AUDIT OF SOLID WASTES FROM HOTELS AND COMPOSTING TRIAL IN HALONG CITY, VIETNAM

by

Hoang, Phuong Chi

A thesis submitted in conformity with the requirements
for the degree of Master of Engineering
Graduate Department of Civil Engineering
University of Toronto

© Copyright by Hoang, Phuong Chi 2005

ABSTRACT

"Audit of Solid Wastes from Hotels and Composting Trial in HaLong City, Vietnam"

Hoang, Phuong Chi

Master of Engineering, 2005

Department of Civil Engineering, University of Toronto

This thesis investigates the feasibility of composting organic wastes from hotels in HaLong City, Vietnam. Three interrelated studies were carried out. First, a waste audit at three hotels was conducted to determine the amount of compostables available for composting. The one-week waste audit process revealed that among disposed waste, approximately 60% was compostables and recyclables made up around 5%. Also, about 250 kg of compostables was determined ready for composting per day during the fruit-growing and tourism season.

For the second part of the research, a composting trial was implemented. After sixty days of composting and maturing, about 60 kg of fine compost was produced from the input of 702 kg of compostables.

Thirdly, some physical and chemical characteristics of the compost were tested and compared to standards of compost quality of some countries in Europe, Australia, and North America. All tested properties, except for level of pathogenic micro-organisms and foreign matter, meet the standards. The thesis ends with recommendations on waste separation at source, seasonal effects, and compost application for improving the implementation of composting in HaLong City.

ACKNOWLEDGEMENTS

Many institutions and individuals, whom I would like to acknowledge, have contributed in one way or the other way to my thesis. First, I would like to express many thanks to the Canadian International Development Agency (CIDA) for financial support of my study in Canada and my research in HaLong, Vietnam as well. A special thank goes to Professor Virginia Maclaren, Ms Sharon Brown, and other Waste-Econ staff for their support and project coordination in University of Toronto, Canada, and to Dr. Nguyen Danh Son, Dr. Nguyen Thi Anh Thu, and Mr. Tang The Cuong (NISTPASS) for providing appropriate contacts in Vietnam. Thanks to Professor Murray Haight, University of Waterloo for his guiding thoroughly the composting process and additional preparation as well as providing input through the project.

Additional thanks to Professor Tran Hieu Nhue and Mr. Nguyen Quoc Cong for their encouragement, suggestions, and advice on the composting trial at all stage of the research, and also for their providing laboratory testing results of compost quality. In addition, I would like to thank the hotel managers and their staff for enabling me to conduct the waste audit and collect organic waste, and to Tran Quoc Trung, and many scavengers who worked enthusiastically with me during the field work activities. Thanks are also extended to Dr. Nguyen Danh Son and his staff in Department of Resources and Environment, Quang Ninh for providing some suggestions and Bai Chay Urban Environmental Company for their cooperation in implementing the composting trial. A sincere thanks goes to Dr. Cao Ky Son and managers of CauDien Compost Plant and BaRia-VungTau Compost plant and Song Gianh Plant for their helpful information.

Lastly, a very special thank you to Professor Philip Byer for his guidance and encouragement during my stay in Canada and, my research in Vietnam. His critical advice and guidance have been instrumental in developing many of the ideas in this paper.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

CHAPTER 1
INTRODUCTION

1.1 Introduction to Vietnam

Located in Southeast Asia, Vietnam shares its borders with China, Laos, and Cambodia. The total area of Vietnam's territory is about 332,000 km^2. As can be seen in Figure 1.1, its territory extends longitudinally over 1,650 km from the north to the south, with the widest point measuring roughly 600 km while the narrowest is only 50km (NEA and UNEP, 2001). Also, it has a long coastline of 3260 km with thousands of islands. One well-known bay, designated as the World Hesitate by UNESCO since December in 1994, is HaLong Bay.

With a long coastline on the Gulf of Tonkin and the South China Sea, Vietnam has a tropical climate characterized by monsoons. From May to September, the country is dominated by southerly to southeasterly winds while the north monsoon is dominant during the rest of the year. Also, Vietnam has a single rainy season when the south monsoon prevails. Rainfall is abundant, with annual rainfall exceeding 1000mm almost everywhere. Temperatures are high all year round for southern and central Vietnam; but northern Vietnam has a definitely cooler season as the north monsoon occasionally advects cold air from China.

In terms of territory area, Vietnam is a small country in the world; however, with the 1999 average population density of 231 persons/km^2, Vietnam is one of the most populated countries. The total estimated population of Vietnam, up to April 1st, 1999, was around seventy million. The average annual growth was 2.1 % from 1979 to 1989, then decreased to 1.7% during the next ten year period from 1989 to 1999 (NEA and UNEP, 1999).

With the convenient geographic location and large population, Vietnam has been seen as the potential market for foreign investors. In particular, after the sixth National congress of Vietnam's Communist Party, held in December 1986, an overall economic renovation policy was introduced. This policy has been known as "Doi Moi", which aims at improving the standard of living of the people through relaxing macro-economic policy and reducing the government intervention in the market. In addition, incentive measures had been introduced to attract foreign direct investment (FDI) that was more than welcomed by the business sector. Since then, Vietnam has developed significantly.

Source: http://halong.net.vn/

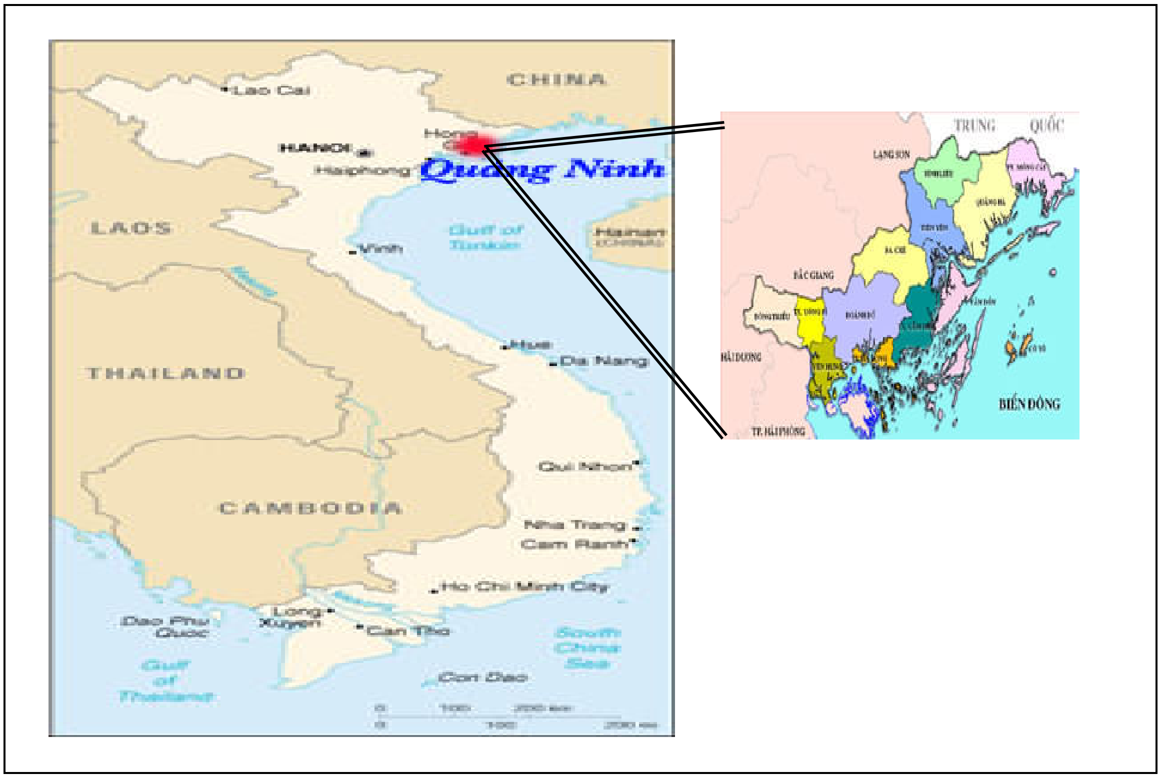


Figure 1.1 Map of Vietnam and Enlarged Map of Quang Ninh Province

Nevertheless, the encouraging development in the economy over the past two decades has appeared to be at the expense of the environment. Land degradation, deforestation, loss of biodiversity, water pollution, air pollution, and solid waste management are not only the familiar concepts, but also the key concerns of the national reports on the state of the environment in Vietnam. Among these critical problems, solid waste management historically drew little attention from environmental managers and decision makers in Vietnam. For many reasons, this situation has changed considerably in recent years, and the current condition of solid waste management has been mentioned in some national reports. NEA and UNEP (1999) states that waste collection efficiencies are very low due to the incomplete establishment of the collection services in most cities. Also, treatment facilities were not properly designed to meet the sanitary requirements.

Unfortunately, these issues still remain and solid waste management represents significant economic and environmental burdens for developing countries in general, and for Vietnam in particular. The environmental issues are normally related to improper services of solid waste management and treatment systems. For many years, the most common method to deal with solid waste has been dumping or landfilling; however, it is causing new problems, such as groundwater contamination from landfill leachate and greenhouse gas emissions from methane generation in landfills. The main culprit is organic waste since it is degraded under the anaerobic condition to produce leachate and methane. Also, organics are the largest category of municipal solid waste (MSW). As shown in Figure 1.2, the solid waste in five big cities within Vietnam is largely composed of organic material which makes up roughly 40%.

Source: (NEA and UNEP, 2001)

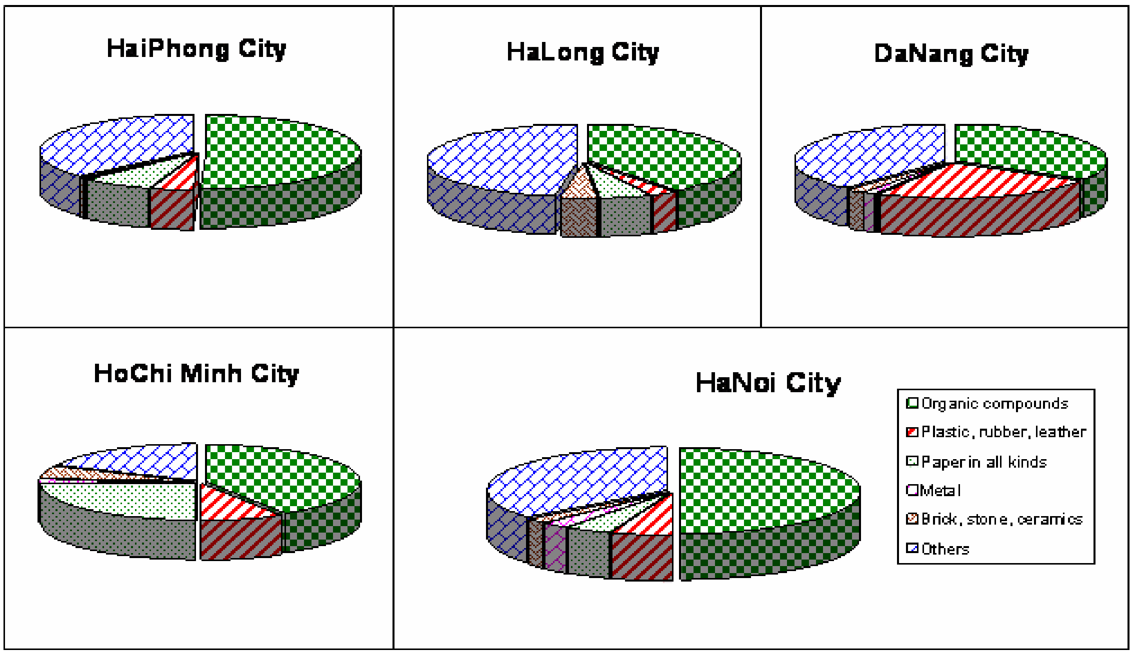


Figure 1.2 Composition of Municipal Solid Waste across Vietnam

To reduce wastes in major cities of developing countries, the diversion of organics from the MSW stream (for composting or animal feed) is now gaining popularity. Furthermore, according to Vietnam's national strategy on solid waste management (NEA and UNEP, 2001), the major methods for treatment of solid waste will be sanitary landfilling and recycling. Therefore, diversion of organic waste in general and composting in particular is important for Vietnam in years to come.

1.2 Review of Compost and Composting

Around the world, there are many working definitions of compost; however, most agree that compost is an entirely natural product:

> *Compost is simply the final result of nature's own recycling system which breaks down organic wastes and return the nutrients back to the soil* (Haight and Taylor, 2000).

The evident example is the natural decomposition process that turns leaves and tree trimmings on the forest floor to humus. By definition, composting is the biological decomposition of waste consisting of organic substrates of plant and animal origin under controlled conditions to a state sufficiently stable for convenient storage and utilization (Diaz, Eggerth et al., 1993). The composting process can occur with or without the presence of oxygen, depending on the species of microorganisms involved. However, the composting process that is discussed and applied in the scope of this study is aerobic decomposition, in which micro-organisms convert the organic material, with the presence of oxygen, into carbon dioxide (CO_2), water (H_20) and humus substances.

$$\text{Organic matters} + O_2 \xrightarrow{micro-organisms,\, nutrients,\, ...} CO_2 + H_20 + \text{compost} + \text{heat.}$$

There are some principle factors that strongly impact the decomposition process:

– *Moisture Content:* Water is necessary for the metabolic processes of the micro-organisms in the compost pile. It also serves as a holding and transport medium for nutrients and micro-organisms. A starting moisture level of 50 – 60% is recommended because the heat of the compost reaction will evaporate a lot of water. The optimal moisture range for composting is 40-65%. If the moisture content of the mass is below 25%, micro-organisms are inactivated, while if it is so high as to displace most of air from the interstices, anaerobic conditions develop within the mass (Epstein, 1997; Haug, 1993).

– *Ratio C/N*: With respect to the nutrient needs of the microbes active in composting, the C:N ratio of the waste to be composted is the most important factor that requires more attention. Both elements are used by the microbes in their metabolism to obtain energy and in the synthesis of new cellular material. The target C:N ratio is within the range from 20:1 to 40:1. If the ratio is too high, it will slow down the composting process, while odour problems will arise if too much nitrogen is present in feedstock (Hoornweg, 1999; Satriana, 1974).

– *Alkalinity:* pH is especially important with raw materials that are high in nitrogen content and which usually have an alkaline pH. Starting pH close to neutral (pH = 7) is desirable (Epstein, 1997).

– *Aeration:* Aerobic composting requires aeration to provide sufficient oxygen to support the microorganisms' activities; without sufficient oxygen, the process can turn anaerobic, creating undesirable odours and incomplete decomposition (Dulac, 2001).

– *Temperature:* Thermophilic temperature is desirable for the destruction of pathogens, insect larvae and weed seeds. However, if it rises to more than 70^0C, some useful microorganisms are also killed. Conversely, if the temperature is less than 30^0C the break-down rate of organics will be slow. Therefore, the optimum temperature range for rapid and complete composting is 55-65^0C (Dulac, 2001; Epstein, 1997).

– *Particle Size:* The significance of particle size is in the air exposure surface area of the waste particles to microbial attack; the greater the ratios of the surface area to mass (or volume), the more rapid the rate of microbial attack. Theoretically, the smaller the particle, the more readily and rapidly it can be broken down. The optimum size ranges from 2 cm to 5 cm (Dulac, 2001; Haug, 1993).

1.3 Waste Econ Program

The research project report here was carried out as part of a Waste-Econ Program between the University of Toronto, Canada and a number of government institutions, universities, and non-governmental organizations (NGOs) in Vietnam, Laos, and Cambodia. The aim of this five-year program, which is funded by the Canadian International Development Agency (CIDA), is to explore methods for recycling, exchanging and reducing wastes in a way that will be beneficial to the economies of the partner countries, the people working in the waste sector and to the environment as a whole. In Vietnam, the Waste-Econ partners are the National Institute for Science & Technology Policy and Strategy Studies (NISTPASS), four leading universities, eight government agencies and a number of NGOs. This research was part of a larger pilot-project on organic waste management for the BaiChay tourism destination, HaLong Bay, Vietnam. The objectives of the pilot project are to assess the existing sources of solid waste and the current status of the solid waste management, and to recommend ways to better manage wastes, especially the organic wastes.

1.4 Research Area

HaLong City is the most populated area within QuangNinh province. According to a recent study (Nhue, 2003), the total solid waste generation from households was about 0.7 kg per capita per day; therefore, it was estimated that 230,000 inhabitants within HaLong City generate approximately 58,000 tons of solid waste annually. This figure is expected to increase due to the population growth as well as the increasing development of socio-economic and tourism activities. There are only two organizations, BaiChay and HaLong Urban Environmental Company (Urenco), having responsibility for collecting and transporting solid waste within HaLong City. JICA (1999) states that if the target collection coverage was about 85% for

HaLong City by 2010, an extra 450,000 m^2 landfilling area should be provided since two current landfills, Deo Sen and Ha Khau, have adequate disposal capacity until 2008. With the increase in population and expansion of the city, it may become difficult to find future waste disposal sites within easy access for solid waste disposal. Reducing the quantity of municipal solid waste (MSW) to be disposed would reduce the need for additional landfill space and the costs for managing the wastes. As shown in Figure 1.2**,** organic waste made up 41% of solid waste in HaLong, and removal of organic waste could lead to a significant reduction of solid waste.

1.5 Purposes and Methods of the Study

Discussions between the study team and local institutions, such as BaiChay Urban Environmental Company and Department of Resources and Environment, revealed their interest in establishing a small-scaled compost plant at HaKhau landfill in order to reduce wastes entering the landfill, and gain some profits from the sale of the compost product. However, more information about local solid waste characteristics, compost production, and compost quality is needed before proceeding with these plans. For this reason, the objectives of this study were to:

- Carry out a waste audit at some hotels in HaLong to assess solid waste quantities and composition. The audit is needed to evaluate whether the amount of organic waste from hotels is sufficient for the compost trial;
- Establish a temporary, low-cost composting pilot facility to test and serve as a model for future facilities, and as a training center for those who would work at such plants; and
- Assess the quality of the compost product from the pilot facility, and compare it to the current standards and regulations on compost quality in Vietnam and other countries.

The study was implemented through field work and information collection during the summer of 2004. The field work for the waste audit and compost trial was carried out by the author of this report in BaiChay, which is a part of HaLong City, while information collection came from data in both published and unpublished reports and working papers by government agencies, and research institutes. The detailed methodology for each specific part of the research is discussed in each chapter.

Some important limitations of the study were:

- Since the study was conducted in the wet season (from June to August, 2004), the results do not reflect the seasonal variability of wastes, and the high humidity in the ambient air may affect the weight of the waste.

- Since the waste audit was conducted in only three hotels (two-star, three-star, and four-star), the results may not represent all hotels within BaiChay.
- The organic waste for the compost trial was almost fully separated at source in three hotels over a period of about one week, and the analysis of compost quality was based on only one composting pile. Thus, the resulting compost quality may not adequately represent the quality of compost that would be produced.

1.6 Structure of the Study

The remainder of this report is divided into four chapters.

- *Chapter 2* presents the waste audit process conducted in three hotels, the analysis of the collected data, and the resulting estimates of the composition and generation rate for each hotel.
- *Chapter 3* describes the composting trial, including source separation, transportation, blending, piling, composting, maturing and screening, and the analysis and evaluation of mass flows and other chemical and physical parameters.
- *Chapter 4* discusses compost quality control in Vietnam and other countries. The quality of the compost from the trial is also analyzed to identify whether or not the compost may be accepted in the market.
- *Chapter 5* summarizes the results of the study and provides some recommendations on waste separation at source, seasonal effects, and compost application in order to improve the feasibility of composting in HaLong City.

CHAPTER 2

HOTEL WASTE AUDIT

2.1 Methodology: Capabilities and Limitations

There are many methodologies for quantifying and characterizing solid waste, including Direct Waste Analysis, Material Flow Analysis, Survey Analysis and Empirical Analysis. Each methodology has certain capabilities and limitations (SENES, 1992)**.** This study applied one of the most commonly encountered methods, Direct Waste Analysis. As the name implies, the method involves direct examination of the waste stream characteristics, such as weight, composition, and existing waste management practices (e.g., reuse, recycling, disposal).

In this study, Direct Waste Analysis is used to measure total amount of waste disposed of and generation rates for three hotels. In practice, the method is very flexible and may be tailored to suit the goals of a specific study. The reporting capabilities are extensive if appropriate information is collected, and data may be reported in various units, including those based on economic activity. Generation rate for each hotel, for example, was reported as per guest per unit of time (e.g. kg/guest/day). Estimation of the composition of the waste was also an important part of this study. Component categories, which were based on waste materials, such as glass, metal, plastics and paper, were estimated for different waste sources (kitchen, garden, and guest/office rooms). Since the study focuses on composting, more detailed information is needed about compostables which was sub-categorized into leftover food, fruit waste, vegetable waste, and yard waste. Finally, statistical methods were applied to the sampling and data analysis procedures.

There are also some major limitations of the method that may affect the results of this study in some ways. First, waste generation rate and composition depend on external factors, such as climate, seasons, and location. The results are only considered valid for each selected hotel and for the tourist season (from June to July). The intensive labour required to physically sort the waste is another drawback to the method applied in the project.

The procedure implemented during the audit process included:

- Hotels were selected on the basis of their size, in terms of the number of rooms, and their rating.
- Hotel management personnel were interviewed informally to identify the numbers of rooms and occupancy levels during the waste audit period. Waste collection processes for

each hotel were observed, and all waste storage areas on the property were recognized. Details of waste collection and removal methods and frequency of removal were recorded (discussed below).

- Each waste collection area was observed before auditing. The hotels were visited at different times during a 24 hour period to make sure all waste generated was accounted for and to identify each waste source and composition. There are three typical sources of waste from hotels: kitchen, guest/staff rooms, and garden. Each of these sources has its own waste composition. For example, waste from the garden contains a lot of leaves and tree trimmings, while there are more vegetable and fruit wastes in kitchen waste.
- Both generation and composition vary with time of day, and day of week. In order to include these variations, a one-week audit was conducted for each hotel. During that time, waste was collected in a storage area where it was physically sorted into the different categories that are listed both in Table 2.3 and in the material column of the audit form presented in Appendix A; then, the sorted waste was weighed to estimate the generation rate, disposal rate and waste composition.

2.2 Solid Waste Collection System for Hotels in HaLong

There are about one hundred hotels in HaLong City, ranging from mini to four-star hotels, and this number is projected to increase considerably in the years to come. Deciding how many hotels and which hotels should be selected for the waste audit process and the compost trial was not an easy task. Therefore, some criteria were chosen, including location, property, size, and rating. This study assumed that hotels with more than 200 rooms are large, those with between 100 to 200 rooms are medium, while small ones have less than 100 rooms. Interestingly, there is a link between the size and the rating of hotel since larger hotels normally have higher rating. No five-star hotel is available in HaLong and also no hotel is registered as one-star. Due to limited time and labour, only three hotels could be selected. Hence, one four-star hotel, one three-star hotel, and one two-star hotel were selected and agreed to participate. Table 2.1 outlines some basic information on the three hotels.

SaiGon-Halong hotel, a four-star hotel, consists of a fourteen-floor building and 5 villas. This is one of the biggest and most modern hotels in BaiChay, HaLong City with the room rate ranging from US$ 50 to US$ 998 per night. With a beautiful garden and other luxury facilities, it attracts more than 90,000 guests annually, mostly from Taiwan, China, Japan, Korean, and Europe.

CongDoan hotel, a three-star, is the favorite destination of both high-income and medium-income guests, since the room rate is from around US $ 15 to US $ 40. Located at the heart of BaiChay, CongDoan hotel had around 50,000 overnight guests in 2003, including more than 20,000 overseas tourists. TienLong hotel, a two-star hotel, is a popular destination of Vietnamese tourists because of its low room rate.

Table 2.1 The Size of Three Chosen Hotels in HaLong

Name	Size	
	Rating	**Guest rooms**
SaiGon-HaLong Hotel	* * * *	228 + 5 villas
CongDoan Hotel	* * *	121
TienLong Hotel	* *	84

In order to design a proper waste audit process that caused little or no effect on the routine business of three participating hotels, the source and collection routes of solid waste were examined thoroughly.

SaiGon-HaLong Hotel:

There are three major sources of solid waste: kitchen/restaurant, garden, and staff/guest rooms. In each guest room, two dust bins are provided, one in the bathroom and one in the bedroom. Housekeeping staff would clean the room in the morning and after guests check out. Waste from guestrooms would be gathered in plastic bags and then thrown to a chute that is located at the end of the hall. Recyclables, theoretically, are not collected because the hotel managers did not allow their staff to touch waste and then make the beds. However, many room cleaners try to collect recyclables before throwing waste through the chute. During the one-week audit, the amount of these recyclable materials that they took out of the waste stream was estimated by asking housekeeping staff to bring these materials to the storage sites so that they could be weighed before they were sold. This approach did not work well because there was a lack of understanding of the purpose of the study and many of the room cleaners were afraid that this issue would be reported to the hotel's managers.

Waste through the chute, then, goes down to a 5 m^2 storage room located on the ground floor (see Picture 2.1), where waste is kept from the elements and vermin, and stays there until the afternoon. Two cleaners have the responsibility to clean the room and take the waste away. However, before doing their duties, one of them opens the plastic bags to collect recyclables. The remainder is brought to three push-carts, located at the back entrance of the hotel, where the BaiChay Urban Environmental Company's compaction trucks come and transport the waste to HaKhau landfill.

In the kitchen, there are many waste containers placed at different locations. Vegetable, fruit, and food were processed at different places, and each place had one or two waste containers. Most leftover food, such as rice, mashed potatoes, cakes, and some types of vegetable wastes, is collected by one pig-farmer for animal feeding every morning. Recyclables, such as plastics and paper, are collected by kitchen staff for selling while reusable materials as beer bottles are collected to return to manufacturers. The remainder is gathered in large containers and brought to the push-carts twice per day.

Picture 2.1 Waste Storage Room under the Chute in SaiGon-HaLong Hotel

Yard waste is dependent on the seasons (e.g. rainy season). Trees are trimmed monthly, even more often during the growing season. With the 15,000 m^2 garden, the amount of waste generated by this activity is estimated to one tonne per month; however, this amount was not considered in the waste audit report, because tree trimming is conducted periodically and there was no tree trimming activity during the one-week waste audit period. Yard waste considered for the waste audit and composting trail was mostly grass clippings, fallen leaves, and small tree trimmings that were collected from the surface of the road and paths within the hotel.

CongDoan and TienLong Hotels:

There is no waste collection system by chute in these two hotels; instead, waste from office and guest-rooms is brought directly to storage areas by cleaners. The storage area at CongDoan hotel is enclosed (Picture 2.2), while that at TienLong hotel is open and at a location where the waste is affected by weather conditions and grazed by animals.

Like staff at SaiGon-Halong hotel, housekeepers at these two hotels try to collect recyclables as much as possible, again in an informal way. Waste from the kitchen is well mixed as there are only one or two waste containers standing at the back door. Urenco's trucks come to CongDoan hotel once per day and to TienLong hotel once every two days.

Picture 2.2 Waste Storage Room in CongDoan Hotel

2.3 Waste Quantification Study

Theoretically, the total quantity of waste generated from hotels, before recyclables are collected by hotel staff, is estimated by an average daily generation rate. Whereas, an average daily disposal rate is defined as the total amount of waste disposed of in the landfill, after most recyclables are removed. However, in fact, recyclable items were removed by hotel staff without reporting; and it was difficult to record their correct weight due to low cooperation from staff. As the result, the generation rate was underestimated. Nevertheless, the disposal rate could be estimated accurately, since determining the precise weight of solid waste gathered at storage areas was possible.

The estimate of the quantity of waste generated or disposed of is determined by the amount of waste from each source. The average generation rate, the amount of waste generated per day, is determined by Equation 2.1.

$$W_{G,i} = \frac{\sum W_{i,Gd}}{n_i} \qquad \text{Equation 2.1}$$

Where

$W_{G,i}$: average waste generated by hotel i over the audit period (kg/day)

$W_{i,Gd}$: waste generated by hotel i on day d of the audit period (kg)

n_i: the number of audit days that hotel i participated in the audit (day)

The average waste disposal rate by a hotel is defined as follows:

$$W_{D,i} = \frac{\sum W_{i,Dd}}{n_i} \qquad \text{Equation 2.2}$$

Where

$W_{D,i}$: average waste disposed by hotel i over the audit period (kg/day)

$W_{i,Dd}$: waste disposed by hotel i on day d of the audit period (kg)

n_i: the number of audit days that hotel i participated in the audit (day)

Since the amount of waste per day fluctuates and is dependent on the number of overnight guests (more guests, more waste), more useful measures of waste generation (or disposal) are the daily amount of waste generated (or disposed) per guest per day and the average amount waste generated (or disposed) per guest per day over the audit period. They are defined by using Equation 2.3a and 2.3b.

$$(1) \quad W_{d,GG,i} = \frac{W_{i,Gd}}{n_{g,d}} \quad \textit{and} \quad (2) \quad W_{A,GG,i} = \frac{\sum W_{i,Gd}}{\sum n_{g,d}} \qquad \text{Equation 2.3a}$$

$$(1) \quad W_{d,DG,i} = \frac{W_{i,Dd}}{n_{g,d}} \quad \textit{and} \quad (2) \quad W_{A,DG,i} = \frac{\sum W_{i,Dd}}{\sum n_{g,d}} \qquad \text{Equation 2.3b}$$

Where

$W_{d,GG,i}$: daily waste generated per guest per day by hotel i on day d (kg/guest/day)

$W_{A,GG,i}$: average waste generated per guest per day by hotel i over the audit period (kg/guest/day)

$W_{d,DG,i}$: daily waste disposed by a guest per day by hotel i on day d (kg/guest/day)

$W_{A,DG,i}$: average waste disposed by a guest per day by hotel i over the audit period (kg/guest/day)

$W_{i,Gd}$: waste generated by hotel i on day d of the audit period (kg)

$W_{i,Dd}$: waste disposed by hotel i on day d of the audit period (kg)

$n_{g,d}$: the number of guests staying in hotel i on day d of the audit period (guest)

To illustrate the use of Equations 2.1, 2.2, 2.3a, and 2.3b, data gathered from TienLong hotel over the one-week audit period is shown in Table 2.2. The amount of waste, both generated and disposed, fluctuated during the one-week audit period. For example, the quantity of waste generated on day 1 was 133.4 kg. This figure increased considerably to 172.7 on day 2, then decreased to 119.5 on day 3. The average waste generated by TienLong hotel during the audit period is shown in the column $W_{G,i}$ (137.2 kg/day) while an average of only 89.2 kg was disposed of every day. Also, if the number of guests is accounted for (shown in row 3), the amount of waste generated and disposed by a guest on each day is calculated, as shown in the last two rows. For the entire 7-day audit period, an average of 0.81 kg and 0.53 kg of solid waste was generated and disposed per guest per day respectively. These and other results are presented and discussed in section 2.6.

Table 2.2 Use of Equation 2.1, 2.2, 2.3 on Data Gathered from TienLong Hotel

	Day 1 Kg/day	Day 2 Kg/day	Day 3 Kg/day	Day 4 Kg/day	Day 5 Kg/day	Day 6 Kg/day	Day 7 Kg/day	$W_{G,i}$ Kg/day	$W_{D,i}$ Kg/day	$W_{A,GG,i}$ Kg/guest/day	$W_{A,DG,i}$ Kg/guest/day
$W_{i,Gd}$	133.4	172.7	119.5	151.7	112.3	126.1	144.8	**137.2**			
$W_{i,Dd}$	81.4	123.1	76.4	102.6	68.3	77.1	95.8		**89.2**		
$n_{g,d}$	174	166	153	226	201	118	147				
$W_{d,GG,i}$	0.77	1.04	0.78	0.67	0.56	1.07	0.99			**0.81**	
$W_{d,DG,i}$	0.47	0.74	0.50	0.45	0.34	0.65	0.65				**0.53**

2.4 Waste Composition Study

As discussed in the previous section, there are three main sources of waste from hotels (office/guest rooms, gardens, and kitchen/restaurant), and each source contains different types of waste. For example, there are a lot of compostables, which can be biologically decomposed, present in kitchen-waste while more recyclables are present in waste from office/guest rooms. To give sufficient information to evaluate different disposal options such as recycling, landfilling, and especially composting in this study, the categories for separation are based on the waste sources. Furthermore, to establish the list of categories (shown in Table 2.3), some hotel staff who worked with solid waste were interviewed and also some published reports (Chopra, 2004; CCME, 1996; Kauffman, 1990; SENES, 1992) on waste audit were reviewed.

Waste from each source was separated into two or three main categories: compostables, recyclables, and miscellaneous. Since the major purpose of the study focuses on composting applicability for hotels, the quantity and composition of compostables was examined thoroughly. In the scope of this study, compostables were divided into seven sub-categories: leftover food, fruit waste, flower waste, vegetable waste, yard waste (including leaves and glass clippings), egg shells, and seafood waste. That is because each category has its own properties that strongly influence composting processes, such as moisture content, pH, and Carbon - Nitrogen ratio.

Recyclables contain four main categories: recyclable paper, glass, metals and recyclable plastics. As shown in Table 2.3, paper and plastics were separated into non-recyclable and recyclable. Non-recyclable paper or plastics are the items that can not be sold and recycled, while recyclable items were valuable for selling. For example, the fibers of tissue paper are too soft and short to be recycled. Therefore, in this study, non-recyclable plastics and paper, along with other wastes like rubber, cloth, and dirt that do not belong to any of the mentioned categories, were placed into a "miscellaneous" category.

The percentage of each main category of the daily waste generated by each hotel and the average proportion of waste generated over the audit period is defined as:

$$(1) \quad P_{G,c,i,d} = \frac{W_{G,c,i,d}}{W_{G,i,d}} 100 \quad and \quad (2) \quad P_{A,G,c,i,d} = \frac{\sum W_{G,c,i,d}}{\sum W_{G,i,d}} 100 \qquad \text{Equation 2.4}$$

Where:

$P_{G,c,i,d}$: % composition of waste in category c generated by hotel i on day d (%)

$P_{A,G,c,i,d}$: average % composition of waste in category c generated by hotel i over the audit week (%)

$W_{G,c,i.d}$: waste in category c generated by hotel i on day d (kg/day)

$W_{G,i,d}$: the total amount of waste generated by hotel i on day d (kg/day).

The percentage of each main category of the daily waste disposed of by each hotel and the average percentage over the audit period are determined by:

$$(1) \quad P_{D,c,i,d} = \frac{W_{D,c,i,d}}{W_{D,i,d}} 100 \quad and \quad (2) \quad P_{A,D,c,i,d} = \frac{\sum W_{D,c,i,d}}{\sum W_{D,i,d}} 100 \qquad \text{Equation 2.5}$$

Where

$P_{D,c,i,d}$: % composition of waste in category c disposed of by hotel i on day d (%)

$P_{A,D,c,i,d}$: average % composition of waste in category c disposed by hotel i over the audit week (%)

$W_{D,c,i.d}$: waste in category c disposed by hotel i on day d (kg/day)

$W_{D,i,d}$: the total amount of waste disposed by hotel i on day d (kg/day).

Also, for compostables, the percentage of each sub-category is given by:

$$(1) \quad P_{O,c,i,d} = \frac{W_{O,c,i,d}}{W_{O,i,d}} 100 \quad and \quad (2) \quad P_{A,O,c,i,d} = \frac{\sum W_{O,c,i,d}}{\sum W_{O,i,d}} 100 \qquad \text{Equation 2.6}$$

Where

$P_{O,c,i,d}$: % composition of compostables in sub-category c for hotel i on day d (%)

$P_{A,O,c,i,d}$: average % composition of compostables in sub-category c for hotel i over the audit week (%)

$W_{O,c,i,d}$: compostables in sub-category c generated or disposed by hotel i on day d (kg/day)

$W_{O,i,d}$: the total amount of compostable generated or disposed by hotel i on day d (kg/day.

Table 2.3 List of Material Categories

Material Category		***Description***
Waste from Guest Room		
Compostables	Fruit waste	Rambutan, watermelon, dragon fruit, litchi, pineapple, mangosteen shells
	Leftover food	Bread, sticky rice
	Flower waste	Daisy, roses
Recyclables	Metal	Aluminum cans
	Glass	Beer bottle, glasses
	Recyclable plastics	Bottles, clear bags
	Recyclable paper	Tissues, cardboard, print paper, newspaper
Miscellaneous	Non-recyclable paper	Damp napkins, tissues
	Non-recyclable plastics	Plastics bags, hard plastics…
	Others	Wood chips, sand, dust, rubber, cloth, …
Waste from Kitchen and Restaurant		
Compostables	Leftover food	Rice, cooked meat, cakes, …
	Fruit waste	Rambutan, watermelon, dragon fruit, litchi, pine-apple
	Vegetable waste	Water-morning glory, pot-herbs, onion, spinach, carrot,
	Egg shells	-
	Sea-food waste	Lobster, crab, shells, fish
Recyclables	Recyclable paper	Tissues, cardboard, print paper, newspaper
	Metal	Aluminum cans
	Glass	Beer bottle, kitchen stuff
	Recyclable plastics	Bottles, clear bags
Miscellaneous	Non-recyclable paper	Damp napkins, tissues
	Non-recyclable plastics	Plastics bags, hard plastics…
	Others	Bone, dirt, sand, cloth, rubber, …
Waste from Garden		
Compostables	Leaves	Pine needles, brush, leaves, tree trimmings
	Grass clippings	-
Miscellaneous	Others	Dirt, sand, rubber, cloth, foam, …

To illustrate the use of Equation 2.4, 2.5, and 2.6, the data gathered for SaiGon-Halong hotel on day 1 are applied and the results are shown in Table 2.4. First, the total weight of each category would be the sum of weight from all sources, since one category, such as recyclables and compostables, can be present in two or three sources. The results of the total weight of each category generated and disposed of are shown in the row titled $W_{G,c,i.d}$ and $W_{D,c,i.d}$ respectively. Equation 2.4, and 2.5 can then be used to determine the percentage of each category in the total waste for day 1 and these calculations can be found in the row titled $P_{G,c,i,d}$, $P_{D,c,i,d}$. To calculate the composition of compostables, the same procedure is applied, and its results are shown in the last two rows. Also, the average values are found in Appendix A (from table A6 to Table A14).

Table 2.4 Use of Equation 2.4, 2.5, 2.6 for Data of SaiGon-HaLong Hotel on Day 1

Generation-based Composition				
	Compostables	**Recyclables**	**Miscellaneous**	**Total**
$W_{G,c,i.d}$ (kg)	291.3	42.3	22.0	355.6
$P_{G,c,i,d}$: (%)	81.9	11.9	6.2	100.0
Disposal-based Composition				
$W_{D,c,i.d}$ (kg)	174.0	2.3	22.0	198.3
$P_{D,c,i,d}$: (%)	87.8	1.1	11.1	100.0

Composition of Compostables							
		Fruit waste	**Leftover food**	**Vegetable waste**	**Yard waste**	**Others** (eggshells, seafood, flower)	**Total**
$Wo_{,c,i.d}$ (kg)	**Generation**	100.7	104.8	58.5	21.4	5.9	291.3
	Disposal	100.7	0.0	46.0	21.4	5.9	174.0
$P\ o_{,c,i,d}$: (%)	**Generation**	34.6	36.9	20.1	7.3	2.0	100.0
	Disposal	57.9	0.0	26.4	12.3	3.4	100.0

2.5 One-Week Waste Audit Process

The waste audit was conducted in two weeks in June, 2004, from 6th to 12th June for SaiGon-HaLong hotel and from 15th to 21st June for the CongDoan and TienLong hotels. Some scavengers and hotel staff participated in conducting the waste audit. Prior to auditing, they were provided with necessary training and information in order to manage their tasks for each day of the audit. Also, some necessary equipment and supplies, such as scales, gloves, plastic bags and record sheets, were provided.

An important point to note is that the hotels needed to operate as usual during the waste audit period; thus the audit process was flexible and depended on the waste disposal route and time schedule. For waste from office and guest rooms, housekeeping staff were asked to place all the waste that they collected from the rooms to the storage areas at their convenience. At the end of the day, black plastic bags with white labels identifying the different categories of waste were provided and two scavengers started sorting waste into the categories shown in Table 2.3. After sorting, each bag of waste was weighed and recorded (see Picture 2.3).

Since kitchen waste is generally wet and sticky, it is very difficult to sort when the wastes are well-mixed. To avoid this problem, the kitchen wastes were kept separately by providing labeled baskets or plastic bags for each category, and placing them at convenient location where staff could easily put waste in the appropriate baskets or plastic bags. Sorted kitchen and restaurant waste was normally weighed twice per day, after breakfast and dinner time, since kitchen waste must be disposed of right after processing due to quick biodegradation of compostables. Yard waste was sorted into its three categories (leaves, glass clippings and miscellaneous), and each of these was placed in a black plastic bag. After being gathered in the waste storage sites, the bags were weighed at the end of the day.

Picture 2.3 Waste from Guest-rooms (left) and Kitchen (right) are Sorted at SG-HL Hotel

2.6 Results, Analysis, and Discussions

2.6.1 Quantity Estimation

The waste quantity data gathered from the three hotels during the one week audit period are shown in Table A1, A2, and A3. To interpret the relationship between the amount generated or disposed with time and the number of overnight guests, various statistical analysis procedures were employed, including measures of central tendency, measures of dispersion, and confidence intervals. Measures of central tendency are concerned with the average (or mean) value of the set of the data; for example, the average amount of waste generated per day. However, since the mean value does not show how the individual data vary around the mean, measures of spread of the data are employed, including standard deviation and range. Finally, the confidence interval for a mean gives the range of values around the mean where we expect the "true" mean is located. To summarize and graphically illustrate the various measures of the central tendency and dispersion of the data, Box-Whisker plots were also used. Figure 2.1 shows the Box-whisker plots for the waste amount generated in the three hotels. All mathematical calculations of the data and explanations on how to interpret all statistical measures and the Box-whiskers plots can be found in Appendix A4.

Table 2.5 summarizes the daily waste quantities, both generated and disposed, for each hotel during the one-week audit period. The table also shows the results of the statistical analysis procedures. The amount of waste generated fluctuated over the one week period. For example, about 356 kg of solid waste was generated in SaiGon-HaLong hotel on day 1 (Sunday). This amount considerably increased to 479 kg on day 2 (Monday); then decreased gradually to 292 kg on day 4 (Wednesday). It steadily rose to 437 kg on the last day of the audit. The same pattern was also found in TienLong hotel. The trend of the generation rate in CongDoan hotel was different since the amount of waste generated increased from 184 kg to 209 kg during the first four days; however, it decreased considerably (by over 20%) over the last four days. Another important feature from Table 2.5 to note is that the range of waste generated each day for all three hotels is quite large: from 292 kg to 479 kg for SaiGon-HaLong hotel, from 163 kg to 209 kg for CongDoan hotel, and from 112 kg to 173 kg for TienLong hotel. The table also shows that the SaiGon-HaLong hotel was the biggest waste generator, with the average generation rate of 359 kg per day. This was two times larger than that of the CongDoan hotel (182 kg/day) and nearly three times if compared with that of the TienLong hotel (137 kg/day). This can be seen clearly in the Box – Whiskers plot shown in Figure 2.1. Correspondingly, the standard deviation for the SaiGon-HaLong hotel was much higher than those for two other hotels. This means that the daily amount of waste generated by SaiGon-HaLong hotel was more fluctuant and dispersed from the average amount. These fluctuations were mainly because the amount of waste per day is dependent on the number of overnight guests, which will be discussed later in this section.

Table 2.5 Quantities of Waste, both Generated and Disposed, for Each Hotel during One Week Audit

Name of Hotel		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	One-week Audit				
									Mean	STDEV	Range		95% CI of mean
											Min	Max	
SaiGon-Halong	*Generation Rate*	*355.6*	479.4	304.1	292.1	299.8	345.1	*437.3*	359.1	72.8	292.1	479.4	291.7 to 426.4
	Disposal rate	*198.3*	328.8	194.2	136.6	144.7	194.0	*226.4*	203.3	63.7	136.6	328.8	144.4 to 262.2
CongDoan	*Generation Rate*	*184.1*	*173.4*	170.2	208.8	169.2	208.3	163.1	182.4	18.9	163.1	208.8	164.9 to 199.9
	Disposal rate	*114.6*	*105.6*	101.8	141.6	100.5	144.3	91.6	114.3	20.7	91.6	144.3	95.1 to 133.5
TienLong	*Generation Rate*	*133.4*	*172.7*	119.5	151.7	112.3	126.1	144.8	137.2	20.8	112.3	172.7	118.0 to 156.5
	Disposal rate	*81.4*	*123.1*	76.4	102.6	68.3	77.1	95.8	89.2	19.1	68.3	123.1	71.6 to 106.9

In Table 2.5, the disposal rate is also included. This rate is of particular interest since it reflects the actual amount of waste from hotels that is discharged to the environment. As can be seen in the table and from the Box-whiskers plot (Figure 2.2), the SaiGon-HaLong hotel disposed the largest amount of waste with the average disposal rate of 203 kg per day, followed by the CongDoan hotel with 114 kg per day, and the TienLong hotel with 89 kg per day. As a result, the ratios of disposal rate to generation rate[1] for three hotels are 57%, 63%, and 65% respectively. Almost all recyclables, such as plastics and paper from staff and guest rooms in SaiGon-Halong hotel were collected for selling by two cleaners who are not paid for cleaning the storage area and transporting waste, but allowed to collect recyclables from waste stream in the hotel. As discussed previously, recyclables from two other hotels were also sorted by house keeping staff, but in the informal way; therefore, they often did not have time to do a thorough job.

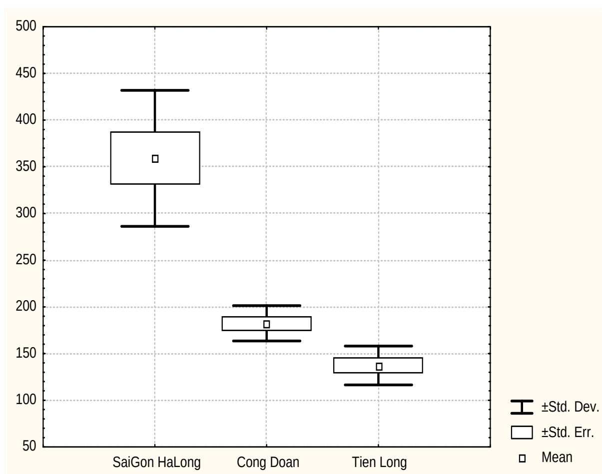


Figure 2.1: Box-Whiskers Plots of Waste Weight Generated per Day for Each Hotel

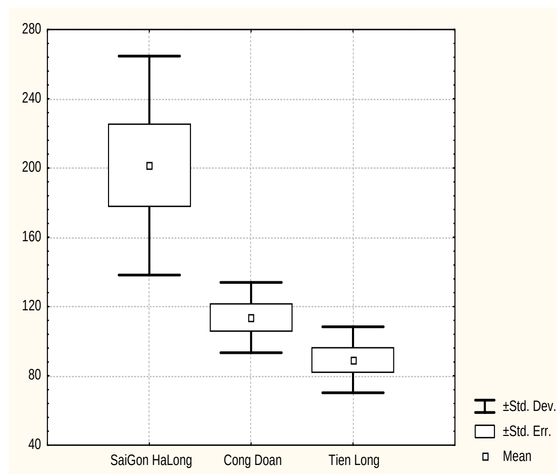


Figure 2.2: Box-Whiskers Plots of Waste Weight Disposed per Day for Each Hotel (kg/day)

As discussed earlier, hotel waste generation can be affected by the number of guests staying in the hotel. To account for this, Table 2.6 shows the amount of waste generated and disposed per guest per day at the three hotels, called "guest-based generation rate and disposal rate". The number of overnight guests can be found in Table A.5a and Table A.5b.

SaiGon-Halong hotel, again, had the highest average guest-based generation rate; on average, each guest produced 0.90 kg per day. TienLong hotel was followed with the rate of 0.81 kg/guest/day and 0.69 kg/guest/day for CongDoan hotel. However, in terms of the average guest-

[1] $\frac{203.3}{359.1}*100\% = 56.6\%$; $\frac{114.3}{182.4}*100\% = 63\%$; $\frac{89.2}{137.2}*100\% = 65\%$;

based disposal rate, SaiGon-HaLong and TienLong had similar amounts of approximately 0.5 kg/guest/day, while 0.43 kg was the average amount of waste disposed by a guest in CongDoan hotel. With only few exceptions, over the one-week audit period, the average generation rate was quite constant. For the SaiGon-Halong hotel, the amount of waste generated and disposed on the second day was over 1.5 times higher than that on other days.

Table 2.6 Waste Generated and Disposed per Guest per Day

Name of Hotel		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average*
SaiGon Halong	Generated	0.83	1.42	0.89	0.85	0.79	0.71	0.90	0.90
	Disposed	**0.46**	**0.98**	**0.57**	**0.40**	**0.38**	**0.40**	**0.47**	**0.51**
Cong Doan	Generated	0.63	0.70	0.55	0.76	0.63	0.83	0.75	0.69
	Disposed	**0.39**	**0.43**	**0.33**	**0.52**	**0.38**	**0.58**	**0.42**	**0.43**
Tien Long	Generated	0.77	1.04	0.78	0.67	0.56	1.07	0.99	0.81
	Disposed	**0.47**	**0.74**	**0.50**	**0.45**	**0.34**	**0.65**	**0.65**	**0.53**

Note: * the average guest-based amount is determined by Equation 2.3a (2) and 2.3b (2).

Some possible explanations for these results are as follows. First, the amount of waste generated or disposed could have been dependent on guests' nationality and purpose for staying in the hotel. According to some house-keeping staff, tourists from China, Taiwan, Vietnam and other Asian countries often bring food and groceries with them; therefore a greater amount of packaging and food waste can be found after those guests checked out. However, guests from Europe or North American bring far less luggage while traveling. Also, guests traveling for business often carry less than tourists; thus often producing less waste. Another reason may be due to hotel rating. The four-star hotel, SaiGon Halong, does not allow its staff to collect recyclable; in particular, leftovers from the kitchen, even when they are still fresh, must be discharged due to so-called "health safety". However, staff in the TienLong and CongDoan hotels was encouraged to preserve leftovers for their own use. Lastly, all three hotels organize workshops or conferences if required. Participants of those events simply come to attend and have meals, but they also generate waste. As a result, some waste collected was not produced from overnight guests.

2.6.2 Composition Estimation

The percent composition of both wastes generated and disposed of are calculated and shown in Table 2.7 and Table 2.8 (detailed information, such as composition-based weight, is described in Appendix A, from Table A6 to Table A11). As mentioned in Section 2.4, there are three main categories, including compostables, recyclables, and miscellaneous, and each category can be used for different purposes. Compostables and recyclables are value feedstock for composting and recycling processes respectively, while miscellaneous is often disposed of into landfills since it has no or little value.

Table 2.7 summarizes the generation-based composition of the daily waste generated by each hotel. Based on a visual comparison, there appear to be no obvious or important differences in the average percent composition among three hotels. Compostables was the largest portion of the waste stream, accounting for more than 70%. This is followed by miscellaneous, with the percentage ranging from 15% to 22 %. In the SaiGon Halong hotel, for example, about 75% of waste generated per day was compostables, while recyclables made up 10%. Waste from two other hotels contained lower proportion of recyclables but the same portion of compostables.

Table 2.7 Generation-based Composition of Solid Waste in Hotels, HaLong

Location	Material Category	Day 1 %	Day 2 %	Day 3 %	Day 4 %	Day 5 %	Day 6 %	Day 7 %	Average* %
SaiGon-HaLong	*Compostables*	*81.9*	72.6	*73.7*	*80.9*	*64.9*	*73.7*	*75.1*	***74.7***
	Recyclables	*11.9*	10.5	*12.6*	*6.0*	*15.9*	*9.3*	*9.4*	***10.7***
	Miscellaneous	*6.2*	16.9	*13.7*	*13.1*	*19.2*	*17.0*	*15.5*	***14.6***
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CongDoan	*Compostables*	*81.7*	*75.4*	*73.2*	*77.7*	*76.3*	*67.7*	*67.0*	***74.2***
	Recyclables	*3.7*	*3.7*	*4.8*	*3.5*	*7.8*	*13.5*	*10.5*	***6.8***
	Miscellaneous	*14.6*	*20.9*	*22.0*	*18.8*	*15.9*	*18.8*	*22.5*	***19.0***
	Total	***100***	***100***	**100**	***100***	***100***	***100***	***100***	***100***
TienLong	*Compostables*	*63.7*	*84.0*	*73.2*	*75.1*	*66.1*	*71.5*	*73.5*	**73.1**
	Recyclables	4.0	*2.4*	*6.3*	2.0	16.1	2.3	*3.0*	***4.7***
	Miscellaneous	32.3	*13.6*	*20.5*	22.9	*17.8*	*26.2*	*23.5*	**22.2**
	Total	***100***	***100***	**100**	***100***	***100***	***100***	***100***	***100***

Note: * the average generation-based composition is determined by Equation 2.4 (2)

However, there are some fluctuations in daily composition over the one-week audit period. For instance, on day 1, 12% of waste generated in SaiGon-Halong hotel was recyclables while only

6% was found on day 4. The same variation was also true for other categories. Based on discussion with hotel staff and waste scavengers, and audit results, the daily composition of the waste generated by any hotel in any one audit day might be influenced by:

- The number of guests staying and having meal in hotels. For example, more compostables are produced if more guests order meals in the hotel.
- Cooperation of hotel staff in reporting the amount of recyclables they collect. For example, on the second day in SaiGon –HaLong Hotel, there was no glass or metal collected. However all three hotels have restaurants that would generate glass and metal wastes from beverage containers. From informal interviews with some hotel staff, it was revealed that housekeeping staff and bar/restaurant servers usually take metal items since they are easy to be flattened and placed into small bags. Also, glass items, such as beer bottles, are taken to be sold back to manufacturers.

The disposal-based composition of the waste disposed of by each hotel is described in Table 2.8 Compostables were still the largest portion of the waste stream, accounting for 60% or 70%. Miscellaneous, with the average percentage ranging from 26% to 34 %, gained the second-place. It can be seen that, in SaiGon-HaLong hotel, most recyclables were removed from the waste stream before it was disposed of; no recyclables were found on the last four days. On the contrary, the average percentage of recyclables in waste disposed of by both CongDoan and TienLong hotels increased to 9 % and 7% respectively, mainly because the large proportion of compostables was collected for animal feeding. Similar to the daily generation-based composition, there are fluctuations in daily disposal-based composition over the one-week audit period, as shown in Table 2.8. The reasons for these fluctuations could be the same as those mentioned for generation-based composition.

2.6.3 Compostables Quantification and Composition

One of the most important pieces of information for a composting facility is the quantity and composition of compostables (Table 2.9); therefore, a closer examination of compostables was conducted. As discussed in Section 2.4, compostables were divided into seven sub-categories: leftover food, fruit waste, flower waste, vegetable waste, yard waste (including leaves and glass clippings), egg shells, and seafood waste. However, based on hotel observation and audit results, the amount of flower, egg shells, and seafood waste was negligible. Hence, these three sub-categories were placed into one category, named “others”.

Table 2.8 Disposal-based Composition of Solid Waste in Hotels, HaLong

Location	Material Category	Day 1 %	Day 2 %	Day 3 %	Day 4 %	Day 5 %	Day 6 %	Day 7 %	Average* %
SaiGon-HaLong	*Compostables*	87.8	72.9	77.1	72.0	60.2	69.7	73.2	**73.3**
	Recyclables	1.1	2.5	1.5	0.0	0.0	0.0	0.0	**0.9**
	Miscellaneous	11.1	24.6	21.4	28.0	39.8	30.3	26.8	**25.8**
	Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CongDoan	*Compostables*	72.0	61.9	55.6	67.2	61.1	54.1	47.7	**60.4**
	Recyclables	4.6	3.7	7.6	5.1	12.1	18.7	12.1	**9.3**
	Miscellaneous	23.4	34.4	36.8	27.7	26.8	27.2	40.2	**30.3**
	Total	***100***	***100***	**100**	***100***	***100***	***100***	***100***	***100***
TienLong	*Compostables*	40.5	78.0	60.9	63.3	45.7	53.4	59.9	**59.3**
	Recyclables	*6.5*	2.9	*7.1*	*2.7*	*25.0*	*3.8*	*4.6*	***6.6***
	Miscellaneous	53.0	*19.1*	*32.0*	34.0	*29.3*	*42.8*	*35.5*	**34.1**
	Total	***100***	***100***	**100**	***100***	***100***	***100***	***100***	***100***

Note: * the average deposition-based composition is determined by Equation 2.5 (2)

The total amount of compostables generated and disposed by the three hotels is summarized in Figure 2.3. SaiGon-HaLong hotel, with the average compostables quantity of 268 kg, was the biggest producers, whereas 135 kg and 100 kg of compostables were generated by CongDoan and TienLong hotel respectively. However, after most leftover food and some vegetables were collected for animal feeding, only about 50% of compostables were disposed of into the environment, and this amount would be seen as a potential source for the composting trial.

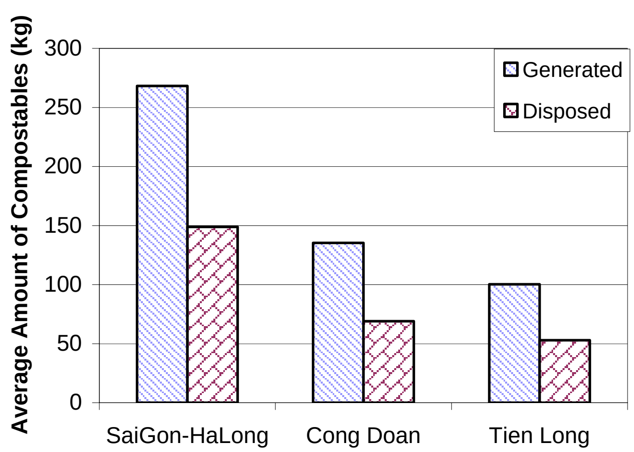


Figure 2.3 The Average Amount of Compostables Generated and Disposed by Hotels.

Table 2.9 Composition of Compostables

Location	Categories of compostable waste		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average*
			%	%	%	%	%	%	%	%
SaiGon-HaLong	Fruit waste	*Generated*	34.6	42.2	29.8	20.0	26.7	31.7	29.8	31.6
		Disposed	**57.9**	**61.4**	**44.7**	**48.0**	**59.7**	**59.5**	**61.8**	**56.8**
	Leftover food	*Generated*	36.0	38.4	31.4	58.4	55.2	46.8	52.1	45.0
		Disposed	**0.0**	**30.0**	**1.9**	**0.0**	**0.0**	**0.0**	**0.6**	**7.3**
	Vegetable waste	*Generated*	20.1	14.9	26.1	9.5	11.6	12.8	13.9	15.5
		Disposed	**26.4**	**2.1**	**34.4**	**22.9**	**25.8**	**24.0**	**28.9**	**21.6**
	Yard waste (leaves and glass clippings)	*Generated*	7.3	2.0	6.6	11.4	2.4	7.7	2.6	5.5
		Disposed	**12.3**	**2.9**	**9.8**	**27.5**	**5.3**	**14.6**	**5.4**	**9.9**
	Others (egg shells, seafood, flower)	*Generated*	2.0	2.5	6.1	0.7	4.1	1.0	1.6	2.4
		Disposed	**3.4**	**3.6**	**9.2**	**1.6**	**9.2**	**1.8**	**3.3**	**4.4**
CongDoan	Fruit waste	*Generated*	27.9	35.3	28.6	31.8	24.3	31.2	23.1	29.1
		Disposed	**50.9**	**70.5**	**62.9**	**54.2**	**51.1**	**56.3**	**57.7**	**57.1**
	Leftover food	*Generated*	33.9	41.3	42.4	31.3	39.9	36.6	48.5	38.5
		Disposed	**1.2**	**3.8**	**1.4**	**0.7**	**1.6**	**0.8**	**2.3**	**1.6**
	Vegetable waste	*Generated*	25.2	17.4	17.9	28.7	28.8	20.3	21.5	23.1
		Disposed	**24.2**	**13.8**	**11.1**	**31.1**	**32.6**	**21.4**	**22.9**	**23.0**
	Yard waste (leaves and glass clippings)	*Generated*	3.1	3.1	4.5	3.1	3.5	4.0	2.9	3.5
		Disposed	**5.7**	**6.1**	**9.9**	**5.3**	**7.3**	**7.2**	**7.3**	**6.8**
	Others (egg shells, seafood, flower)	*Generated*	9.8	2.9	6.7	5.1	3.5	7.9	3.9	5.8
		Disposed	**17.9**	**5.8**	**14.7**	**8.7**	**7.3**	**14.3**	**9.8**	**11.5**
TienLong	Fruit waste	*Generated*	12.7	2.0	14.2	24.8	10.0	4.9	25.1	13.2
		Disposed	**32.7**	**3.0**	**26.7**	**43.6**	**23.7**	**10.7**	**46.5**	**25.1**
	Leftover food	*Generated*	61.2	33.8	40.3	37.0	61.3	48.1	50.0	45.7
		Disposed	**0.0**	**0.0**	**0.6**	**0.3**	**8.0**	**3.4**	**7.3**	**2.3**
	Vegetable waste	*Generated*	2.4	6.6	18.7	14.1	12.4	22.2	10.3	12.0
		Disposed	**6.1**	**9.9**	**22.4**	**13.9**	**29.5**	**31.6**	**19.2**	**17.4**
	Yard waste (leaves and glass clippings)	*Generated*	21.2	57.0	23.7	24.0	14.8	19.1	9.4	26.6
		Disposed	**54.5**	**86.1**	**44.5**	**42.2**	**35.3**	**41.7**	**17.4**	**50.5**
	Others (egg shells, seafood, flower)	Generated	2.6	0.6	3.1	0.0	1.5	5.8	5.2	2.5
		Disposed	**6.7**	**0.9**	**5.8**	**0.0**	**3.5**	**12.6**	**9.6**	**4.7**

Note: * the average percent composition of compostables is determined by Equation 2.6 (2)

In addition, as seen in Table 2.9, among compostables generated by the hotels, leftover food accounted for the largest percentage at around 40% to 45%, followed by fruit waste, vegetable waste, and yard waste. However, since most of leftover food was collected by pig raisers, the amount of leftover food present in disposed compostables is extremely low, only 2% to 7%. Therefore, the main categories of compostables in the disposed waste are fruit waste, vegetable waste, and yard waste. This conclusion may help hotel composters set up a desired feedstock recipe for composting processes.

2.7 Conclusions

The solid wastes from three hotels in BaiChay were collected, separated and weighed over the one-week period. The quantities and composition of both generated and disposed wastes were estimated. Key findings that relate to the composting of the organic component are:

- The average amount of waste generated in each hotel ranged from about 140 to 360 kg/day.
- After removal of some recyclables and leftover food, the average amount of waste disposed ranged from about 90 to 200 kg/day. Thus, approximately 35% to 45% of the waste was recycled or reused.
- The amount of waste generated per guest ranged from about 0.7 to 0.9 kg/guest/day. Also, if these amounts were based on the disposal rate, they dropped to around 0.4 to 0.5 kg/guest/day.
- Of the amount generated, approximately 75% was compostables and 5% to 10% were recyclables. However, after some recyclables and leftover food were collected for selling and feeding pigs, the percentage of compostables in the disposed waste reduced to about 60% to 70%. The main categories of the disposed compostables were fruit waste, vegetable waste, and yard waste.
- The three hotels disposed a total of approximately 250 kg of compostables per day, which could be available for the composting trial if separated from the noncompostables. The composting trial is described in the next chapter.

CHAPTER 3
COMPOSTING TRIAL

There is no existing composting facility in HaLong, Vietnam. The main approach to solid waste management is disposal into two landfills: DeoSen and HaKhau. However, through some discussions with the author, BaiChay Urban Environmental Company (Urenco) and other local institutions were considering establishing a small-scale compost facility at the HaKhau landfill with the expectation that few compostables would enter the landfill. Nevertheless, lack of knowledge on compost production and facilities prevent them from doing this. In addition, after the objectives of the study had been discussed with some hotel managers, it became clear that none of them were familiar with the composting process and its benefits, and they also recognized that some problems, such as odours, rodent attraction, and leachate, may affect their business if composting piles were established inside or near their hotels. Therefore, in order to test composting and show a composting facility to potential participants, a composting trial was conducted as part of this study. It would also serve as a training center for those who would develop and work in a permanent compost plant. The success of the composting trial could also help gain the awareness of the public and other hotels.

3.1 Description of Composting Trial

The composting trial was located within the administration area at HaKhau landfill, HaLong City. The overview of HaKhau landfill can be seen in Picture 3.1. The selected site was temporary and closed after the study was completed on August 29th, 2004. This location was chosen for the following reasons:

- The distance to the closest residential area is approximately 200m, therefore minimizing the effects of the compost facility to surrounding residents.
- Since waste from hotels is transported by Urenco's trucks to the landfill, there would be no additional cost for transportation of source-separated compostables from the three selected hotels to the landfill.
- There would be no cost for the use of the site.
- Urenco's staff at the landfill could participate in operating and monitoring the compost process on a daily basis.
- The existing roof could be used to protect the compost workers and compost facility from the excessive rain and sun during the hot and wet weather.

Picture 3.1 a. Overall Picture of Ha Khau Landfill (left) and b. Selected Site for Compost Facility (right)

The facility was approximately 6 meters by 5 meters, which is the minimum space required for different steps of the process. The small building at the landfill (Picture 3.1a) was used to house necessary supplies, including rakes, shovels, watering can, typical amendments like rice hulls, wood chips, coconut shells, and potential finished compost products. The empty area (Picture 3.1b – left side) was used for blending, making, and maturing compost. The facility was built with available materials, including bamboo for making triangular aeration and plastic sheets for fencing. It was necessary to build a fence to keep animals, such as dogs and rats, out of the site.

3.2 Process Steps of the Composting System

The windrow composting system that was used includes the main steps shown in Figure 3.1 and described below. A diary of activities is shown in Table 3.1.

3.2.1 Source Separation and Transport of Compostables to the Site.

Compostables from kitchens and gardens in the three chosen hotels was separated at source by hotel staff. During the waste collection period, three or four separate waste baskets were provided and placed nearby waste sources at each hotel (see Picture 3.2). One contained yard waste, including leaves and tree trimmings, placed in the garden. Other baskets were nearby the food processing places in the kitchen. Fruit waste, such as coconut shells, watermelon and pineapple, and vegetable waste like pot-herbs, spinach, or tomatoes were gathered in different baskets, while non-compostable materials were either kept for selling or disposed at the landfill. At the end of the day, hotel staff brought the sorted waste to storage places where Urban Environmental Company’s trucks would pick up and transport it to the compost facility at the landfill, along with the remaining mixed waste to be disposed in the landfill.

Picture 3.2 Source- separated Compostables are Collected at SaiGon-HaLong Hotel

3.2.2 Blending and Piling

The incoming material was gathered in the paved receiving area. Waste was weighed and recorded before it was cut and blended. For large materials, hand cutting was used to reduce their size to less than 5 cm in order to increase the air exposure area to speed up decomposition. Then, the materials were mixed well with shovels and rakes, and piled up after "resting" for a few hours at the receiving area (see Picture 3.3 - leftside) before adding to the composting pile. During the mixing, non-compostable materials such as plastic bags, gravels, and small pieces of metal were removed to purify the feedstock.

Picture 3.3. Blending (left) and Piling up (right) Organic Waste over Triangular Bamboo Aerator

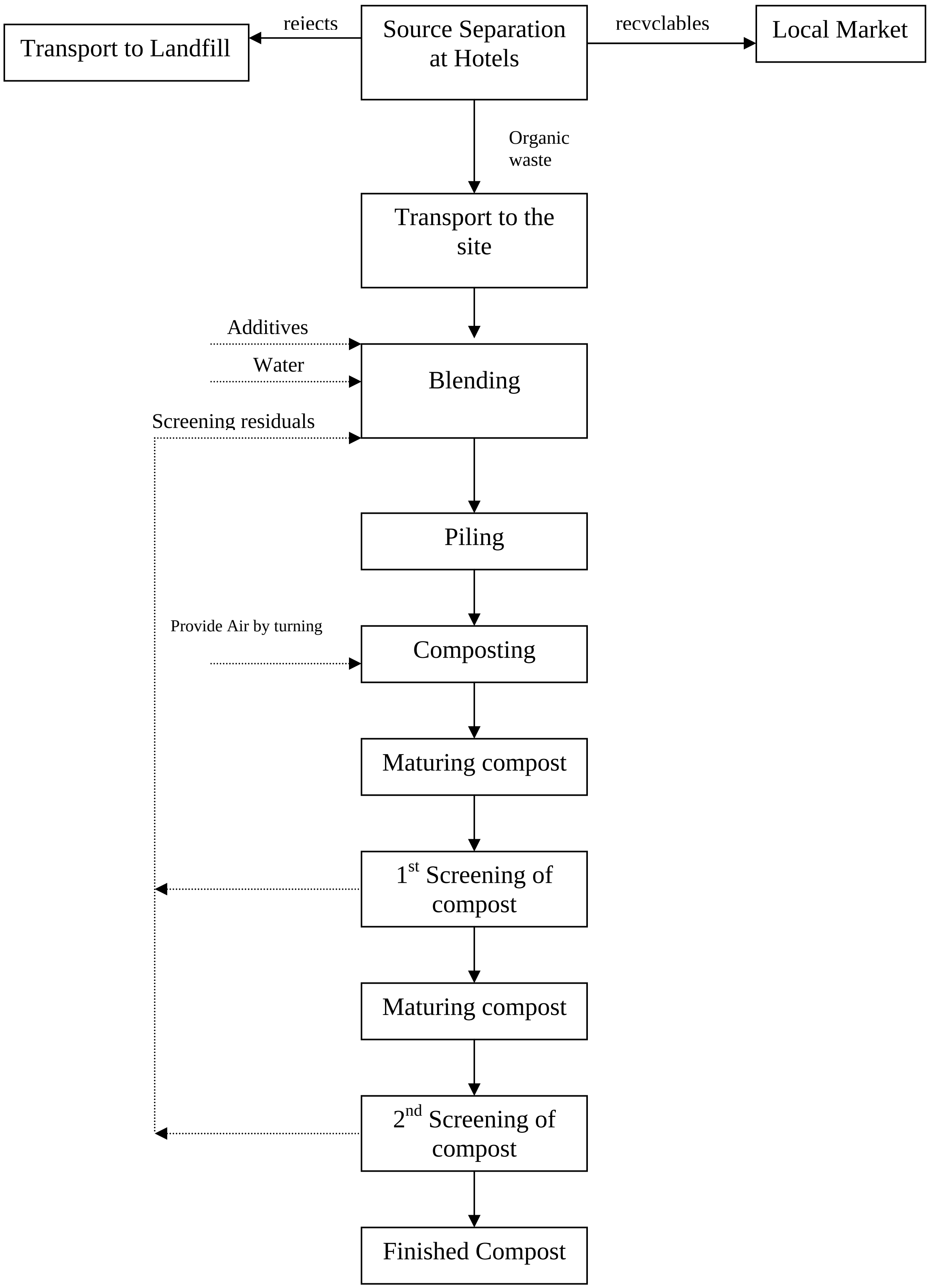


Figure 3. 1 Flow Chart of the Composting Process

Seven days of compostables were added to the compost pile over a 12-day period. Table B.1 shows the detailed record of daily feedstock; there were 340.8 kg of fruit waste, 241.4 kg of vegetable waste, and 62.1 kg of yard waste. No waste was collected and added on several of these days due to the non-cooperation of either hotels or Urenco's staff, poor accessibility of collection bins, and conflicting schedules among participating partners that will be discussed in Section 3.4.

There was concern about achieving appropriate C/N ratio, moisture content, and aeration:

C:N ratio: An efficient composting process needs a C:N ratio with the range of 20:1 to 40:1. According to Rynk et al (1992), the C:N ratio of vegetable ranges from 11:1 to 13:1, that of fruit wastes is 20:1 to 49:1, while yard waste has the ratio of 40:1 to 80:1. Based on calculations displayed in Appendix B.2, the C:N ratio of mixed waste (between wastes from kitchen and garden) collected from hotels ranged from about 21:1 to 38:1 which is within the optimum ratio for composting.

Moisture content and aeration: Waste from the hotels was too wet for composting since its initial moisture content is about 80%; therefore rice hulls were added. Coconut shells were also provided to increase the porosity of the pile. A total of 58 kg of these were added to the process, as shown in Table B.1. These additions are noted in Table 3.1 by the term "adding".

The material was then piled around a bamboo aerator **(**see Picture 3.3 – right side**)** with the dimensions of 1.5m long and 0.5 m high which enabled a favourable aeration. At the end of the first 12-day period, the wastes were remixed carefully to avoid the formation of layers in the pile.

3.2.3 Turning and Monitoring

Since the composting process was aerobic, oxygen was required for the decomposition. If the supply of oxygen is limited, the composting process will slow down. In addition to adding porous materials such as rice hulls and coconut shells, the pile was turned to provide more air to the windrow and spread it evenly within the pile. Also, moisture and temperature can be adjusted by turning.

The turning was conducted manually with shovels and rakes. As shown in the Picture 3.4 (left-side), the materials from the exterior of the old piles must be moved to the interior of a new pile. The pile was also turned occasionally when the average temperature of the piles reach 55^0C or when the moisture content was high. During the second week of decomposition, the composting pile was turned more often (about 3 turnings per week) since the moisture content reached higher than 70% (see Table B.4).

Picture 3.4 Turning the Pile (left) and Temperature Monitoring (right).

Table 3.1 Diary of Composting Trial

Date	Duration (hour)	Task	Date	Duration (hour)	Task
29-Jun	1:00	* Sorting * Blending * Piling	**15-Jul**	0:30	* Turning
30-Jun	1:00	* Sorting * Blending * Adding	**19-Jul**	1:00	* Turning
1-Jul	1:00	* Sorting * Blending * Adding	**24-Jul**	0:30	* Turning
4-Jul	1:00	* Sorting * Blending * Adding	**27-Jul**	0:30	* Turning
5-Jul	1:30	* Sorting * Blending * Adding * Turning	**1-Aug**	0:30	* Turning
7-Jul	1:30	* Sorting * Blending * Adding * Turning	**21-Aug**	1:30	* Screening * Piling
10-Jul	2:00	* Sorting * Remixing * Piling * Turning	**29-Aug**	1	*Screening

The temperature of the pile was recorded daily by a thermometer during the decomposition period while moisture content was tested by hand-squeezing. Composting materials should be about as moist as a wrung-out sponge. If water trickles out without squeezing, the material too wet; if no water can be squeezed out of the handful; it is too dry. However, simply squeezing material is subjective and inaccurate, and it does not provide a quantitative measure of the moisture content. Therefore, some samples were also taken for moisture content determination by the standard method of drying and weighing. The trends of both temperature and moisture content are discussed in Section 3.3, while the detailed records on temperature and moisture content are presented in Table B.3 and Table B.4.

3.2.4 Maturing and Screening

After 37 days of decomposition, the organics changed to a dark colour and had an earthy odour. Then, the pile was left without adding additives or turning for 23 more days of maturing to make sure that the compost was mature and safe for use. .

Picture 3.5 Screening the Finished Compost

After 15 days of maturing, the compost was first screened by a wire mesh screen (opening size of 1 cm with the wooden framework 0.8 m x 1.2 m). The less than 1 cm pieces passed through the screen while the larger pieces (or rejects) were retained. The first screened compost continued to be matured for one more week, at which time it was screened by a 4 mm screen. The fine compost was collected, ground, and stored for quality testing while residuals (the larger pieces of organic material) were kept for other purposes, such as for feedstock of a new composting pile if conducted in the future.

3.3 Evaluation of the Composting Process

This section discusses the mass flow, the trends of temperature and moisture content during the decomposition process. Some chemical parameters, including nutrients (N, P, K), pH, and metal, could not determined during the composting process due to the insufficiency of local laboratory facilities. Although only one pile was used, it was carefully implemented and monitored. Also, because of time limitation, financial aspects were not analyzed in this study.

3.3.1 Mass Flow

Weight reduction during the composting process was precisely calculated. Before materials were mixed, matured, and screened, they were weighed to determine the actual loss of the dry matter and the conversion rate of raw material into compost. That means the output is the fine compost (particle size is less than 4 mm) while larger pieces, called organic residuals, were kept in the store house for further use; for example, it can be used as good feedstock for a new composting pile. Mass flow of the pilot composting pile is displayed in Figure 3.2.

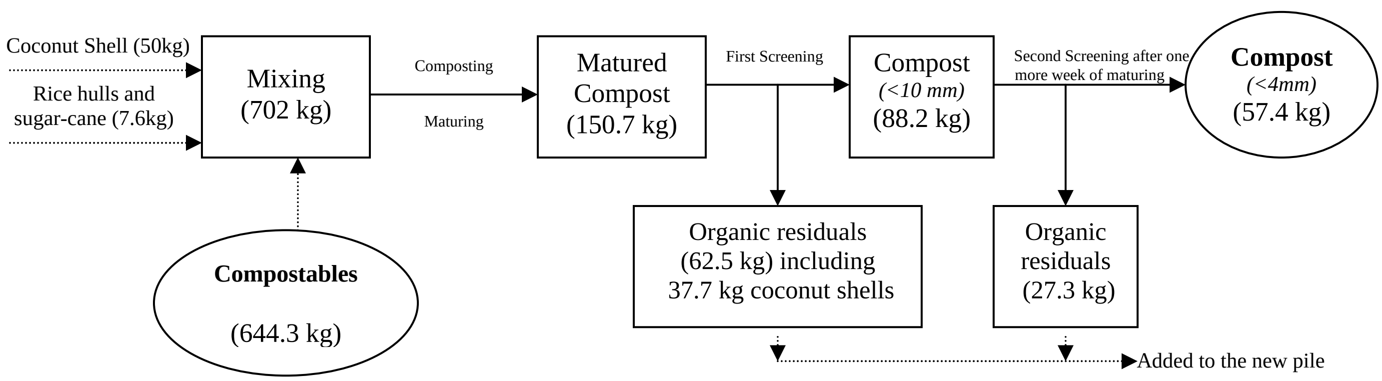


Figure 3.2 Mass Flow of the Composting Pile

After two months of the decomposition and maturing period, the material quantity was about 21%[2] of its initial weight. The loss of material weight is through two following process:

- the formation of carbon dioxide; and
- the volatilization of water. The water content decreased from 83.6% (input) to 46.3% (output)

To evaluate the composting process, the conversion rate is of particular concern. In other words, how much fine compost, which is ready for use, can be produced from one ton of compostables.

---

2 $= \frac{57.4 + 27.3 + 62.5}{702} * 100\%$ *if including organic residuals*

In theory, organic waste, sooner or later, will be completely composted to fine product; nevertheless, it will take a longer time for large and rigid pieces. However, in the scope of the composting trial, only fine compost produced during the two month trial was considered product. The conversion rate of the composting trial was 8.9%[3]; based on this, 89 kg of compost would be produced from one ton of raw compostable waste.

3.3.2 Trends of Temperature

Temperature measurement was taken in the morning to examine the composting process; thus, problems with the temperature being too low or the pile overheating were solved quickly, as required. Also, measurements were taken at two different locations of the pile since temperature can vary within the pile. The detailed temperature readings are shown in Table B.3.

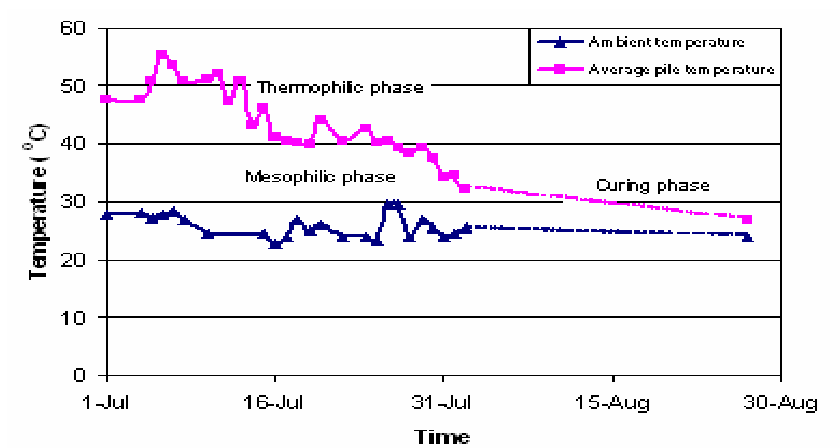


Figure 3.3 Temperature Curve of the Composting Pile

The average pile temperatures and the ambient air temperatures are shown in Figure 3.3. The drops in temperature are caused by either turnings or the reduction of ambient air temperature. The decomposition process can be divided into two main phases that are based on the temperature of the composting pile. During the preliminary and intensive decomposition process, high temperature was achieved within a relatively short period of time and easily decomposed compostable materials were converted; this period is named the themorphilic phase (>40^0C). The whole phase lasted only 26 days, during which temperatures of more than 50^0C were maintained over seven days. The second phase, the mesophilic phase (20-40^0C), lasted for another 33 days. During this phase, the less easily decomposed materials are broken down and clay-humus complexes are formed; the result is matured compost (Dulac, 2001; Haug, 1993; Satriana, 1974).

---

3 $= \frac{amount\ of\ fine\ compost}{amount\ of\ compostables\ (excluded\ additives)} = \frac{57.4}{644.3} * 100\%$

One important thing to note is that the above temperature conditions were not ideal, since the temperature of the pile was not high enough (for example, a minimum temperature of 55^{0}C over an unbroken period of two weeks, or 65^{0}C over 1 week) needed to kill pathogens (CCME, 2000; Epstein, 1997; Tchobanoglous and Vigil, 1993). Unlike other facilities with addition of animal dung or septic sewage, the pilot composting pile consisted of only compostables from "clean sources" at hotels, such as the kitchen and garden. Also, the collected waste was sorted at source and transported separately to the operation site. Nevertheless, the composting pile may have been infected by pathogenic organisms since the operation site was located next to the landfill which receives mixed solid waste everyday. Hence, pathogenic indicators of finished compost, such as E-coli, were tested, as explained in Chapter 4.

3.3.3 Trends of Moisture Content

The change in moisture content of the material is very dependent on the volatilization of water and the formation of leachate during the composting process. The simple "hand squeezing" test was carried out frequently to ensure the optimum environment for micro-organisms. Nevertheless, some samples for moisture content determination in a laboratory were taken, usually after turning.

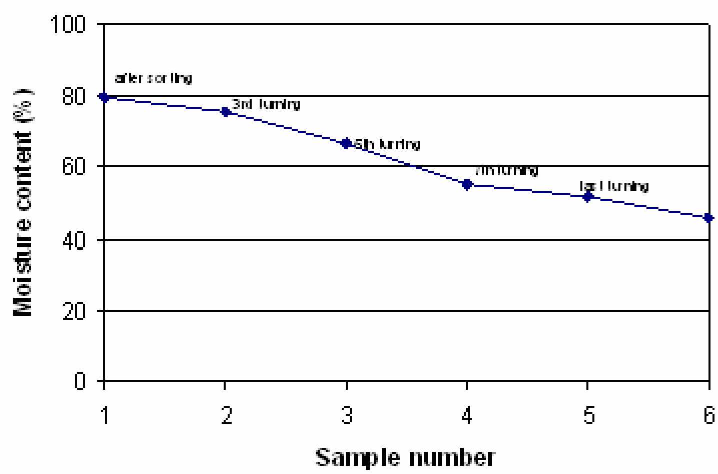


Figure 3.4 Trends of Moisture Content

As seen in Figure 3.4, the initial moisture content of the raw material (source-separated from hotels) was about 80% which is considered too wet for composting; thus more rice hulls or dried sugarcane refuse and frequent turning were provided until the moisture reached the optimum range of 40-65%. In addition, a steel roof protected the pile from the excessive rain since the trial was carried out during the wet season, and the air moisture was always higher than 80%. For these reasons, no water was added during the process. After the fifth turning, the moisture content reduced to about 67% and then to about 52% before the compost pile was cured.

3.4 Problems and Troubleshooting

This section discusses some concerns and problems that arose when planning and during the composting trial, and solutions that were applied. Problems expressed by involved partners were:

Problems at hotels

- No fixed time collection; since Urenco's trucks sometimes came in the very early morning (4:00 am), but sometimes in the afternoon (4:30 pm);
- Difficulties in separating waste at sources and poor accessibility of collection bins; and
- Waste falls down from the bins when moved to the trucks.

Problems at the compost facility

- Odour is emitted from the composting site;
- Leachate runs from the pile; and
- The high level of flies.

To minimize these problems, various solutions were provided and some gained encouraging results. For the unsatisfactory collection system, the pilot project worked with the leaders of BaiChay Urban Environmental Company to improve the collection schedule. The company agreed to go to hotels at a fixed time in the afternoon (from 4:00 pm to 5:00 pm). Staff at hotels could move their sorted waste to the receiving place before that time. Also, some eighty-liter bins covered with plastic bag were provided and placed in the kitchen at the staff's convenience. Therefore each day, bags of waste, rather than the bins, were moved from the kitchen to the truck collection place.

For the problems caused by the composting process, the pilot project and staff at the landfill deliberated about whether the odour was coming from the composting pile or the landfill. While the answer was not clear, some steps were taken to mitigate odours from composting. Initially, materials were blended with additives, such as rice hulls and sugarcane waste to avoid anaerobic conditions within the compost pile for long periods of time. Also, the use of the bamboo triangular aerator and pile turning allowed the compost pile to receive air to maintain the aerobic process. In addition, to allow leachate to run off and be collected, a layer of sand covered with a plastic sheet with a minimum 2% slope was constructed under the pile. The existing roof prevented rainfall from getting in the pile. The frequency and timing of turning was also adjusted to help:

- Replenish oxygen in the interstitial air spaces;
- Remove excess water vapour, odours and other gasses; and
- Disrupt the fly breeding cycle by transferring ova and larvae from cooler surface layers to the hot core zone where they are thermally destroyed.

3.5 Conclusions

The composting trial was widely accepted and appreciated by many local institutions and local residents from its beginning to the end. Generally, local people, including hotel and urban environmental company staff, actively participated in establishing, operating and controlling the compost facility. Administrative organizations in QuangNinh, such as the Department of Resources and Environment kept a positive attitude to the pilot project due to some positive results that can be seen from the pilot, including:

- The simple technology of compost production (windrow composting system) was readily applied using materials, including compostables and additives, which were available in the local area.
- The length of a full composting process is about two months.
- The large volume of waste reduced after decomposition with the conversion rate of 8.9%. Therefore, composting is an environmentally friendly approach to reduce waste; not only because there is a nearly 79 %[4] reduction in weight of waste after two months, but also because some fine compost is produced from this process.
- Common problems, which arose from high moisture content, odours, and overheating, can be fixed by turning and addition of dry material, such as sugar-cane waste and rice hulls, which are available in HaLong City.

Since the quality of compost is of concern among involved people, the pilot project tested the quality of the compost as explained in the next chapter.

4 $= \frac{(input - output)}{input} = \frac{702 - (57.4 + 27.3 + 62.5)}{702} * 100\%$ *if including organic residuals*

CHAPTER 4

STANDARDS AND TESTING OF COMPOST QUALITY

This chapter, first, presents information on compost quality standards in some countries around the world, including Canada, the United States, Australia, and some European countries, and the approach to compost quality control in Vietnam. Then, the analysis and results of the quality of the compost produced by the trial are presented in relation to recognized compost standards.

4.1 Review of Compost Quality Standards in Europe, North America, and Australia

There are many success stories on composting in Europe or North America (Haug, 1993; IIA, 2000); however, consumption capacity of compost in many countries has been very low. Many studies (Hansen, 1996; Hoornweg et al., 1999; and Gray-Donald, 2002) have concluded that the poor quality of finished compost that does not meet the market's requirement is one of the common reasons for this. Therefore, to protect both the environment and consumers, as well as to promote the composting industry through the production of high-quality compost, some countries have established requirements (regulations, guidelines and standards) for both the composting process and the compost quality. In the Australian Standards for Composts, Soil Conditioners and Mulches published in 1999, the stated objective of the standard is

> *'to provide manufacturers, local government bodies, consumers and growers with the minimum requirements for the physical, chemical and biological properties of composts, soil conditioners and mulches as well as labelling and marking requirements, in order to facilitate the beneficial recycling and use of organic materials with minimal adverse impact on the environment and public health.' (Hogg, Barth et al., 2002b).*

Concepts of compost quality and compost testing standardization were essentially unknown worldwide as recently as 1985. In particular, the increasing public awareness and the active involvement of health regulators and other stakeholders have promoted the introduction of compost quality standards and regulations (Brinton, 2000). There are three basic approaches to develop regulations that relate to product use: no-net degradation approach, risk-based approach, and best-achievable approach (Epstein, 1997). The no-net degradation concept is based on the premise that application of compost should not increase the level of a heavy metal or other contaminants in the soil (Epstein, 1997). However this approach raises some controversial questions, such as what base levels should be used since soil quality varies greatly within a small area. For example, soil within industrial areas may contain much higher levels of heavy metals than agricultural areas. As a result, regional standards have to be based on differences in soil quality. The risk-based approach takes the potential risk to individuals and the environment into account, while the best-achievable approach considers technology and economic aspects, rather than health and environment. In practice, the first two approaches, no-net degradation and risk-based, are the two principal methods used to set regulations.

There are no universal criteria for compost quality around the world. However, compost quality assessments that have evolved in different places address the following five main categories which are discussed below:

- Maturity;
- Foreign matter;
- Heavy metals;
- Pathogenic organisms; and
- Other characteristics.

4.1.1 Maturity

Maturity is one of the most important indicators used to evaluate the stability and quality of compost since immature product will adversely affect soil and plants. A number of criteria can be used to judge whether or not compost is mature. For example, the Canadian Council Environment Ministry (CCEM, 2000) suggests that the compost is mature if it meets two of the following four sets of criteria (Hogg, Barth et al., 2002c):

- a C/N ratio < *25;*
- an oxygen uptake < *150* mg 02/kg volatile solids per hour; and
- a germination and growth test, using cress *(Lepidium sativum)* seeds and radish *(Raphanus sativus)* seeds, demonstrates an absence of phytotoxic effects.

or

- Compost will not reheat upon standing to greater than 20^0C above ambient temperature; and
- Compost must be allowed to mature for at least 21 days after the thermophilic phase is completed.

or

- Reduction of organic matter must be roughly 60 percent by weight; and
- Compost must be allowed to mature for at least 21 days after the thermophilic phase is completed.

or

- If no other determination of maturity is made, the compost must be cured for a six month period. The state of the curing pile must be conducive to aerobic biological activity. The curing stage begins when the pathogen reduction process is complete and the compost no longer reheats to thermophilic temperatures.

4.1.2 Foreign Matter

Foreign matter is any matter with a dimension exceeding 3 mm that may cause damage or injury to humans and animals during or resulting from its intended use. They can be organic or inorganic constituents such as metal, glass and synthetic polymers (e. g., plastic and rubber). As shown in Table 4.1, each country has different criteria for foreign matter. For the CCEM, the compost must not contain any sharp foreign matter measuring over 3 mm in any dimension and any foreign matter greater than 25 mm, while compost in Sweden must contain less than 0.5% of visible impurities, such as plastics, glass, and metal.

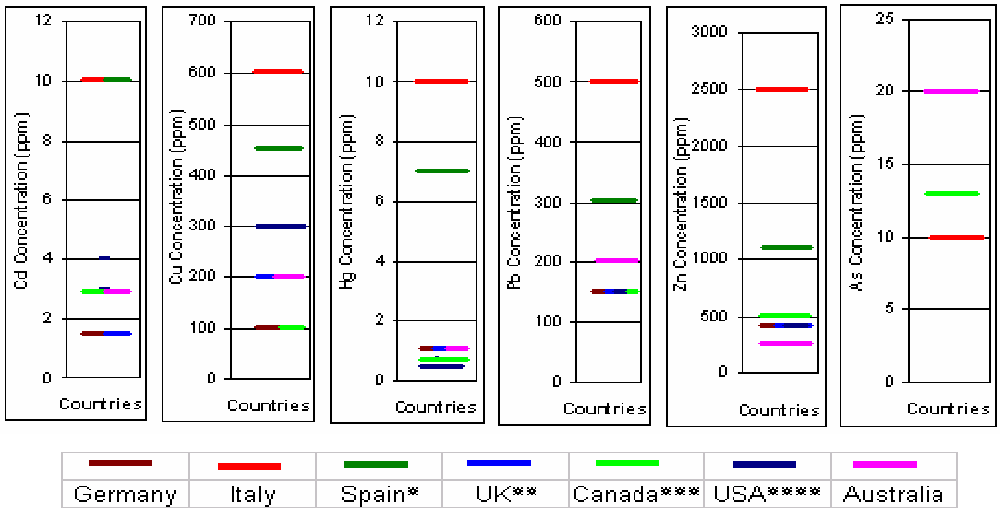
Table 4.1 Standards on Foreign Matter in Some Countries

Countries	Foreign matter	
	Description	%
Australia	Glass, metal, rigid plastics >2mm	≤ 0.5
	Plastics – light, flexible or film >5 mm	≤ 0.5
	Stones and lumps of clay	≤ 0.5
Italy	Inert material	≤ 3
	Glass (≥3mm)	≤ 0.3
	Plastics	≤ 1
	Metals	≤ 0.5
Sweden	Visible impurities (plastics, glass, metal etc.)	≤ 0.5
Canada (CCEM)	Sharp foreign matter measuring over 3mm	0
	Any foreign matter greater than 25 mm	0

Sources: (Hogg, Barth et al., 2002a, 2002b, 2002c, 2002d, 2002e)

4.1.3 Heavy Metals

Compost can contain high concentrations of heavy metals, depending on the sources of the raw materials. If sludge from a mixed industrial-domestic source is used in the compost, concentrations of lead, zinc, and nickel may be very high (Obeng, Wright, 1987). Figure 4.1 shows that there are great differences across countries in the maximum permissible concentration of six heavy metals of concern: lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), Mercury (Hg), and Arsenic (As). For example, the maximum permissible concentration of Zinc in Italy is ten times higher than that in Australia.



Source: Hogg, Barth et al. (2004) & Brinton (2000)

**: Order 28/v/1998on fertilizer B.O.E.n'm.131.2 June 1998; **: Composting Association Quanlity;*

****: BNQ Types AA, CCME Category A; ****: Rodale Organic Seal of Compost Quality*

Figure 4.1 Standards on Heavy Metals in Some Countries

4.1.4 Pathogenic Organisms

Pathogenic organisms are any viruses, bacteria, and other substances capable of causing disease (Epstein, 1997). Since faecal coliforms and Salmonella are of the most difficultly controlled bacteria, they are addressed in the majority of standards. To adequately reduce health risks, most countries that have standards require that the faecal coliform be less than 1000 MPN/g and that Salmonellae be less than 3 MPN/4g or absent in 25 g of compost, as shown in Table 4.2.

Table 4.2 Maximum Level of Pathogens in Composts Offered by Some Countries

Countries	Maximum level of pathogen	
	Salmonellae	Faecal Coliforms
Spain	Absence in 25 g	10^3 MPN/g
Italy	Absence in 25 g	10^3 MPN/g
CCEM	Absence in 25 g	10^3 MPN/g
USA	<3MPN/4g	10^3 MPN/g

Source: (Hogg, Barth et al., 2002a, 2002b, 2002c, 2002d, 2002e & Brinton, 2000)

4.1.5 Other Characteristics

In addition to foreign matter, maturity, pathogenic organisms and heavy metals, other characteristics, such as organic matter, moisture content, nutrients and pH affect compost quality. Some countries require specific characteristics, as shown in Table 4.3. Compost in Australia, for instance, must have a pH of 5-7.5, and a maximum Ammonium concentration of 300 mg/l. However, some countries, such as Spain, Canada, and Sweden, do not set specific limits for these and certain other characteristics, but instead require that the levels simply be declared before the compost is marketed. The measured values recorded in the declaration must be updated during a certain time period and must be in agreement with the average values of the analyses over that time.

Table 4.3 Some Characteristics Required in Standards on Compost Quality

ELEMENT	Unit	Massachusetts USA	Canada (CCEM)	Australia	Spain	Italy	Sweden
pH		5.5-7.5	declared	5-7.5	declared	6-8.5	-
Phosphorous soluble	mg/l	-	declared	≤5 for products which claim to be for phosphorus- sensitive plants. No requirement otherwise.	declared	-	-
Phosphorus total	%	-	declared	≤0.10 for products which claim to be for phosphorus sensitive plants. No requirement otherwise	declared	>0.5	declared
Ammonium	mg/l	-	declared	<300	declared	-	declared
Nitrogen, total	%	-	declared	≥0.8 if a contribution to plant nutrition is claimed	declared	<1	declared
Potassium	%	-	declared		declared	>0.4	declared
Organic matter	%	-	>30	≥25	≥25	≥20	20
Maximum particle size	mm	<25	-	<15	declared	0.5-25	declared
Moisture Content	%	35-55	<60	> 25	> 40	> 40	<50

Source: (Hogg, Barth et al., 2002a, 2002b, 2002c, 2002d, 2002e & Brinton, 2000)

4.2 Standards for Compost Quality in Vietnam

Under the government Decree, No 113/2003/NĐ promulgated in 2003, Ministry of Agriculture and Rural Development (MARD) has the following responsibilities:

- Preside over and combine with other ministries and industries involved in developing plans and policies of fertilizer use and organic fertilizer production;
- Edit and promulgate legal documents, procedures, norms, standards and policies on fertilizer use and organic fertilizer production; and
- Arrange for testing and acknowledge new types of fertilizers each year.

Annually, MARD promulgates the catalogue of fertilizers that are allowed to be produced and distributed within Vietnam's market. This catalogue includes some new types of fertilizers and also excludes some old types that adversely affect production and the environment. As mentioned earlier, Vietnam considers compost as organic fertilizer; however, there are no uniform criteria for it. If a compost producer wants to market its product, it must get approval from MARD by having a sample tested by an authorized institution such as Institute for Soil and Fertilizer or Agriculture Agency. The sample must be tested for certain nutrients (Ammonium, P_2O_5, K_2O), toxicity, including heavy metals (Pb, Hg, Cd, As), and disease causing microorganisms (E. Coli, Salmonella), especially if the fertilizers are produced from municipal waste. After evaluating the test results, MARD will acknowledge the compost as a new type of organic fertilizer. Also, there are no certain standards for compost quality; thus, compost producers have responsibilities for declaring their product quality by providing information on nutrient concentrations (nitrogen (N), phosphate (P_2O_5), potassium (K_2O), organic matter, and water content. These characteristics of the compost that will be marketed must be maintained the same as the declared quality. Local authorized institutions randomly visit the composting plants and analyze the compost quality to make sure that the quality is maintained.

There are several compost plants registered for their product quality, including the Cau Dien plant in Hanoi. This plant adds nitrogen, phosphorous and potassium (NPK) fertilizers into compost before marketing it in order to increase the concentration of nutrients and control the quality of compost near the registered quality. Table 4.4 summarizes some of criteria that the Cau Dien plant registered before marketing their compost. The table also shows the results of a project conducted by Hanoi Agriculture University to produce compost from on-source separation and composting of domestic waste and agricultural by-products. This was allowed to be sold in Hanoi's market with the price 700 VND/kg. As can be seen from the table, the criteria used to measure the quality of two compost products mostly emphasize the nutrient concentrations and organic content, not the toxicity which are important concerns among European and North American countries.

Table 4.4 Compost Quality of Some Plants and Projects in Vietnam

Parameter	Unit	CauDien Plant (1)	Project conducted by Agriculture University (2)
Organic matter	%	13.27	12.0
Nitrogen, total	%	0.57	1
Phosphorous, total	%	0.44	1.8
Phosphorous, soluble	-	0.37 %	42 (mg/100g)
Potassium, total	%	1.03	0.92
Potassium, soluble	-	0.38 %	120 (mg/100g)
Moisture Content	%	24.95	35
pH		8	6.8

Source: (1) : (Tien, 2003); (2): Provided by Professor Dao Chau Thu, Project Leader

4.3 Trial Compost Testing: Methodology

A methodology was established to test the quality of the compost produced in the single pile at the trial compost facility. First, it was necessary to get a representative sample from the 57.4 kg of fine compost that had been produced. To do this, the compost was mixed well and handfuls of compost were taken from different places of the pile. The compost was mixed thoroughly again and put in small zipped plastic bags to maintain the moisture content of the samples. Eight zipped plastic bags containing about 1.5 kg of well-mixed compost were then transported to the Lab of the Environment Department, Hanoi University for testing certain chemical and physical parameters.

As mentioned in Section 4.2, there are no certain standards for compost quality in Vietnam. Thus, in order to decide which parameters need to be tested, an overview of other countries' standards and criteria for compost quality assessment is necessary. The choice of parameters also depends on the capacity of local laboratories. Table 4.5 summarizes the chosen chemical and physical parameters and their measurement methods. A test of maturity was done with a temperature test or a visual test that is mentioned in Section 4.1.1. Concentrations of main heavy metals, such as

Cu, Zn, Cd, and Pb, were determined by an atomic absorption spectrometer, while nutrient levels were measured by an atomic absorption method. Other characteristics, such as pH, organic matter, moisture content, particle size, and foreign matter, were also tested using the methods shown in Table 4.5. In terms of pathogen organisms, E-coli index was measured by either the multiple tube fermentation method or membrane filtration.

Table 4.5 The Methods for Analyzing Chemical and Physical Parameters

Parameters	Method
Maturity	Comparison with criteria mentioned in Section 4.1.1
pH	Glass electrode method
Organic Matter	Dry combustion method
Ammonium	Kjeldal
Nitrogen, total	Mirco kjeldal method
Phosphorous soluble	Using a spectrometer by using ammonium molybdate in ascorbic acid
Phosphorous total	Using a spectrometer by using ammonium molybdate in ascorbic acid
Potassium total	Using atomic absorption spectrometer
Potassium soluble	Using atomic absorption spectrometer
Zn, Cd, Pb, Hg, As, Cu,	Using atomic absorption spectrometer
E coli	MTF: Multiple Tube Fermentation or MF: Membrane Filtration
Moisture Content	Gravimetric method
Foreign matter	Screening, Sorting, and Weighing
Particle size	Sieve screening

4.4 Trial Compost Quality: Test Results

The results of the testing of the compost are presented below along, with a discussion of how they compare with the quality criteria discussed in section 4.1.

4.4.1 Maturity

Visually, compost from the trial appeared to be mature with a dark brown colour and earthy odour. It also meets some of the criteria required by CCME; for example, the compost pile did not reheat for 23 days after the thermophilic phase was completed and organic matter was reduced around 80 percent by weight.

4.4.2 Foreign Matter

The compost did not contain plastics, sharp pieces of metal or glass; however, Table 4.6 shows that 33.1 % of product is sand, grave, and rice hulls. This percentage is much higher than criteria for foreign matter found in other countries (Table 4.1). Since rice hulls are very rigid, it takes a long time for them to decompose completely, and after two months of composting, only a small proportion of rice hulls were decomposed. With regards to sand and grave, one possible reason for the relatively high amounts is that the HaKhau landfill was at the end of its construction phase and transportation of construction materials past the composting site inadvertently caused the addition of construction materials into the pile.

Table 4.6 Percentage of Foreign Matter in the Compost from the Trial

Elements	Percentage (%)
Sand	8.3
Gravel	6.8
Rice hulls	18

4.4.3 Heavy Metals

Major heavy metals, including Zn, Cd, Pb, Hg, As, and Cu, were tested, and their concentrations are shown in Table 4.7. The concentration of Zinc was the highest with 91.2 ppm, followed by copper at about 26 ppm. Concentrations of Lead and Cadmium are less than 5 ppm and 0.1 ppm respectively. Also, concentrations of other important heavy metals, such as As and Hg, in the compost are negligible as organic waste was separated at source. Compared with maximum allowable concentrations of heavy metals required by many countries that are listed in Figure 4.1, those of the trial compost are much lower.

Table 4.7 Concentration of Some Heavy Metals in the Compost from the Trial

Metal	Percentage (ppm)
Copper	26.3
Lead	<5
Zinc	91.2
Cadmium	<0.1
Arsenic	negligible
Mercury	negligible

4.4.4 Pathogenic Organisms

The testing showed that there were 10^5 CFU[5] of E. coli in compost. This is one hundred times higher than the acceptable criteria for pathogens in other countries (Table 4.2). It is not clear why the pathogenic level was so high; however, source-separated organic waste may be contaminated by municipal solid waste since they were both transported to the landfill in the same trucks, and it may be due to the temperatures in the composting pile. As discussed earlier, a high temperature of around 50 ^{0}C was maintained for only one week, which is not long enough to kill most of the bacteria in question, such as faecal coliforms (E coli) and Salmonella.

4.4.5 Other Characteristics

Although some characteristics listed in Table 4.3 are not considered in many countries' standards, compost users are concerned about whether the compost product they choose is suitable for their plants or soil. Thus, organic matter, moisture content, nutrients and pH of the compost from the trial were tested and their results are displayed in Table 4.8.

Table 4.8 Other Characteristics of the Compost from the Trial

Elements	Unit	Results
pH	-	8
Phosphorous soluble	mg/100g	270
Phosphorus total	%	0.816
Ammonium	mg/100g	9.1
Nitrogen, total	%	0.994
Potassium total	%	1.868
Potassium soluble	mg/100g	1688
Organic matter	%	40.9
Maximum particle size (mm) *<0.25* *0.25 – 1* *1-2* *2-3* *>3*	%	5.85 51.8 21.75 4.6 16
Moisture content	%	45.2

[5] CFU means "Colony Forming Unit" and MPN is "Most Probable Number". The traditional membrane filtration tests for bacterial water quality actually county 'colonies' of bacteria and thus is reported as CFU. However, the newer defined substrate tests such as Colisure or Coliert report data as MPN which is a statistical representation of what level of *E. Coli* is likely present in a sample. For the purposes of reporting these terms have been used interchangeably

With pH = 8, the compost was alkaline, which is more suitable for acidic soil. The compost is high in organic matter (41%) and moisture content (45%), if compared to some compost produced in Vietnam (see Table 4.4). These levels of organic matter and moisture content meet requirements of all countries listed in Table 4.3. Nevertheless, nutrient levels in the trial compost are lower than those of the compost produced by Hanoi Agriculture University, except for the soluble potassium concentration which is fourteen times higher. As described in Section 3.2.4, compost was sieved by a wire mesh screen (with an opening size of 4 mm); therefore, only compost with the size of less than 4mm could pass through while the larger pieces (or rejects) were retained. As a result, the final compost products should be smaller than 4mm. Also, the testing results revealed that around 80% of the trial compost has a size of less than 2 mm which conforms to the standards of Italy, the U.S., and Canada.

4.5 Conclusions

The quality of compost is one of the most important concerns among producers as well as users. In general, users place great value on the appearance of compost, including grain size, colour, smell, foreign matter, and moisture. The compost produced from the trial had acceptable concentrations of nutrients and heavy metals, but contained high levels of foreign matter and pathogenic microorganisms.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the average generation and disposal rates, and composition of solid wastes produced by the three hotels in HaLong City that were audited during one week in the summer of 2004. It also summarizes results from the trial composting process and the testing of the compost quality with respect to the feasibility of a windrow composting system for hotel waste. Lastly, some recommendations on at-source waste separation, seasonal effects, and composting of compostables for other hotels in HaLong are also discussed.

5.1 Summary of Results from Hotel Waste Audit and Composting Trial

5.1.1 Hotel Waste Audit

A one-week waste audit was carried out at three hotels (SaiGon-HaLong, CongDoan, and TienLong) in HaLong City in June, 2004. Waste from guest rooms, gardens, and kitchen/ restaurant was separated into compostables, recyclables, and miscellaneous. Key results related to the feasibility of composting organic wastes from hotels are:

1. The three hotels generated, on average, 359, 182 and 137 kg /day of waste, for a total of 678 kg/day. However, after most leftover food and recyclables were collected by hotel staff for either selling or animal feeding, the average amount of waste disposed (i.e. sent to the landfill) by these hotels was 203, 114 and 89 kg/day, for a total of 405 kg/day, or about 60% of the amount generated.
2. The average amount of waste generated per overnight guest ranged from 0.7 to 0.9 kg/guest/day. While the waste quantities included wastes generated by the restaurants serving patrons, e.g. meeting attendees, who were not overnight guests, the number of such patrons was not included since this data was not available. The quantities of waste disposed by the hotel on a per guest basis ranged from 0.4 to 0.5 kg/guest/day.
3. Compostable made up the largest portion of wastes at all three hotels. Approximately 75% of the wastes generated, and about 60% to 73% of the waste disposed at each of the three hotels were compostables. As shown in Figure 5.1, the amount disposed for landfilling consisted of only about half of the compostables that were generated.
4. The quantities of compostable wastes disposed; on average, by the three hotels were 149, 68 and 52 kg/day. As shown in Figure 5.1, these consist primarily of fruit waste, vegetable waste, and yard waste.

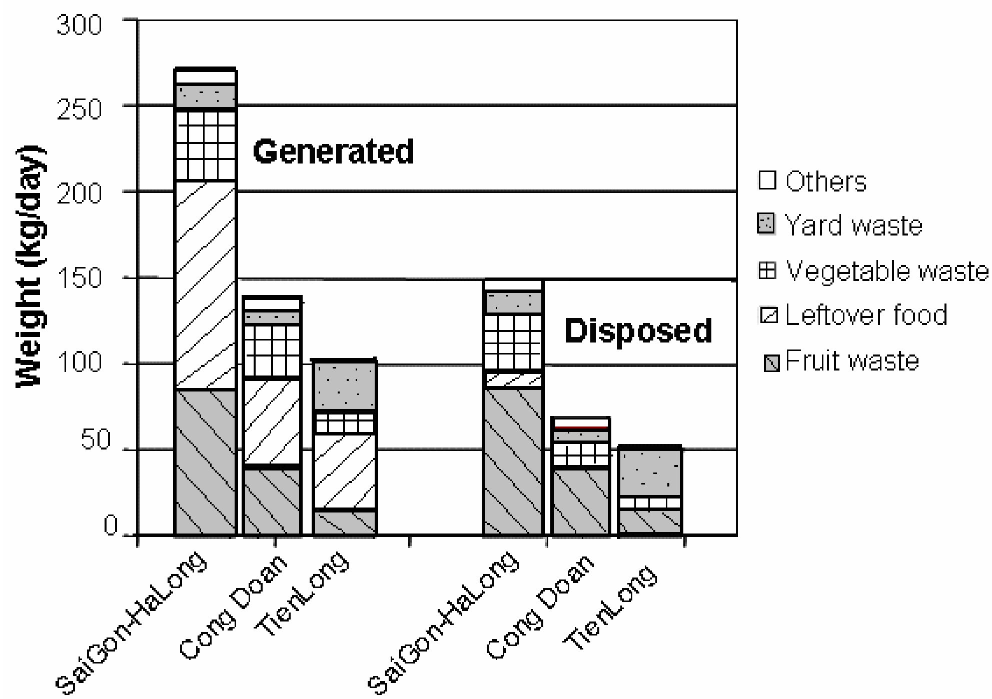


Figure 5.1 Composition of Compostables Generated and Disposed from Hotels

5.1.2 Composting Trial

With support from some local institutions, a composting pilot project, using a "windrow" system, was conducted in the HaKhau landfill over almost two months. Some important points about the project are as follows:

1. The compost production process included seven main steps of source separation, transportation, blending, piling, composting, maturing and screening, as illustrated in Figure 3.1.
2. During the first week of July, 2004, about 644 kilograms of compostables which were separated at source in all three hotels were collected and transported to the compost facility at the landfill. After being well mixed with about 58 kilograms of additives, blended waste was piled around a bamboo aerator.
3. To control the composting process, occasional turning and daily monitoring of temperature and moisture content were carried out, and dry material, such as sugarcane waste and rice hulls, was added to balance the moisture content in compost pile.
4. After sixty days of composting and maturing, 57.4 kg of fine compost was produced from the 644 kg of compostables from the hotels, resulting in a conversion rate of 8.9%. In addition, 90 kg of other organic residuals (mostly coconut shells) were

stored for future uses, such as for adding to a new compost pile to provide more time for them to be fully composted.

5.1.3 Compost Quality

The fine compost was tested for chemical and physical properties listed in Table 4.5, and the results were compared to compost quality standards in Australia, the United States, Canada, and European countries. There are no compost quality standards in Vietnam. Some important findings are:

1. The compost product contains a high percentage of foreign matters that are mostly sand, grave, and rice hulls; 18 % was rice hulls, and gravel accounted for nearly 7%.
2. There were 10^5 CFU of E. Coli in the compost product, which is one hundred times greater than the acceptable level for pathogenic organisms in other countries.
3. The concentrations of heavy metals in the compost were lower than the allowable amounts set by the standards for other countries as shown in Figure 4.1. Other characteristics, such as nutrient level, pH, organic matter, and moisture content, also conform the standards on compost quality of Italy, the U.S., and Canada.

5.2 Conclusions

Some important conclusions drawn from the waste audit and composting trial in HaLong City are:

1. The compositions of the solid wastes from the three participating hotels, which had different quality ratings, appeared to be similar. Compostables, which are essential to the composting process, were present in the largest proportion. However, since non-compostables in the feedstock can affect the composting process, it is important to separate the compostables from the non-compostables.
2. The composting trial showed that the windrow composting process is a simple technology that can produce a high quality compost. While the compost that was produced during the trial was high in foreign matter and pathogens, and there were some operational problems, such as low temperatures, odours and flies, during the compost trial, which affected the compost quality. These can be addressed in the future through actions such as those listed in Table B.5.
3. The testing results of the trial compost quality showed that source separation of waste is an environmentally and technically good way to achieve a good quality final compost.

The compost had acceptable concentrations of nutrients and heavy metals when compared with the standards in Australia, North American, and Europe. Although, the trial compost was high in foreign matter and pathogenic organisms, the major reasons for those issues may be addressed and solved by actions which are mentioned in Table B.5

5.3 Recommendations for Future Work

Future work can improve the implementation of composting in HaLong City and other cities in Vietnam. Below are some recommendations:

1. The participating hotels in HaLong City showed their high willingness to participate in separating waste at source during the one-week audit period. However, other hotels may not be as willing. Therefore, a study should be carried out to identify the factors that would affect hotel participation in an ongoing source separation program to support composting.

2. Observations revealed that hotel staff had very little knowledge about how to separate waste appropriately and the sites of waste bins were not convenient for both staff and guests. Therefore, studies should be carried out on what information should be provided to hotel staff and guests to improve source separation.

3. To expand to other hotels, the composting trial should be documented in the form of a brochure that provides hotels with information about composting and its benefits, about what the hotel would need to do to participate, and about the experiences gathered during this study (see Table B.5) can be used to improve future composting activities.

4. Since the compost trial was conducted in the summer, the results may not be true for other seasons. Research should be carried out on the effects of seasonal factors, such as ambient temperature and waste composition, on the composting process. Both waste audits and composting trials should be carried out again during the dry season in HaLong.

5. The use of compost in hotel gardens should be studied, especially the appropriate amount and mixture of compost to apply and timing to apply compost. Experiments should be conducted on the use of pure compost and mixtures of compost and soil at different ratios on different types of plant; as a result, the best “recipe” could then be chosen.

REFERENCES

Benedict, A. H., E. Epstein, et al. (1988). Composting Municipal Sludge: a Technology Evaluation. Park Ridge, N.J., U.S.A., Noyes Data Corp.

Brinton, W. F. (2000). Compost Quality Standards & Guidelines, Woods End Research Laboratory, Inc.

Canadian Council of Ministers of Environment, CCME (1996). Waste Audit Users Manual: A Comprehensive Guide to the Waste Audit Process, Frenco MacLaren Inc & Angus Environmental Inc.

Canadian Council of Ministers of Environment, CCME. (2000). Support Document for Compost Quality Criteria - National Standard of Canada (CAN/BNQ)

Chopra, S. (2004). Quantification and Composition Audit of Waste Generated at the Early Morning Market in Vientiane, Lao PDR. M.Eng. thesis, Department of Civil Engineering, University of Toronto, Toronto.

Concern, W. and Sandec (2001). Assessment of a Decentralized Composting Scheme in Dhaka, Bangladesh: Technical, Operational, Organizational, and Financial Aspects.

Department, S. (2004). QuangNinh Statistical Yearbook, 2003, Statistics Publishers.

Diaz, L. F., G. M. Eggerth, et al. (1993). Composting and Recycling Municipal Solid Waste, Lewis Publishers.

Dulac, N. (2001). The Organic Waste Flow in Integrated Sustainable Waste Management.

Epstein, E. (1997). The Science of Composting. Lancaster, Pa., Technomic Pub. Co.

European Commission. Environment Directorate-General (2000). Success stories on composting and separate collection. [Lanham, Md., Office for Official Publications of the European Communities ; Bernan Associates, distributor].

FIRST Consulting Group. and Recycling Council of Ontario. (1994). Backyard Composting : Summary of Results of the Model Community Projects, December 1994.

Gasser, J. K. R. and Environment Research Programme. (1985). Composting of Agricultural and Other Wastes. London, Elsevier Applied Science Publishers.

Golueke, C. G. (1977). Biological Reclamation of Solid Wastes. Emmaus,, PA, Rodale Press.

Gray-Donald, L. (2002). The potential for Education to Improve Solid Waste Management in Vietnam: A focus on Hanoi. M.A thesis, Department of Geography and Institute of Environmental Studies, University of Toronto,Toronto.

Haight, M. and P. Taylor (2000). A Manual for Composting in Hotels, Canadian University Consortium - Urban Environmental Management Project

Hansen, J. A., Ed. (1996). Management of Urban Biodegradable Wastes: Collection, Occupational Health, Biological Treatment, Product Quality Criteria and End User Demand, James & James Ltd, London.

Haug, R. T. (1993). The Practical Handbook of Compost Engineering. Boca Raton, Lewis Publishers.

Hogg, D., J. Barth, et al. (2002a). Review of Compost Standards in Sweden: Nation Specific Supplement 14. Waste and Resources Action Program (WRAP).

Hogg, D., J. Barth, et al. (2002b). Review of Compost Standards in Australia: Nation Specific Supplement 16. WRAP.

Hogg, D., J. Barth, et al. (2002c). Review of Compost Standards in Canada: Nation Specific Supplement 18. WRAP.

Hogg, D., J. Barth, et al. (2002d). Review of Compost Standards in Spain: Nation Specific Supplement 13. WRAP.

Hogg, D., J. Barth, et al. (2002e). Review of Compost Standards in Italy: Nation Specific Supplement 9. WRAP.

Hogg, D., J. Barth, et al. (2004).Comparison of Compost Standards within the EU, North America and Australasia. WRAP.

Hoornweg, D., et al. (1999). Composting and Its Applicability in Developing Countries, the International Bank of Reconstruction and Development, World Bank.

IIA (2000). Vermi-Compost Chemical and Physical Characterization from Raw and Mixed Organic Wastes, Instituto de Investigaciones Agropecuarias.

Infra, J. P. (2003). Vietnam Three Cities Sanitation Project, Haiphong Sub-project.

JICA – Japan International Cooperation Agency. (1999). The Study on Environmental Management for Ha Long Bay - Vol I, III, IV.

Kauffman, C. R. (1990). Quantity and Composition of Household Solid Wastes Collected in Kuala Lumpur, Malaysia. M.A.Sc. thesis, Department of Civil Engineering, University of Toronto, Toronto.

Ministry of Agriculture and Rural Development. (2001). Proceedings of Vietnam Agricultural Standards, Vol II, Hanoi.

Mathur, S. P., B. Voisin, et al. (1996). The Use of Compost as a Greenhouse Growth Media : Final Report of a Study. [Toronto], Ontario, Waste Reduction Branch, Ministry of the Environment.

McBean, E. A. and F. A. Rovers (1998). Statistical Procedures for Analysis of Environmental Monitoring Data and Risk Analysis. Prentice Hall.

McGarry, M. G., J. Stainforth, et al. (1978). Compost, Fertilizer and Biogas Production from Human and Farm Wastes in the People's Republic of China. Ottawa, International Development Research Centre.

Metropolitan Toronto (Ont.). Dept. of Works., Metropolitan Toronto (Ont.). Works Dept. Solid Waste Management Division., et al. (1990). Site Selection Process: Composting. [Toronto, Ont.], Dept. of Works, Solid Waste Management Division.

NEA and UNEP (1999). State of the Environment in Vietnam, Ministry of Science, Technology and Environment of Vietnam

NEA and UNEP (2001). State of the Environment in Vietnam, Ministry of Science, Technology and Environment of Vietnam

Nhue, T. H. (2003). The Pilot Study on the Organic Waste Management for the BaiChay Tourism Destination, HaLong Bay in Vietnam.

Obeng, L. A. and F. W. Wright (1987). The Co-composting of Domestic Solid and Human Wastes. UNDP Project Management Report, World Bank.

Platt, B. (1992). In-depth Studies of Recycling and Composting Programs : Designs, Costs, Results. Washington, D.C., Institute for Local Self-Reliance.

Rasula, J. (2002). This Compost: Ecological Imperatives in American poetry. Athens, University of Georgia Press.

Raymond, F. (2002). Lettres Compost. Outremont, Quâebec, Quebecor.

Rynk, R. et al. (1992). On Farm Composting Handbook, Northeast Regional Agricultural Engineering Services.

Satriana, M. J. (1974). Large Scale Composting. Park Ridge, N.J., Noyes Data Corp.

SENES (1992). Waste Stream Quantification and Characteration Metholodogy, Solid Waste Management Division, Environment Canada.

Tien, N. V. (2003). Studying and Proposing Recommendations on Management of Production and Marketing Organic Fertilizers within Hanoi City, Hanoi Agriculture and Rural Development Department.

Tchobanoglous, G. H. T., and A. Vigil (1993). Integrated Solid Waste Management - Engineering Principles and Management, McGraw-Hill, Inc.

U.S. Composting Council (2002). Workshop on Sharing Experience in Composting Municipal Solid Waste, Hanoi Department of Science and Technology.

APPENDIX A

WASTE AUDIT

Table A.1 Quantity and Composition of Waste in SaiGon-HaLong Hotel during the One-Week Audit Period

Material Category	6-Jun			7-Jun		
	Description	Net weight	Remark	Description	Net weights	Remark
Waste from guest rooms and staff rooms				**Waste from guest rooms and staff rooms**		
Fruit waste	rambutan, watermelon, dragon fruit, apple pealing, banana, pine-apple, litchi fruit	23.7	disposed	rambutan, watermelon, , banana, pine-apple, litchi fruit, mango	64.1	disposed
Leftover food	-	-	-	-	-	-
Flower waste	roses, leaves	1.8	disposed	roses, leaves	3.9	disposed
Non-recyclable Paper	damp napkins, tissue paper	3.4	disposed	damp napkins, tissue paper	6.3	disposed
Metal	cans	2	collected for selling	-		
Glass	bottles	2	collected for selling	-		
Non-recyclable plastics	plastic bags, hard plastics	5.3	disposed	plastic bags, hard plastic	12.7	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	19.2	collected for selling	tissues, cardboard, print paper, newspaper	12.1	collected for selling
Recyclable plastics	bottles, clear bags	14.5	collected for selling	bottles, clear bags	22.6	collected for selling
Others	wood chips, sand, dust, rubber, cloth, shoes, foam, cigars	8.5	disposed	wood chips, sand, dust, rubber, cloth, shoes, foam, cigars	17.9	disposed
Total		**80.4**			**139.6**	
Waste from garden				**Waste from garden**		
Leaves	pine needles, brush	21.4	disposed	pine needles, brush	7	disposed
Grass clippings	-	-	-	-	-	-
Others	wood chips, sand, dust, foam	2.5	disposed	wood chips, sand, dust, foam	3	disposed
Total		**23.9**			**10**	
Waste from kitchen and restaurant				**Waste from kitchen and restaurant**		
Leftover food	rice, poultry, chicken, smoke meat, cake, mash potato, bean.	104.8	collected for animal feeding	rice, soup, poultry, chicken, smoke meat, cake, mash potato, bean, …	133.7	collected for animal feeding, except for 72kg of mixed food waste disposed
Fruit waste	rambutan, watermelon, dragon fruit, mangosteen, pine-apple	77	disposed	rambutan, watermelon, dragon fruit, pine-apple	83	disposed
Vegetable waste	salad, onion peels, dill, carrot, cabbage, tomatoes, potato peels, cucumber, water-morning glory	58.5	disposed, except for 12.5 kg collected for animal feeding	onion, dill, carrot, ,cabbage, tomatoes, potato peels, cucumber, pot-herbs, spinach	51.8	collected for animal feeding, except for 5kg of dill, carrot, pot-herbs,…
Egg shell		3.5	disposed	-	3.3	disposed
Sea-food waste	shells	0.6	disposed	shell, crab	1.4	disposed
Non-recyclable paper	used napkin,	2.1	disposed	-	-	-
Recyclable paper	-	-	-	-	-	-
Glass	kitchen-stuff, bottle	-	-	bottles	6	disposed
Non-recyclable plastics	plastic bags, hard plastic	2.3	disposed	plastic bags, hard plastic	2.2	disposed
Recyclable Plastics	bottles, clear bags	1.8	collected for selling	bottles, clear bags	6.4	collected for selling
Metal	cans	0.5	collected for selling	cans	1	collected for selling
Others	foam, dust	0.2	disposed	foam, bone, dust,	41	disposed
Total		**251.3**			**329.8**	
Total amount of waste generated:		***355.6***			***479.4***	
Total amount of waste disposed of:		***198.3***			***328.8***	

Table A.1 Quantity and Composition of Waste in SaiGon-HaLong Hotel during the One-Week Audit Period (cont'd)

Material Category	8-Jun			9-Jun		
	Description	Net weights	Remark	Description	Net weights	Remark
Waste from guest rooms and staff rooms				**Waste from guest rooms and staff rooms**		
Fruit waste	rambutan, watermelon, dragon fruit, apple pealing, banana, pine-apple, orange	9.4	disposed	litchi fruit, watermelon, dragon fruit, mango, banana,	3.7	disposed
Leftover food	bread, rice	2.9		-	-	-
Flower waste	roses, daisy	2.7	disposed	-	-	-
Non-recyclable Paper	damp napkins, tissue paper, wet paper	9	disposed	damp napkins, tissue paper	3	disposed
Metal	-			-	-	-
Glass	bottles	1.5	collected for selling	bottles	-	-
Non-recyclable plastics	plastic bags, hard plastics	6.9	disposed	plastic bags, hard plastics	5.3	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	19.3	collected for selling	tissues, cardboard, print paper, newspaper	9.5	collected for selling
Recyclable plastics	bottles, clear bags	13.4	collected for selling	bottles, clear bags	6	collected for selling
Others	wood chips, sand, dust, rubber, cloth, shoes, foam, cigars.	2.7	disposed	wood chips, sand, dust, rubber, cloth, shoes, foam, cigars.	8.5	disposed
Total		**67.8**			**36**	
Waste from garden				**Waste from garden**		
Leaves	pine needles, brush, coco nut leaves	7.2	disposed	pine needles, brush	3	disposed
Grass clippings	-	7.5	disposed	-	24	disposed
Others	wood chips, sand, dust, foam, cloth	8	disposed	wood chips, sand, dust, foam	1	disposed
Total		**22.7**			**28**	
Waste from kitchen and restaurants				**Waste from kitchen and restaurant**		
Leftover food	rice soup, rice, poultry, chicken, smoke meat, cake, carrot, fish, cookies, bean, …	67.5	collected for animal feeding,	rice, poultry, chicken, smoke meat, cake, mash potato, bean, bean sprout, lemon, cucumber …	138	collected for animal feeding,
Fruit waste	rambutan, watermelon, dragon fruit, pine-apple	57.5	disposed	watermelon, dragon fruit, pine-apple	43.5	disposed
Vegetable waste	onion peels, pot-herbs, carrot, cabbage, tomatoes, potato peels, cucumber,	58.5	disposed except for 7kg of spinach and cabbage collected for animal feeding,	onion peels, pot-herbs, carrot, cabbage, tomatoes, potato peels, cucumber	22.5	disposed
Egg shell	-	11	disposed	-	1	disposed
Sea-food waste	shells		disposed	shells	0.6	disposed
Non-recyclable paper	used napkin,	1	disposed	used napkin,	7.5	disposed
Recyclable paper	-	-	-	-	-	-
Glass	broken kitchen-stuff, bottle	3	disposed	-	-	-
Non- recyclable plastics	plastic bags, hard plastics…	8.7	disposed	plastic bags, hard plastics…	0.5	disposed
Recyclable Plastics	bottles, clear bags	0.7	collected for selling	bottles, clear bags	2	collected for selling
Metal	cans	0.5	collected for selling	-	-	-
Others	foam, dirt	5.2	disposed	foam, dirt, bone	12.5	disposed
Total		**213.6**			**228.1**	
Total amount of waste generated:		***304.1***			***292.1***	
Total amount of waste disposed of:		***194.2***			***136.6***	

Table A.1 Quantity and Composition of Waste in SaiGon-HaLong Hotel during the One-Week Audit Period (cont'd)

Material Category	10-Jun			11-Jun			12-Jun		
	Description	Net weight	Remark	Description	Net weight	Remark	Description	Net weight	Remark
	Waste from guest rooms and staff rooms			**Waste from guest rooms and staff rooms**			**Waste from guest rooms and staff rooms**		
Fruit waste	litchi fruit, watermelon, dragon fruit, mango, lemon, banana,	8.5	disposed	litchi fruit, watermelon, dragon fruit, mango, banana,	25.5	disposed	rambutan, watermelon, dragon fruit,	31	disposed
Leftover food	-	-	-	-			bread,	1	disposed
Flower waste	roses, leaves	2.2	disposed	roses, leaves	1	disposed	roses	0.5	disposed
Non-recyclable Paper	damp napkins, tissue paper	2.7	disposed	damp napkins, tissue paper	8.5	disposed	damp napkins, tissue paper	16	disposed
Metal	-	-	-	-			-	-	-
Glass	-	-	-	bottles	2.5	collected for selling	bottles	4.3	collected for selling
Non-recyclable plastics	plastic bags, hard plastics…	3.2	disposed	plastic bags, napkin, hard plastics…	15.1	disposed	plastic bags, hard plastics	7.8	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	15.2	collected for selling	tissues, cardboard, print paper, newspaper	23.2	collected for selling	tissues, cardboard, print paper, newspaper	15	collected for selling
Recyclable plastics	bottles, clear bags	15.2	collected for selling	bottles, clear bags	6.4	collected for selling	bottles, clear bags	12	collected for selling
Others	wood chips, sand, dust, rubber, cloth, shoes, foam, cigars.	9.4	disposed	wood chips, sand, dust, rubber, cloth, shoes, foam, cigars.	8.2	disposed	-	-	-
Total		**56.4**			**90.4**			**87.6**	
	Waste from garden			**Waste from garden**			**Waste from garden**		
Leaves	pine needles, brush	4.6	disposed	pine needles, brush	19.7	disposed	pine needles	8.5	disposed
Grass clippings	-	-	-	-	-	-	-	-	-
Others	wood chips, sand, dust, foam	5.8	disposed	-	-	-	-	-	-
Total		**10.4**			**19.7**			**8.5**	
	Waste from kitchen and restaurant			**Waste from kitchen and restaurant**			**Waste from kitchen and restaurant**		
Leftover food	rice, chicken, smoke meat, cake, bean, cucumber …	107.5	collected for animal feeding,	rice, poultry, chicken, cake, mash potato, cucumber …	119	collected for animal feeding,	rice, poultry, chicken, meat, bean, cucumber …	170	collected for animal feeding
Fruit waste	watermelon, dragon fruit,	43.5	disposed	watermelon, pear pine-apple	55	disposed	watermelon, banana	66.8	disposed
Vegetable waste	salad, onion, pot-herb, carrot,, cabbage, tomatoes, cucumber	22.5	disposed	water morning glory, pot-herbs, onion, carrot,,	32.5	disposed	pot-herbs, onion, tomatoes, potato peels, cucumber	45.7	disposed, except for 10kg
Egg shell	-	3	disposed	-	-	-	-	2.8	disposed
Sea-food waste	fish	2.8	disposed	shrimp, crap	1.5	disposed	shell	2	disposed
Non-recyclable paper	used napkin,	0.5	disposed	used napkin, wet paper	1	disposed	used napkin,	10.5	disposed
Recyclable paper	cardboard	10	collected for selling	-	-	-	cardboard	7	collected for selling
Glass	-	-	-	-	-	-	-	-	-
Non-recyclable plastics	plastic bags, hard plastics	0.5	disposed	-	-	-	plastic bags, hard plastics	7.8	disposed
Recyclable Plastics	bottles, clear bags	5	collected for selling	-	-	-	bottles, clear bags	1.3	collected for selling
Metal	can	2.2	collected for selling	-	-	-	can	1.3	collected for selling
Others	foam, dirt, bone	35.5	disposed	foam, dirt, bone, cinder	26	disposed	foam, dirt, bone	26	disposed
Total		**233**			**235**			**341.2**	
Total amount of waste generated:		***299.8***			***345.1***			***437.3***	
Total amount of waste disposed of:		***144.7***			***194.0***			***226.4***	

Table A.2 Quantity and Composition of Waste in TienLong Hotel during the One-Week Audit Period

Material Categories	15-Jun			16-Jun		
	Description	Net weight	Remark	Description	Net weigh	Remark
Waste from guest rooms and staff rooms				**Waste from guest rooms and staff rooms**		
Fruit waste	litchi fruit, watermelon, orange, pine-apple	2.8	disposed	litchi fruit, cucumber, mango	2.9	disposed
Leftover food	-	-	-	-	-	
Flower waste	roses, leaves	0.9	disposed	-	-	disposed
Non-recyclable Paper	damp napkins, tissue paper	1.3	disposed	damp napkins, tissue paper	2.5	disposed
Metal	-	-	-	cans	0.3	should be collected for selling, but disposed of actually
Glass	-	-	-	-	-	-
Non-recycled plastics	plastic bags, hard plastics…	2	disposed	plastic bags, hard plastics	0.6	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	2.1	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	1.2	should be collected for selling, but disposed of actually
Recyclable plastics	bottles, clear bags	0.6	should be collected for selling, but disposed of actually	bottles, clear bags	1.4	should be collected for selling, but disposed of actually
Others	sand, rubber, cloth, shoes, soaps, cigars.	1.5	disposed	wood chips, tea bags, sand, dust, rubber, cloth,	2.7	disposed
Total		**11.2**			**11.6**	
Waste from garden				**Waste from garden**		
Leaves	leaves, brush	18	disposed	brush	82.7	disposed
Grass clippings	-	-	-	-	-	-
Others	wood chips, sand, dust, foam	1.2	disposed	wood chips, sand, dust, foam	1.2	disposed
Total		**19.2**			**83.9**	
Waste from kitchen and restaurant				**Waste from kitchen and restaurant**		
Leftover food	rice, poultry, chicken, vegetable, noodle	52	collected for animal feeding	rice, poultry, seafood, cooked vegetable	49	collected for animal feeding,
Fruit waste	rambutan, watermelon,	8	disposed	rambutan, watermelon, dragon fruit, pine-apple		disposed
Vegetable waste	onion, cucumber, water-morning glory	2	disposed	onion peels, tomatoes, cucumber, pot-herbs,	9.5	disposed
Egg shell	-	1.3	disposed	-	-	-
Sea-food waste	-	-	-	shells, crabs	0.9	disposed
Non-Recyclable paper	used napkin,	2.5	disposed	used napkin, wet paper	2.6	disposed
Recyclable paper	-	-	-	-	-	-
Glass	kitchen-stuff, bottle	2.6	disposed	plates, bottles	0.7	disposed
Non-recyclable plastics	plastic bags, napkin, hard plastics	5.1	disposed	Plastic bags, hard plastics	4.9	disposed
Recyclable Plastics	-	-	-	-	-	-
Metal	-	-	-	cans	0.6	collected for selling
Others	foam, cloth, mixed food	29.5	disposed	foam, dirt, bone, cloth,	9	disposed
Total		**103**			**77.2**	
Total amount of waste generated:		***133.4***			***172.7***	
Total amount of waste disposed of:		***81.4***			***123.1***	

Table A.2 Quantity and Composition of Waste in TienLong Hotel during the One-Week Audit Period (cont'd)

Material Categories	17-Jun			18-Jun		
	Description	Net weight	Remark	Description	Net weight	Remark
	Waste from guest rooms and staff rooms			Waste from guest rooms and staff rooms		
Fruit waste	peach, pine-apple, orange, banana, cucumber	8.2	disposed	litchi fruit, watermelon, dragon fruit, banana, mandarin fruit.	4.9	disposed
Leftover food	bread, shell	0.3	disposed	Cake, rice	0.2	disposed
Flower waste	roses	0.3	disposed	-	-	-
Non-recyclable Paper	damp napkins, tissue paper, wet paper	5.4	disposed	damp napkins, tissue paper, wet newspaper	1.8	disposed
Metal	-	-	-	-	-	-
Glass	-	-	-	-	-	-
Non-recycled plastics	plastic bags, hard plastics	1.5	disposed	plastic bags, hard plastics	0.7	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	0.8	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	0.6	should be collected for selling, but disposed of actually
Recyclable plastics	bottles, clear bags	1.6	should be collected for selling, but disposed of actually	bottles, clear bags	1.9	should be collected for selling, but disposed of actually
Others	sand, dust, rubber, cloth, foam, cigars,	3.5	disposed	sand, dust, cloth, shoes, foam, soap	3.5	disposed
Total		**21.6**			**13.6**	
	Waste from garden			Waste from garden		
Leaves	brush, leaves	20.7	disposed	brush, leaves	27.4	disposed
Grass clippings	-	-	-	-	-	-
Others	wood chips, sand, dust, cloth	4	disposed	wood chips, sand, dust, foam	4	disposed
Total		**24.7**			**31.4**	
	Waste from kitchen and restaurant			Waste from kitchen and restaurant		
Leftover food	rice, chicken, vegetable, seafood, noodle	35	collected for animal feeding,	rice, poultry, chicken, cooked vegetable,	42	collected for animal feeding,
Fruit waste	watermelon, litchi fruit	4.2	disposed	watermelon, dragon fruit, pine-apple	23.4	disposed
Vegetable waste	onion peels, spinach, carrot, tomatoes, water-morning glory	16.4	disposed of, except for 6kg of water-morning collected for animal feeding	onion, pot-herbs, ,carrot,, water-morning	16.1	disposed of, except for 7.1 kg of water-morning collected for animal feeding
Egg shell	-	0.9	disposed	-	-	-
Sea-food waste	shrimps	1.5	disposed	-	-	
Non-Recyclable paper	used napkin,	4	disposed	used napkin,	4	disposed
Recyclable paper	-	-	-	-	-	-
Glass	broken kitchen-stuff, bottle	3	disposed	broken kitchen-stuff, bottle	0.3	disposed
Non-recyclable plastics	plastic bags, hard plastics	2.1	disposed	plastic bags, hard plastics	4.8	disposed
Recyclable Plastics	bottles, clear bags	1.4	collected for selling	-	-	-
Metal	cans	0.7	collected for selling	-	-	-
Others	foam, rice straw, cloth	4	disposed	sand, dirt, cloth, bone	16.1	disposed
Total		**73.2**			**106.7**	
Total amount of waste generated:		***119.5***		***Total amount of waste generated:***	***151.7***	
Total amount of waste disposed of:		***76.4***		***Total amount of waste disposed of:***	***102.6***	

Table A.2 Quantity and Composition of Waste in TienLong Hotel during the One-Week Audit Period (cont'd)

Material Categories	19-Jun			20-Jun			21-Jun		
	Description	Net weight	Remark	Description	Net weight	Remark	Description	Net weight	Remark
Waste from guest rooms and staff rooms				**Waste from guest rooms and staff rooms**			**Waste from guest rooms and staff rooms**		
Fruit waste	watermelon, orange, mango, lemon, banana,	4.4	disposed	watermelon, mango, coco-nut fruit, banana, peach	4.4	mainly litchi; disposed	litchi fruit, orange, watermelon, mango, peach	13.4	mainly litchi; disposed
Leftover food	poultry, sticky rice	2.5	disposed	rice, bread, pork	1.4	disposed	bread, seafood, rice,	4.2	disposed
Flower waste	-	-	-	-			-	-	-
Non-recyclable Paper	napkins, tissue paper	2.2	disposed	damp napkins, tissue paper	2.3	disposed	damp napkins, tissue paper	2.7	disposed
Metal	cans	0.2	should be collected for selling, but disposed of actually	cans	0.2	should be collected for selling, but disposed of actually	cans,	0.2	disposed
Glass	broken bottles	0.2	disposed	broken bottles	0.3	disposed	-		-
Non-recycled plastics	plastic bags, napkin, hard plastics…	1.5	disposed	plastic bags, napkin, hard plastics	0.7	disposed	plastic bags, napkin, hard plastics…	1.5	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	1.8	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	0.4	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	1.7	should be collected for selling, but disposed of actually
Recyclable plastics	bottles, clear bags	1	should be collected for selling, but disposed of actually	bottles, clear bags	1.7	should be collected for selling, but disposed of actually	bottles, clear bags	1.4	should be collected for selling, but disposed of actually
Others	wood chips, sand, dust, rubber, cloth, shoes,	4.9	disposed	wood chips, sand, dust, rubber, cloth, sanitary pads	3.4	disposed	used pen, cloth, rubber, sanitary pads, wood chips,	3.3	disposed
Total		**18.7**			**14.8**			**28.4**	
Waste from garden				**Waste from garden**			**Waste from garden**		
Leaves	leaves, brush	11	disposed	leaves, brush	17.2	disposed	leaves	10	disposed
Grass clippings	-	-	-	-			-	-	-
Others	sand, dust, foam	2	disposed	wood chips, dust, foam	3	disposed	sand, dust, foam	5	disposed
Total		**13**			**20.2**			**15**	
Waste from kitchen and restaurant				**Waste from kitchen and restaurant**			**Waste from kitchen and restaurant**		
Leftover food	rice, poultry, chicken, vegetable, noodle	43	collected for animal feeding,	rice, poultry, cooked vegetable, noodle	42	collected for animal feeding,	rice, poultry, cooked vegetable, noodle	49	collected for animal feeding,
Fruit waste	Watermelon, litchi fruit	3	disposed	watermelon, dragon		disposed	watermelon, apple	13.3	disposed
Vegetable waste	onion, carrot, cabbage	9.2	disposed	spinach, onion peels, carrot, garlic peels, water-morning glory	20	disposed, except for 7 kg of water-morning glory collected for animal feeding	onion, pot-herbs, carrot, tomatoes, cucumber	11	disposed
Egg shell	-	0.2	disposed			negligible	-		-
Sea-food waste	craps, shells	0.9	disposed	shrimp, crap	5.2	disposed	shell	5.5	disposed
Non-Recyclable paper	used napkin,	4.5	disposed	used napkin, wet paper	1	disposed	used napkin,	1.5	disposed
Recyclable paper	-	-	-	-			broken bottles, plates	1.1	disposed
Glass	kitchen-stuff, bottle	13.9	disposed	broken glasses,	0.3	disposed	-	-	-
Non-recyclable plastics	plastic bags, napkin, hard plastics	2.9	disposed	bottles, clear bags	0.1		plastic bags, napkin, hard plastics	0.6	disposed
Recyclable Plastics	bottles, clear bags	1	collected for selling	-			-	-	-
Metal	-	-	-	-			-	-	-
Others	sand, dirt, bone	2	disposed	foam, cloth, bone, dirt,	22.5	disposed	foam, bone, mixed food	19.4	disposed
Total		**80.6**			**91.1**			**101.4**	
Total amount of waste generated:		***112.3***			***126.1***			***144.8***	
Total amount of waste disposed of:		***68.3***			***77.1***			***95.8***	

Table A.3 Quantity and Composition of Waste in CongDoan Hotel during the One-Week Audit Period

Material Category	16-Jun			17-Jun		
	Description	Net weight	Remark	Description	Net weight	Remark
	Waste from guest rooms and staff rooms			Waste from guest rooms and staff rooms		
Fruit waste	rambutan, watermelon, jack fruit, banana, pine-apple,	36	mainly litchi fruit disposed	watermelon, , jack fruit, litchi fruit,	29.6	disposed
Leftover food	crap, bread	1	disposed	bread	2.5	
Flower waste	roses, daisies	2.1	disposed	roses	1	disposed
Non-recyclable Paper	napkins, tissue paper	8.9	disposed	damp napkins, tissue paper	8.7	disposed
Metal	cans	0.3	should be collected for selling, but disposed of actually	-	-	-
Glass	kitchen-stuff	0.3	disposed	-	-	-
Non-recycled plastics	plastic bags, hard plastic	3.6	disposed	plastic bags, hard plastics	5.7	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	2.8	should be collected for selling, but 1kg disposed of actually	tissues, cardboard, print paper, newspaper	2.6	should be collected for selling, but disposed of actually
Recyclable plastics	bottles, clear bags	1.9	should be collected for selling, but disposed of actually	bottles, clear bags	1.3	should be collected for selling, but disposed of actually
Others	wood chips, sand, dust, rubber, cloth, foam,	2.9	disposed	sand, dust, rubber, cloth,	2.6	disposed
Total		**58.8**			**54**	
	Waste from garden			Waste from garden		
Leaves	leaves, brush	4.7	disposed	brush, leaves	4	disposed
Grass clippings	-	-	-	-	-	-
Others	-	-	-	wood chips, sand, dust, foam	2.3	disposed
Total		**4.7**			**6.3**	
	Waste from kitchen and restaurant			Waste from kitchen and restaurant		
Leftover food	rice, poultry, seafood, cooked vegetable	51	collected for animal feeding	rice, poultry, chicken,	51.5	collected for animal feeding,
Fruit waste	rambutan, watermelon, dragon fruit, mangosteens, pine-apple	6	disposed	watermelon, litchi fruit	16.5	disposed
Vegetable waste	garlic, onion peels, ,carrot,, cabbage, tomatoes, cucumber, spinach, water-morning glory	38	disposed, except for 18kg of water-morning glory collected for animal feeding	onion, garlic,, carrot, ,cabbage, ,spinach, water-morning glory	22.8	collected for animal feeding, except for 9kg of spinach and onion, carrot
Egg shell		0.4	disposed		0.3	disposed
Sea-food waste	craps, shell, fish	12.3	disposed	shells	2.5	disposed
Non-recyclable paper	used napkin, wet paper	0.5	disposed	used napkins	6	disposed
Recyclable paper	-	-	-	-	-	-
Glass	bottles	1	disposed	-	-	-
Non-recyclable plastics	plastic bags, hard plastics	2.9	disposed	plastic bags, hard plastics	2	disposed
Recyclable Plastics	-	-	-	-	-	-
Metal	cans	0.5	collected for selling	cans	2.5	collected for selling
Others	foam, cloth, dirt, bone, ash	8	disposed	foam, bone, cloth	9	disposed
Total		**120.6**			**113.1**	
Total amount of waste generated:		***184.1***		***Total amount of waste generated:***	***173.4***	
Total amount of waste disposed of:		***114.6***		***Total amount of waste disposed of:***	***105.6***	

Table A.3 Quantity and Composition of Waste in CongDoan Hotel during the One-Week Audit Period (cont'd)

Material Category	18-Jun			19-Jun		
	Description	Net weight	Remark	Description	Net weight	Remark
Waste from guest rooms and staff rooms				**Waste from guest rooms and staff rooms**		
Fruit waste	watermelon, dragon fruit, orange, litchi fruit	21.8	disposed	litchi fruit, watermelon, peach, jack fruit	34.6	disposed
Leftover food	bread, rice	0.8	disposed	bread, noodle	0.7	disposed
Flower waste	roses, daisy	0.4	disposed	rose, leaves	0.4	disposed
Non-recyclable Paper	napkins, tissue paper,	5.7	disposed	napkins, tissue paper	7.9	disposed
Metal	cans	0.6	should be collected for selling, but disposed of actually	cans	2.9	disposed
Glass	glasses	0.6	disposed	-	-	-
Non-recycled plastics	plastic bags, hard plastics…	3.2	disposed	plastic bags, hard plastics…	4.8	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	3.6	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	2.2	should be collected for selling, but disposed of actually
Recyclable plastics	bottles, clear bags	1.7	should be collected for selling, but disposed of actually	bottles, clear bags	0.6	should be collected for selling, but disposed of actually
Others	sand, dust, rubber, cloth, shoes, foam,	7.4	disposed	wood chips, sand, dust, rubber, cloth, shoes, foam,	4.2	disposed
Total		**45.8**			**58.3**	
Waste from garden				**Waste from garden**		
Leaves	brush, leaves	5.6	disposed	pine, brush	5	mainly pine
Grass clippings	-	-	-	-	-	-
Others	-	-	-	-	-	-
Total		**5.6**			**5**	
Waste from kitchen and restaurant				**Waste from kitchen and restaurant**		
Leftover food	rice, poultry, …	52	collected for animal feeding,	rice, poultry, sea-food, bean sprout, cucumber …	50	collected for animal feeding,
Fruit waste	watermelon, pine-apple	13.8	disposed	watermelon, pine-apple	17	disposed
Vegetable waste	onion, carrot, cabbage, tomatoes, water-morning glory	22.3	collected for animal feeding, except for 6.3kg of and onion, carrot	Onion, ,pot-herbs, cabbage, tomatoes, potato peels, cucumber, spinach, water-morning glory	46.6	disposed, except for 17kg of water-morning glory
Egg shell	-	-	disposed	-	-	-
Sea-food waste	craps, shells	7.9	disposed	shells, craps	7.9	disposed
Non-recyclable paper	used napkin,	5.7	disposed	used napkin, wet paper	3.6	disposed
Recyclable paper	-	-	-	-	-	-
Glass	kitchen-stuff, bottle	1.2	disposed	plates and glasses	1.2	disposed
Non-recyclable plastics	plastic bags, hard plastics	1.5	disposed	plastic bags, hard plastics	1.8	disposed
Recyclable Plastics	-	-	-	bottles	0.2	collected for selling
Metal	cans	0.4	collected for selling	cans	0.4	disposed
Others	foam, dirt	14	disposed	dirt, sand, cloth, bone	16.8	disposed
Total		**118.8**			**145.5**	
Total amount of waste generated:		***170.2***			***208.8***	
Total amount of waste disposed of:		***101.8***			***141.6***	

Table A.3 Quantity and Composition of Waste in CongDoan Hotel during the One-Week Audit Period (cont'd)

Material Category	20-Jun			21-Jun			22-Jun		
	Description	Net weight	Remark	Description	Net weight	Remark	Description	Net weight	Remark
Waste from guest rooms and staff rooms									
Fruit waste	litchi fruit, watermelon, dragon fruit,	25.4	mainly litchi fruit; disposed	litchi fruit, watermelon, dragon fruit, mango, banana,	38	disposed	rambutan, watermelon, dragon fruit,	22	disposed
Leftover food	bread, rice	0.97	disposed	rice, noodle	0.6		bread,	1	disposed
Flower waste	-	-	-	roses, leaves	1.2	disposed	roses	0.8	disposed
Non-recyclable Paper	damp napkins, tissue paper	7	disposed	damp napkins, tissue paper	11.7	disposed	napkins, tissue paper	9	disposed
Metal	cans	1.5	should be collected for selling, but disposed of actually	cans	1	disposed	cans	1.2	should be collected for selling, but disposed of actually
Glass	broken plates	0.4	disposed	bottles	7	should be collected for selling, but disposed of actually	bottles	0.7	should be collected for selling, but disposed of actually
Non-recycled plastics	plastic bags, hard plastics…	4.3	disposed	plastic bags, hard plastics…	7	disposed	plastic bags, hard plastics…	5.1	disposed
Recyclable paper	tissues, cardboard, print paper, newspaper	3.4	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	11.7	should be collected for selling, but disposed of actually	tissues, cardboard, print paper, newspaper	1.4	should be collected for selling, but disposed of actually
Recyclable plastics	bottles, clear bags,	1.8	should be collected for selling, but disposed of actually	bottles, clear bags	3.5	should be collected for selling, but disposed of actually	bottles, clear bags	2	should be collected for selling, but disposed of actually
Others	wood chips, sand, dust, rubber, cloth, shoes, foam,	2.3	disposed	wood chips, sand, dust, rubber, cloth, shoes,	2	disposed	Dust, foam, cloth	1.7	disposed
Total		**47.1**			**83.7**			**44.9**	
Waste from garden									
Leaves	brush	4.5	disposed	pine, brush	5.6	mainly pine	leaves	3.2	mainly pine, disposed
Grass clippings	-	-	-	-	-	-	-	-	-
Others	-	-	-	-	-	-	-	-	-
Total		**4.5**			**5.6**			**3.2**	
Waste from kitchen and restaurant									
Leftover food	rice, poultry, vegetable	50.5	collected for animal feeding,	rice, poultry	51	collected for animal feeding,	rice, poultry, chicken, meat, bean, cucumber …	52	collected for animal feeding,
Fruit waste	watermelon, dragon fruit, pine-apple	6	disposed	watermelon, dragon fruit, pine-apple	6	disposed	watermelon, dragon fruit, pine-apple	3.2	disposed
Vegetable waste	onion, garlic, water-morning glory,, cabbage, tomatoes,	37.2	disposed, except for 17.2kg of water-morning glory	water-morning glory,, carrot, pot-herbs	28.7	disposed, except for 12kg of water-morning glory	Onion, ,pot-herbs, carrot,, cabbage, tomatoes, potato ,	23.5	disposed, except for 13.5kg of water-morning glory and spinach collected for animal
Egg shell	-	-	-	-	-	-	-	-	-
Sea-food waste	lobsters, crabs, ,shells	4.5	disposed	shrimp, craps, shells	10	disposed	shell	3.5	disposed
Non-recyclable paper	used napkin,	7.2	disposed	used napkin, wet paper	6.5	disposed	used napkin,	3.5	disposed
Recyclable paper	-	-	-	-	-	-	cardboard	3	collected for selling
Glass	kitchen-stuff, bottle	5.5	disposed	-	4.8	disposed	kitchen-stuff, bottle	5.8	disposed
Non-recyclable plastics	plastic bags, hard plastics	3.8	disposed	plastic bags, hard plastics	2	disposed	plastic bags, hard plastics	5.2	disposed
Recyclable Plastics	bottles, clear bags,	0.3	collected for selling	-	-	-	bottles, clear bags	2.4	collected for selling
Metal	can	0.3	collected for selling	-	-	-	can	0.6	collected for selling
Others	bones, dirt, mixed food	2.3	disposed	foam, dirt, bone, cinder	10	disposed	foam, dirt, bone	12.3	disposed
Total		**117.6**			**119**			**115**	
Total amount of waste generated:		***169.2***			***208.3***			***163.1***	
Total amount of waste disposed of:		***100.5***			***144.3***			***91.6***	

A.4 Statistical Procedure (McBean and Rovers, 1998)

1. Mean

The arithmetic mean is the first moment about the origin (sometimes referred to as the data's centre of gravity) as calculated by the following equation:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad Where: \quad \bar{x}: arithmetic\ mean$$

$$n: the\ number\ of\ samples$$

2.Standard Deviation

The more representative of the measures of dispersion of the data (in that they reflect the array of data) is standard deviation which is defined as

$$S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad Where: \quad S: Standard\ Deviation;$$

$$x_i: the\ value\ of\ observation\ i$$

3. Measures of the Range of Data

An additional measure of dispersion or spread of data is the range. The range of a data set is simply the difference between the largest and the smallest value. Since only two of the values from the entire data set are utilized, the range is not a very useful parameter because it is sensitive to only these two values.

4. Confident Interval

A confident interval establishes a concentration range to contain a specified proportion of the population with a specified confidence, so that a specified proportion of monitoring observations should fall within this interval. The steps to determine the confidence interval as follows:

- Compute the mean and standard deviation as presented above.
- Construct the upper and lower intervals as

$$CI = \bar{x} \pm k * S \quad where\ k: the\ one-sided\ normal\ tolerance\ factor$$

5. Box-Whisker Plots

The Box-Whisker plots present a useful and quick graphical summary of data from different locations. Box-Whisker plots are potentially useful ways of summarizing the various measures of the spread or dispersion of the data. Box-Whisker plots are effective for exploratory data analysis as a way to visualize the spread of the data. Specifics of Box Whisker plots vary from one application to another, but the essence involves depiction of the mean, a measure of the spread, and the range. The spread is the "box" and the range is the "Whiskers". Figure 2.3 provides an example of a Box-Whisker plot.

Table A.5a Waste Generated per Guest per Day

SaiGon-HaLong Hotel

Date	Number of Overnight Guests	Total Weight of waste kg/day	Waste Weight per guest per day kg/guest/day
Day 1	429	355.6	0.83
Day 2	337	479.4	1.42
Day 3	341	304.1	0.89
Day 4	343	292.1	0.85
Day 5	378	299.8	0.79
Day 6	484	345.1	0.71
Day 7	484	437.3	0.90
Average	399.4	359.1	0.90*

CongDoan Hotel

Date	Number of Overnight Guests	Total Weight of waste kg/day	Waste Weight per guest per day kg/guest/day
Day 1	293	184.1	0.63
Day 2	248	173.4	0.70
Day 3	309	170.2	0.55
Day 4	274	208.8	0.76
Day 5	267	169.2	0.63
Day 6	250	208.3	0.83
Day 7	217	163.1	0.75
Average	265.4	182.4	0.69*

TienLong Hotel

Date	Number of Overnight Guests	Total Weight of waste kg/day	Waste Weight per guest per day kg/guest/day
Day 1	174	133.4	0.77
Day 2	166	172.7	1.04
Day 3	153	119.5	0.78
Day 4	226	151.7	0.67
Day 5	201	112.3	0.56
Day 6	118	126.1	1.07
Day 7	147	144.8	0.99
Average	169.3	137.2	0.81*

*Note: * The average guest-based amount is determined by Equation 2.3a (2).*

Table A.5b Waste Disposed per Guest per Day

SaiGon-HaLong Hotel

Date	Number of Overnight Guests	Total Weight of waste kg/day	Waste Weight per guest per day kg/guest/day
Day 1	429	198.3	0.46
Day 2	337	328.8	0.98
Day 3	341	194.2	0.57
Day 4	343	136.6	0.40
Day 5	378	144.7	0.38
Day 6	484	194.0	0.40
Day 7	484	226.4	0.47
Average	399.4	203.3	0.51*

CongDoan Hotel

Date	Number of Overnight Guests	Total Weight of waste kg/day	Waste Weight per guest per day kg/guest/day
Day 1	293	114.6	0.39
Day 2	248	105.6	0.43
Day 3	309	101.8	0.33
Day 4	274	141.6	0.52
Day 5	267	100.5	0.38
Day 6	250	144.3	0.58
Day 7	217	91.6	0.42
Average	265.4	114.3	0.43*

TienLong Hotel

Date	Number of Overnight Guests	Total Weight of waste kg/day	Waste Weight per guest per day kg/guest/day
Day 1	174	81.4	0.47
Day 2	166	123.1	0.74
Day 3	153	76.4	0.50
Day 4	226	102.6	0.45
Day 5	201	68.3	0.34
Day 6	118	77.1	0.65
Day 7	147	95.8	0.65
Average	169.3	89.2	0.53*

*Note: * The average guest-based amount is determined by Equation 2.3b (2).*

Table A.6 Generation-based Waste Composition in SaiGon-HaLong Hotel

Material Category	Description	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		One-week Audit Average*	
		Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %
Compostables	Leftover food, fruit , yard , vegetable, seafood waste, and egg shells	291.3	*81.9*	348.2	72.6	224.2	*73.7*	236.3	*80.9*	194.6	*64.9*	254.2	*73.7*	328.3	*75.1*	268.2	*74.7*
Recyclables	Paper, plastics, metal, and glass	42.3	*11.9*	50.3	10.5	38.4	*12.6*	17.5	*6.0*	47.6	*15.9*	32.1	*9.3*	40.9	*9.4*	38.4	*10.7*
Miscellaneous	Rubber, cloth, dirt, cigars, bones Non-recyclable paper, non-recyclable plastics	22.0	*6.2*	80.9	16.9	41.5	*13.7*	38.3	*13.1*	57.6	*19.2*	58.8	*17.0*	68.1	*15.5*	52.5	*14.6*
Total		**355.6**	**100**	**479.4**	**100.0**	**304.1**	**100**	**292.1**	**100**	**299.8**	**100**	**345.1**	**100**	**437.3**	**100**	**359.1**	**100**

Note: the average generation-based composition is determined by Equation 2.4 (2).*

Table A.7 Generation-based Waste Composition in TienLong Hotel

Material Category	Description	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		One-week Audit Average*	
		Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %
Compostables	Leftover food, fruit , yard , vegetable, seafood waste, and egg shells	85.0	*63.7*	145.0	*84.0*	87.5	*73.2*	114.0	*75.1*	74.2	*66.1*	90.2	*71.5*	106.4	*73.5*	100.3	73.1
Recyclables	Paper, plastics, metal, and glass	5.3	4.0	4.2	*2.4*	7.5	*6.3*	2.8	2.0	18.1	16.1	2.9	2.3	4.4	*3.0*	6.5	4.7
Miscellaneous	Rubber, cloth, dirt, cigars, bones Non-recyclable paper, non-recyclable plastics	43.1	32.3	23.5	*13.6*	24.5	*20.5*	34.9	22.9	20.0	*17.8*	33.0	*26.2*	34.0	*23.5*	30.4	22.2
Total		**133.4**	***100***	**172.7**	***100***	**119.5**	**100**	**151.7**	***100***	**112.3**	***100***	**126.1**	***100***	**144.8**	***100***	**137.2**	***100***

*Note: * the average generation-based composition is determined by Equation 2.4 (2).*

Table A.8 Generation-based Waste Composition in CongDoan Hotel

Material Category	Description	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		One-week Audit Average*	
		Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %
Compostables	Leftover food, fruit , yard , vegetable, seafood waste, and egg shells	150.5	*81.7*	130.7	*75.4*	124.6	*73.2*	162.2	*77.7*	129.1	*76.3*	141.1	*67.7*	109.2	*67.0*	135.3	*74.2*
Recyclables	Paper, plastics, metal, and glass	6.8	*3.7*	6.4	*3.7*	8.1	*4.8*	7.4	*3.5*	13.2	*7.8*	28.0	*13.5*	17.1	*10.5*	12.4	*6.8*
Miscellaneous	Rubber, cloth, dirt, cigars, bones Non-recyclable paper, non-recyclable plastics	26.8	*14.6*	36.3	*20.9*	37.5	*22.0*	39.2	*18.8*	26.9	*15.9*	39.2	*18.8*	36.8	*22.5*	34.7	*19.0*
Total		**184.1**	***100***	**173.4**	***100***	**170.2**	**100**	**208.8**	***100***	**169.2**	***100***	**208.3**	***100***	**163.1**	***100***	**182.4**	***100.0***

Note: the average generation-based composition is determined by Equation 2.4 (2).*

Table A.9 Disposal-based Waste Composition in SaiGon-HaLong Hotel

Material Category	Description	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		One-week Audit Average*	
		Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %	Weight kg	Percentage %
Compostables	Leftover food, fruit , yard , vegetable, seafood waste, and egg shells	174.0	87.8	239.7	72.9	149.7	77.1	98.3	72.0	87.1	60.2	135.2	69.7	158.3	73.2	148.9	73.3
Recyclables	Paper, plastics, metal, and glass	2.3	1.1	8.2	2.5	3.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1..9	0.9
Miscellaneous	Rubber, cloth, dirt, cigars, bones Non-recyclable paper, non-recyclable plastics	22	11.1	80.9	24.6	41.5	21.4	38.3	28.0	57.6	39.8	58.8	30.3	68.1	26.8	52.5	25.8
Total		**198.3**	**100.0**	**328.8**	**100**	**194.2**	**100**	**136.6**	**100**	**144.7**	**100**	**194.0**	**100**	**226.4**	**100**	**203.3**	**100**

Note: the average generation-based composition is determined by Equation 2.5 (2).*

Table A.10 Disposal-based Waste Composition in CongDoan Hotel

Material Category	Description	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		One-week Audit Average*	
		Weight *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*
Compostables	Leftover food, fruit , yard , vegetable, seafood waste, and egg shells	82.5	72.0	65.4	61.9	56.6	55.6	95.2	67.2	61.4	61.1	78.1	54.1	43.7	47.7	69.0	60.4
Recyclables	Paper, plastics, metal, and glass	5.3	4.6	3.9	3.7	7.7	7.6	7.2	5.1	12.2	12.1	27.0	18.7	11.1	12.1	10.6	9.3
Miscellaneous	Rubber, cloth, dirt, cigars, bones Non-recyclable paper, non-recyclable plastics	26.8	23.4	36.3	34.4	37.5	36.8	39.2	27.7	26.9	26.8	39.2	27.2	36.8	40.2	34.7	30.3
Total		**114.6**	**100**	**105.6**	**100**	**101.8**	**100**	**141.6**	**100**	**100.5**	**100**	**144.3**	**100**	**91.6**	**100**	**114.3**	**100**

Note: the average generation-based composition is determined by Equation 2.5 (2).*

Table A.11 Disposal-based Waste Composition in TienLong Hotel

Material Category	Description	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		One-week Audit Average*	
		Weight *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*	*Weight* *kg*	*Percentage* *%*
Compostables	Leftover food, fruit , yard , vegetable, seafood waste, and egg shells	33.0	40.5	96.0	78.0	46.5	60.9	64.9	63.3	31.2	45.7	41.2	53.4	57.4	59.9	52.9	59.3
Recyclables	Paper, plastics, metal, and glass	5.3	*6.5*	3.6	2.9	5.4	*7.1*	2.8	*2.7*	17.1	*25.0*	2.9	*3.8*	4.4	*4.6*	5.9	*6.6*
Miscellaneous	Rubber, cloth, dirt, cigars, bones Non-recyclable paper, non-recyclable plastics	43.1	53.0	23.5	*19.1*	24.5	*32.0*	34.9	34.0	20.0	*29.3*	33.0	*42.8*	34.0	*35.5*	30.4	34.1
Total		**81.4**	**100**	**123.1**	**100**	**76.4**	**100**	**102.6**	**100**	**68.3**	**100**	**77.1**	**100**	**95.8**	**100**	**89.2**	**100**

Note: the average generation-based composition is determined by Equation 2.5 (2).*

Table A.12 Quantification and Composition of Compostables in SaiGon-HaLong Hotel

Categories compostables		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Average*	
		Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)
Fruit waste	Generated	100.7	34.6	147.1	42.2	66.9	29.8	47.2	20.0	52.0	26.7	80.5	31.7	97.8	29.8	84.6	31.6
	Disposed	100.7	57.9	147.1	61.4	66.9	44.7	47.2	48.0	52.0	59.7	80.5	59.5	97.8	61.8	84.6	56.8
Leftover food	Generated	104.8	36.0	133.7	38.4	70.4	31.4	138.0	58.4	107.5	55.2	119.0	46.8	171	52.1	120.6	45.0
	Disposed	0.0	0.0	72.0	30.0	2.9	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	10.8	7.3
Vegetable waste	Generated	58.5	20.1	51.8	14.9	58.5	26.1	22.5	9.5	22.5	11.6	32.5	12.8	45.7	13.9	41.7	15.5
	Disposed	46.0	26.4	5.0	2.1	51.5	34.4	22.5	22.9	22.5	25.8	32.5	24.0	45.7	28.9	32.2	21.6
Yard waste (leaves and glass clippings)	Generated	21.4	7.3	7.0	2.0	14.7	6.6	27.0	11.4	4.6	2.4	19.7	7.7	8.5	2.6	14.7	5.5
	Disposed	21.4	12.3	7.0	2.9	14.7	9.8	27.0	27.5	4.6	5.3	19.7	14.6	8.5	5.4	14.7	9.9
Others (egg shells, seafood, flower)	Generated	5.9	2.0	8.6	2.5	13.7	6.1	1.6	0.7	8.0	4.1	2.5	1.0	5.3	1.6	6.5	2.4
	Disposed	5.9	3.4	8.6	3.6	13.7	9.2	1.6	1.6	8.0	9.2	2.5	1.8	5.3	3.3	6.5	4.4
Total	Generated	291.3	100	348.2	100	224.2	100	236.3	100	194.6	100	254.2	100	328.3	100	268.2	100
	Disposed	174.0	100	239.7	100	149.7	100	98.3	100	87.1	100	135.2	100	158.3	100	148.9	100
Disposed/Generated	%	59.7		68.8		66.8		41.6		44.8		53.2		48.2		55.5	

Note: the average generation-based composition is determined by Equation 2.6 (2).*

Table A.13 Quantification and Composition of Compostables in CongDoan Hotel

Categories of compostables		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Average*	
		Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)
Fruit waste	Generated	42.0	27.9	46.1	35.3	35.6	28.6	51.6	31.8	31.4	24.3	44.0	31.2	25.2	23.1	39.4	29.1
	Disposed	42.0	50.9	46.1	70.5	35.6	62.9	51.6	54.2	31.4	51.1	44.0	56.3	25.2	57.7	39.4	57.1
Leftover food	Generated	51.0	33.9	54.0	41.3	52.8	42.4	50.7	31.3	51.5	39.9	51.6	36.6	53.0	48.5	52.1	38.5
	Disposed	1.0	1.2	2.5	3.8	0.8	1.4	0.7	0.7	1.0	1.6	0.6	0.8	1.0	2.3	1.1	1.6
Vegetable waste	Generated	38.0	25.2	22.8	17.4	22.3	17.9	46.6	28.7	37.2	28.8	28.7	20.3	23.5	21.5	31.3	23.1
	Disposed	20.0	24.2	9.0	13.8	6.3	11.1	29.6	31.1	20.0	32.6	16.7	21.4	10.0	22.9	15.9	23.0
Yard waste (leaves and glass clippings)	Generated	4.7	3.1	4.0	3.1	5.6	4.5	5.0	3.1	4.5	3.5	5.6	4.0	3.2	2.9	4.7	3.5
	Disposed	4.7	5.7	4.0	6.1	5.6	9.9	5.0	5.3	4.5	7.3	5.6	7.2	3.2	7.3	4.7	6.8
Others (egg shells, seafood, flower)	Generated	14.8	9.8	3.8	2.9	8.3	6.7	8.3	5.1	4.5	3.5	11.2	7.9	4.3	3.9	7.9	5.8
	Disposed	14.8	17.9	3.8	5.8	8.3	14.7	8.3	8.7	4.5	7.3	11.2	14.3	4.3	9.8	7.9	11.5
Total	Generated	150.5	100	130.7	100	124.6	100	162.2	100	129.1	100	141.1	100	109.2	100	135.3	100
	Disposed	82.5	100	65.4	100	56.6	100	95.2	100	61.4	100	78.1	100	43.7	100	69.0	100
Disposed/Generated	%	54.8		50.0		45.4		53.6		47.6		55.4		43.7		51.2	

Note: the average generation-based composition is determined by Equation 2.6 (2).*

Table A.14 Quantification and Composition of Compostables in TienLong Hotel

Categories of compostables		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Average*	
		Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)	Weight (kg)	Percentage (%)
Fruit waste	Generated	10.8	12.7	2.9	2.0	12.4	14.2	28.3	24.8	7.4	10.0	4.4	4.9	26.7	25.1	13.3	13.2
	Disposed	10.8	32.7	2.9	3.0	12.4	26.7	28.3	43.6	7.4	23.7	4.4	10.7	26.7	46.5	13.3	25.1
Leftover food	Generated	52.0	61.2	49	33.8	35.3	40.3	42.2	37.0	45.5	61.3	43.4	48.1	53.2	50.0	45.8	45.7
	Disposed	0.0	0.0	0.0	0.0	0.3	0.6	0.2	0.3	2.5	8.0	1.4	3.4	4.2	7.3	1.2	2.3
Vegetable waste	Generated	2.0	2.4	9.5	6.6	16.4	18.7	16.1	14.1	9.2	12.4	20.0	22.2	11	10.3	12.0	12.0
	Disposed	2.0	6.1	9.5	9.9	10.4	22.4	9.0	13.9	9.2	29.5	13.0	31.6	11	19.2	9.2	17.4
Yard waste (leaves and glass clippings)	Generated	18.0	21.2	82.7	57.0	20.7	23.7	27.4	24.0	11.0	14.8	17.2	19.1	10.0	9.4	26.7	26.6
	Disposed	18.0	54.5	82.7	86.1	20.7	44.5	27.4	42.2	11.0	35.3	17.2	41.7	10.0	17.4	26.7	50.5
Others (egg shells, seafood, flower)	Generated	2.2	2.6	0.9	0.6	2.7	3.1	0.0	0.0	1.1	1.5	5.2	5.8	5.5	5.2	2.5	2.5
	Disposed	2.2	6.7	0.9	0.9	2.7	5.8	0.0	0.0	1.1	3.5	5.2	12.6	5.5	9.6	2.5	4.7
Total	Generated	85.0	100	145.0	100	87.5	100	114.0	100	74.2	100	90.2	100	106.4	100	100.3	100
	Disposed	33.0	100	96.0	100	46.5	100	64.9	100	31.2	100	41.2	100	57.4	100	52.9	100
Disposed/Generated	%	38.8		66.2		53.1		56.9		42.0		45.7		53.9		52.7	

Note: the average generation-based composition is determined by Equation 2.6 (2)*

APPENDIX B

COMPOSTING TRIAL

Table B.1 The Record of Weigh of the Daily Feedstock

Date	Fruit Waste		Yard waste		Vegetable Waste		Additives	
	Composition	*Weight (kg)*	*Composition*	*Weight (kg)*	*Composition*	*Weight (kg)*	*Composition*	*Weight (kg)*
29-Jun	litchi fruit, mango, pine apple, water lemon,	35.2	leaves, tree trimmings	35.4	carrot, cabbage, onion, spinach, pot-herbs	17.5	coconut shell rice hull	5 2
30-Jun	rambutan, mango, pine apple, water lemon,	48.7	leaves, tree trimmings	-	carrot, cabbage, onion, potatoes, tomatoes, garlic	46.5	coconut shell rice hulls	6 2
1-Jul	rambutan, mango, pine apple, water lemon,	45	leaves, tree trimmings	7	carrot, cabbage, onion, potatoes, tomatoes, garlic	21	coconut shell rice hulls	6 0.5
4-Jul	rambutan pine apple, water lemon, mangosteen	43.5	leaves, pine needle	7.2	carrot, cabbage, onion, potatoes, spinach, tomatoes, garlic	42.5	coconut fruit	5
5-Jul	pine apple, watermelon, plum	38	leaves, pine needle	3.4	carrot, cabbage, onion, potatoes, tomatoes, garlic, pot-herbs	11.9	coconut shell rice hulls	6 1
7-Jul	litchi fruit, pine apple, water melon, rambutan	41.4	pine needle, leaves	6.1	carrot, cabbage, onion, potatoes, tomatoes, garlic	34	coconut shell rice hulls	7 3.1
10-Jul	litchi fruit, pine apple, water melon, rambutan, mango, mangosteen, plum	89	pine needle	3	carrot, cabbage, onion, spinach, water-morning glory, tomatoes, garlic	68	coconut shell rice hulls dried sugar-cane refuse	9.5 2 .5 2
Sub-Total	340.8		62.1		241.4		57.6	
Total	**701.9**							

B.2 Calculation of C: N Ratio:

According to on-farm composting handbook (Rynk et al., 1992)

Elements	MinimumC:N ratio	Maximum C:N ratio
Vegetable waste	11:1	13:1
Fruit waste	20:1	49:1
Yard waste	40:1	80:1

The minimum C:N ratio of waste collected from hotels: $\frac{11*340.8+20*62.1+241.4*40}{340.8+62.1+241.2} = 20.9$

The maximum C:N ratio of waste collected from hotels: $\frac{13*340.8+49*62.1+241.4*80}{340.8+62.1+241.2} = 38.2$

Table B.3 Record of Temperature of the Compost Pile

Date	Time	Ambient Air		Composting heap	
		Temperature (F)	Description	Temperature (F)	Average Temperature (F)
1-Jul	10:00 a.m.	82 (27.8^{o}C)	sunny	point 1: 120 (48.9^{o}C) point 2: 115 (46.1^{o}C)	117.5 (47.5^{o}C)
4-Jul	9:00 a.m.	82.5 (28.1^{o}C)	sunny	point 1: 115 (46.1^{o}C) point 2: 120 (48.9^{o}C)	117.5 (47.5^{o}C)
5-Jul	10:00 a.m.	81 (27.2^{o}C)	rainy	point 1: 127 (52.8^{o}C) point 2: 120 (48.9^{o}C)	123.5 (50.8^{o}C)
6-Jul	10:00 a.m.	82 (27.8^{o}C)	sunny	point 1: 130 (54.4^{o}C) point 2: 133 (56.1^{o}C)	131.5 (55.3^{o}C)
7-Jul	10:00 a.m.	83 (28.3^{o}C)	sunny	point 1: 127 (53.8^{o}C) point 2: 130 (54.4^{o}C)	128.5 (53.6^{o}C)
8-Jul	10:00 a.m.	80 (26.7^{o}C)	rainy	point 1: 122 (50.0^{o}C) point 2: 125 (51.7^{o}C)	123.5 (50.8^{o}C)
10-Jul	10:30 a.m.	76 (24.4^{o}C)	sunny	point 1: 122 (50.0^{o}C) point 2: 126 (52.2^{o}C)	124 (51.1^{o}C)
11-Jul	10:00 a.m.	-	sunny	point 1: 141 (60.6^{o}C) point 2: 110 (43.3^{o}C)	125.5 (51.9^{o}C)
12-Jul	10:00 a.m.	-	sunny	point 1: 117 (47.2^{o}C) point 2: - -	117 (47.2^{o}C)
13-Jul	10:00 a.m.	-	sunny	point 1: 127 (52.8^{o}C) point 2: 120 (48.9^{o}C)	123.5 (50.8^{o}C)
14-Jul	10:00 a.m.	-	sunny	point 1: 115 (46.1^{o}C) point 2: 105(40.6^{o}C)	110 (43.3^{o}C)
15-Jul	9:45 a.m.	76 (24.4^{o}C)	rainy	point 1: 115 (46.1^{o}C) point 2: 115 (46.1^{o}C)	115 (46.1^{o}C)
16-Jul	8:00 a.m.	73 (22.8^{o}C)	rainy	point 1: 107 (41.7^{o}C) point 2: 105 (40.6^{o}C)	106 (41.1^{o}C)
17-Jul	8:00 a.m.	75 (23.9^{o}C)	sunny	point 1: 105 (40.6^{o}C) point 2: 105 (40.6^{o}C)	105 (40.6^{o}C)
18-Jul	8:30 a.m.	80 (26.7^{o}C)	sunny	point 1: 105 (40.6^{o}C) point 2: 104 (40.0^{o}C)	104.5 (40.3^{o}C)
19-Jul	9:00 a.m.	77 (25.0C)	sunny	point 1: 105 (40.6^{o}C) point 2: 103 (39.4^{o}C)	104 (40.0^{o}C)
20-Jul	9:00 a.m.	79 (26.1^{o}C)	rainy	point 1: 112 (44.4 ^{o}C) point 2: 110 (43.3^{o}C)	111 (43.9^{o}C)
22-Jul	4:00 p.m.	75 (23.9^{o}C)	rainy	point 1: 105 (40.6^{o}C) point 2: 105 (40.6^{o}C)	105 (40.6^{o}C)
24-Jul	9:00 a.m.	75 (23.9^{o}C)	rainy	point 1: 110 (43.3^{o}C) point 2: 107 (41.7^{o}C)	108.5 (42.5^{o}C)
25-Jul	3:00 p.m	74 (23.3^{o}C)	cloudy	point 1: 105 (40.6^{o}C) point 2: 104 (40.0^{o}C)	104.5 (40.3^{o}C)
26-Jul	9:00 a.m.	85 (29.4^{o}C)	sunny	point 1: 105 (40.6^{o}C) point 2: 105 (40.6^{o}C)	105 (40.6^{o}C)
27-Jul	9:00 a.m.	85 (29.4^{o}C)	sunny	point 1: 103 (39.4^{o}C) point 2: 102 (38.9^{o}C)	102.5 (39.2^{o}C)
28-Jul	9:00 a.m.	75 (23.9^{o}C)	rainy	point 1: 100 (37.8^{o}C) point 2: 102 (38.9^{o}C)	101 (38.3^{o}C)

29-Jul	9:00 a.m.	80 (26.7^{0}C)	rainy	point 1: 102 (38.9^{0}C) point 2: 103 (39.4^{0}C)	102.5 (39.2^{0}C)
30-Jul	9:00 a.m.	78 (25.6^{0}C)	rainy	point 1: 100 (37.8^{0}C) point 2: 99 (37.2^{0}C)	99.5 (37.5^{0}C)
31-Jul	9:00 a.m.	75 (23.9^{0}C)	rainy and cloudy	point 1: 95 (35.0^{0}C) point 2: 92 (33.3^{0}C)	93.5 (34.2^{0}C)
1-Aug	9:00 a.m.	76 (24.4^{0}C)	rainy and sunny	point 1: 95 (35.0^{0}C) point 2: 93 (33.9^{0}C)	94 (34.4^{0}C)
2-Aug	9:00 a.m.	78 (25.6^{0}C)	rainy and sunny	point 1: 91 (32.8^{0}C) point 2: 89 (31.7^{0}C)	90 (32.2^{0}C)
27-Aug	9:15 a.m.	75 (23.9^{0}C)	sunny	point 1: 81 (27.2^{0}C) point 2: 79(26.1^{0}C)	80 (26.7^{0}C)

Note: $1^0F = 32+(9/5) * 1^0C$

Table B.4 Record of Moisture Content of the Compost Pile

Date	**Weight of dish with waste before heating**	**Weight of dish with waste after heating**	**Moisture**	**Note**
	g	g	%	
1-Jul	405.5	83.5	79.4	after sorting (*source- separated raw materials from hotels*)
10-Jul	562.0	138.0	75.4	after 3rd turning
19-Jul	459.5	153.2	66.7	after 5th turning
27-Jul	350.0	156.0	55.4	after 7th turning
1-Aug	497.5	240	51.8	after the last turning (*before curing*)

Table B.5 Lessons Learned from the Composting Trial

Problems	Possible Reasons	Trouble-shooting
Waste Separation at Source		
- Low participation level of hotels and their staff	- Lack of easily-accessible facilities	- Provide waste bins with clear labels and place them in suitable locations.
	- Low awareness and understandings of source separation	- Mobilize, propagandize, and educate benefits and procedures of source separation to enhance public awareness
Composting Process		
- Odour (rotten smell)	- Material mixture low in bulking material - Lack of oxygen or compacted material - Too high in nitrogen	- Adding bulking material, such as coconut shell. - Turning the pile more frequently
- High levels of flies	- Food remain are near surface and not covered	- Turning the pile more frequently to move fly larvae into hotter area of the pile - Cover the pile with a thin layer of leaves or rice hulls
- Seepage water	- Material too wet	- Add dry material, such as rice hulls, sugar-cane waste - Turning the pile more frequently
- Pile fail to heat	- Material too wet (especially moisture content >60% - Small size pile (with the height of less than 1 m) - Low oxygen	- Add dry material, such as rice hulls, sugar-cane waste - Turning the pile more frequently - Adding bulking material, such as coconut shells
Composting Quality		
- High in foreign matter	- Mixed with plastics, metals, sand, etc.	- Source separation - Protect composting facilities from external factors.
- Pathogens	- Low temperature - Infected by external factors.	- Any mentioned approach to fix “Pile fails to heat” - Keep the compost facilities away from pathogen source (such as open dumping)