts all the recycling activities Participant observation in Haikou reveals that there is a market for recyclables Informal sector does not interfere with formal collection systems
Resource recovery	<ul style="list-style-type: none"> Local industries often dependent of secondary processed materials Methods of resource recovery are inefficient and hazardous to occupational health Informal sector plays a key role 	<ul style="list-style-type: none"> Reuse of cardboard Some restaurants sell organic waste to pig farmers Method of resource recovery have not been examined

7.5 Future directions for research

The current study was an exploratory study and it enabled the identification of other issues that merit examination. Some future directions for this research are provided below:

- Best composting practices should be established for Hainan province. These practices should be based upon longer term work in Hainan province. They should be established with the input of local waste managers and local and provincial government officials. Specific areas of concern for the waste practitioners should be identified and current best practices should be suggested.
- Based on the best practices a more detailed training program that suits the needs of Hainan province should be developed. Two types of programs should be established one for provincial and local officials, the second for workers and implementers.
- Seasonal studies that examine changes in the composition of the waste stream throughout the seasons should be conducted.
- Ways of optimizing waste management systems should be studied-- in terms of labour/ technology/ time/ process and land. A one time case study does not provide sufficient empirical data to make accurate projections for optimization.
- Vegetation studies, which assess the quality of the compost, should be carried out.
- Market studies of market integration should be carried out.
- Creative marketing and production such as making semi-organic fertilizer mixes should be considered.
- The human component should be examined once the permanent composting site is established specifically: NIMBY, willingness to source separate, occupational concerns and impacts.

7.6 Concluding statement

Applying composting in Baisha Hainan provides an opportunity for Baisha to upgrade its waste management system and produce a renewable resource. Ultimately, the feasibility of applying composting at the market, residential and commercial level cannot be accurately assessed through this one time case study, however, the results of this research study indicate that there is potential for

composting at the market level and the commercial and residential level. Composting may be successful if the following necessary factors are considered and addressed. If anyone of these factors are not considered and addressed it could potentially jeopardize the viability of the implementation of composting.

- Governmental support must be present.
- Funds must be made available since operating cost of the waste management system will increase.
- Best practices for composting must be established.
- Training for waste workers must be provided.
- A market (or end use) for the final product must be established.
- NIMBY needs to be addressed.
- Source separation should be applied.

If the abovementioned factors are considered and addressed when forming and implementing the compost policy then there is potential for successful composting at the township level. If insufficient attention is paid to any of these factors this lack of attention could potentially jeopardize the success of composting.

Appendix A

Breakdown of the type of people interviewed and reason for interviewing them

Category of people interviewed through Semi-structured interviews	Number	Reason for interview
Market Sellers Fish seller Meat sellers Fruit sellers <ul style="list-style-type: none"> • Booths • Vendors Vegetable sellers Tofu sellers Cloth sellers Shoe seller Convenience store Pharmacy Medical center	53	<ul style="list-style-type: none"> • The market sellers are the waste producers in the market thus they can provide insight into the type of waste they produce • To understand the current material flow • Current self reported waste management practices. • To understand perceptions about the current waste management system • To assess whether source separation would be possible • To gain some future indication as to whether these people would be willing to separate their waste • What were current attitudes towards waste management and composting • To understand seasonal variations in waste production
Formal Waste Workers	4	<ul style="list-style-type: none"> • These were the people who would be responsible for collecting the waste and maintaining the compost • To understand their current perceptions • If they had any significant concerns in terms of work that is not done • What type of occupational health hazards they were concerned about • To gain their insight as to how to optimize the waste management system
Informal Waste Workers	6	<ul style="list-style-type: none"> • To understand the informal resource recovery sector.

People affected by the dump	9	<ul style="list-style-type: none"> To understand perceived or real concerns that people had about the dump
Government officials (Department of Planning, Land, Sanitation)	7	<ul style="list-style-type: none"> To understand the institutional structure To understand the lines of responsibility To understand the local attitude towards composting To understand the administration of the current waste management system Sanitation department provided details regarding the current waste management system
People in surrounding villages	12	<ul style="list-style-type: none"> To understand the current method of organic waste management in rural areas To understand the potential of expanding composting to the rural areas
Businesses and residents of Baisha township 20 business 10 residents*	30	<ul style="list-style-type: none"> To understand the current waste management practices To understand the potential of expanding composting to these streams in waste
Total	122	

*most market sellers were also residents

Appendix B:

Questions Asked of Market Vendors, Commercial and Residential Waste Producers

Market vendors were asked the following questions:

Do you produce the products you sell or do you act as a secondary distributor?

Have you heard of waste composting?

Is there fluctuation (daily or seasonal) in the amount of waste you produce?

Do you reuse any of your waste?

Are you concerned about your waste?

Are you willing to separate your waste?

Commercial vendors were asked the following questions:

Do you recycle?

Do you pay waste collection fees?

Is the waste fee too high?

Would you be opposed to raising the waste fee?

Are you concerned about waste?

Are you willing to separate waste?

Would you be opposed if waste was only collected one per day?

Have you heard of waste composting?

How often do you dump your waste?

What do you do with your left over food?

Residents were asked the following questions:

Do you recycle?

Do you pay waste collection fees?

Is the waste collection fee too high?

Would you be against increasing the waste collection fee?

Are you concerned about waste?

Are you willing to separate your waste?

Have you ever heard of waste composting?

What do you do with your left over food?

Appendix C

Background to questions

Market Vendors

Do you produce the products you sell or do you act as a secondary distributor?	The partners initially believed that the vendors were also producers. The initial objective was to promote loop closing. In a way so that the compost could be given or sold to vendors. Thus the waste would be kept in a closed system.
Have you heard of waste composting?	The literature indicated that human acceptance is an important. The first step to acceptance is awareness, through participant observation it appeared that many local people did not know about composting. This question was asked to verify if people knew about composting.
Is there fluctuation (daily or seasonal) in the amount of waste you produce?	This question is significant in order to know about the amount and type of waste produced. This is important to enable planning.
Do you reuse any of your waste?	This question was asked to learn about the current resource reuse pattern.
Are you concerned about your waste?	This question was asked in order to know if people were concerned about their waste- if that

	kind of public awareness was present.
Are you willing to separate your waste?	to apply source separation. This question was asked to market vendor had towards source separation.

Commercial and Residential Waste

Do you recycle?	To understand the current waste management system. The current resource flow- potential for recycling.
Do you pay waste collection fees?	Who pays waste collection fees.
Is the waste fee too high?	To understand if the waste fee is accessible
Would you be opposed to raising the waste fee?	To understand if there is potential to raise waste fees without public opposition.
Are you willing to separate waste?	The literature revealed that it is often difficult to apply source separation. This question was asked to understand the self reported attitudes that market vendor had towards source separation.
Are you concerned about waste?	This question was asked in order to know if people were concerned about their waste- if that kind of public awareness was present.
Have you heard of waste composting?	The literature indicated that human acceptance is an important. The first step to acceptance is

	awareness, through participant observation it appeared that many local people did not know about composting. This question was asked to verify if people knew about composting.
What do you do with your left over food?	This question was asked in order learn specifically about the organic portion of food.
Would you be opposed if waste was only collected one per day? Asked only of the commercial waste producers	Currently waste collection occurs two times per day. The waste management system might be more effective if waste management occurred only once per day.
How often do you dump your waste? Asked only of the commercial waste producers	This question was asked in order to know if people dumped their waste more than one time per day. If people dumped their waste once a day or less than it could be coordinated with the commercial vendors to put waste out only once per day this would enable the reduction of collection times.

Appendix D

Types of commercial activities that occur in the market and type of waste that is produced

Type of Vendor	Total number	N=	What they sell	What type of waste they produce
1. Vegetable vendor	121	15	Assorted vegetables both imported from the mainland and domestically grown	Vegetable leaves and plastic bags Some clean the vegetables at home so they do not produce waste at the market.
2. Clothing shop/booth	95	5	Clothing	Boxes, Bags, plastic wrapping, food waste.
3. Fruit vendor	50	4	Longyan fruit, Jackfruit, peanut, watermelon, banana, guava	Leaves, twigs, longyan peels and seeds, fruit peels.
4. Fish vendor & booth	32	4	Fish (Most of the fish is initially alive then they are killed gutted and sold)	Fish insides, fish scales, fish dung, plastic bags
5. Convenience Shop/ convenience store	31	1	detergent, lighters, magazines, snacks, cigarettes, soft drinks, cooking oil, towels, shampoo, dried noodles, garlic, ginger No Fruits or Vegetables	Boxes, Cardboard, Bags, plastic wrapping, food waste
6. Meat Vendor	21	6	Pork, chicken, ham, dumplings	Pigs hair, dung inside pigs body, useless things inside of the pig, paper napkin, plastic bags
7. Assorted Product Shop Booth	21	1	Pens, hair accessories, needles, notebooks, cutlery, mirrors, knives, ear picks, mosquito killers toothpicks, batteries, ink, lighters	Waste paper, paper bags, cardboard
8. Fish vendor (dried fish)	18	1	Dried Fish	Cardboard, Styrofoam, paper, plastic
9. Small restaurant & large Restaurant	17	2	Bread, steamed bun, soft drinks, ice cream, noodles, fast Chinese food, rice, roast meat, fish	Fish bones, pig bone, rice, beer bottles assorted foods, pop can, wrapping, cardboard, plastic bags
10. Tofu vendor	16	1	Tofu	Plastic bags, fruit skins (from personal consumption)
11. Livestock	17	5	Live chicken, live duck, live pig, jinzhu chicken, rabbit, pigeon, Anchun birds,	Dung of animals, excess feathers and hair

12. Lottery & gambling Booth	11	0	Lottery tickets and maja (service)	Paper
13. Fruit booth	9	4	Fruit longan fruit, grape, peach, honeydew melon, apple, pear, guava, watermelon, mango, huo long guo, muskmelon,	Plastic wrapping, plastic bags
14. Shoes and clothing stores	8	0	Shoes and clothing	Boxes, plastic wrapping bags
15. Farming store	6	0	Herbicide, pesticide, bucket, wash basin, umbrella, pots, mattresses, fish nets, insect repellent, iron nails, chains	Boxes, plastic wrapping bags
16. Egg vendor	6	1	Fresh eggs, preserved eggs	Cartons, plastic bags
17. Clam vendor	5	0	Clams and water snail	Shells
18. Shoe shop	4	0	Shoes	Boxes, plastic bags
19. Pickled food Vendors	4	0	Assorted pickled foods	Boxes and bags
20. Sewing booth	3	0	Service: sewing	Cloth, thread, spools
21. Pharmacy	3	1	Medicine, needles, hygiene products	Boxes, bags, empty medicine
22. Noodle vendor	3	0	Fried noodles	Plastic bags, chopsticks, empty Styrofoam container
23. Household product Store	3	0	Leather shoes, slippers, cotton bedding, coat hangers, mattresses, cloth, cupboards, pillows, back packs, toys	Boxes, wrappers
24. Household appliances	3	1	Buckets, washbasins, electrical fan, mattresses, ceramics, chairs, cloth	Boxes, wrappers
25. CD Booth	3	0	CD, Tapes, DVDs, VCD	Plastic wrapping, bags, boxes
26. Jewelry Shop	2	0	Jewelry	Plastic bags, boxes
27. Seed booth	2	0	Assorted seeds, lighters, tobacco, soft drink, spring water, ice cream, longyan fruit	Lighters, cans, spring water bottles, twigs and longyan peels
28. Roasted meat	2	0	Roast meat	Bottles, bones, skin
29. Rice vendor	2	0	Uncooked Rice	Bags
30. Porridge vendor	2	0	Porridge	Bags
31. Washroom	1	0	Washroom	paper napkin, feminine hygiene products
32. Tractor shop	1	0	Tractors	
33. Tobacco Booth	1	0	Tobacco	bags

34. Store that sell things for dead people	1	0	Assorted funeral products	Paper, wrapping, bags
35. Rice and vegetable vendors	1	0	Rice and assorted vegetables	Bags, vegetable stems
36. Rice Husks	1	0	Rice husks	Plastic bags
37. Peanut Vendor	1	0	Roast peanuts	Peanut shells
38. Peanut oil shop	1	0	Peanut oil shop	Bags
39. Magazine Booth	1	0	Magazines	Paper and bags
40. KTV	1	0	Entertainment facility	Beer and baijiu bottles, spring water bottles, cans, fruit skins
41. Hospital	1	1	Provide medical service	Waste disposed of in the market consists of bags, paper and recycled cardboard.- medical waste is disposed of at the peoples hospital
42. Drink store	1	0	Drinks in plastic cups, assorted soda and spring water	Empty plastic cups, spring water bottle, cans
43. Comb Vendor	1	0	Combs	Plastic bag, cardboard
44. Bedding shop	1	0	Bedding pillows blankets	Plastic bags, cardboard
45. Barber shop	1	0	Cut hair	Hair, shampoo bottles,
Total	535			

Fruit vendor and fruit booth****

Vendor and Booth****

Appendix E

List of Key Informants

Number	Key Informant name
1	(Market Vendor)- Vegetable Vendor
2	(Market Vendor)- Vegetable Vendor
3	(Market Vendor)- Vegetable Vendor
4	(Market Vendor)- Vegetable Vendor
5	(Market Vendor)- Vegetable Vendor
6	(Market Vendor)- Vegetable Vendor
7	(Market Vendor)- Vegetable Vendor
8	(Market Vendor)- Vegetable Vendor
9	(Market Vendor)- Vegetable Vendor
10	(Market Vendor)- Vegetable Vendor
11	(Market Vendor)- Vegetable Vendor
12	(Market Vendor)- Vegetable Vendor
13	(Market Vendor)- Vegetable Vendor
14	(Market Vendor)- Vegetable Vendor
15	(Market Vendor)- Vegetable Vendor
16	(Market Vendor)- Clothes Vendor
17	(Market Vendor)- Clothes Vendor
18	(Market Vendor)- Clothes Vendor
19	(Market Vendor)- Clothes Vendor
20	(Market Vendor)- Clothes Vendor
21	(Market Vendor)- Clothes Vendor
22	(Market Vendor)- Fruit Vendor
23	(Market Vendor)- Fruit Vendor
24	(Market Vendor)- Fruit Vendor
25	(Market Vendor)- Fruit Vendor
26	(Market Vendor)- Fish Vendor
27	(Market Vendor)- Fish Vendor
28	(Market Vendor)- Fish Vendor
29	(Market Vendor)- Fish Vendor
30	(Market Vendor)- Convenient Store
31	(Market Vendor)- Meat Vendor
32	(Market Vendor)- Meat Vendor
33	(Market Vendor)- Meat Vendor

34	(Market Vendor)- Meat Vendor
35	(Market Vendor)- Meat Vendor
36	(Market Vendor)- Meat Vendor
37	(Market Vendor)- Assorted Products
38	(Market Vendor)- Dried Fish Vendor
39	(Market Vendor)- Restaurant
40	(Market Vendor)- Restaurant
41	(Market Vendor)- Tofu Vendor
42	(Market Vendor)- Live Stock
43	(Market Vendor)- Live Stock
44	(Market Vendor)- Live Stock
45	(Market Vendor)- Live Stock
46	(Market Vendor)- Live Stock
47	(Market Vendor)- Fruit Booth
48	(Market Vendor)- Fruit Booth
49	(Market Vendor)- Fruit Booth
50	(Market Vendor)- Egg Vendor
51	(Market Vendor)- Hospital
52	(Market Vendor)- Pharmacy
53	(Market Vendor)- Household Appliances
54	(Commercial Establishments)- Restaurant Owner
55	(Commercial Establishments)- Restaurant Manager
56	(Commercial Establishments)- Restaurant Owner
57	(Commercial Establishments)- Restaurant Owner
58	(Commercial Establishments)- Restaurant Owner
59	(Commercial Establishments)- Restaurant Owner
60	(Commercial Establishments)- The Manager of a Tea House
61	(Commercial Establishments)- The Owner of a Tea House
62	(Commercial Establishments)- The Manager of a Coffee House
63	(Commercial Establishments)- The Owner of a Clothing Store
64	(Commercial Establishments)- The Owner of a Convenient Store
65	(Commercial Establishments)- The Owner of a Rice Store
66	(Commercial Establishments)- The Owner of a Supermarket
67	(Commercial Establishments)- The Manager of a Barber Shop
68	(Commercial Establishments)- The Owner of a Snack Shop
69	(Commercial Establishments)- The Manager of a KTV (Karaoke Television)
70	(Commercial Establishments)- The Manager of a Hotel
71	(Commercial Establishments)- The Owner of a Fertilizer Shop

72	(Commercial Establishments)- The Owner of a Paint Shop
73	(Commercial Establishments)- The Receptionist of a veterinary Hospital
74	(Baisha Resident)
75	(Baisha Resident)
76	(Baisha Resident)
77	(Baisha Resident)
78	(Baisha Resident)
79	(Baisha Resident)
80	(Baisha Resident)
81	(Baisha Resident)
82	(Baisha Resident)
83	(Baisha Resident)
84	(Landfill Impact Claimer)- Miao Village Resident
85	(Landfill Impact Claimer)- Miao Village Resident
86	(Landfill Impact Claimer)- Miao Village Resident
87	(Landfill Impact Claimer)- Miao Village Resident
88	(Landfill Impact Claimer)- Miao Village Resident
89	(Landfill Impact Claimer)- Miao Village Resident
90	(Landfill Impact Claimer)- Fang Xiang Government Official
91	(Landfill Impact Claimer)- Fang Xiang Government Official
92	(Landfill Impact Claimer)- Fang Xiang Youth Farm Government Official
93	(Villager) Nan Kai District- Nan Lan Villager
94	(Villager) Nan Kai District- Nan Lan Villager
95	(Villager) Nan Kai District- Nan Lan Villager
96	(Villager) Nan Kai District- Nan Lan Villager
97	(Villager) Nan Kai District- Nan Lan Villager
98	(Villager)- Nan Kai District – Nan Mei Villager
99	(Villager)- Nan Kai District – Nan Mei Villager
100	(Villager)- Nan Kai District – Nan Mei Villager
101	(Villager)- Nan Kai District- Nan Mei Villager
102	(Villager)- Xi Shui District- Fanglun Village
103	(Villager)- Xi Shui District- Fanglun Village
104	(Villager)- Xi Shui District- Fanglun Village
105	Yuan Men District- Nan Xun Village
106	Government official- Sanitation Station
107	Government official
108	Government official

109	Government official
110	Government official
111	Government official
112	Government official
113	Informal Waste picker- bicycle
114	Informal waste picker- bicycle
115	Informal waste picker
116	Informal waste picker
117	Formal waste picker
118	Formal waste picker
119	Formal waste worker
120	Formal waste worker
121	Waste worker
122	Waste worker

Appendix F

Calculations of volume, labor and space requirements needed for the active phase and curing phase of the compost based on the data from the pilot composting project

Total Volume of Waste Composted

In our composting pilot project we made a pyramid of waste with a rectangular base that measured.

Length 230 cm

Width 380 cm

Height 93 cm

This means the total volume of waste we disposed of in this composting project was equal to $2.30 \text{ m} \times 3.80 \text{ m} \times 0.93 \text{ m} \times 1/3^{80}$ thus the total volume of organic waste disposed of was 2.7094 m^3

Time requirements two months based on the composting pilot project

Activity by worker-hour

1. The sorting process of separating the waste took 6 workers 1.30 hours to complete = 9 hours total
2. Throughout the composting process the windrow method required us to turn the composting pile a total of 6 times = this required 2 workers working $1^{1/2}$ hours = 18 hours
3. After the compost had completed the active phase the compost required screening in order to remove contaminants and larger pieces that have not decomposed. This required 2 workers to screen for three hours = 6 hours

Total labour requirements for 2.71 meter^3 of waste: 33 hours (1980 minutes)⁸¹

Hours required per one meter³ of waste = 730 minutes 12 hour 10 minutes

minutes required per one meter of waste * the amount of waste

Amount of commercial and residential waste per day is 11.36 m^3

$730 \text{ minutes} \times 11.36 \text{ meter} = 8292.8 \text{ minutes per day (total time required)}$

138.21 hours per day

⁸⁰ The volume V of a pyramid with a rectangular base of area $A = lw$ is $V = 1/3 Ah$.

⁸¹ One hour daily monitoring need to add daily monitoring time- this time is a fixed cost.

If each worker works 8 hour per day than 17 workers are needed

Amount of Market Waste Per Day = 1.63m^3

$730 \text{ minutes} * 1.63\text{m}^3 = 1189.9 \text{ minutes per day} = 20 \text{ hours}$

I If each worker works 8 hours per day than 2.5 workers are needed

This section calculates the total space required for composting the market waste over 35 days and composting the commercial and residential waste for over 35 days. The duration of 35 days is chosen because this is the time that the composting case indicates that the active phase is over. Additional space will be required for the curing process. However the compost can be stored in larger heaps as the peak temperatures would have already been completed.

If the windrow method is employed and the base of the prism is 2 meters wide⁸², while the height is 1.5 meters tall. The space required for composting the market waste (1.635 m^3) is equal to the height (1.5m) x width (2m) x the unknown (the length) divided by 2. The length is determined by the volume per day.

From the formula:

Volume = width * length * height / 2

Width = 200 cm

Height = 150 cm

Therefore Volume

$$\begin{aligned}\text{Volume} &= 200 \text{ cm} * 150 \text{ cm} * \text{length} / 2 \\ &= 30000 * \text{length} / 2 \\ &= 15000 * \text{length}\end{aligned}$$

Therefore the formula for length is: $\text{Length} = \text{Volume} / 15000$

Thus if 1.635 m^3 of waste is produced every day the length in cm will be:

$$\begin{aligned}\text{Length} &= 1.635 * 1\,000\,000 / 15\,000 \\ &= 109\text{cm}\end{aligned}$$

The length per day will be 1.09m.

The volume of waste in 35 days will be:

$$\begin{aligned}1.635\text{m}^3 * 35 \\ = 57.225\text{m}^3\end{aligned}$$

If the total volume

⁸² As suggested by Haight and Taylor 2000.

The length need it for 35 days will be:

$$\text{Length} = 57.225000 / 15000$$

$$= 3815 \text{ cm}$$

$$= 38.15 \text{ m}$$

Length is equal to 38.15m

Hence the total meters squared required for composting the market waste produced for 35 days is equal to 38.15m Length* 2 Meters Wide.

Thus 76.3 meter squared is required for the active phase of the composting process⁸³.

Once the active phase is completed a curing phase is needed. The curing should take several months. Below is the calculation of the amount of space required for each additional month that the compost cures.

Each additional month:

$$1.635 * 30 \text{ days}$$

$$49.050 \text{ m}^3$$

If a pile is constructed in the shape of a cone which will be about 2 meters⁸⁴ high than:

Given that

$$V = A^2 * h / 3$$

$$A = 3.14 r^2$$

$$V = 3.14 r^2 * h / 3$$

$$r^2 = 3V / 3.14h$$

$$r = \sqrt{3V / 3.14 * h}$$

In this case height is equal to 2m

$$\text{Hence } r = \sqrt{3V / 3.14 * h}$$

$$r = \sqrt{3V / 6.28}$$

If the volume per day is equal to 1.635 for 30 days

$$1.635 * 30 = 49.05$$

$$= \sqrt{3 * 49.05 / 2 * 3.14}$$

⁸³ It should be noted that additional space will be required in order to flip the compost this depends upon the specific site design

⁸⁴ The height is established at 2 meters high because it would be difficult to pile the waste higher using only manual labor, if additional machineries are employed than the area required to cure the compost may be minimized.

$$= \sqrt{147.15/6.28}$$

$$= \sqrt{23.43}$$

$$r = 4.84 \text{ meters}$$

$$\text{diameter} = 2 * r$$

$$\text{diameter} = 9.68$$

Therefore one month's compost from market waste can be cured in a pile of compost with the diameter of the base of 9.68 m and the height of 2m⁸⁵.

The Commercial and Residential Waste

The volume of waste is 11.36m³/day

The length per day will be;

$$\text{Length} = 11.36 * 1000000 / 15000$$

$$= 757.33 \text{ cm}$$

$$= 7.5733 \text{ m}$$

The volume of waste in 35 days will be:

$$\text{Volume} = 11.36 * 35$$

$$= 397.60 \text{ m}^3$$

The length for 35 days will be:

$$\text{Length} = 397.60 * 1000000 / 15000$$

$$= 26506.666 \text{ cm}$$

$$= 265.07 \text{ m}$$

$$(\text{total area} = 530.14 \text{ m})$$

Hence the total meters squared required for composting the residential and commercial waste produced for 35 days is equal to 265.07m Length* 2 Meters Wide. This is a total of 530.14 m² required. Again additional space may be required for turning the windrows.

For the curing phase

The volume per day is equal to 11.36. Thus the volume per month is equal to 340.80.

$$r = \sqrt{3v/3.14 * h}$$

Knowing that h=2 meters

$$r = \sqrt{3 \times 340.8 / 6.28}$$

$$r = \sqrt{162.808}$$

$$r = 12.759$$

$$\text{diameter} = 2 \times r$$

$$2 \times 12.759$$

$$\text{diameter} = 25.52$$

$$(\text{total area} = 511.16)$$

⁸⁵ This is a general idea, precise amounts will need to consider: shrinkage, the amount of plastics removed, as well as the amount of large pieces of carbon and other foreign matter removed prior to the curing phase.

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