QUANTIFICATION AND COMPOSITION AUDIT OF WASTE GENERATED AT THE EARLY MORNING MARKET IN VIENTIANE, LAO PDR

By

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Abstract

Waste characterization is important to properly establish an Integrative Waste Management (IWM) system. This thesis describes an audit for estimating the quantity and composition of commercial wastes generated at the Early Morning Market (EMM) in Vientiane, Lao PDR and assess the feasibility of a compost program for market wastes.

The waste audit was conducted over a nine-day period in the wet season. The average daily quantity and composition of waste generated was estimated for six types of vendors identified in the EMM: Fruits and Vegetables; Packaged Goods; Meat, Fish and Eggs; Rice and Charcoal; Noodles and Blood; and Food Stalls. The composition was determined by physically sorting waste from each vendor-type into one of the nine following categories: green organics, brown organics, paper products, animal food wastes, hard plastics, soft plastics, metals, glass and other (miscellaneous items). Day-to-day variation in waste characteristics was evaluated.
Moisture content analysis on green and brown organic wastes from three vendor-types was completed. The results from the EMM audit provide a tool for understanding the nature of waste generated by similar vendor-types at other Vientiane markets.

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1. Introduction

1.1 Introduction to Lao People's Democratic Republic

This research work investigates the quantity and composition of waste generated at markets in Vientiane, Lao People's Democratic Republic (Laos). Laos is a landlocked nation that shares borders with China, Myanmar, Thailand, Cambodia and Vietnam and covers 235,000 sq. km.

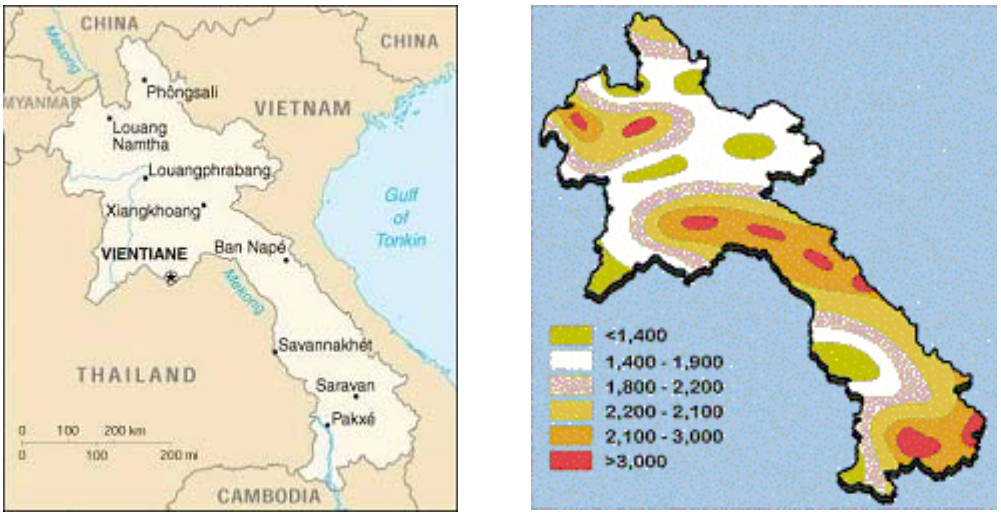


FIGURE 1-1: MAP OF LAOS (LEFT) AND MAP SHOWING ANNUAL RAINFALL IN MM (RIGHT)

Laos' economy is highly dependent on its natural resources. Although agriculture accounts for 52.1% of the Gross Domestic Product (GDP), it employs over four fifths of the population [Phissamay, 2003]. The main agricultural production zones are found along the Mekong River Valley's fertile flood plains, which are also the location of the two largest urban centers, the capital city of Vientiane and Savannakhet.

In July 2003, Laos' estimated population was 5, 921, 545 with an expected annual population growth rate of 2.45% [CIA, 2003]. The highest population density is found in the municipality of Vientiane, which is the administrative and commercial center of the country with a population of 600,000 and an annual growth rate of 4.7% {Phissamay, 2002].

Laos experiences two basic seasons: the wet season and the dry season. The wet season arrives between May and July and lasts until November. The rainfall varies according to altitude as shown in Figure 1-1. Vientiane receives 1500 mm – 2000 mm of rain [Cummings, 2002] during

this time. Generally speaking, the monsoon season produces severe rain that lasts for short periods of time. The dry season is divided into two parts. The first part (November to May) begins with lower relative temperatures and cool breezes. The second part occurs between March and May, during which time the temperatures are relatively higher. The highest temperatures occur in March and April (approaching 38°C) and the lowest in December and January (as low as 15°C) [Cummings, 2002].

1.2 Background

Waste-Econ is a five-year collaborative program between the University of Toronto and a number of government institutions, universities, and NGOs in Vietnam, Laos and Cambodia that is funded by the Canadian International Development Agency (CIDA). Through its promotion of Integrated Waste Management (IWM), Waste-Econ supports a waste economy that provides enhanced earnings and working conditions, while promoting sustainability, waste reduction and recycling in these countries [Waste-Econ, 2003].

In May 2003, a pilot project was launched by Waste-Econ to determine the feasibility and sustainability of establishing a permanent composting facility for handling wastes from Vientiane markets. The design and implementation of such a facility depends on the quantity and composition of waste generated at the markets. With adequate data, informed decisions about composting capacities can be made, undue financial risks can be prevented and progress towards meeting national or local waste reduction goals can be evaluated [Martin, 1995]. Omitting a quantitative and qualitative analysis of a facility's solid waste in the planning process can lead to problems in the design of an integrated waste management (IWM) system.

The need to study solid waste generation and composition from Vientiane markets was first identified during a six-week training course in the summer of 2002 organized by Waste-Econ. One of the exercises during the course explored the economic value of wastes and the collection of decomposed wastes at the Sikhai and Thong Khankham (TKK) markets in Vientiane respectively. These short studies identified the main types of businesses in the markets and estimated the composition of the wastes generated by businesses in the Sikhai Market. Personal interviews were conducted to develop a list of retail and grocery stores and the volume of decomposed waste produced in TKK. To present the results and findings from these short studies, summary reports were completed as part of the course. Although these summary

reports made an initial attempt to audit the markets in Vientiane, the analyses lacked rigor since a discussion of the data collection process and the significance of the findings were not provided. These limitations render the results presented in the reports questionable and unable to be replicated to ensure continuity and consistency.

An important lesson from the training course was that information regarding the nature of waste generated at Vientiane markets was scarce but crucial for proper implementation and design of an IWM facility. As a result, to properly integrate composting into the existing solid waste management program in Vientiane, it is vital to know the quantity and characteristics of the waste from the markets.

1.3 Waste Audit

To ascertain whether solid wastes are suitable for composting, consistent information on waste quantity and character through a *waste composition and quantification study* (also known as a waste audit or survey) is required. A waste audit is a step-by-step physical analysis that employs reliable sampling techniques to ascertain the quantity and composition of waste generated in a facility [Haight, 2003]. A *waste quantification study* estimates the amount of waste that is collected every day and a *waste composition study* involves carrying out a physical sort of a representative sample from the facility to determine the percent composition of components of interest. Sometimes, a composition study can also include estimating physical and chemical characteristics of the wastes. Combined, these studies deduce the character of the constituents, identify the sources of waste, assess the range of compositions and quantities of each waste type produced and project the increase in quantities of each waste stream in order to plan for future provision of facilities [Cannon, 2001].

1.4 Composting

Composting is a biochemical process that decomposes the putrescible fraction of organic material under controlled conditions [Robinson, 1986]. The physical properties of compost can improve soil quality and agricultural activities by providing additional plant nutrients and replacing the organic matter in the soil [Hoornweg, 2003].

There are two general types of biochemical decomposition processes: aerobic and anaerobic. Aerobic decomposition occurs when bacteria and microorganisms (aerobes) use large volumes of oxygen to efficiently and rapidly oxidize organic matter into minerals, humus, carbon dioxide and water. Anaerobic (without oxygen) decomposition is a slower and therefore less efficient process in which anaerobic microorganisms (anaerobes) reduce organic matter into minerals, humus, methane and carbon dioxide. If an aerobic composting process is controlled, it will continue to decompose organic matter aerobically. If the aerobic composting process is improperly controlled, it can turn anaerobic, producing offensive odours.

Since project sustainability is key to the success of a permanent composting facility in Vientiane, it has been recommended by experts that the composting operation be reliable, simple and more labour intensive than mechanical [Haight, 2000]. As such, it is expected that the permanent composting facility will employ aerobic decomposition and consist of a compost pile that will be regularly mixed by hand to facilitate the movement of oxygen through the pile.

Aerobic decomposition involves a variety of organisms that naturally breakdown organic materials. These bacteria can be divided into three broad groups:

- psycrhophilic (live at < 20°C)
- mesophilic (live at 20-40°C)
- thermophilic (live at > 40°C)

Aerobic, thermophilic microorganisms accomplish the most rapid composting. Therefore it is important to provide an environment that is suitable to them. Such an environment does not only include the correct temperature but also has an adequate carbon:nitrogen ratio (C:N), moisture content , oxygen, and pH.

1.4.1 Carbon:Nitrogen Ratio

Bacteria use carbon and nitrogen from organic materials as an energy source and for cell building respectively. Decomposition involves reducing the relative proportion of these elements, known as the carbon to nitrogen ratio (C:N ratio). C:N ratios are reported as the number of units of carbon per unit of nitrogen [CCC, 2003]. The original C:N may range from 20:1 to 70:1 and is ideally between 30:1 and 35:1 [Holmes, 1981]. When the available carbon has been consumed and activity ceases, the C:N ratio ranges between 15:1 and 20:1 [Holmes, 1981].

To ensure that decomposition occurs at an acceptable speed, organic mixtures have to provide the microorganisms with the correct balance of carbon and nitrogen. For example, if the C:N is too high (more carbon), the microbes lack the tools to break down the carbon sources and the process can be very slow. Low C:N ratios (high nitrogen) are undesirable for a different reason. Any nitrogen in excess of what the microbes need to break down the available carbon can easily be lost to the atmosphere as ammonia gas [CCC, 2003].

Items high in carbon or nitrogen can be visually identified in a compost pile as brown or green organics respectively. Brown organics (browns) are high-carbon wastes that are commonly dry, hard and rigid. These materials do not easily break down nor create unpleasant odours in a pile. On the other hand, green organics (greens) are materials that are high in nitrogen, have food value, are soft, commonly moist and compact quickly (Haight, 2000). These materials tend to break down and create unpleasant odours in a short time. An easy way to manage the C:N ratio in a compost pile is to ensure that a correct balance of browns or greens is maintained.

The C:N ratio of incoming materials can change seasonally. To maintain optimum conditions for composting, an evaluation of the seasonal C:N fluctuations can be useful for maintaining optimum composting conditions.

1.4.2 Moisture Content

Microorganisms are very sensitive to the moisture content in their environment. Moisture content is the percent of water that makes up the total weight of the solid waste. If the moisture content falls to between 35-40%, the metabolic activity of microorganisms slows down and the decomposition rates decrease significantly. If the moisture content is below 30%, biochemical decomposition essentially stops [Holmes, 1981]. If there is too much moisture, anaerobic conditions prevail as water fills the spaces in the mixture making it difficult for air to circulate.

The ideal moisture content throughout the composting process should be controlled to between 50% and 60% [Tchobanoglous, 1993]. Moisture can be adjusted by blending of components or by addition of water or other liquids to the pile when the moisture content is low. Turning or adding dry materials to the compost pile can reduce higher moisture contents.

1.4.3 Oxygen Requirements

Since aerobes consume oxygen during composting, it must be constantly re-supplied. The amount of oxygen available to aerobes is influenced by the porosity of the pile, pile turning and

the rate of oxygen consumption. The porosity impacts the oxygen flow through a pile. Mixing and turning improves porosity, hence air dispersion through the pile.

The rate of oxygen consumption varies with the waste. Turning the pile to increase oxygen supply or adding water and oxygen-consuming materials to decrease available oxygen helps control different compost piles.

1.4.4 pH control

The pH of the refuse that is being composted is a parameter important to the microbial environment. The pH of compost varies with time during the composting process and is a good indicator of the extent of decomposition within the compost mass [Holmes, 1981]. The initial pH of solid waste that is three days old is between 5.0 and 7.0. In the first two to three days of composting, it drops to 5.0 and then begins to rise to about 8.5 for the remainder of the composting process. If the process becomes anaerobic, the pH drops to less than 4.5 [Holmes, 1981]. Thus the normal pH range for composting is 5.5 to 8.

1.5 Purpose and Structure

The purpose of this work is to conduct a waste audit of the waste generated in a Vientiane market during the wet season. There are many markets in the Vientiane prefecture[1]. The market studied in this work is the Early Morning Market (EMM) at TKK. The reasons why EMM was selected for this work are provided in section 2.2.1.

The study included:

1. Carrying out a waste audit of the EMM by type of vendor, including an estimation of:
    a. The quantity of commercial wastes generated at the EMM;
    b. The composition of commercial waste generated at the EMM;
    c. The moisture content for browns and greens categories sorted for the fruit and vegetable (FV), food stalls (FS) and noodles and blood (NB) vendors from a two-day audit during the wet season;

[1] The markets in Vientiane are described in Section 2.2.

2. Providing a means for estimating the quantity and composition of wastes generated at similar markets in the wet season using the results from this study;
3. Establishing a reference to assist in developing sampling methodologies for conducting waste audits at other markets in Laos in the future.

The main goal of the waste audit is to provide waste quantity and composition data that will assess the feasibility of composting organic wastes from the EMM and other markets in Vientiane. The estimate of waste generation by vendor-type will provide a tool to approximate the waste generated by similar vendor-types. By conducting a compositional analysis of the waste by vendor-type, the results from this work will isolate and locate the source of generation for specific waste streams. The audit will identify the waste streams that must be removed from each vendor-type such that the feedstock to a compost pile will not complicate the composting process. Finally, information on recyclables might help future studies decide if formal recycling programs are a viable and necessary means of handling wastes from markets in Vientiane.

On the whole, the background information and sampling methodology developed in this work will also offer guidance for waste audits being organized in other regions of Laos and throughout Southeast Asia. Furthermore, it is hoped that the findings from a waste audit on one market will be useful for understanding similar markets in the Vientiane prefecture.

In Section 2, the sampling methodology and procedure for the waste audit is outlined. Section 3 presents the results from the waste audit and discusses the waste quantity, composition and moisture content estimates based on the data gathered. Section 4 summarizes the findings of the thesis, evaluates the reliability of the results from this work, makes recommendations to improve the design of a waste audit sampling methodology and offers suggestions for future work.

2. Sampling Methodology and Procedure for Waste Audit

At the time of this work, there was no standardized methodology for conducting waste audits in Southeast Asian markets during the wet season. For this reason, the planning stages of this study involved establishing a suitable procedure for conducting a waste audit in the Laotian context. Developing the methodology involved:

- Selecting a location suitable for conducting the physical sort and the waste audit team;
- Understanding operation and the solid waste management (SWM) system of the EMM;
- Determining how to obtain a good representative sample;
- Selecting the categories for the waste composition study; and
- Establishing the most reliable means of quantifying the daily waste disposed at the EMM.

To develop a sampling methodology, it was necessary to undertake trial audits, make reference to previous waste audits carried out for waste generated from different sources and to seek information from experts in the areas of waste auditing and composting. Local environmental consultants, market vendors and management provided suggestions that were key to the development of the procedures discussed in this section.

2.1 Selection of Physical Sort Location and Waste Audit Team

Nabong Agricultural University (Nabong), which is located 35 km north of the Monument Building, Patuxai in the Vientiane prefecture (see Figure 2-2) was selected as the location for the physical sort. Nabong was selected as the location for the physical sort during a meeting between members of the National Science Council (NSC), the head of Nabong and the Waste-Econ field team at the university on June 23, 2003. It was decided that Nabong would be a good location for the sort because:

- There was ample room at the campus for carrying out the sort;

- No special construction was required to ensure that a sheltered area was available for the sort;
- Nabong students involved in the waste audit could participate in the work on campus, resulting in minimal disruption to their regular curriculum.

FIGURE 2-1: LOCATION OF PHYSICAL SORT AT NABONG

A sheltered area that was being used for parking vehicles was selected as the prime location for sorting the waste. During waste audit activities, the vehicles in this area were removed, providing ample room for conducting the physical sort. Figure 2-1 shows the location for the physical sort.

The audit team comprised of five second and third year students from Nabong, one translator and one to two employees of the NSC. Training was provided to all members of the waste audit team throughout the audit process. The first training session was provided in Trial Audit 1 (Appendix 1) on June 30, 2003 during which a seminar was organized by Waste-Econ for members of the waste audit team, market managers, staff of the NSC and members of the local steering committee. On July 1, 2003, all attendees to the seminar were invited for a day at Nabong for a demonstration of the waste audit procedures during the first pilot audit. Subsequent training was provided between the seven-day and two-day waste audit periods[2]. At this time, major issues that were raised from the seven-day audit such as the proper classification of brown and green organics was discussed (see Table 2-7). The importance of the categories in the physical sort were also discussed.

2.2 Markets in Vientiane

The first part of this study was to identify the main markets in Vientiane and gain an understanding of their daily operations. By touring the city, it was found that there are many markets throughout the Vientiane prefecture. The five largest and most central markets in the districts throughout the city included Thalat Khaudin, Thalat That Luang, Thalat

[2] Information on the 7-day and 2-day waste audit periods is provided in Section 3.1.1.

Thongkhankham (TKK) Thalat Sikhai and Thalat Sao (The Morning Market). Day and night operations were observed in the first three markets.

TABLE 2-1: MARKETS IN VIENTIANE[3]

Market	Hours of Operation	Items Sold
Thalat Khaudin	4 am – 8 am	Fruits and Vegetables
	8 am – 6 pm	Mixture of Food items, textiles, packaged goods
	7 pm onwards	Vendors and wholesalers of organic foods (not run by regional district)
Thalat That Luang	3am – 9 am	Fruits and vegetables, meat and fish
	5 am – 7:30 pm	Textiles, packaged goods, food
Thalat Thongkhankham	TKK Night Market (5 am – 11 am)	Fruits and vegetables, meat, fish, eggs
	Early Morning Market (EMM) (5 am – 11 am)	Fruits and vegetables, meat, fish, eggs, packaged goods
	8am – 5 pm	Fruits and vegetables, cooked food, textiles, packaged goods
Thalat Sikhai	5am – 7pm	Fruits and vegetables, clothing, textiles and packaged goods
Thalat Sao	8 am – 5 pm	Packaged goods, cooked foods, textiles, jewelry, clothing, electronics, furniture, appliances, tourist items, books and magazines

Only day operations were observed at the last two markets. Night operations were observed at Thalat Khaudin. Visual observations of the items sold by the vendors in each of the market were noted while walking through the markets during operation. Discussions with locals, vendors and market managers were also carried out to obtain useful information about the markets. Table 2-1 outlines the hours of operations and main items sold in these five markets. The markets discussed in Table 2-1 are identified on the map of Vientiane shown in Figure 2-2.

[3] Information on the various markets was also obtained from Genevieve Wong (Masters of Engineering student researching options for separating and transporting market wastes to a potential composting facility during Summer 2003 in Vientiane, Lao PDR).

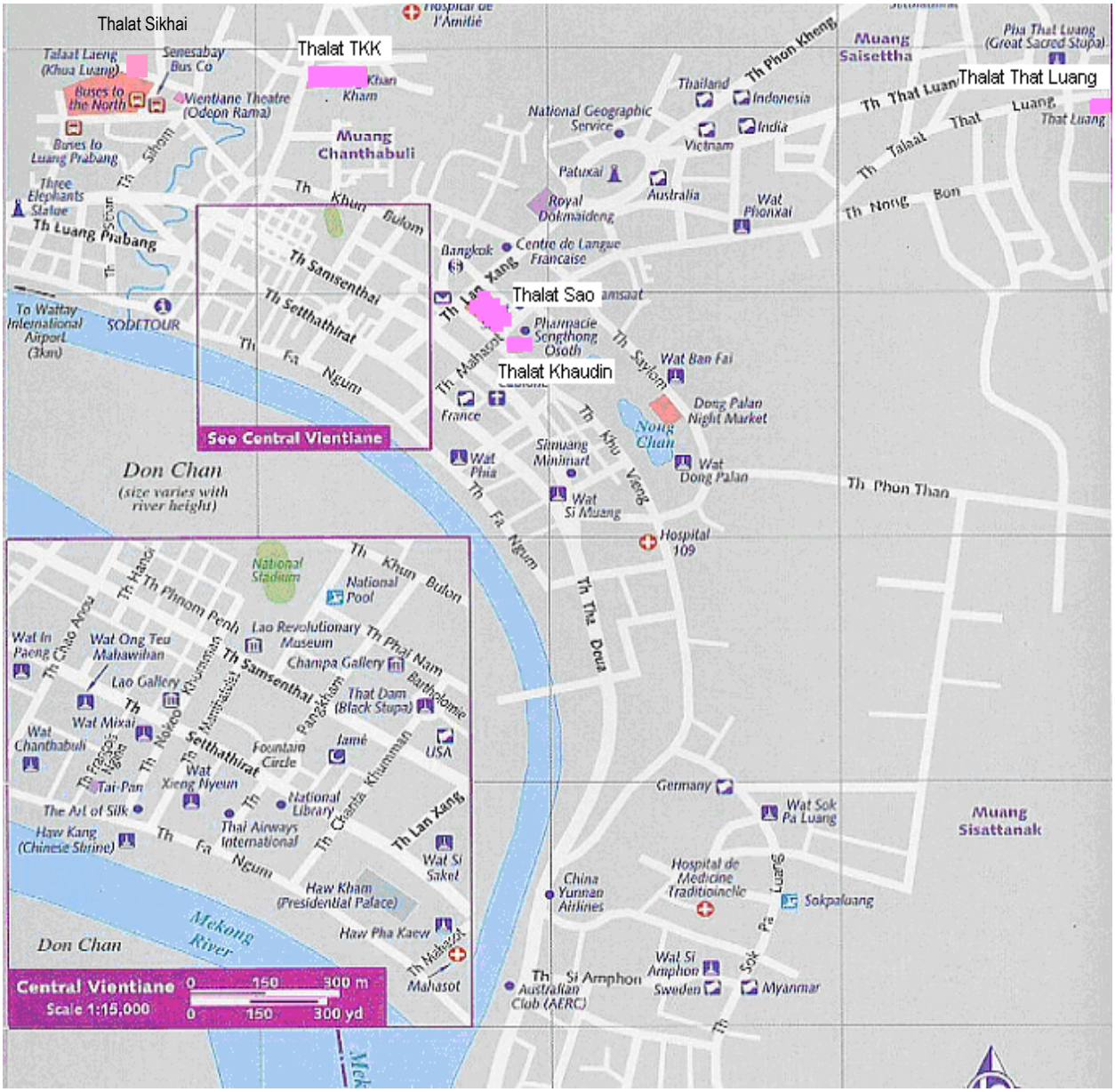


FIGURE 2-2: MAP OF VIENTIANE LOCATING THE MARKETS (HTTP://WWW.VISIT-LAOS.COM/SABBAIDEE/GEOGRAPHY.HTM)

2.2.1 Waste Collection Systems in the Markets

The waste collection systems at the markets in Table 2-1 were obtained through discussions with market managers, market vendors and locals. Visits were also made to the landfill located approximately 18 km from Patuxai (commonly referred to as KM 18) and the Recycle Bank located in Phakao Village to discuss the waste management system with the managers of both facilities respectively.

The vendors in the markets employ different means of handling daily waste. At the time of this work, it was found that fruit and vegetable vendors generally placed their daily waste around

the perimeter of their stall. Vendors who generated large quantities of waste, stored it in large wicker baskets, while a small few who generated a moderate quantity stored waste in wicker baskets or in plastic bags at their stall (Figure 2-3). Usually, recyclable materials such as metal cans and plastic bottles were not found in the waste stream with all other waste materials.

Discussions with the central waste authority, market vendors and managers and workers at the recycle bank revealed that these items were separated either by the informal sector or taken away by the vendors themselves at end of day. The informal sector includes waste pickers and private companies such as the Recycle Bank that are part of an intricate and economically based waste collection system for recyclables [Cannon, 2003]. The waste pickers sort through the waste generated by vendors in the markets as well as at various locations throughout the city to find valuables such as plastic water bottles, metal pop cans and corrugated cardboard boxes (Figure 2-4).

FIGURE 2-3: WICKER BASKET FOR STORING DAILY WASTE UNDER STALL

FIGURE 2-4: WASTE-PICKER SORTING THROUGH JICA BIN (LEFT), WASTE-PICKER TRANSPORTING RECYCLABLES (RIGHT)

After collecting these items, the waste-pickers sell them to an individual or company who in turn sells the recyclable materials to a larger purchaser of recyclable wastes (Recycle Bank in Phontan shown in Figure 2-5). This process undergoes several iterations in this manner until the recyclable materials are eventually taken to a private company such as the Recycle Bank located seven kilometers north of Patuxai in Phakao Village (Figure 2-5). Here the plastic bottles are

shredded and sold at 3,300 KIP/kg (≈0.44 CND/kg), bundled plastic bags at 1,100 KIP/kg (≈0.15 CND/kg) and compressed metal cans at different prices depending on the metal

FIGURE 2-5: RECYCLE BANK LOCATED IN BAN PHONTAN (LEFT), RECYCLE BANK – PHAKAO VILLAGE (MIDDLE AND RIGHT)

[Thaiphachanh, 2003]. The recyclables purchased by this company are sold in Thailand, Vietnam and China and are exported in trucks that arrive with imports to Laos.

2.2.2 Thongkhankham (TKK) Market Description

The TKK market is located in the village of Thong Khankham, Chantabury District, Vientiane Municipality. It covers a total area of 16,120 m^2 and was established in 1987 by private investors who were interested in distributing food products from farmers within the municipality [SWTC, 2002].

The TKK market is comprised of an early morning market and a daytime market. In total, these markets have approximately 137 packaged goods vendors, 27 Food stall vendors and 304 fruit and vegetable and meat vendors for a total of 468 vendors. To the west of the TKK markets is a 6,683 m^2 independently owned and managed early morning market that is separated by a narrow mud path. The waste audit was conducted in this latter market, referred to as the Early Morning Market (EMM) hereafter (Figure 2-6)

FIGURE 2-6: EMM DURING HOURS OF OPERATION FROM THE SOUTHWEST CORNER

2.2.3 EMM Operations

The EMM is a commercial facility that consisted of 170 vendors at the time of the waste audit. The vendors opened for business around 5:00 am and cleaned up the areas surrounding their stalls for market closing around 11:00 am. This market was selected for the waste audit because its hours of operation were conducive to conducting a waste audit and the management and vendors were cooperative, interested and willing to participate in the pilot project.

Each vendor in the market can be identified as a "vendor-type" based on the type of items that they predominantly sold. This distinction helps differentiate one vendor from another. Details of the main vendor type categories found in the EMM are shown in Table 2-2.

FIGURE 2-7: VENDOR-TYPES AT THE EMM – FOOD STALLS (LEFT), PACKAGED GOODS (MIDDLE), NOODLES AND BLOOD (RIGHT) VENDOR-TYPES

The average size of the stalls for the Fruit and Vegetables (FV), Meat, Fish and Eggs (MFE), Food Stalls (FS), Noodles and Blood (NB), and Rice and Charcoal (RC) and Clothing (Cl) was between 2x2 m^2 and 2x6 m^2. The Packaged Goods (PG) vendors had standard size stalls of 3x3 m^2. These stall sizes were standard for each different vendor-type throughout the EMM. The stalls were shaded with umbrellas to protect items sold by the vendors from the rain and sun. Figure 2-8 shows the EMM layout identifying each vendor in the market by vendor-type as explained in the legend

TABLE 2-2: VENDOR TYPES AT EMM

Vendor Type	Number of Vendors	Items Sold
Fruits and Vegetables[1] (FV, C, GO)	94	Organic items including green leafy vegetables, pumpkin, onions, garlic, banana flowers, coconut, melons, rambutan, mango steen, banana flower, limes, red peppers and eggplant, sometimes Paa Dek[2]. This includes 6 coconut (C) vendors that sold shredded coconut and 4 Garlic and Onion (GO) vendors selling primarily garlic, onions, ginger, red chilis3.
Packaged Goods (PG)	38	Dry items packaged in plastic, glass or paper which are taken away for use by the customer e.g. personal hygiene items, packaged foods, household cleaners
Meat, Fish, Eggs (MFE)	12	Unpacked fresh meat and fish and/or eggs.
Food Stalls (FS)	11	Small restaurant-type stalls where noodle soup, cooked rice and meat dishes could be purchased and eaten at the stall. Drinks such as cold coffee, soft drinks and bottled water could also be purchased from these vendors.
Noodles and Blood (NB)	7	Uncooked noodles and soft blocks of blood.
Clothing (Cl)	5	Towels, undergarments, shirts, pants, children's clothing,
Rice and Charcoal (RC)	3	Variety of rice and charcoal
TOTAL	**170**	

[1]This is the total number of FV vendors including both the large (2' x 6') and small vendor stalls (2' x 2').

[2]Various vendor-types sell Paa Dek (fermented fish) throughout the market. Since vendors explained that there was very little to no waste from the sale of Paa Dek, the sale of this item at any stall should not impact the quantity and composition of waste generated by the vendor.

[3]C and GO vendors were originally included in the FV vendor-type category because both sell primarily organic items at their stalls. It was only during analysis of the results and observations in the market that revealed that these two vendor-types should have been sub-stratified (see Section 3.1.3 of the report).

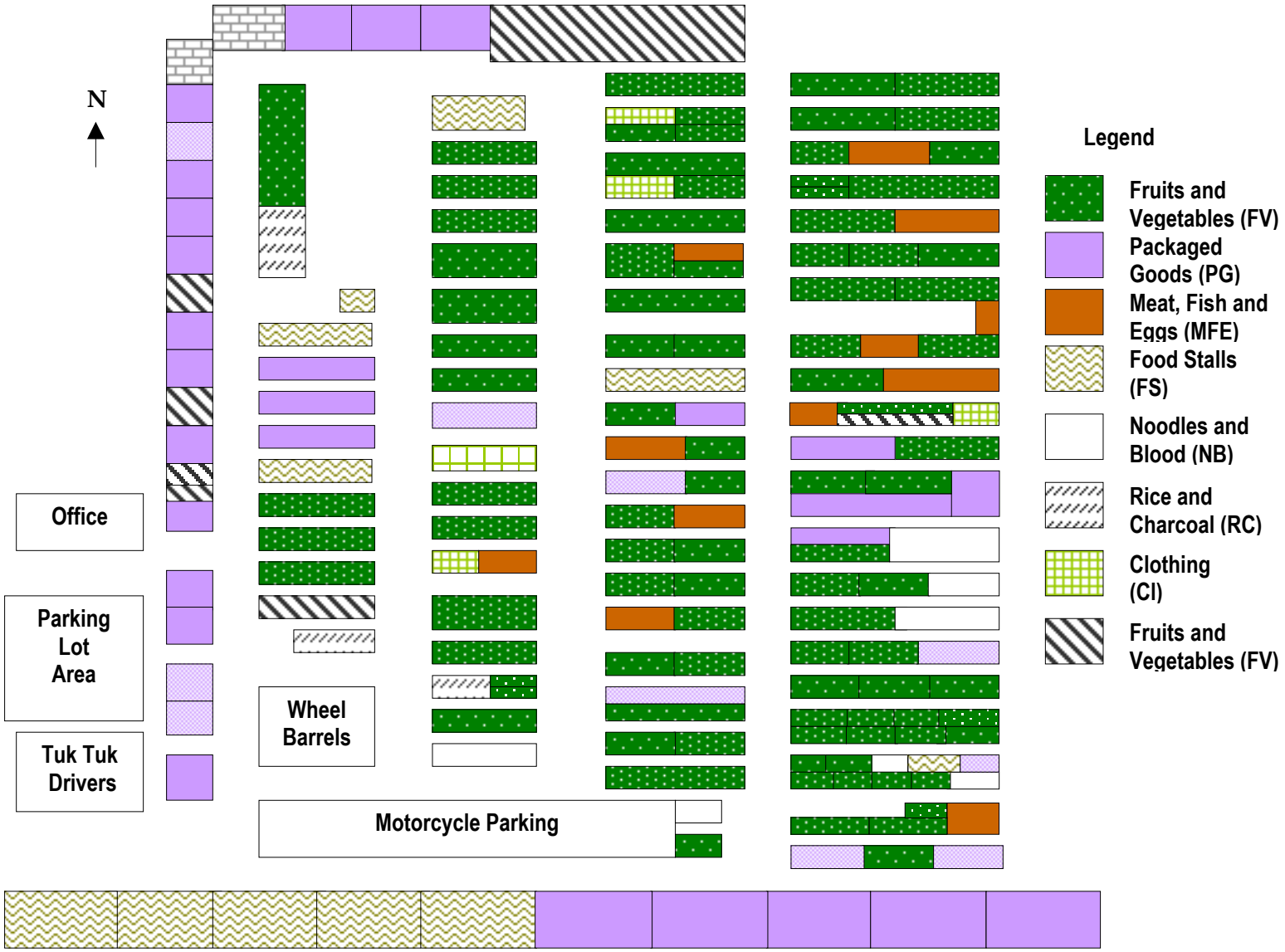


FIGURE 2-8: EMM LAYOUT IDENTIFYING MAIN VENDOR-TYPES

2.2.2 Waste Management System at the EMM

FIGURE 2-9: JICA BIN LOCATED AT THE BACK OF EMM

As of July 2003, waste cleaners employed by the EMM collect daily waste from vendor stalls and transfer it to blue bins put into place by the Japanese International Cooperation Agency (JICA) located southwest of the market. The blue JICA dumpster that contained several days waste is emptied every 2-4 days by Urban Cleaning Service (UCS). A hydraulic lift truck arrives at the market, removes the full JICA bin and replaces it with an empty bin for waste collected over the next few days. The dumpster, which is estimated to hold approximately 1.5 – 2 tons of waste, is taken directly to KM 18 [Wong, 2003]. Figure 2-9 shows the JICA dumpster and KM 18. Trial Audit 1 revealed that the management at KM 18 does not keep formal records of the daily quantity of the waste collected from the EMM (See Appendix 1). Even if formal records were kept for the JICA bin that is assigned for waste coming from the EMM, there is no guarantee that all the waste in the bin comes solely from this market. It is highly possible that residential wastes and wastes from surrounding markets could be added to the bin before it is taken to KM 18.

Each vendor pays 1000 KIP per day (≈0.13 CND per day) to the market manager for having their waste collected at the end of every working day. Some of the vendors have purchased and own wicker baskets in which they place the waste that they generate throughout the day. Other vendors leave their daily waste on the floor surrounding their stalls. The waste is collected by waste pickers hired by the EMM management irrespective of how it is left by the vendors.

The management at KM 18 claims that during the dry season, approximately 3.3 tons of waste is sent to KM 18 per day from all of the TKK markets. This increases to 3.8 tons/day during the wet season [Wong, 2003]. There are no specific records for the daily quantity of waste collected at the EMM alone.

2.3 Design of Sampling Methodology

2.3.1 Trial Audits

Trial audits were planned to help develop and finalize the methodology for conducting the waste audit of the EMM. These one-day trials allowed the audit team to:

- Test the logistics for collecting a representative sample, transporting it to Nabong, conducting a physical sort over one-day periods, recognizing issues and making changes to improve the sampling methodology;
- Finalize the categories for the compositional analysis of the representative sample including clarifying the distinction between browns and greens; and
- Determine if the waste audit would be conducted on waste *collected* or waste *generated* over one working day.

Appendix 1 contains the procedures and results from each of the trial audits.

2.3.2 Obtaining a Representative Sample for Waste Composition Study

Sampling is necessary when a study of the entire population is expensive or physically impossible. A representative sample is "a sample of a universe whole, which can be expected to exhibit the average properties of the universe or the whole." [SWER, 2002]. To obtain a good representative sample of a material of uniform composition is quite simple (Kauffman, 1990). However, the refuse at EMM was quite variable and heterogeneous in nature.

During the trial audits, the size of a well-mixed sample obtained from a pile of daily waste was the criteria used for judging whether or not it was representative for the waste composition study (see Appendix 1). However, the weight of the sample could not be employed as a criterion for obtaining a representative sample during the actual audit. The actual audit proposed to conduct a quantity and compositional analysis of the waste by *vendor-type* rather than a means for characterizing the overall waste from the EMM, as done in Trial Audits 1 and 2 (Appendix 1). For this reason, a stratified random sampling technique was used.

Stratification makes it possible to improve the precision in the estimate of waste characteristics of the whole market. The basic idea is to divide a heterogeneous population into sub-populations, each of which is internally homogenous. If each stratum is homogenous, in

that the measurements vary little from unit to another, a precise estimate of any stratum mean can be obtained from a small sample in that stratum. These estimates can then be combined into a precise estimate for the whole population [SWER, 2002].

The population being studied (vendors) during the audit period was subdivided into smaller decision units (vendor-types). Each decision unit was expected to produce similar type of waste at the point of waste generation, from a single batch operation, over a specified time [SWER, 2002]. Table 2-2 outlines the items generally sold by each vendor-type. Vendors in the same vendor-type category that tend to sell similar items were anticipated to produce similar waste. Each decision unit is defined such that the observed variability in the waste produced within each is less than that observed over the entire population or between the different decision units [Gilbert, 1987].

Including a statistically representative number of vendor participants from each vendor-type was important for the characterization and quantification of the waste from each vendor-type. As the sample size increases, the reliability and confidence in the estimates of generation and composition also increases [Kauffman, 1990]. Since, the number of vendors included in the study was relatively small and highly depended on the willingness of vendors from each vendor-type to participate in auditing activities, a sample size (i.e. number of vendors) could not be statistically pre-determined. Instead, the process involved collecting as many samples as was possible.

Prior to determining which vendors would participate in the waste audit, the vendor types that would be studied were established. Of the seven vendor types identified in Table 2-2, six were chosen for this study. These vendors included: Fruits and Vegetables (FV), Packaged Goods (PG), Meat, Fish and Eggs (MFE), Food Stalls (FS), Noodles and Blood (NB) and Rice and Charcoal (RC)[4]. Stratification by six vendor-types were considered important to the audit for two main reasons. The first was that visual observations and discussions with the vendors during the trial audits revealed that the six selected vendor-types produced the greatest proportion of the market's waste The second was that these same vendor-types were found in other markets and appeared to contribute greatly to the waste in those markets as well [Wong, 2003]. Therefore, knowledge of the quantity of waste collected from or generated by these six

[4] The C and GO vendors were grouped with the FV vendor-type during the waste audit because like other FV vendors, they sold organic items and occupied stalls of area similar to the FV vendors. Section 3 evaluates how these vendors are different from the FV vendor-type and therefore should have been sub-stratified.

vendor types could be useful for estimating the quantity and composition of wastes at other markets.

As previously mentioned, the market vendors paid the market manager 1000 KIP per day (≈0.13 CND per day) for having the waste around their stall collected at the end of each working day. To encourage vendor participation in the audit, an agreement was devised by members of the National Science Council (NSC) in Laos and the EMM manager whereby each vendor that agreed to participate in the waste audit would be offered 1000 KIP per day (≈0.13 CND per day) for their waste and the market manager would also be given 1000 KIP for every day (≈0.13 CND per day) that each vendor participated in the audit.

All vendors in the EMM that fit in the six vendor-type categories were asked if they would be interested in participating in a seven-day waste audit. The purpose of the waste audit, the role of the vendor and the conditions for participation were explained to each participant by a Lao translator.

Of the 170 vendors in the market, 166 were approached, which includes one clothing vendor, 12[5]. 47 of the 165 vendors in the EMM (~28%) initially agreed to participate in the waste audit. As the audit proceeded, vendors 12 and 36 dropped out of the audit process. Figure 2-10 shows the map of the EMM identifying all vendors that initially agreed to participate in the audit, including vendors 12 and 36. Table 2-3 summarizes the overall percentage of vendors from each vendor-type that *agreed to participate* in the waste audit at the onset of the waste audit. This table also shows that almost 25% of the vendors from each vendor-type in the market participated in the waste audit. Note that although the RC vendor-type shows the greatest number of vendors that agreed to participate, the number of samples from this vendor-type was the smallest. The converse is true for the FV vendor-type.

[5] The remaining clothing vendors claimed to generate insignificant quantities of waste at their stalls and therefore refused to participate in the audit. Vendor 12 dropped out of the audit after the first day of the waste audit.

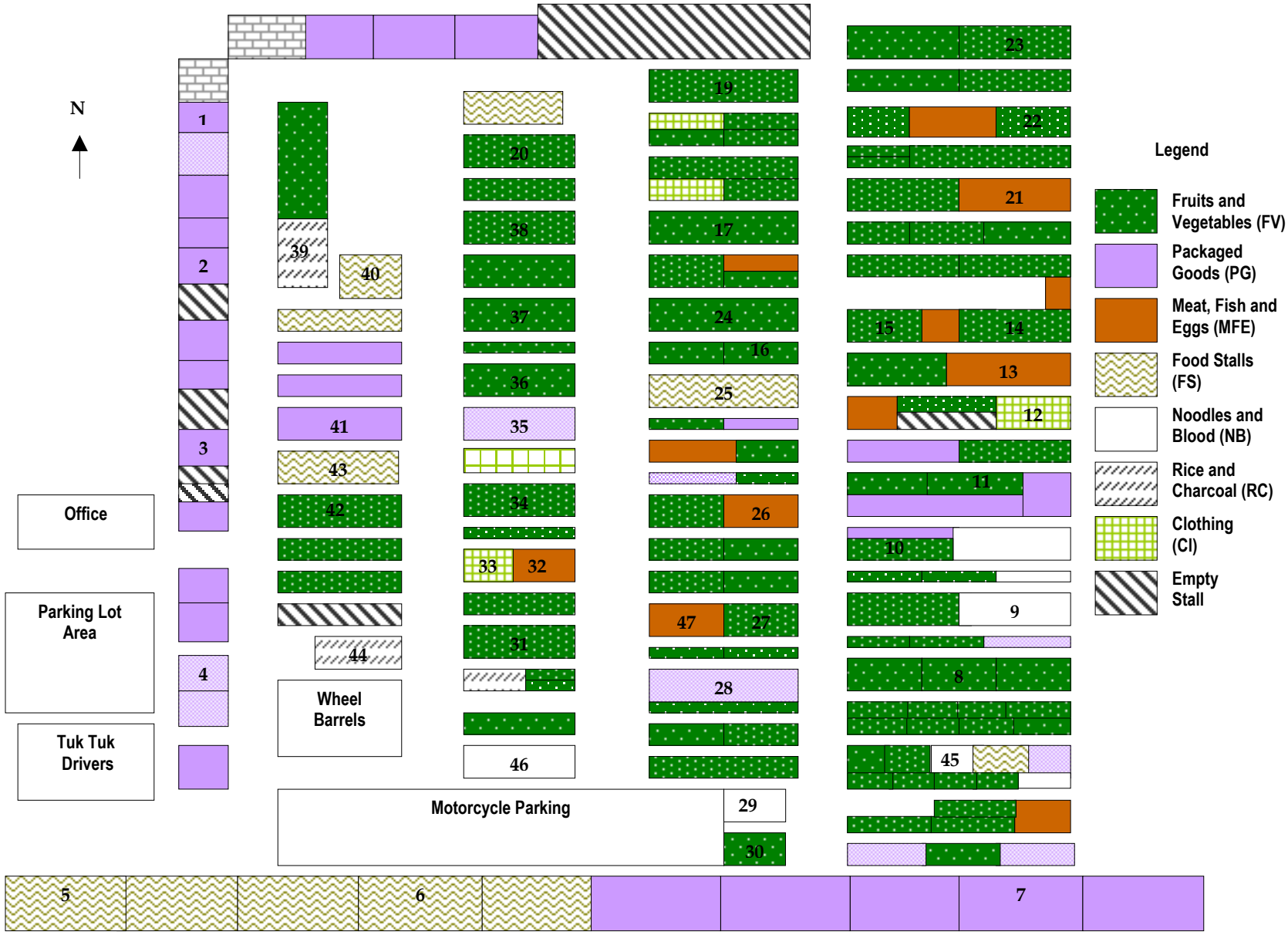


FIGURE 2-10: VENDORS FROM THE EMM THAT AGREED TO PARTICIPATE IN THE WASTE AUDIT

TABLE 2-3: VENDORS AT EMM THAT AGREED TO PARTICIPATE IN WASTE-AUDIT ACTIVITIES AT ONSET

Vendor Type	Number of vendors that agreed to participate in the audit	% Participation from vendor-type
Fruits and Vegetables	20	21.2%
Packaged Goods	9	23.7%
Meat, Fish, Eggs	5	41.7%
Food Stalls	5	45.6%
Noodles and Blood	4	57.1%
Rice and Charcoal	2	66.7%
TOTAL PARTICIPATING VENDORS	**45**	

The items sold by each of these vendors are summarized in Appendix 2.

2.4 Waste Quantification Study

The waste audit conducted in this work determines the amount of daily waste *generated by or collected* from each vendor and the composition of that waste following the removal of waste by the informal sector. The informal sector removes recyclable items that are viewed as valuables rather than waste, thereby taking care of these items through a viable recycling program that provides financial incentives to vendors and waste-pickers. As a result, the removal of recyclable items impacts the composition and quantity of waste produced by each vendor. Since the informal sector behaves in the same way in similar markets, reasonable quantity and composition estimates can be made from the point that recyclables have been removed by the informal sector.

To estimate the average waste generated by a vendor-type, first the average waste generated by each vendor in that vendor-type for the entire audit period was determined using Equation 2-1.

$$W_i = \frac{\sum_d W_{i,d}}{n_i} \qquad \textbf{EQUATION 2-1}$$

Where:

W_i Average waste generated by vendor i in a vendor-type over the-audit period (kg/day)

$W_{i,d}$ Waste generated by vendor i in a vendor-type on day d of the audit that the vendor participated in audit activities (kg/day)

n_i Total number of audit days that vendor i participated in the audit (days)

The average waste generated by a vendor-type is determined by calculating the average of the average waste generated by each vendor in a vendor-type as expressed in Equation 2-2.

$$W_{VT} = \frac{\sum W_i}{N_{VT}} \quad \textbf{EQUATION 2-2}$$

Where:

W_{VT} Average waste generated by a vendor in vendor-type (kg/day)

N_{VT} Total number of vendors participating from the vendor-type

In order to estimate the weight of all the waste collected at the EMM from each vendor-type, Equation 2-3 should be employed.

$$WT_d = \sum_I W_{d,i} \quad \textbf{EQUATION 2-3}$$

Where:

WT_d Total waste collected at the EMM on day d of the waste audit (kg/day)

$W_{d,i}$ Waste collected from each participating vendor i in a vendor-type on day d of the waste audit (kg/day)

The estimate for the quantity of waste generated at the EMM is determined by the quantity of the waste generated by each vendor-type. The assumption in this work is that similar vendor-types, selling similar items and renting stalls of relatively the same size are representative of all vendors of that type. Therefore, the amount of waste from each vendor-type can be extrapolated to determine the total amount of waste typically generated in the market. To estimate the amount of waste generated in the EMM, Equation 2-4 is employed.

$$TW = \Sigma(X_{VT} \times W_{VT}) \quad \textbf{EQUATION 2-4}$$

TW Total daily waste generated at the EMM (kg/day)

X_{VT} Total number of vendors in vendor-type VT in the EMM

To demonstrate the use of Equations 2-1, 2-2 and 2-4, data gathered for the RC vendor-type over the nine-day audit period will be employed. Table 2-4 displays the data gathered from all participating vendors from this vendor-type over the audit period. First Equation 2-1 is

employed to determine the average waste generated by each vendor over the audit period. There were only two participating vendors representing the RC vendor-type, vendors 39 and 44. The average waste generated by each of these vendors during the audit period is shown in the column W_i. Once this is completed, Equation 2-2 is employed. This results in an estimate for the average waste generated by the RC vendor-type, which is 2.22 kg/day. Similar estimates are conducted for all other vendor-types. Once the estimates are completed, then Equation 2-4 can be employed to determine the total daily waste generated at the EMM.

TABLE 2-4: USE OF EQUATIONS 2-1 AND 2-2 ON RC VENDOR-TYPE DATA

Vendor	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	W_i
39	1.8	0.5	0.4	0.5	0.9	0.1	4.2	0.1	0.8	1.03
44	-	1.5	5.3	2.2	5.9	1.1	2.5	-	5.4	3.41
WT_d	1.8	2.0	5.7	2.7	6.8	1.2	6.7	0.1	6.2	
									$W_{VT} = W_{RC}$	2.22

2.5 Vendor Participation during Waste Audit

The waste audit was carried out over a nine-day audit period[6]. Vendors that agreed to participate in the waste audit activities were provided with a labeled plastic bag between 6:30 and 7:30 AM in the morning in which their daily waste could be placed for the audit day (see procedure outlined in section 2.7). On any given audit day, the vendors that initially agreed to

TABLE 2-5: DESCRIPTION OF VENDORS THAT AGREED TO PARTICIPATE IN AUDIT ON ANY GIVEN AUDIT DAY

Group	Description
1	**Do not generate any waste nor participate in the audit activities because:**
	- Not present in the market
	- Not provided with a plastic bag for their waste in the morning
	- Leave no waste for collection by audit team at market close
2	**Generate waste but do not participate in waste audit activities because:**
	- Present in the market
	- Provided with a plastic bag for their waste in the morning
	- Do not leave any waste for collection by audit team at market close
3	**Participate in waste audit activities because:**
	- Present in the market
	- Leave their daily waste for collection by the audit team at market

[6] Details on selection of the waste-audit period for this study are provided in Section 3.2 and 3.3 of this report.

participate in the waste audit are grouped into one of the three groups in Table 2-5.

In this study, the average waste generated by a single vendor in a vendor-type is estimated using a sample pool that includes vendors that fall in group three from Table 2-5. The percent of vendors in each vendor-type that make up group three from Table 2-5 for each audit day is determined by using Equation 2.5.

$$\%P_{VTd} = \frac{N_{VT,d}}{N_{VT}} \times 100\% \qquad \textbf{EQUATION 2-5}$$

Where:

$\%P_{VT,d}$ Percent presence of vendors in a vendor-type VT that agreed to participate in the waste audit on day d of the waste audit and did participate in audit activities (%)

N_{VT} Total number of vendors from a vendor-type VT that agreed to participate in audit activities[7]

The percent presence of a vendor-type determined by Equation 2-5 for each audit day provides information on the percent of vendors that did not participate in the waste audit by default (i.e. 100% - % P_{VT}). However, the percent presence of a vendor-type determined by Equation 2-5 does not allow a means of differentiating between the percentage of non-participating vendors in group one from those in group two described in Table 2-5.

To demonstrate the use of Equation 2-5 vendor presence data gathered for the RC vendor-type over the nine-day audit period will be employed. Table 2-6 displays the number of vendors in the RC vendor-type that were present on each day of the waste audit and participated in audit activities ($N_{VT,d}$). Table 2-3 shows that there were a total of two vendors from the RC vendor-type (N_{VT}) that agreed to participate in the waste audit activities.

TABLE 2-6: % PRESENCE FOR EACH AUDIT DAY FOR THE RC VENDOR-TYPE

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	AVG
$N_{VT,d}$	1	2	2	2	2	2	2	1	2	1.78
$\%P_{VT} = \%P_{RC}$	50%	100%	100%	100%	100%	100%	100%	50%	100%	89%

2.6 Waste Composition Study

The nine categories that were selected for the compositional analysis of the waste were:

[7] The total number of vendors from a vendor-type VT that agreed to participate in audit activities are provided in Table 2-3.

1. Green Organics (fruits and vegetable scraps high in nitrogen);
2. Brown Organics (fruits and vegetable scraps high in carbon, soiled paper);
3. Animal food waste;
4. Paper (unsoiled tissue, newspaper, corrugated cardboard, etc.);
5. Soft Plastics (film type plastics like cellophane);
6. Hard Plastics (plastic used for water bottles);
7. Metals;
8. Glass;
9. Other (textiles, rubber, string, cigarettes, candy wrappers, and other miscellaneous items).

Green and brown organics and paper could be applied directly as feedstock to the composting facility[8]. Knowledge of animal food waste was deemed useful because such items can be a nuisance if added to a compost pile and therefore should be removed. Information about the quantity of the waste as classified by the remaining categories is useful because waste from these categories would have to be removed from the feedstock to the composting facility[9]. Furthermore, not much extra work was required to further separate the waste into these additional categories to gain additional details on waste characteristics.

Lessons learned from the trial audits helped develop Table 2-7 by which organic items could be categorized into browns and greens. This table was created with the help of experts in the field and consultation with environmental professionals who were familiar with the organic items sold in Vientiane markets. It was eventually decided that tough, fibrous materials would be categorized as brown organics while moist and soft items would be categorized as greens.

Observations of market operations revealed that market vendors generated only a small amount of paper waste. The largest contribution to the paper category was expected to come from packaged goods vendors, who received items in large cardboard boxes. However,

[8] Activities of the informal sector were not expected to impact the quantity of organic waste generated by any vendor. The main categories affected by the activities of the informal sector included unsoiled paper (mostly corrugated cardboard), hard plastics (water bottles), glass (soft drink bottles) and others.

TABLE 2-7: GREEN AND BROWN ORGANICS

Green Organics (materials rich in Nitrogen)	Brown Organics (materials rich in Carbon)
Soft and moist fruit and vegetable scraps	Wood
Brewery waste, hops, pomace[1]	Sawdust and wood shavings
Fresh leaves, green and spent plants[1]	Small twigs and woodchips
Flowers	Shredded newspaper
Horse manure	Egg shells
Spoiled juice	Corn cobs
Entire banana flowers, mangosteen, rambutan	Bread and grains
Inside of a banana flower, mangosteen, rambutan[1]	Wood ashes
Shredded coconut	Old potting soil
	Food-soiled paper towels, cardboard and napkins
	Nutshells
	Coconut shells, banana flower leaves, rambutan, lychees and mangosteen shells
	Dried flowers
	Leaves from banana trees
	Entire coconut and coconut shells
	Feathers[1]
	Coffee grounds and filters, tea bags[1]
	Straw and hay
	Leaves from the banana flower plant[1]
	Rice
	Noodles

[1]Various sources placed these items in different organics categories. They have been separated in this table as shows as per email consultation with M. Haight on Monday, July 7, 2003.

discussions with the vendors revealed that these boxes were not disposed but were sold by many of the vendors at 1000 KIP per kilogram (≈0.13 CND per kilogram). This activity appeared to be part of the informal sector-recycling program discussed in section 1.2. Due to the low quantity of different types of paper, all unsoiled paper, was grouped into one category. Market observations also indicated that a lot of paper waste from the market was generally soiled by food. Soiled paper was therefore placed in the brown organics category since it has some food value, has high carbon content and is not recyclable.

9 Recyclables such as metals, glass, plastics and unsoiled paper that were found in the bags collected from vendors were audited. These were generally items that were not taken from the vendors by waste pickers (informal sector).

The results from the trial audits revealed that the percentage of metals and glass in the daily waste was insignificant. Most of the potential glass waste in the market came from soft drinks, which were not found in the waste because they are used or sold by the vendors. The source of metal waste was generally condensed milk cans, which were found in small numbers. Despite the apparent insignificance of these materials to the overall characterization of the waste, they were separated into two different categories because the waste characteristics could change over the audit period and gathering information on the proportion of metals and glass at the EMM could be useful for future projects.

The plastics were divided into soft, film type plastics and hard plastics. Observations in the market showed that the soft plastics were a bigger issue due to the use of shopping bags. It was suspected that the informal sector removed hard plastics, which included plastic water bottles from the waste for recycling [Thaiphachanh, 2003]. All plastics, cardboard and metals collected by the informal sector eventually make it to recycle banks such as the one located in Phakao Village on KM 13 South (see Section 1.2.2). The others category was assigned to miscellaneous items that did not fit into any of the other eight categories. These items constituted an insignificant percentage of the waste collected in the trial audits.

The total amount of daily waste sorted for each vendor-type is determined using Equation 2-6.

$$C_{VT,d} = \sum_{c} C_{c,VT,d} \qquad \textbf{EQUATION 2-6}$$

$C_{VT,d}$ Total amount of waste sorted from all participating vendors in vendor-type VT on day d of the waste audit (kg/day)

$C_{c,VT,d}$ Waste generated in category c for vendor-type VT on day d of the waste audit (kg/day)

The percent composition of the daily waste sorted by each vendor-type over the audit period is determined using Equation 2-7.

$$\% C_{c,VT,d} = \frac{C_{c,VT,d}}{C_{VT,d}} \qquad \textbf{EQUATION 2-7}$$

Where:

$\% C_{c,VT,d}$ % composition of waste by category c for vendor-type VT on day d of the waste audit

The % average waste composition for the waste audit period is determined using Equation 2-8.

$$\%C_{c,avg} = \frac{\sum \% C_{c,VT,d}}{D} \quad \textbf{EQUATION 2-8}$$

Where:

$\%C_{c,avg}$	% average composition of waste sorted for category c of vendor type VT over the audit period
$\% C_{c,VT,d}$	% Waste sorted for category c by vendor-type VT on each day of the audit
D	Number of days in audit period (D = 9 for this audit)

In order to estimate the amount of waste sorted by category for each vendor-type, first the waste sorted for a single vendor in a vendor-type needs to be estimated on each day of the audit period using Equation 2-9.

$$C_{s,c,VT,d} = \frac{C_{c,VT,d}}{N_{VT,d}} \quad \textbf{EQUATION 2-9}$$

Where:

$C_{s,cVT,d}$	Total waste sorted for a single vendor s vendor-type VT for category c on day d of the audit (kg waste sorted for a single vendor in vendor-type VT/day)
$N_{VT,d}$	Number of vendors from vendor-type VT participating on day d of the audit

The average waste sorted per category for a single vendor in a vendor-type over the audit period is determined using Equation 2-10.

$$C_{s,c,VT} = \frac{\sum C_{s,VT,d}}{D} \quad \textbf{EQUATION 2-10}$$

To demonstrate the use of Equations 2-6 and 2-10, data gathered for the RC vendor-type over the nine-day audit period will be employed. Table 2-8 displays the data gathered from all participating vendors from this vendor-type over the audit period. First, Equation 2-6 is used to determine the amount of waste generated by category for the vendor-type being studied on each audit day. This calculation can be found for each category in Table 2-8 in the row titled $C_{c,VT,d}$. Once the amount of waste generated by category is determined, then the total waste generated by the vendor-type can be obtained by adding the amount of wastes generated in each category together to find $\sum C_{c,VT,d}$. Equation 2-7 can then be used to determine the % of each category in the total waste for each audit day. This calculation can be found for each category in Table 2-8 in the row titled $\% C_{c,VT,d}$. The average waste composition for the audit period is

found by using Equation 2-8. These averages are reported for each category under the AVG column in row titled $\%C_{c,avg}$.

To estimate the mass of waste sorted for each category, first the amount of waste from a single vendor-type is estimated using Equation 2-9 for each audit day. These estimates are found in Table 2-8 in the row titled $C_{s,c,VT,d}$. The average waste generated by category is then determined using Equation 2-10, for which the results are found under the AVG column in the row titled $C_{s,c,VT}$.

TABLE 2-8: COMPOSITIONAL DATA FOR RC VENDOR-TYPE

Category		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9		AVG
	$N_{VT,d}$	1.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0		1.8
Green	$C_{c,VT,d}$	0.00	0.00	0.00	0.00	2.20	0.70	0.40	0.00	0.00		0.37
	$C_{s,c,VT,d}$	0.00	0.00	0.00	0.00	1.10	0.35	0.20	0.00	0.00	$C_{s,c,VT}$	0.18
	% $C_{c,VT,d}$	0.0%	0.0%	0.0%	0.0%	32.4%	63.1%	5.5%	0.0%	0.0%	$\%C_{c,avg}$	11.2%
Brown	$C_{c,VT,d}$	0.40	0.10	4.50	0.10	3.10	0.00	4.80	0.00	4.70		1.97
	$C_{s,c,VT,d}$	0.40	0.05	2.25	0.05	1.55	0.00	2.40	0.00	2.35	$C_{s,c,VT}$	1.01
	% $C_{c,VT,d}$	19.0%	14.3%	81.8%	7.1%	45.6%	0.0%	66.2%	0.0%	90.2%	$\%C_{c,avg}$	36.0%
Animal Food Waste	$C_{c,VT,d}$	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01
	$C_{s,c,VT,d}$	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$C_{s,c,VT}$	0.01
	% $C_{c,VT,d}$	4.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	$\%C_{c,avg}$	0.5%
Paper Products	$C_{c,VT,d}$	0.10	0.10	0.10	0.40	0.40	0.10	0.50	0.00	0.00		0.19
	$C_{s,c,VT,d}$	0.10	0.05	0.05	0.20	0.20	0.05	0.25	0.00	0.00	$C_{s,c,VT}$	0.10
	% $C_{c,VT,d}$	4.8%	14.3%	1.8%	28.6%	5.9%	9.0%	6.9%	0.0%	0.0%	$\%C_{c,avg}$	7.9%
Soft Plastics	$C_{c,VT,d}$	0.70	0.20	0.70	0.70	0.70	0.20	0.10	0.10	0.40		0.42
	$C_{s,c,VT,d}$	0.70	0.10	0.35	0.35	0.35	0.10	0.05	0.10	0.20	$C_{s,c,VT}$	0.26
	% $C_{c,VT,d}$	33.3%	28.6%	12.7%	50.0%	10.3%	18.0%	1.4%	100.0%	7.7%	$\%C_{c,avg}$	29.1%
Hard Plastics	$C_{c,VT,d}$	0.00	0.10	0.00	0.00	0.10	0.01	0.20	0.00	0.10		0.06
	$C_{s,c,VT,d}$	0.00	0.05	0.00	0.00	0.05	0.01	0.10	0.00	0.05	$C_{s,c,VT}$	0.03
	% $C_{c,VT,d}$	0.0%	14.3%	0.0%	0.0%	1.5%	0.9%	2.8%	0.0%	1.9%	$\%C_{c,avg}$	2.4%
Metals	$C_{c,VT,d}$	0.00	0.00	0.00	0.00	0.10	0.00	0.05	0.00	0.00		0.02
	$C_{s,c,VT,d}$	0.00	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.00	$C_{s,c,VT}$	0.01
	% $C_{c,VT,d}$	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.7%	0.0%	0.0%	$\%C_{c,avg}$	0.2%
Glass	$C_{c,VT,d}$	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.02
	$C_{s,c,VT,d}$	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$C_{s,c,VT}$	0.01
	% $C_{c,VT,d}$	0.0%	28.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	$\%C_{c,avg}$	3.2%
Other	$C_{c,VT,d}$	0.80	0.00	0.20	0.20	0.20	0.10	1.20	0.00	0.01		0.30
	$C_{s,c,VT,d}$	0.80	0.00	0.10	0.10	0.10	0.05	0.60	0.00	0.01	$C_{s,c,VT}$	0.20
	% $C_{c,VT,d}$	38.1%	0.0%	3.6%	14.3%	2.9%	9.0%	16.6%	0.0%	0.2%	$\%C_{c,avg}$	9.4%
Total Waste from sum of components at Nabong	$\sum C_{c,VT,d}$	2.1	0.7	5.5	1.4	6.8	1.11	7.25	0.10	5.21		

2.7 Seven-Day Waste Audit Process

The seven-day audit was carried out between Monday, July 14, 2003 and Sunday, July 20, 2003. Members of the audit team were assigned a specific task for each day of the audit. Their duties were rotated over the course of the week but were not changed during a single audit day. For example, the person assigned to recording sample weights was expected to take this responsibility for the whole audit day. Assigning specific roles to each person was intended to reduce precision errors expected in the sampling methodology and the waste audit process.

During the seven-day waste audit, each vendor was provided with one or two blue plastic bags (61 x 76 cm) each morning between 6:30 and 7:30 AM. The bag had a white label identifying each vendor by name and number. Each vendor was requested to place all the waste that they generated from the time that they opened their stall to the time their stall was closed around 11:00 AM. Most of the vendors opened their stalls between 5:00 and 5:30 AM. The market manager and the participating vendors suggested that the bags be handed out between 6:30 and 7:30 AM each morning as opposed to between 5:00 and 5:30 AM because the latter was a very busy time in the EMM.

Between 11:00 and 11:30AM, members of the waste audit team collected the bags with the daily waste from each vendor. The bags were taken to a pick-up truck parked in a shaded area that was used for motorbike parking during market operation located on the southwest side of the market (see Figure 2-11). The scale on the truck was zeroed before any bag was weighed. Then each bag was weighed, labeled by vendor-type on the bag and then placed in one of the 5 kg bins for transport to Nabong. The bags containing heavier garbage, such as coconut shells were placed at the bottom of the bin and bags with lighter items, such as garlic peels, were kept at the top of the bin. Care was taken such that the contents in the bin were not compressed by shaking the bin a few times. The truck departed for Nabong between 1:00 and 1:30 PM. Appendix 3 contains the field data sheets that were used for recording the weight of the waste collected at the market. Note that each vendor is assigned a number and is grouped with similar vendor-types on this worksheet. The numbers assigned to

FIGURE 2-11: PICK-UP TRUCK AT THE EMM

each vendor are identified on the map of the EMM in Figure 2-10. The truck arrived at Nabong around 2:00 PM. The bags were unloaded from the truck and taken to the sheltered parking area. The bags were grouped according to vendor-type. The physical sort was conducted six times, once for each vendor-type studied. For example, the waste collected from all FV vendors would be sorted together, but separately from the waste collected from the other vendor-types.

For each physical sort, all the bags from a vendor-type were combined and transferred onto a 1 cm grid wood-framed wire mesh (Figure 2-12) The mesh covered the mouth of 5 kg bins and fully covered the area of the tables on which the physical sort was carried out. The bags were opened on the wire mesh that was placed on a 5 kg bin and shaken to allow water and items smaller than 1 cm fall into the empty bin. Once the bag was emptied, it was placed into a 5-kg bin where all plastic bags that were previously filled with waste collected from the same vendor-type were being collected. These bags were then weighed at the end of each audit day to determine the contribution of the plastic bags to the total weight of waste collected from the vendor-type. The wire mesh with the waste was carefully carried to the sorting table where the material on the mesh was physically sorted by constituent and placed into smaller 1 kg labeled bins. The weight of the waste for each category was determined by weighing the bin when it was full. The weight of the bin was subtracted from

FIGURE 2-12: 1-CM GRID WIRE MESH (LEFT) AUDIT TEAM AT WIRE MESH (RIGHT)

the bin was subtracted from the weight of the waste from a waste category. The weight of the waste for that vendor-type was recorded by category on the Field Data sheets similar to those included in Appendix 3. The scale was zeroed prior to weighing any sample at Nabong. At the end of the audit, the 5 kg bin was weighed to determine the weight of water and items smaller than 1 cm. These latter items were not sorted because they were generally browns and greens that had been mixed together and contaminated by moisture, making them difficult to classify. The weight of the plastic bags used to collect waste from that vendor-type was also recorded.

This process was followed six times for each vendor-type each audit day.

2.8 Two-Day Audit

A subsequent 2-day audit was conducted on Sunday, August 3 and Monday, August 4, 2003. This audit was conducted for two main reasons. The first was to gather moisture content data for the browns and greens collected from the FV, NB and FS vendors for the wet season. Moisture content is the percent weight of water in the sample being tested and is described by Equation 2-11.

$$MC = \frac{\text{Initial Weight} - \text{Final Weight} \times 100\%}{\text{Initial Weight}} \qquad \textbf{EQUATION 2-11}$$

The trial and seven-day audits showed that FV, NB and FS vendor-types were the largest contributors to brown and green organic wastes at the EMM. The second reason for the two-day audit was to gather more waste data for a Monday in the wet season because of the low vendor participation rate noted on the Monday of the seven-day audit.

FIGURE 2-13: CONING AND QUARTERING TECHNIQUE

The procedures for the physical sort and compositional analysis were the same as those employed during the seven-day audit. After the brown and green waste streams were sorted from the samples collected from the FV, NB and FS vendors, they were weighed along with the other waste streams. When the compositional study was complete, the browns and greens for the vendor-type were placed into two piles on a clean tarp on the floor of the sheltered area. A sample splitting technique known as coning and quartering was employed to obtain a representative sample for the moisture content analysis (Figure 2-13). This technique is generally employed when a field sample is significantly larger than the required analytical sample [SEWR, 2002]. In this work, it allowed the auditor to reduce the mass of the greens and browns gathered from the vendor-type of interest such that the sample analyzed would reflect the average properties of the entire field sample.

Using the coning and quartering technique, a pile of greens or browns on the tarp was piled up into a cone with a shovel. This cone was split into four quarters. A grab sample was collected from the first quarter using barbecue tongs. This was placed in a pre-labeled, tightly sealable Ziploc bags. One of the quarters from the original sample was then selected and re-coned. This cone was quartered and a grab sample was collected and placed into a pre-labeled, tightly sealable Ziploc bags. On the first day of the two-day audit, the coning and quartering was conducted three times and three grab samples were collected for analysis. On the second day of the waste-audit, the coning and quartering was conducted twice and two grab samples were analyzed.

The Ziploc bags were taken immediately to the Nabong laboratory for analysis. Each sample was placed into a pre-weighed aluminum dish and the sample weight was determined (Figure 2-14). Then the dishes were placed in a drying oven at 103˚C overnight. The dish was re-weighed after a 24-hour period. The loss in sample moisture (Equation 2-9) over the 24-hour period provided insight on the sample moisture content for the brown and green separated organics for the FV, NB and FS vendor-types.

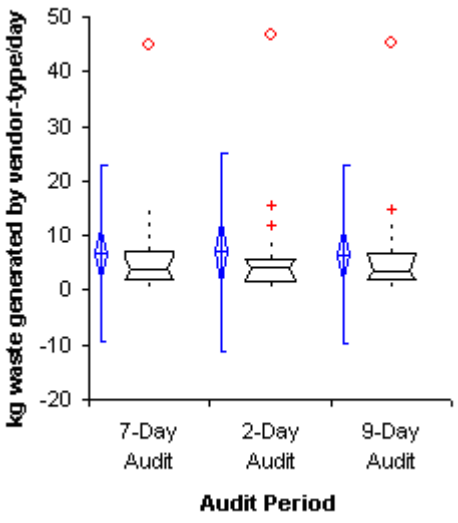
FIGURE 2-14: MOISTURE CONTENT SAMPLES COLLECTED IN ZIPLOC BAGS (LEFT) BROWN ORGANICS IN ALUMINUM DISH (RIGHT)

3 Results and Analysis

3.1 Waste Quantification

3.1.1 Audit-Period Studied

As explained in section 2, the waste audit was conducted first over a seven-day period and later over a two-day period, for a total of nine days. Appendices 4a – 4f contain waste quantity data gathered at the EMM during the seven and two-day waste audits for each vendor-type. All mathematical calculations of the data can also be found in these appendices. In order to combine the data from both audits and estimate waste quantities for an audit period called the *nine-day* audit, it was necessary to confirm that the data gathered during all nine audit days was from the same sample population. It was expected that since both audits were carried out in the same season, that the quantity and composition of the waste during the two periods would be similar.



A software package called Analyse-It was employed to conduct statistical analysis of the data for the seven-day, two-day and nine-day audit periods for each vendor-type. Box-whisker plots of the average waste generated by each vendor per audit day during the three audit periods were prepared for each vendor-type. Figure 3-1 shows the box-whisker plots for the FV vendor-type. An explanation of how to interpret the box-whisker plot has been included in Appendix 5. Table 3-1 summarizes the average

FIGURE 3-1: BOX-WHISKER PLOTS FOR THE FV VENDOR-TYPE

waste generated by the FV vendor-type over the seven, two and nine-day audit periods. It also provides the standard deviation for the average waste generated by the vendors in the FV vendor-type as well as the 95% confidence interval of the mean for the three audit periods.

TABLE 3-1: COMPARISON OF STATISTICAL DATA FROM SEVEN, TWO AND NINE-DAY AUDITS FOR FV VENDOR-TYPE

Audit Period	Number of vendors (n)	kg waste generated by vendor-type/day				
		AVG	STDEV	Range of Data		95% CI of Mean
				Minimum	Maximum	
7-Day	20	6.61	9.81	0.52	44.96	2.02 to 11.20
2-Day	17	7.09	11.03	0.40	46.80	1.42 to 12.76
9-Day	20	6.50	9.92	0.52	45.37	1.85 to 11.14

AVG – Average
STDEV – Standard Deviation
CI – Confidence Interval

Figure 3-1 visually shows that the data from the seven-day audit is similar to the data from the two-day audit. As a result, the box-whisker plot for the nine-day audit period is comparable to these two audit periods. Table 3-1 shows that the average waste generated by the FV vendor-type in the seven-day audit is comparable to that generated in the two-day and nine-day audits. Similar comparisons have been completed for all vendor-types (Appendix 4). They show that data from the seven-day audit is similar to the data gathered during the two-day audit for the FV, PG, MFE, RC and FS vendor-types[10]. Since the seven-day and two-day audits both study the same population (same vendors) from the same market in the same season, it is justifiable to combine the data from both audits and to analyze it over a nine-day audit period. This analysis uses a larger pool of data for the analysis and is expected to increase confidence in the waste quantity estimates.

3.1.2 Waste Generation Estimates by Vendor-Type

Table 3-2 summarizes the average waste generated by each vendor-type during the nine-day audit. The raw data and the calculations completed using the data are included in Appendices 4a – 4f. Table 3-2 shows that the largest quantity of waste generated is from the FV vendor-type. The smallest quantity of waste generated is from the PG vendor-type. It can also be seen from Table 3-2 that the standard deviation for the estimate of the waste generated by the FV vendor-type is greater than the estimate for the average waste generated by this vendor-type. For all other vendor-types the standard deviation is less than the average waste generated by the vendor-type. Additionally, the range of waste generation estimates for each vendor in the

FV vendor-type is quite large. Finally, care must be taken in accepting the estimates for the RC vendor-type since only two vendors participated in the audit from this vendor-type.

TABLE 3-2: ESTIMATES OF AVERAGE WASTE QUANTITY GENERATED BY A VENDOR FROM EACH VENDOR-TYPE

Vendor-Type	Number of vendors (sample number)	kg waste generated by vendor-type/day				
		AVG	STDEV	Range		95% CI of mean
				Minimum	Maximum	
FV-1	20	6.49	9.92	0.52	45.37	1.85 to 11.14
PG-1	9	0.59	0.43	0.15	1.37	0.26 to 0.92
MFE	5	0.62	0.33	0.38	1.20	0.21 to 1.03
RC	2	2.22	1.68	1.03	3.41	-12.9 – 17.4
NB	4	1.41	0.37	0.88	1.70	0.81 to 2.00
FS	5	2.41	0.84	1.55	3.82	1.37 to 3.46
Total	**$\sum$ = 45**					

FV-1 and PG-1 are the initial estimates for the FV and PG vendor-types respectively. Subsequent estimates are made later on in this section.

3.1.3 Analysis of Waste Quantity Data

In general, the amount of daily waste generated by a vendor did not change significantly from day-to-day during the nine-day audit period. Appendix 4 shows that with the exception of a few audit days, each participating vendor generated similar waste quantities everyday of the audit period. Table 3.3 provides the average, standard deviation and range of the waste generated per day for each vendor over the nine-day audit period.

Analysis of the average daily waste generated by each vendor within a vendor-type reveals that there are variations in the waste generated by the vendors within a single vendor-type. The vendors that have average daily waste estimates significantly greater or less than other vendors within the same vendor-type have been highlighted in Table 3-3. Details of the different items sold by each vendor that participated in the waste audit are included in Appendix 1.

Fruit and Vegetable Vendor-Type

Analysis of the data collected, market observations and discussions with the vendors showed that some vendors within the FV vendor-type could have been sub-stratified into separate categories. Although these vendors generated organic waste like other vendors in the FV

[10] Comparative statistical analysis of the waste quantity data can be completed to confirm whether or not the data collected for most of the vendor-types during both of the audit periods is from the same sample population. Such statistical analysis is not completed in this report as it is outside the scope of work.

TABLE 3-3: AVERAGE WASTE GENERATED BY EACH VENDOR

Vendor-Type	Vendor Location on Map	Number of Samples Collected in Audit	kg waste generated by vendor-type/day		Range	
			AVG	STDEV	Minimum	Maximum
FV	8	6	3.45	2.09	1.00	5.90
	10	8	3.83	1.18	2.40	5.60
	11	9	5.60	2.80	2.70	11.80
	14	9	13.29	3.36	9.40	20.70
	15	8	2.28	0.85	1.30	3.90
	16	9	0.92	0.19	0.60	1.20
	17	9	45.37	28.10	12.50	110.10
	18	5	1.20	1.05	0.30	2.60
	19	8	2.16	0.91	0.70	3.50
	20	8	4.76	2.02	1.60	6.80
	22	5	0.52	0.38	0.30	1.20
	23	9	3.37	1.74	1.90	7.40
	24	9	0.94	1.31	0.30	4.40
	27	8	3.19	1.71	0.80	5.90
	30	7	14.69	5.94	4.30	23.70
	31	6	1.67	0.70	0.80	2.80
	34	6	7.15	2.18	4.40	9.90
	37	7	6.83	2.57	2.50	9.90
	38	8	6.69	5.80	1.60	16.40
	42	4	2.00	0.59	1.20	2.50
PG	1	7	0.15	0.12	0.05	0.40
	2	9	0.34	0.19	0.10	0.70
	3	7	0.31	0.13	0.10	0.50
	4	9	0.20	0.09	0.10	0.40
	7	9	0.59	0.21	0.40	0.90
	28	8	1.08	0.39	0.40	1.80
	33	7	1.37	1.50	0.30	4.60
	35	8	0.36	0.38	0.20	1.30
	41	8	0.88	0.62	0.10	1.60
MFE	13	6	0.48	0.21	0.30	0.80
	21	8	0.49	0.40	0.10	1.40
	26	6	1.20	1.68	0.20	4.60
	32	6	0.55	0.39	0.20	1.30
	47	6	0.38	0.13	0.20	0.50
RC	39	9	1.03	1.29	0.10	4.20
	44	7	3.41	2.04	1.10	5.90
NB	9	9	0.88	0.41	0.40	1.60
	29	9	1.70	1.84	0.40	6.00
	45	8	1.64	2.00	0.30	5.20
	46	8	1.41	0.25	1.10	1.80
FS	5	7	2.27	1.23	0.60	4.20
	6	7	2.10	0.63	1.00	2.80
	25	8	3.82	2.01	1.10	6.70
	40	8	2.33	1.51	0.10	5.10
	43	8	1.55	0.49	0.90	2.10

decision unit, they generated significantly different quantities of waste with potentially different composition. The first sub-stratification of the FV vendors could be made for the coconut vendors. There were two vendors that participated in the audit from the FV vendor-type that could be sub-stratified as coconut vendor-types (C). These were vendor numbers 14 and 30 (Figure 3-2). Although the coconut vendors occupied a stall of similar size to the other FV vendors, sold organic items and produced predominately organic wastes, they generated a significantly greater quantity of waste than other vendors in the FV vendor-type category. For this reason, they should have been placed in a category of their own. Since

FIGURE 3-2: ITEMS SOLD BY VENDORS 14 (LEFT) AND 30 (RIGHT)

the coconut vendors were also observed to be the greatest producers of browns and greens, knowledge of their waste quantity and composition along with the location of their stall in the market could be useful for a composting facility that might treat organic wastes from the EMM. Table 3-3 also shows that vendors 14 and 30 add a significant quantity of waste to the total waste collected from vendors each day of the waste audit.

The second sub-stratification of the FV vendors could have been made for vendors 16, 18, 22 and 24. These four vendors (the only of their kind at the EMM) all had the lowest quantity of waste in the FV vendor-type and commonly sold garlic, onions, ginger, powder or fresh chilis and sometimes paa dek. As a result, they could have been sub-stratified into

FIGURE 3-3: GARLIC PEELS FROM GO VENDOR-TYPE

a Garlic and Onion vendor-type (GO). The waste generated by these vendors generally consisted of peels from garlic that the vendor peeled during market operation. As a result, the weight of the waste generated was light in comparison to that generated by other vendors in the FV vendor-type. Figure 3-3 shows waste collected from a GO vendor on day 2 of the waste audit. Note that although some GO vendors sold paa dek, the sale of this item had very little

impact on the waste generated by these vendors since there was no observable waste generated from their sale. This observation was confirmed by discussions with locals as well as vendors in the market.

FIGURE 3-4: FV VENDOR NUMBER 17

One vendor in the FV vendor-type that was different from other vendors in FV vendor-type was vendor 17. Data from vendor 17 shows that this vendor generated a significantly larger quantity of waste than the other FV vendors. This can be attributed partly to the size of vendor's stall, which was twice the size of the average FV vendor stall and therefore allowed the vendor to sell more organic items than the other FV vendors in the market. Figure 3-4 shows the stall run by vendor 17. The nature of the items sold by vendor 17 generated a very large quantity of green and brown organic waste. Finally, some of the items sold by vendor 17, such as the banana flower were not sold at any other stall in the EMM. A large portion of the organic items sold by vendor 17 included the banana flower, which made-up a large portion of the brown and green waste from this vendor[11]. Table 3-3 shows that Vendor 17 adds a significant quantity of waste to the total waste that was collected from vendors each day of the waste audit. Furthermore, the range of waste generated by vendor 17 over the audit period is quite wide, which leads to the high standard deviation shown in Table 3-3 for the average daily waste generated by this vendor over the audit period.

Table 3-4 shows estimates of the quantity of waste generated by the vendors from the C (vendors 14 and 30) and GO vendor-types (vendors 16, 18, 22, 24) and the quantity of waste generated by vendor 17 per day. Removing these vendors from the FV vendor-type category impacts the estimate the average daily waste generated by a vendor in the FV vendor-type. For this reason, an estimate for the average waste generated by a FV vendor was re-calculated with the exclusion of vendors 14, 16, 17, 18, 22, 24 and 30 in Table 3-4.

[11] Waste from banana flower was found at other vendor stalls because various vendors peeled this vegetable while sitting at their stalls during market operations.

TABLE 3-4: ESTIMATES OF AVERAGE WASTE QUANTITY GENERATED FOR FV VENDOR-TYPE AND SUB-STRATIFIED VENDOR-TYPES WITHIN THE FV VENDOR-TYPE CATEGORY

Vendor-Type	Number of Samples (n)	kg waste generated by vendor-type/day			
		AVG	STDEV	Range	
				Minimum	Maximum
FV-1	20	6.49	9.92	0.52	45.37
FV-2[1]	13	4.07	1.95	1.67	7.15
C	2	13.99	0.99	13.29	14.69
Vendor 17[2]	1	45.37	28.10	12.50	110.10
GO	4	0.90	0.28	0.52	0.96

[1]Excludes vendors 14, 16, 17, 18, 22, 24 and 30 from the estimate
[2]The average waste generated by this vendor is determined over the audit period using data for the single vendor.

If the waste generated by the FV vendor-type is estimated by excluding vendors 14, 16, 18, 22, 24 and 30 from the calculation, there is a decrease in the estimate of the daily waste generated by the FV vendor-type from 6.49 to 4.07 kg/day. Furthermore, the standard deviation for FV-2 is 1.95 kg/day with the removal vendors 14, 16, 17, 18, 22, 24 and 30 from the estimate as opposed to 9.92 kg/day for FV-1. To assess whether the estimate of FV-2 is more representative of the FV vendor-type than FV-1, Appendix 2 needs to be re-visited. From the list in this appendix, it can be seen that there is greater similarity in the items sold by vendors included in the waste generation estimate for the FV vendor-type in Table 3-4 when the C and GO vendor-types and vendor 17 are sub-stratified than there is when these vendor-types are not sub-stratified from the estimate in Table 3-2. Figure 3-5 shows pictures of some of the vendors included in the waste generation estimate for the FV

FIGURE 3-5: FV VENDORS 10 (LEFT), 20 (TOP RIGHT), 26 (BOTTOM RIGHT)

vendor-type in Table 3-4, showing that these vendors sell similar items. Since vendors selling similar items are expected to generate similar waste (section 2.3.2), then the vendors included in the waste generation estimate for the FV vendor-type in Table 3-4 is preferable to the estimate for the same vendor-type in Table 3-2.

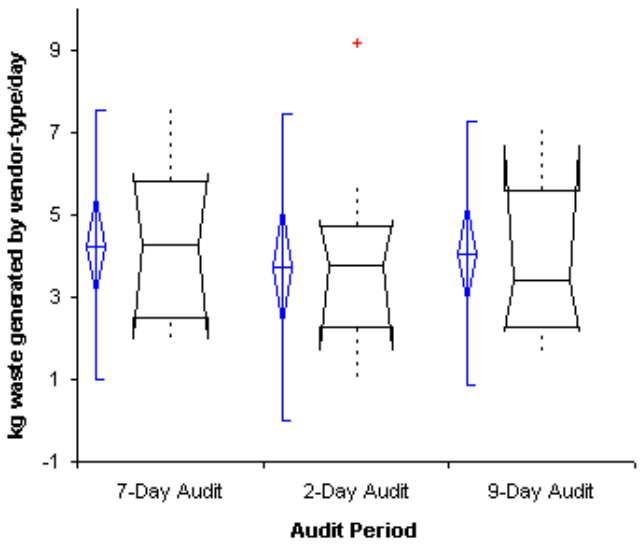


FIGURE 3-6: BOX-WHISKER PLOTS FOR FV-2 VENDOR-TYPE

Furthermore, comparison of the new box-whisker plot in Figure 3-6 for the FV-2 vendor-type to the box-whisker plot for FV-1 in Figure 3-1 shows that there are fewer data outliers with the sub-stratification of the FV vendor-type as described in this section.

Packaged Goods Vendor-Type

Two vendors in the PG vendor-type that generated waste quantities slightly higher than other vendors in the same category were vendors 28 and 33. This difference in waste quantity can be attributed to the completely different products sold by these two vendors. While most of the vendors in the PG vendor-type sold packaged hygiene, food and/or household products, vendors 28 and 33 were the only vendors in the PG vendor-type category that sold bamboo products and dishes respectively (Figure 3-6). These vendors were included in the PG vendor-type because they were observed to generate similar waste to other PG vendors (mostly paper and soft plastic waste). However, when the waste generated by the PG vendor-type is estimated with the exclusion of vendors 28

FIGURE 3-7: PG-3 VENDORS 28 (LEFT) AND 33 (RIGHT)

and 33, the estimate of the average waste generated by this vendor-type decreases slightly from 0.59 to 0.41 kg/day for PG-1 and PG-2 respectively as shown in Table 3-5. In addition, there is a slight decrease in the standard deviation for the estimate of waste generated by the PG-2 vendor-type than the PG-1 vendor-type from 0.43 to 0.25 kg/day. An estimate for the sub-stratified vendors 28 and 33 is also shown in Table 3-5. The waste generated by these vendors is higher than that estimated for the PG vendor-type.

TABLE 3-5: ESTIMATES OF AVERAGE WASTE GENERATED BY PG VENDOR-TYPE AND SUB-STRATIFIED VENDORS WITHIN THE PG VENDOR-TYPE

Vendor-Type	Number of Samples (n)	kg waste generated by vendor-type/day			
		AVG	STDEV	Range	
					Maximum
PG-1	9	0.59	0.43	0.15	1.37
PG-2[1]	7	0.41	0.25	0.15	0.88
Vendors 28 and 33 (PG-3)	2	1.22	0.21	1.08	1.37

[1]Excludes vendors 28 and 33 in estimate.

Vendors 28 and 33 were the only two vendors of their kind at the EMM. As a result, they will both be considered as a separate vendor-type, PG-3 for the purposes of estimating the total daily waste generated at the EMM.

FIGURE 3-8: RC VENDOR 39

Rice and Charcoal Vendor-Type

There were two vendors participating in the waste audit from the RC vendor-type group (Vendors 39 and 44). Both of these vendors occupied stalls of similar sizes and sold the exact same items. Since only two RC vendors participated in the audit, the estimate for the waste generated by this vendor-type should be applied with caution when estimating waste generation of RC vendors in other markets. However, because there are only three RC vendors in the EMM, the estimate for the RC vendor-type is acceptable for estimating the total waste generated by all RC vendors in the EMM.

3.1.4 Waste Generated by Vendor-Types (Revised)

Based on the analysis conducted in the above section of the report, the waste generation rates by vendor-type are revised in Table 3-6.

TABLE 3-6: ESTIMATES OF AVERAGE WASTE GENERATED BY A VENDOR FROM EACH VENDOR-TYPE

Vendor-Type	Number of vendors (sample number)	kg waste generated by vendor-type/day				
		AVG	STDEV	Range		95% CI of mean
				Minimum	Maximum	
FV-2	13	4.07	1.95	1.67	7.15	2.90 – 5.25
17	1	45.37	28.10	12.5	110.1	N/A
C	2	13.99	0.99	13.29	14.69	5.11 – 22.86
GO	4	0.90	0.28	0.52	0.96	0.45 – 1.34
PG-2	7	0.41	0.25	0.15	0.88	0.17 – 0.64
PG-3	2	1.22	0.21	1.08	1.37	-0.66 – 3.11
MFE	5	0.62	0.33	0.38	1.20	0.21 to 1.03
RC	2	2.22	1.68	1.03	3.41	-12.9 – 17.4
NB	4	1.41	0.37	0.88	1.70	0.81 to 2.00
FS	5	2.41	0.84	1.55	3.82	1.37 to 3.46
Total	**∑ = 45**					

The estimates for average quantity of waste generated by vendor-type in Table 3-6 can be employed to estimate the waste generated by similar vendors in other markets in Vientiane. If the hours of operation for these markets are similar to those of the EMM, the nature of the items sold by the vendors similar to those sold by the vendors participating in this study (see Appendix 10) and the stall size occupied by the vendors are similar to those at the EMM.

Using the average waste generation rates in Table 3-6 and Equation 2-3 from section 2.4.1, the total daily waste generated by each vendor type and by the entire EMM is estimated in Table 3-7.

The total daily waste generated at the EMM is estimated to be approximately 540 kg/day or 0.54 ton/day. This seems reasonable, considering that the JICA bin for the EMM that is emptied every two to four days and holds about 1.5 to 2 tons of waste. Furthermore, the management at KM 18 claims that during the wet season, approximately 3.8 ton of waste is sent to KM 18 per day from the TKK markets (including the EMM). There are approximately 468 vendors in the

TKK markets and 170 vendors in the EMM. Since the EMM is much smaller than the TKK Market, it would be reasonable for the EMM to generate approximately 0.54 ton of waste per day.

TABLE 3-7: ESTIMATE OF TOTAL WASTE GENERATED AT THE EMM PER DAY WITH SUB-STRATIFICATION

Vendor Type	Total Number of Vendors	Average daily waste generated by vendor-type (kg waste/vendor-type*day)	Average daily waste generated at EMM (kg waste/day)
FV	83	4.07	337.8
17	1	45.37	45.4
C	6	13.99	83.9
GO[1]	4	0.90	3.6
PG-2[2]	36	0.41	14.8
PG-3	2	1.22	2.4
MFE	12	0.62	7.4
RC	3	2.22	6.7
NB	7	1.41	9.9
FS	11	2.41	26.5
TOTAL	**165**		**≈ 538.4**

[1]The only four GO vendors in the market participated in the waste audit
[2]PG-2 includes all vendors except vendors 28 and 33, which are grouped together as PG-3

If sub-stratification of the FV and the PG vendor-types were not completed, then the estimate of the total daily waste generated by each vendor-type and by the entire EMM would be different. In this case, the average waste generation rates in Table 3-2 and Equation 2-3 would be employed to yield the estimates shown in Table 3-8. The table shows that without sub-stratification of the FV and PG vendor-types, the total daily waste generated at the EMM is estimated to be approximately 683 kg/day or 0.68 ton/day. This estimate is 22% greater than the estimate for total waste generated at the EMM with sub-stratification of the PG and FV vendor-types.

Most of the daily waste in the EMM was generated by the FV vendors, which were the largest vendor-type present in the EMM. Although there were not many C vendors in the EMM, it can be seen from Table 37 that a single vendor from this vendor-type generates the largest daily quantity of waste when compared to a single vendor from any other vendor-type.

TABLE 3-8: ESTIMATE OF TOTAL WASTE GENERATED AT THE EMM PER DAY WITHOUT SUB-STRATIFICATION

Vendor Type	Total Number of Vendors	Average daily waste generated by vendor-type (kg waste/vendor-type*day)	Average daily waste generated at EMM (kg waste/day)
FV-1	94	6.49	610.1
PG-1	38	0.59	22.42
MFE	12	0.62	7.44
RC	3	2.22	6.67
NB	7	1.41	9.87
FS	11	2.41	26.51
TOTAL	**170**		**683.01**

3.2 Vendor Participation

As discussed in section 2.5, the average waste generated by a single vendor in a vendor-type has been calculated only for the days that the vendor was present in the EMM and participated in audit activities. The calculation inherently assumes that vendors belonging to groups one and two defined in Table 2-4 do not influence the calculation of the average waste generated by a vendor over the audit period and therefore do not impact the estimate of the average waste generated by a vendor-type. Consequently, the estimates for average waste generated by vendor-types in Table 3-8 report potentially higher averages for the waste generated by vendor-types. Although a vendor that was absent on an audit day could not participate in the waste audit and actually generated zero waste on a given audit day, the waste generation calculation implies that this vendor generated at least the average waste quantity generated for that vendor over the audit period. Furthermore, any vendor that was present on a given audit day, yet did not participate in audit activities was also assumed to generate the average waste generated by that vendor over the audit period, even though this vendor might have not have generated waste equivalent the average amount estimated for that vendor-type over the audit period.

Consider the data reported in Table 2-4 for the RC vendor-type. In this table, it can be seen that vendor 44 did not participate in the waste audit on Days 1 and 8 of the audit. The waste generation calculation assumes that vendor 44 generated at least 3.41 kg waste each on Days 1 and 8 of the audit. It is possible that the vendor was absent one day and did not participate in the waste audit. In this case, the assumption that vendor 44 generated 3.41 kg of waste is an overestimation since the vendor actually generated no waste (0 kg). It is also possible that

vendor 44 was present, generated waste but did not participate in the waste audit, also making the 3.41 kg an overestimation of the waste generated by the vendor on that audit day. Since there is no way of differentiating between present and absent vendors that did not participate in the waste audit, there is no way of knowing if vendors that did not participate in the waste audit were present or absent, the estimate for waste generation for each vendor over the audit period and for each vendor-type could either be an overestimation.

A participation factor was calculated for each vendor in a vendor type for each audit day. These participation factors along with the average participation rate for each vendor-type over the nine-day audit is shown in Table 3-9.

TABLE 3-9: VENDOR PARTICIPATION FOR EACH VENDOR-TYPE DURING WASTE-AUDIT

Vendor -Type	Total Number of Participating Vendors	Day of the Audit									
		1	2	3	4	5	6	7	8	9	AVG
FV	20	55.0%	75.0%	85.0%	85.0%	90.0%	85.0%	95.0%	85.0%	75.0%	81.1%
PG	9	55.6%	100.0%	100.0%	100.0%	88.9%	77.8%	100.0%	88.9%	88.9%	88.9%
MFE	5	60.0%	40.0%	80.0%	80.0%	80.0%	80.0%	80.0%	60.0%	60.0%	68.9%
RC	2	50.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50.0%	100.0%	88.9%
NB	4	75.0%	100.0%	100.0%	100.0%	75.0%	75.0%	100.0%	100.0%	100.0%	91.7%
FS	5	40.0%	80.0%	100.0%	100.0%	100.0%	100.0%	60.0%	80.0%	100.0%	84.4%

The information in Table 3-9 shows that the vendor participation was significantly lower on the first Monday of the audit than the remaining eight audit days. The participation rate improved to 80% or greater as the audit proceeded over the remainder of the audit period. To uncover other reasons for the low participation rate on the first Monday, the waste-audit was repeated for a Monday during the two-day audit (day nine). The participation rate on the second Monday (Day 9) improved to match the participation rates between day 2 and 9 of the audit. The participation rate on day nine and discussions with the vendors revealed that the low participation rate on the first day of the audit was attributed to difficulties vendors had in understanding the audit process.

3.3 Waste Composition

The composition of the waste by each vendor-type provides important information for a permanent composting facility that obtains waste from the EMM. It estimates the amount of brown and green waste generated by each vendor-type and also the amount of waste from the market that could contaminate a compost pile (e.g. meat and fish can be a nuisance).

Although it was possible to sub-stratify vendor-type categories in the waste quantification study based on the audit results, discussions with locals and market vendors and market observations, this is not possible for the waste composition study. The composition of the waste can only be reported for the vendor-types whose waste was physically sorted as reported in Table 3-2.

3.3.1 Audit-Period Studied

The composition of the waste generated by each vendor-type was estimated using data gathered over the nine-day audit period. Appendix 6 contains the raw data collected from the physical sort during the seven and two-day waste audits for each vendor-type. This data and the calculations conducted with the data are found in Appendix 6 and a summary of the waste composition for the seven, two and nine-day audits is also included at the end of Appendix 6. From the waste composition summary in Appendix 6, it can be seen that some of the estimates of the average waste generated by category during the seven-day audit are different from the estimates for the average waste generated for the same categories during the two-day audit. On the whole, however, the waste composition for each vendor-type from the seven-day and two-day audits is comparable. For this reason, combining the compositional data from the seven and two-day audits to conduct an analysis for a *nine-day audit* is considered reasonable. Furthermore, a nine-day compositional analysis maintains a study period consistent with that employed in the waste generation analysis conducted in section 3.1. Choosing the same study periods for both studies allows a relevant discussion of waste quantity and composition data interchangeably to assess waste characteristics.

3.3.2 Waste Composition Estimate

Table 3-10 summarizes the average % composition of the daily waste generated by each vendor-type as determined by Equations 2.4 to 2.6. The percentages in Table 3-10 show the compositional break-down of the average daily waste generated by vendor-type.

TABLE 3-10: % COMPOSITION BREAK-DOWN OF AVERAGE DAILY WASTE GENERATED BY VENDOR-TYPE

Vendor-Type	Categories									
	Greens	Browns	Animal Food Wastes	Paper Products	Soft Plastics	Hard Plastics	Metals	Glass	Others	Total
FV	49.6%	48.8%	0.1%	0.3%	0.9%	0.1%	0.0%	0.0%	0.1%	100.0%
PG	18.0%	33.1%	1.5%	21.1%	17.3%	5.4%	0.0%	0.2%	3.4%	100.0%
MFE	23.5%	21.2%	16.1%	6.8%	26.9%	1.7%	0.0%	2.8%	1.1%	100.0%
RC	11.2%	36.0%	0.5%	7.9%	29.1%	2.4%	0.2%	3.2%	9.4%	100.0%
NB	36.7%	28.5%	0.1%	14.0%	16.7%	1.2%	0.7%	1.1%	1.1%	100.0%
FS	42.9%	22.5%	12.7%	1.8%	12.3%	0.6%	2.5%	2.9%	1.7%	100.0%

In order to estimate the average quantity of waste generated by category for a single vendor in a vendor-type, Equation 2-6 needs to be employed. Table 3-11 summarizes the mass composition of waste generated by a single vendor in a vendor-type per day.

TABLE 3-11: AVERAGE WASTE GENERATED BY CATEGORY FOR EACH VENDOR-TYPE PER DAY

Vendor-Type	Greens	Browns	Animal Food Wastes	Paper Products	Soft Plastics	Hard Plastics	Metals	Glass	Others	Average Waste Generated by Vendor-Type (kg/day)
FV	3.90	3.97	< 0.01	0.03	0.06	<0.01	< 0.01	< 0.01	< 0.01	7.96
PG	0.11	0.21	< 0.01	0.12	0.11	0.03	< 0.01	< 0.01	0.02	0.60
MFE	0.18	0.08	0.10	0.06	0.14	< 0.01	< 0.01	< 0.01	< 0.01	0.56
RC	0.18	1.00	< 0.01	0.11	0.26	0.03	< 0.01	<0.01	0.20	1.77
NB	0.49	0.35	< 0.01	0.18	0.26	0.02	< 0.01	0.02	0.02	1.34
FS	1.64	1.08	0.52	0.09	0.53	0.03	0.12	0.13	0.07	4.21

Although the quantities of waste generated by C and GO vendor-types, FV vendor 17 and PG-3 were estimated from the daily waste quantity data collected, the waste from these sub-stratified groups cannot be characterized because a separate physical sort was not completed for the waste generated by the sub-stratified groups. Instead, the percent and mass compositions in Tables 3-9 and 3-10 respectively are reported for the six vendor-types whose waste was sorted.

The results in Table 3-11 are very gross estimates of the mass of waste generated by a single vendor in each vendor-type for the nine categories. A comparison of the average daily wastes

generated by each vendor-type in Table 3-2 to those reported in Table 3-11 shows significant variation in the results obtained using the two estimation techniques. In fact, the estimates for waste generation by vendor-type reported in Table 3-2 are more accurate than those reported in Table 3-11. Firstly, in estimating the amount of waste generated by category for a single vendor in Table 3-11, it was assumed that an equal amount of green, brown, animal food waste, paper products, soft plastics, hard plastics, metals, glass and others waste was generated by all vendors in a vendor-type participating in the waste audit on any given audit day. Since some vendors in a vendor-type may generate more green than brown waste for example, this assumption leads to questionable numbers for the mass composition of the waste for each vendor-type. This in turn over estimates the total waste generated by each vendor-type. On the other hand, the estimate for the average quantity of waste generated by vendor-type estimated in Table 3-2 is obtained by determining the total amount of waste generated by a single vendor within a vendor-type and then takes an average of all the waste generated by vendors within that vendor-type. This latter estimate takes into account the variation of waste generated by each vendor within a vendor-type.

The mass composition of the waste generated by vendor-type could also have been determined by multiplying the % composition information in Table 3-10 to the estimates for the average waste quantity reported for the original six vendor-type groups in Table 3-2. The problem with doing this is that information of the waste gathered at the EMM would be combined with the % composition of the sorted waste at Nabong to obtain mass compositions of the vendor-type wastes. In addition, the estimates for average waste quantity in Table 3-2 are questionable because of further sub-stratification of groups that is required as per Section 3.1.3.

From Table 3-10, it can be seen that the largest percentage of green and brown waste was generated by the FV, FS and NB vendor-types. The FS and MFE vendor-types generated the largest amount of animal food wastes. Unsoiled paper waste was predominantly generated by the PG, NB, RC and FS vendor-types. Soft plastics were largely generated by the RC, FS and NB vendor-types. The RC vendor-type produced the most wastes in the others category (generally charcoal). Very little of the remaining categories of waste were generated by any of the vendor-types.

The sample obtained at the EMM during the waste audit was the primary sample. As this sample was handled, transported and prepared for analysis during the physical sort, changes

could have occurred in the sample, such as the gain or loss of constituents such as moisture, at each stage of the waste audit. These changes can result in the accumulation of errors throughout the sampling process such that decisions made on relatively small samples (often less than 1 gram) may no longer represent the population of interest. Table 3-11 highlights waste quantities by each vendor-type that are considered insignificant.

Table 3-12 summarizes the minimum and maximum percent compositions of waste generated by each vendor-type over the audit period. It also summarizes the standard deviations of the percent compositions observed for each category, by vendor-type. This table shows that the range of percent compositions of the waste generated by all vendor- types is quite wide for most of the categories over the audit period. The categories with ranges of minimum and maximum percentages greater than 10% are highlighted in Table 3-12.

Examination of the results in Appendix 6 allows some general observations from the audit period. Firstly, the top two waste generating categories fluctuate between being higher and lower than each other throughout the waste audit for some vendor-types. For example, the FV vendor-type tends to generate predominantly brown and green wastes. On some days, there are more browns and fewer greens; on other days, the converse is true. The same observation holds for the PG vendor-type that is a large generator of browns (consisting mostly of soiled paper) and paper products. Secondly, there are some extreme results for vendor-types over the audit period. For example, on Day 8 of the audit, the percent composition of the soft plastics generated by the RC vendor-type is 100%. This makes the percentage of waste in all other categories 0% on that day for the RC vendor-type. This result is quite different from that observed on Day 9 of the audit, when the percent composition of browns was about 90% and both RC vendors participated in the audit. These fluctuating results can be attributed to the fact that there was only one RC vendor participating in the audit on Day 8 and two on Day 9 of the audit. Similarly, on Day 2 of the audit, there was a higher percentage of green waste from the MFE vendor-type. This can also be related to the two rather than five possible MFE vendors that participated in the audit that day.

Based on market observations, discussions with vendors and market management and audit results, the composition of the waste generated by any vendor-type in any one audit day can be influenced by:

- The amount of waste generated by the vendor-type;

- The number of vendors present and participating in the audit from the vendor-type;
- Variations in the items sold by vendors in a vendor-type;
- Removal of waste items by the informal sector.

TABLE 3-12: VARIATION IN % COMPOSITION OF WASTE GENERATED BY VENDOR-TYPE

	FV			PG			MFE			RC			NB			FS		
	SD	Min	Max	SD	Min	Max	SD	Min	Max	SD	Min	Max	SD	Min	Max	SD	Min	Max
Greens	12.8%	33.1%	74.5%	16.1%	0.0%	55.1%	27.0%	0.0%	73.7%	22.1%	0.0%	63.1%	14.3%	10.0%	59.3%	23.4%	4.3%	85.7%
Browns	12.2%	25.0%	62.8%	21.0%	2.7%	66.7%	18.8%	0.0%	60.0%	35.8%	0.0%	90.2%	13.2%	6.0%	48.8%	14.7%	10.6%	57.8%
Animal Food Waste	0.1%	0.0%	0.3%	2.0%	0.0%	5.4%	14.0%	0.0%	33.3%	1.6%	0.0%	4.8%	0.1%	0.0%	0.4%	13.3%	0.0%	36.6%
Paper Products	0.3%	0.0%	0.8%	10.9%	11.1%	48.5%	8.7%	0.0%	19.2%	9.0%	0.0%	28.6%	12.2%	0.0%	38.5%	1.2%	0.0%	3.9%
Soft Plastics	0.5%	0.3%	2.1%	11.8%	6.3%	45.9%	8.5%	13.5%	41.7%	30.5%	1.4%	100.0%	14.5%	6.4%	53.9%	7.0%	0.0%	21.9%
Hard Plastics	0.3%	0.0%	0.8%	9.6%	0.0%	30.6%	4.2%	0.0%	12.5%	4.6%	0.0%	14.3%	2.8%	0.0%	8.3%	0.5%	0.0%	1.4%
Metals	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	1.5%	2.0%	0.0%	6.0%	2.0%	0.0%	5.6%
Glass	0.0%	0.0%	0.0%	0.5%	0.0%	1.6%	8.3%	0.0%	25.0%	9.5%	0.0%	28.6%	3.3%	0.0%	10.0%	4.1%	0.0%	11.5%
Other	0.2%	0.0%	0.5%	2.8%	0.0%	8.1%	2.2%	0.0%	6.7%	12.4%	0.0%	38.1%	1.5%	0.0%	4.0%	2.1%	0.0%	6.8%

TABLE 3-13: GENERAL OBSERVATIONS ABOUT THE WASTE GENERATED AT THE EMM

Vendor-Type	Comments on % Composition
FV	Browns and greens were largest waste generating categories and about equal amounts.
	There was little to no waste generated in all other categories.
PG[1]	Largest % composition was expected to be for paper products. However, since much of the paper was soiled, most of the waste consisted of browns.
MFE[1]	Soft plastics were largest waste generating category (primarily from meat packing and plastic bags in which the meat, fish or eggs are sold).
	Generally little to no hard plastics, metals, glass and others in the waste generated.
RC	Browns, followed by soft plastics were the overall largest waste generating category.
NB	Browns and greens were overall the largest waste generating categories.
FS	Browns and greens were overall the largest waste generating categories.

[1]Some brown and green waste is generated. These categories are expected to be low waste generators for this vendor-type based on the nature of the items sold by the vendor-type. However, organic items purchased by the vendor during market operations (e.g. food or fruits and vegetables) could have resulted in the higher percentage of this waste.

Although the range of percent compositions for most categories in a vendor-type is wide and there are inconsistencies in the results, the standard deviations for the daily percent composition by category are not nearly as large. As a result, despite the wide range of percent compositions for all vendor-types, the information from the physical sort (Tables 3-9 to 3-12) provides some useful general observations about each vendor-type, which are summarized in Table 3-13. These can be helpful towards the design and development of a permanent composting facility for which feedstock will be obtained from the EMM.

3.3.3 Change in Sample Quantity from EMM to Nabong

In order to uncover potential loss or gain in the sample during transport to Nabong, the total waste generated each day of the audit at the EMM is compared to the estimate of the waste sorted during physical sort at Nabong. For example, as each bag was collected at the EMM, it was weighed prior to being placed in the 5-kg bin. The total waste collected that audit-day was obtained by adding the weight of all the bags collected to each other. At Nabong, the waste in each category was weighed. At the end of the sort, the total was sorted was obtained by adding the amount of waste sorted into each category together. Table 3-14 compares the total daily sample as weighed at the EMM to the estimated weight of the total sample at Nabong. The change in the sample weight is shown both in kilograms per day as well as percent. Note that an increase and decrease in sample weight is associated with positive and negative weight changes respectively in the representative sample taken from the EMM to

TABLE 3-14: DAILY WEIGHT CHANGE IN TOTAL SAMPLE COLLECTED FROM EMM

	Day of the Audit									
	1	2	3	4	5	6	7	8	9	AVG
Total Waste (EMM)	170.5	108.9	162.3	117.2	133.5	142.6	166.9	143.3	146.3	143.5
Total Waste (Nabong)	208.9	106.7	167.5	113.8	121.9	158.2	200.7	125.4	133.7	148.5
% change in Sample Weight	18.4%	-2.1%	3.1%	-2.9%	-9.5%	9.9%	16.8%	-14.3%	-9.4%	1.1%

A negative change in sample represents loss in sample mass from the EMM to Nabong
A positive change in sample represents gain in sample mass from the EMM to Nabong

Nabong. The average daily waste generated by a single vendor in a vendor-type at the EMM cannot be compared to the weight of the sample collected from each vendor-type at Nabong because the bag collected from each vendor was not re-weighed at Nabong.

From Table 3-14, it can be seen that on some days of the waste audit, there was sample loss and on other audit days, there was gain in sample quantity. A loss in sample from the point of

collection at the EMM to the physical sort at Nabong can be explained by the loss of moisture or waste smaller than 1-cm during the physical sort. For example, bags collected from the FV and FS vendors generally had water at the bottom of the bag and bags collected from the MFE and NB vendors had blood. When bags from these vendors were emptied onto the 1-cm grid mesh, some of the moisture fell into the 5-kg bin and the rest remained inside the bag. This resulted in sample loss. Table 3-15 shows the average weight of sample and moisture loss through the 1-cm grid mesh and into the 5 kg bin. Large items that fell in the bin and could be distinguished by category were sorted and the remainder was considered lost sample. Items in the lost sample were too mixed up to separate into appropriate categories. Sample loss could be attributed to the weight of plastic bags in which the waste was collected. This weight was included in the weights recorded at the EMM but was not included in the estimate of the waste at Nabong.

TABLE 3-15: WEIGHT OF SAMPLE LOSS TO 5-KG BIN UNDER THE MESH

Vendor-Type	Average Weight Lost Sample (kg sample/vendor-type*day)	Average Weight of Empty Plastic Bags (kg/vendor-type*day)
FV	0.14	0.7
PG	0.04	0.2
MFE	0.18	0.1
RC	0.37	0.1
NB	0.58	0.1
FS	0.53	0.2

Although the weight of the plastic bags may have contributed to the sample loss between the EMM and Nabong, Table 3-15 shows that the average weight of the plastic bags in which waste was gathered from all participating vendors was generally insignificant to the total weight of the sample sorted on any given audit day. The weight of the plastic bags was recorded after the bags were emptied at Nabong. Moisture and small contents of the sample remained inside some bags.

The gain in sample weight on Days 1, 3, 6 and 7 was an unexpected result. During the physical sort, there was no addition of waste to the sample from the EMM. The bags were tied up prior to storage in the 5-kg bins and during transport to Nabong. Throughout the physical sort, there was no waste in the sorting area that was added to the samples being sorted. As a result, the gain in the weight of the waste sample between storage at the EMM and Nabong can only be

explained by human error, the level of accuracy of the weighing scale employed and potentially improper calibration of the scale both at the EMM and at Nabong. Although one person was assigned the duty of weighing samples in one day, different team members were involved in weighing samples over the waste audit period. Incorrect reading or recording of sample weights at any point of the waste audit could be attributed to the higher sample weights at Nabong. In order to maintain precision in waste quantity results, a single or team of two people should have been assigned the specific task of reading ad recording waste quantities throughout the audit period.

3.4 Moisture Content

During the seven-day audit, it was noted that the largest contributors to the browns and greens categories were the FV, NB and FS vendor-types (see Section 3.2). In order to assess the moisture content of the feedstock from the high organic waste generators at the EMM, moisture content analysis was conducted on the brown and green wastes from these vendor-types. As mentioned in Section 1.3.2, the ideal moisture content during the composting process is between 50 and 60%. The moisture content analysis would ascertain the moisture content of feedstock obtained from the EMM during the wet season and help determine whether or not it falls within this range. Secondly, throughout the waste-audit, there were questions about items being separated into each the brown and green categories. The moisture content analysis could help confirm that the organic waste had been separated into appropriate categories during the waste audit. It was expected that the moisture content of the sample taken from the brown waste pile would have less moisture than the sample from the green waste.

In order to determine the moisture content of the brown and green wastes from these vendor-types, a two-day moisture-content analysis was completed at the Nabong laboratory. The raw data from the analysis is provided in Appendix 7. Table 3-16 summarizes the average moisture content of the brown and green samples collected from the vendor-types of interest over the two days.

The data in this table shows that the moisture content for the samples collected from the waste separated as browns was less than that for waste categorized as greens. Furthermore, it indicates that the moisture content of waste in the brown and green categories exceeds the

moisture content range to be maintained in the composting process. The moisture content of the pile can be adjusted at the facility.[12]

TABLE 3-16: MOISTURE CONTENT RESULTS

Vendor Type	Moisture Content (%)	
	Browns	Greens
FV	68.4%	90.9%
FS	66.5%	88.8%
NB	69.4%	79.4%

3.5 Wet Season

The waste audit was conducted during the wet season in Laos during July 2003. During this season, the nature of the organic waste is expected to be different from what it might be in the

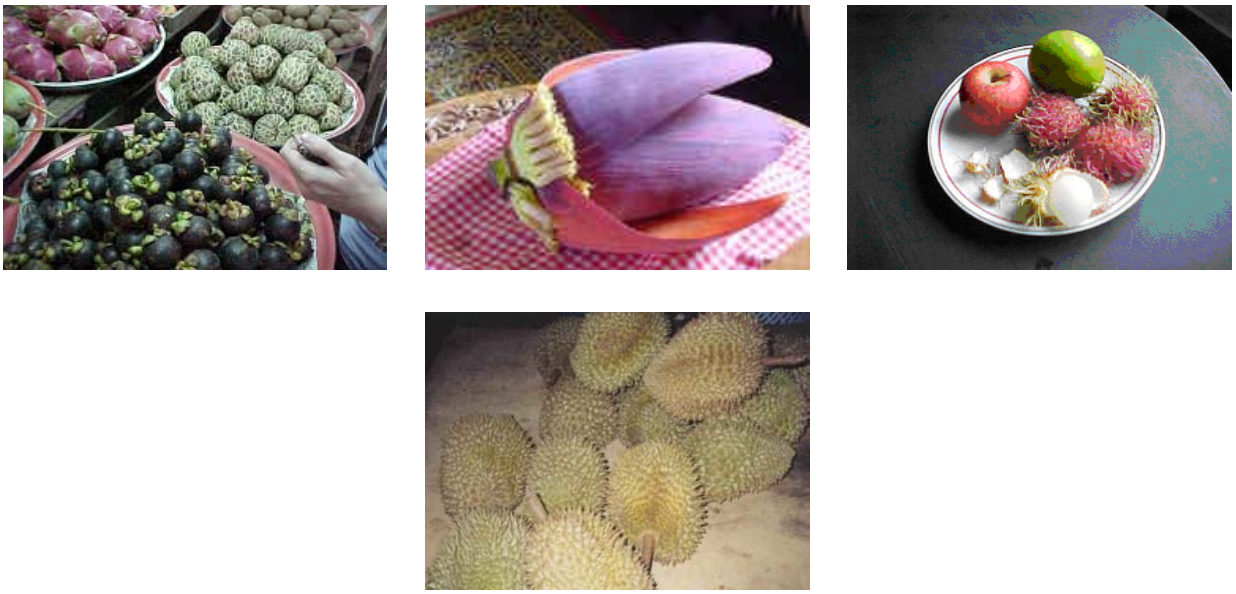


FIGURE 3-9: ORGANIC ITEMS FOUND IN VIENTIANE MARKETS IN WET SEASON - MANGO STEEN, DRAGON FRUIT (TOP LEFT), BANANA FLOWER (TOP MIDDLE), RAMBUTAN, LIMES AND APPLE (TOP RIGHT), DURIAN (BOTTOM)

dry season. Seasonal variations in the items sold in the market are expected to change the nature of waste generated in the EMM. The audit completed in this work captures the composition and quantity of the waste given the organic items that were predominantly sold in the EMM during the wet season. To account for seasonal variations in waste composition, a waste audit of the EMM should be conducted for the dry season. Figure 3-8 shows some of the

[12] Moisture content in a composting pile can be reduced by adding strong, fibrous, dry organic materials high in carbon and increased by materials with high nitrogen content such as sludge from wastewater treatment plants.

different organic items that would contribute to market waste in the wet season, which may be unavailable in Vientiane during the dry season.

Although the audit was conducted during the wet season, there was very little rain during this time. Daily temperatures were between 31°C and 38°C, with an average temperature of about 33.6°C and a standard deviation of 2.74°C for the nine-day audit (Appendix 4). Most days during the audit were extremely hot with clear and sunny skies. There was light rain for a short time on Day 1 of the audit between 6:30 and 7:00 am when bags were being handed out to vendors and between 11:00 am and 12:00 pm on Day 2 when bags were being collected from vendors (see Appendix 10). The Vientiane Times reported that the rainfall in Vientiane was low from the end of June because the southwest monsoon was weak. During July, all parts of the country had soft rain [Vientiane Times, 2003]. As a result, although this work was completed for the wet season, the low rainfall in July and August 2003 might not be representative of the climate normally experienced during the wet season. Albeit, since the weather was consistent for all audit days, the results obtained are consistent for the type of weather that was experienced during the audit period.

3.6 Observations throughout the Waste Audit

Appendix 8 provides major observations that were made when the bags were being handed out to vendors, when bags were collected and during the physical sort. These observations may be helpful in interpreting results. Some of the major observations are summarized herein.

- The bags collected from the FS vendors were often highly soiled with coffee grains, which were difficult to separate from waste of other waste categories;
- The bags collected from RC vendors were highly soiled with food;
- The bags collected from the NB vendors contained blood at the bottom of the bags;
- Most of the paper generated by vendors was classified as browns because it had been soiled by food;
- Leaves from the banana flower in the waste from vendor-types other than FV were found because the vendor peeled banana flowers at the stall and took the inside (edible portion) of the banana flower home at market-close;

- Animal food wastes obtained from vendor-types other than MFE, FS and NB were usually dead rats that were found throughout the market;
- Animal food wastes from MFE, FS and NB vendor-types were generally bones (buffalo or cow) or nails (pig);
- Condensed milk cans were the largest contributor to the metals category;
- If a vendor is absent from stall for ≥ four days, someone else can occupy their space

4 Summary and Recommendations

This chapter summarizes the average quantity and physical characteristics (composition and moisture content) of the commercial waste generated at the Early Morning Market (EMM) in Vientiane during the nine-day audit in the wet season. These results may be employed to assess the feasibility of composting organic wastes from the EMM and other similar markets in the Vientiane prefecture. The chapter also identifies the waste streams that should be removed from each vendor-type such that the feedstock to a compost pile would not complicate the composting process. In addition, the reliability of the results from this work and the suitability of the sampling methodology to conduct waste audits at similar markets in Vientiane and throughout Southeast Asia are also discussed. Finally, the chapter discusses the feasibility of designing a permanent composting facility based on the findings from this work and a series of recommendations for further work are made.

4.1 Summary of Results for the EMM

This thesis provides waste data for the EMM market during the wet season. This data may also be useful for similar markets within the Vientiane prefecture.

4.1.1 Quantity Estimate

The total estimated amount of commercial waste generated at the EMM in Vientiane is

TABLE 4-1: SUMMARY OF ESTIMATES FOR AVERAGE DAILY WASTE AT EMM

Vendor Type	Total Number of Vendors	(kg waste/vendor in vendor-type*day)	Average daily waste generated at EMM (kg waste/day)
FV	83	4.07	**337.8**
17	1	45.37	**45.4**
C	6	13.99	**83.9**
GO	4	0.90	**3.6**
PG-2	36	0.41	**14.8**
PG-3	2	1.22	**2.4**
MFE	12	0.62	**7.4**
RC	3	2.22	**6.7**
NB	7	1.41	**9.9**
FS	11	2.41	**26.5**
TOTAL	**170**		**≈ 538.4 ≈ 0.54 ton/day**

0.54 ton/day.

For the purposes of a permanent composting facility, the average quantity of waste generated by the Fruit and Vegetable (FV), Coconut (C) and Garlic and Onion (GO) vendor-types and vendor 17 are the most important pieces of information in Table 4-1. The quantities of waste from the remaining vendor-types helps estimate the total waste generated at the EMM.

The most important findings from the estimate of waste generation at the EMM are:

- The chief waste generators in the EMM are the FV, C, GO vendor-types and vendor 17. Jointly they make up just over 50% of the vendor population at EMM;
- The largest quantity of organic wastes in the EMM with high observable quantities of brown and green wastes is generated by the C vendor-type;
- The GO vendor-type is the smallest producer of wastes within the FV vendor-type;
- The smallest quantity of daily waste per vendor is generated by the Packaged Goods (PG-1, PG-2 or PG-3) vendor-type. As a result, even though this vendor-type has the second largest number of vendors (~25%) in the EMM, its contribution to the overall quantity of daily waste generated at the EMM is minimal.

4.1.2 Composition Estimate

Table 4-2 summarizes the estimated composition of daily waste generated at the EMM during the dry season by vendor-type.

TABLE 4-2: SUMMARY OF ESTIMATES FOR AVERAGE DAILY WASTE AT EMM

Vendor-Type	Categories									
	Greens	Browns	Animal Food Wastes	Paper Products	Soft Plastics	Hard Plastics	Metals	Glass	Others	Total
FV	49.6%	48.8%	0.1%	0.3%	0.9%	0.1%	0.0%	0.0%	0.1%	100%
PG	18.0%	33.1%	1.5%	21.1%	17.3%	5.4%	0.0%	0.2%	3.4%	100%
MFE	23.5%	21.2%	16.1%	6.8%	26.9%	1.7%	0.0%	2.8%	1.1%	100%
RC	11.2%	36.0%	0.5%	7.9%	29.1%	2.4%	0.2%	3.2%	9.4%	100%
NB	36.7%	28.5%	0.1%	14.0%	16.7%	1.2%	0.7%	1.1%	1.1%	100%
FS	42.9%	22.5%	12.7%	1.8%	12.3%	0.6%	2.5%	2.9%	1.7%	100%

The waste composition estimates for each vendor-type and observations made throughout the physical sort yield some useful qualitative information of the waste generated by each vendor-type such as:

- The FV vendor-type is the largest generator of brown and green organic wastes. The locations of vendors in this vendor-type at the EMM are identified in Figure 2-10. This Figure along with the information in Table 4-2 can be used to isolate and locate high brown and green organic waste generators in the EMM;
- The NB and FS vendor-types generate the second largest percentage of brown and green organic wastes in the EMM. However, since these vendor-types do not generate a large quantity of daily waste and are not present in large numbers at the EMM, the quantity of browns and greens generated by these vendor-types is expected to be insignificant to the overall generation of organic wastes at the EMM;
- Brown and green wastes that were sorted for vendors that do not sell organic items came from purchases made by vendors during market operations. These purchases led to the unexpected influx of organic wastes from that vendor and are not representative of the items sold by the vendor. This comment indicates that a vendors' daily activities at his/her stall during market operations can impact the waste they generate;
- The largest quantity of animal food waste comes from the FS followed by the MFE vendor-types;
- Insignificant quantities of metals and glass wastes are generated in the EMM. A very small amount of this type of waste is generated by the FS vendor-type;
- Few to no recyclable items (i.e. plastic water bottles, pop cans, corrugated paper, etc.) were found in the daily waste generated by market vendors. It is suspected that the informal sector as well as the vendors themselves removed these items to participate in a viable informal recycling program in place in Vientiane to handle the recyclable wastes;
- There were no major variations in the quantity of daily waste generated by each participating vendor from day-to-day over the audit period.

4.1.3 Moisture Content Estimate

The average moisture content for the largest organic waste generators FV, NB and FS vendor-types for the wet season are summarized in Table 4-3.

TABLE 4-3: MOISTURE CONTENT RESULTS FOR BROWN AND GREEN ORGANIC WASTES GENERATED BY FV, FS AND NB VENDOR-TYPES

Vendor Type	Moisture Content (%)	
	Browns	Greens
FV	68.4%	90.9%
FS	66.5%	88.8%
NB	69.4%	79.4%

The ideal moisture content to maintain during the composting process is between 50 and 60%. The moisture content analysis confirms that the organic wastes from the FV, FS and NB vendor-types in the EMM during the wet season fall within the ideal moisture content range.

4.2 Design of Sampling Methodology

The design of the sampling methodology used in this thesis is described in detail in Section 2. The stratified random sampling technique employed in this work had many advantages, which were useful for fulfilling the goals of the pilot project. These advantages included:

- Ensuring a uniform coverage of the waste generated by the vendor population within the EMM;
- Ensuring that decision units (vendor-types) that contribute to the overall variability of the waste generated at the EMM were included in the representative sample;
- Providing a cost-effective method for characterizing the waste;
- Enabling an understanding of the quantity and composition of waste generated at Vientiane markets with consideration to the local context;
- Providing information on the amount and percentage of organic waste found in the EMM while isolating and locating the key organic waste generators in the EMM.

The stratified random sampling technique allowed the development of a sampling methodology with sufficient consideration to the EMM operations. As a result, both qualitative and quantitative information from this work is useful to characterize the feedstock obtained from the EMM for a permanent composting facility. Furthermore, this sampling methodology

provides a viable methodology for qualifying and quantifying the waste generated at other similar Vientiane markets.

While there were several advantages to the stratified random sampling technique, some issues arose from its application. These included:

- Incomplete selection of "decision units" for waste audit conducted. The FV and PG vendor-types should have been further sub-stratified into C and GO vendor-types;
- Inability to classify every vendor in the market accurately. Some vendors could be classified into more than one different vendor-type category;
- Insufficient participants in the waste audit from various vendor-types studied. For example, the RC vendor-type included very few vendors, resulting in a small sample size.

These issues impact the reliability of the data obtained from the audit for each strata and thus the conclusions that can be made from the audit results.

4.3 Recommendations for Improving Audit Methodology

In order to improve future waste audits conducted in the Vientiane prefecture, it would be beneficial to:

- Conduct a thorough review of market operations to identify all possible vendor-types at the onset of the waste audit survey. This would avoid sub-stratification in the analysis of the results. It would also enable a compositional analysis of key vendor-types that were sub-stratified in this analysis[13], therefore providing a better understanding of the composition of the daily waste generated;
- Separate moisture content analysis should be conducted for the green and brown wastes generated by the sub-stratified organic vendor-types. Moisture content results for the sub-stratified FV vendor-types would provide useful information for large brown and green waste generators in the EMM;

[13] Very large organic waste generators such as vendor 17 and the C vendor would not be grouped with lower organic waste generators in the physical sort.

- Involve only a maximum of six individuals in the actual waste sorting process (maximum three sorters per table). On some audit days, there were many assistants participating in the physical sort at Nabong. It was found that greater efficiency and accuracy in sorting wastes was achieved when no more than three sorters worked at each station;
- Assign a single or team of two people to the specific task of reading ad recording waste quantities throughout the audit period to maintain precision in waste quantity results;
- Encourage more participation by vendors in audit activities to increase the number of samples obtained from each vendor-type. A larger sample size is expected to provide greater confidence in the results obtained from a waste audit;
- Carry out waste audit at different times of the year in order to capture seasonal variation in waste generation and composition;

Avoid providing financial compensation to the vendors and market managers for participating in waste audit activities. Although financial reward initially encourages vendor participation, it does not guarantee 100% daily participation from the vendors that agreed to participate.

4.4 Reliability of Results

Prior to accepting the waste quantification and composition results by vendor-type from this work, it is important to discuss the reliability of the results that have been presented in this report.

While the audit provides data that should prove useful for the management of the market wastes, the results are somewhat of an overestimation of the average waste generated per vendor within each vendor-type at the EMM. It was appropriately assumed that vendors that did not participate in the waste audit generated on average the same quantities of waste as those vendors within that vendor-type who did participate. However, another assumption led to an overestimate of the average quantity of waste generated: if a vendor did not participate on a particular day, it was assumed that the vendor was still present at the market and would have generated waste. Instead, the vendor may not have been at the market on some of these days, thereby not generating any waste. In effect, it was assumed that all participating vendors were

present on both days that they did provide waste as well as days that they did not provide any waste.

Other issues that affected the reliability of the results include:

- The sub-stratification and estimate of waste quantity by the PG-3 vendor-type, which includes only two vendors selling completely different items. Although both vendors are different from the vendors in the PG vendor-type and the only of their kind in the EMM, they are also different from each other;
- There were only two RC vendors that participated in the waste audit. As a result, the number of samples obtained to estimate the quantity of waste generated by a single vendor from the RC vendor-type was quite small;
- The moisture content analysis was conducted for a limited number of sampling. There would be greater confidence in these results if the moisture content analysis had been conducted on more audit days;
- The wet season is generally characterized by short periods of heavy rains. However, the climate throughout the nine-day audit period was consistently clear, hot and sunny.

With the methodology and various assumptions, the estimate of the total daily waste generated at the EMM, is comparable to that estimated by the management at KM 18.

In the absence of any other data on quantity and composition of waste generated per vendor in any vendor-type, the data reported in this work can be employed to determine the average waste generated and its composition for similar markets in Vientiane during the wet season.

4.4 Application of Waste Audit Results to other Vientiane Markets

In the absence of data at other markets, the average waste quantity and qualitative information on composition of the wastes generated by the vendor-types studied in this work can be used to estimate the wastes generated at other markets in Vientiane. To ensure that a reasonable understanding of other Vientiane markets is gained from the results presented in this thesis, the following characteristics must hold for the market:

- The daily hours of operation of the market should be the similar to the EMM (5:00 AM – 11:00AM);
- The size of the vendor-stalls for each vendor-type in the market should be close to the size of the stalls[14] of the same vendor-types at the EMM
- The vendors in the market should be stratified based on the nature of the items that they sell. Appendix 10 provides details on the items sold by each vendor that participated in the waste audit and the vendor-type to which they belong in the EMM. This list can be used as a tool to categorize vendors in other Vientiane markets;
- Information is being sought for the wet season.

4.2 Implementing Composting Operations

In general, based on the combined results from the waste quantification and composition studies, the organic waste generated at the EMM can be used as feedstock for a permanent composting facility in Vientiane. Waste generated by the FV vendor-type, which is characterized by a high percentage of organic wastes should be employed as feedstock for a composting facility is a feasible option for handling a rather large portion of the waste generated at this market. Table 4-2 shows that the waste from this vendor-type is composed largely of brown and green organic wastes. Based on the size of the composting facility and the amount of waste generated by a single vendor from the FV vendor-type, the number of FV vendors from which waste would need to be gathered can be estimated. The small amount of non-organic waste generated by the vendors in this vendor-type would be difficult to separate from the feedstock to the compost facility. It is unclear if this level of contamination is expected to present a problem to the compost pile.

If waste from other vendor-types with significant quantity of organic material is sent to A composting facility, it must be ensured that animal food waste is first removed from the feedstock. Animal food waste includes bones from animals as well as rotten meat that is disposed of by the vendor. This waste can be of nuisance to the compost pile. The Noodles and Blood (NB) and Food Stalls (FS) vendor-types generate a significant amount of organic waste. If

[14] As mentioned in Section 2.3.2, the average stall sizes for the FV, MFE, FS, NB, and RC was between 2x2 m^2 and 2x6 m^2. The PG vendors had standard size stalls of 3x3 m^2.

it is decided that the organic waste from these vendor-types should be sent to a composting facility, a means of separating the animal food waste needs to be determined. In general, waste from the Meat, Fish and Eggs (MFE) vendor-type should be excluded from the feedstock sent to a composting facility.

4.3 Recommendations for Future Work

The following areas of research are recommended for the future:

- Conduct waste audit for the dry season;
- Repeat the waste audit for the wet season for the ten vendor-types identified in this work. Complete the audit for one week at the beginning of the wet season and one week at the end of the wet season. Ensure that a moisture content analysis is completed for both of the audit periods;
- In future audits of market wastes, metals, glass, hard plastics and soft plastics can be classified together in the "other" category, since the amounts of such wastes are relatively insignificant ;
- Develop a method for separating and transporting the organic portion of the waste generated at the market to the location assigned for a permanent composting facility;
- Considering the existing role of the informal sector in removing recyclables from the waste generated at the EMM, evaluate whether or not a formal recycling program is necessary to handle a portion of the market wastes.

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List of Appendices

Appendix 1: Procedures and Results from Trial Audits

Trial Audit 1

The main objectives of Trial Audit 1 were to:

- Test the effectiveness of a method for determining the quantity and composition of daily waste collected at the TKK morning market;
- Understand the logistics of daily waste collection activities at TKK morning market;
- Establish logistics for collecting a representative sample, transporting it to Nabong and conducting a physical sort;
- Carry out a physical sort that demonstrated how the audit would be carried out to the audit team.

Prior to conducting trial audit, the management of the TKK Morning Market informed the audit team that the blue JICA dumpster located southwest of the market only contained garbage collected by the cleaners from the TKK morning market for that working day. Market management also claimed that records of that daily weight could be obtained from the management at the local dumpsite (KM 18). It was therefore resolved that daily waste quantity data for the JICA bin would be sought from the management at KM 18.

In order to determine the composition of the waste collected on the day of Trial Audit 1, a representative sample of the total waste in the JICA bin was to be obtained and sorted. It was decided that a 100 kg sample would be obtained from the JICA dumpster for the waste composition study. This weight seemed reasonable considering a study carried out by Klee and Carruth (1970), which concluded that small samples of 200 lb (~90 kg) are expected to yield

as valid a result in determining the composition of a given supply of solid waste as would a larger sample (Kauffman, 1990). The 100 kg sample collected for this work was therefore expected to be representative of daily market waste composition. To further increase confidence in the collected sample, the load was mixed thoroughly with rakes before it was placed into large, clear garbage bags (66 x 91.4 cm).

Once the sample was collected, the bags were transferred into large pre-weighed 5-kg bins and placed on a pick-up truck for transport to Nabong. The bins were stored overnight in a by waste audit team members returning to Nabong. The next day, the bins with the bags of collected waste was location of the physical sort.

The bags were removed from the bins and placed on a wood-framed wire mesh with a 1 cm

grid that sat on top of a 5-kg bin. The mesh covered the mouth of the 5 kg bins fully and the area of the tables on which the physical sort would be carried out. Each bag was opened on the wire mesh, allowing liquid and items less than 1 cm from the bag to fall into the bin. The mesh was then carefully taken to the sorting table and the bag was removed. The materials were sorted by waste stream and placed into plastic bags with appropriate labels. The eight waste streams during Trial Audit 1 were:

- Green Organics (fruits and vegetable scraps high in nitrogen)
- Brown Organics (fruits and vegetable scraps high in carbon, soiled paper)
- Meat and fish
- Paper (unsoiled tissue, newspaper, corrugated cardboard, etc.)
- Soft Plastics (film type plastics like cellophane)
- Hard Plastics (plastic used for water bottles)
- Metals & Glass
- Glass

- Other (textiles, rubber, string, cigarettes, candy wrappers, and other miscellaneous items)

The weight of each category was determined by weighing the bags for each category on a weighing machine. The weight of the waste was recorded by category.

The 5 kg bin was weighed at the end of the waste audit to determine the weight of water and items smaller than 1 cm. These latter items not sorted because they were browns and greens that had been mixed together and contaminated by moisture, making them difficult to classify.

Results from Trial Audit 1

The composition results from Trial Audit 1 are shown in Table 1.

Table 1% Composition By Category from Trial Audit 1

Category	Weight (kg)	% Composition
Green Organics	40.0	39.5%
Brown Organics	44.3	43.8%
Meat and Fish	0.4	0.4%
Paper Products	6	5.9%
Soft Plastics	7.5	7.4%
Hard Plastics	1.0	1.0%
Metals and Glass	0.8	0.8%
Other Wastes	1.2	1.2%
TOTAL COMPONENT WASTE	101.2	

The others category during Trial Audit 1 included items such as a flip-flop, a Lao skirt (sinh), elastic bands, shoulder pads from a blouse and a nail brush. The weight of contaminated organics and water that fell into the 5 kg bins was 9 kg.

Trial Audit 1 revealed that:

- There were difficulties identifying browns and greens. For example, items such as the banana flower had a rigid and high fibrous peel, but the inside was soft and moist, which constitutes a green organic.
- The percentage of hard plastics was low (see Table 1) even though plastic water bottles were sold throughout the market. This confirmed that some waste was being removed from the market between the point of generation and collection by the informal sector. As a result, any waste audit conducted on the TKK Morning Market would provide information on the *waste collected* rather than the *waste generated*.
- There could have been of the TKK Morning Market waste in the JICA dumpster with domestic waste from surrounding villages or with waste from surrounding markets. Based on this information, the assumption that the full JICA bin represented daily waste collected only from the TKK morning market was questionable;
- The records for the quantity of waste in the JICA bin were unavailable. Authorities at KM 18 claimed that records of such information was not kept;
- Placing sorted waste into garbage bags leads to loss of waste during the physical sort;
- It was difficult to ensure that waste stored overnight at Nabong would be kept in a sheltered area. Furthermore, it is possible that the browns could have had a higher moisture content due to contamination with the greens during overnight storage of the waste. This would increase the weight of the browns category and the sum for all the component wastes might be greater than the actual waste collected at the market. Finally, overnight storage of the waste caused biodegradation of the collected sample, which resulted in odour problems on the day of the sort.
- Although the quantity of metals and glass was observed to be low, these categories should be separated for the one-week waste audit due to possible variations in the composition of the waste over the week;
- Maintaining a record of the waste collected at the market is necessary so that the difference between the weight of the sample collected at the market and the weight of waste prior to the physical sort can be compared.

Trial Audit 2

Based on the problems that were observed in Trial Audit 1, changes were made in Trial Audit 2. In trial Audit 2, an assumption was made that all the waste found on the floor around vendor stalls on the day of the audit equated the total quantity of waste generated in the market that day. The team arrived at the site between 11:00 and 11:30AM and gathered all the waste found throughout the market and placed it into 18 clear garbage bags (66 x 91.4 cm). Each bag was weighed, labeled and placed on the truck. Once the floor in the market had been cleaned and all the waste collected, the waste was transported to Nabong.

The truck arrived at Nabong at approximately 14:00 on the same day the sample was collected and the physical sort commenced around 14:30. The physical sort was conducted in a manner similar to Trial Audit 1, with the following changes:

- The waste was separated into nine categories. Metals and glass categories were split into two separate categories;
- The weight of the waste collected at the market and the weight of the waste at Nabong was recorded for comparison;
- The physical sort was conducted on the same day as the sample was collected;
- The waste was separated by category into plastic bags that were placed in 1 kg black bins. Each full bin was weighed and the weight by component was recorded;
- Clarification was sought for differentiating between green and brown organics. There were several disagreements between sources on whether some of the items were brown or green. Furthermore, it was difficult to categorize organic waste from regionally produced fruits such as rambutan, lychees, mango steen and the banana flower. From the visual observations made during Trial Audit 1, it was decided that tough, fibrous materials would be categorized as brown organics while moist and soft items would be categorized as greens (see Table 2-7).

Results from Trial Audit 2

The composition results from Trial Audit 2 are shown in Table 2.

The total weight of the 18 bags at the TKK morning market and Nabong was 189.5 kg 193.9 kg respectively. The weight of the bags was 4.4 kg (or 2.2%) greater than the weight of the 18 bags at the market. This increase in weight of the waste can be attributed to contamination of the browns with moisture from the greens, which could have increased the weight of the brown organics. Another cause for this change in weight could be that different auditors from those at the market might have been re-weighing bags and reading the scale at Nabong.

Table 2: % Composition By Category from Trial Audit 2

Category	Weight (kg)	% Composition
Green Organics	130.8	64.3%
Brown Organics	58.1	28.6%
Meat and Fish	1.2	0.6%
Paper Products	3.1	1.5%
Soft Plastics	7.3	3.6%
Hard Plastics	0.2	0.1%
Metals	0.8	0.4%
Glass	0.2	0.1%
Other Wastes	1.6	0.79%
TOTAL COMPONENT WASTE	203.3	

The sum of the component wastes is about 7.3% and 4.8% greater than the total weight of the bags at the market and the total weight of the bags at Nabong respectively. It is believed that contamination of the brown by greens was largely responsible for this increased weight in total component waste.

The main problems with Trial Audit 2 were that:

- There was no way to ensure that the waste gathered from the floor of the TKK morning market was generated solely in that market. Waste from other sources could have been thrown into the piles around the stalls.

- There is no certainty that the waste gathered was the total waste generated in the market that day. It is highly possible that some waste could have been collected prior to the arrival of the audit team or left behind by the audit team.

Appendix 2: Items sold by Vendors that Agreed to Participate in the Waste-Audit

Vendor Number	Vendor-Type	Items Sold
1	PG	Shampoos, detergents, toothpaste, packaged foods (noodles, biscuits, etc.), cigarettes, condensed milk, drinking boxes, incense, chocolate
2	PG	Shampoos, detergents, toothpaste, packaged foods (noodles, biscuits, etc.), cigarettes, condensed milk, drinking boxes, incense, chocolate
3	PG	Shampoos, detergents, toothpaste, packaged foods (noodles, biscuits, etc.), cigarettes, condensed milk, drinking boxes, incense, chocolate
4	PG	Candies, stickers, wholesale snacks (chips, biscuits, etc.), children's costume jewelry
5	FS	Serves cooked food and beverages
6	FS	Same as 5
7	PG	Same as 1
8	FV	Lettuce, mint, scallions, green beans
9	NB	Noodles, blood, tofu
10	FV	Red peppers, green beans, limes, cabbages
11	FV	Potatoes, onions, garlic, pumpkin, ginger
12	REMOVED	Towels, undergarments, clothes, lentils, dried peppers
13	MFE	Eggs
14	FV	Crushed coconut
15	FV	Red chili peppers, banana flowers, eggplants, green beans
16	FV	Garlic, onions, dried red chilies
17	FV	Onions, red chilies, cabbage, ginger, banana flower, cabbages, eggplant
18	FV	Garlic, onions, ginger
19	FV	Tomatoes, ginger, green and red peppers, fruits
20	FV	Cabbage, limes, potatoes
21	MFE	Eggs, dried sausage, dried seafood, packaged dried meats
22	FV	Garlic, onions, red chilies
23	FV	Green onions, tomatoes, ginger, pumpkin, garlic, red peppers
24	FV	Paa dek, garlic, onions, chili powder
25	FS	Noodle soup, barbecued meat
26	MFE	Fresh meat
27	FV	Green beans, hot peppers, cabbage, cucumber, corn

Vendor Number	Vendor-Type	Items Sold
28	PG	Dried bamboo sticks
29	NB	Noodles and blood
30	FV	Crushed coconut
31	FV	Little bananas, pumpkins, paa dek, tamarind
32	MFE	Fresh Meat
33	PG	Dishes (ceramic plates and bowls), glasses
34	FV	Green beans, green onions, tomatoes
35	PG	Packaged cakes, cookies, bread
36	FV	Cabbage, beans, pumpkins, leafy vegetables
	REMOVED	
37	FV	Rambutan, mangosteen, pineapple, durian, apples
38	FV	Garlic, onions, potatoes, pumpkins, hot peppers
39	RC	Rice and charcoal
40	FS	Soft Drinks, barbecued meat, noodle soup, coffee
41	PG	Shampoos, detergents, toothpaste, packaged foods (noodles, biscuits, etc.), cigarettes, condensed milk, drinking boxes, incense, chocolate
42	FV	Cabbages, potatoes, ginger, bitter melon
43	FS	Noodle soup, meats, etc.
44	RC	Rice and charcoal
45	NB	Noodles, blood, tofu
46	NB	Noodles, blood, tofu
47	MFE	Fresh meat

APPENDIX 8 - Observations during Waste Gathering and Physical Sort

Day	Weather Conditions	Vendor-Type	Category	Notes	General Notes
1	Sunny and clear day (rainy at 6:30-7:00 AM when bags being handed out)	FV		Sanitary pads were found in waste (Vendor 18)	Lowest participation of the entire waste audit (55%)
		RC		Plastic Bags heavily soiled with food. Result is loss of waste during physical sort.	
2	Rained during bag collection in the market. Clear at the time of the audit	RC		One of RC bag was sorted with the FV vendor-type	
		FS	Metals	Labels on condensed milk cans not removed	All plastic bags were highly soiled with coffee
3	Clear, sunny, hot day	FV	Others	Elastic bands, candy wrappers, string, cardboard and plastic mixes (clear plastic tape with cardboard stuck on sticky side)	
		MFE	SP	Bags highly soiled with meat	
		FS	AFW	Big buffalo bones	Rice and noodle bits fell through the mesh that was used in the audit Plastic bags highly soiled with coffee
			PP	Mostly tissue and toilet rolls	
			SP	Soiled with black coffee	
			HP	All straws	
			Metals	All from condensed milk (paper on cans not removed)	
			Other	Styrofoam and elastic bands	
		NB	Browns	Consisted of banana leaves and paper soiled with food	Blood found at the bottom of the bag.
			Others	Elastic bands and Styrofoam	
		RC	PP	Newspaper and tissue	
4	Clear, sunny, hot day	FV	Others	All elastic bands	
		PG	PP	Corrugated cardboard, cigarette boxes	
		MFE	Others	2 elastic bands (negligible weight)	
		NB	Others	Styrofoam, mixed plastic coffee package and elastics	Blood found at bottom of bag

Day	Weather Conditions	Vendor-Type	Category	Notes	General Notes
		FS	Greens	Coffee grains attached to greens (due to moisture)	Plastic bags soiled with coffee.
			AFW	Buffalo bone	
			PP	Mostly unsoiled tissue	
			SP	Plastic bags soiled with coffee	
			HP	Straws	
			Others	Included charcoal	
5	Dry, clear, hot, sunny day	FV	Greens and Browns	Because of moisture in greens, some of the brown waste could not be separated from greens category (negligible)	
		PG	Greens	Mak Thong (type of fruit) found here. It is felt that the vendor might have been eating the fruit at the site and then threw it out with the rubbish.	
			AFW	A whole rat (many in market)	
			PP	Cigarette boxes	
		MFE	AFW	Pig meat with bone	
		RC	Greens	Waste pineapple found. Probably from a surrounding vendor (not much)	
			PP	Cigarette boxes	
			HP	Straws	
			Others	Candles, hair clip, candy wrappers, elastic bands	
		NB	AFW	Fish bones	Blood found at bottom of the bag.
			HP	Straws	
			Metals	Condensed milk can – soiled with coffee (label unremoved)	
			Others	Elastic bands, piece of cement, strainer	
6	Dry, sunny and clear day	FV	Others	Elastic bands and Styrofoam	
		PG	PP	Mostly cigarette cartons, corrugated paper	
			HP	1 plastic water bottle	
		MFE	AFW	Pig's bone	
			PP	Tissue	
		RC	Others	Some charcoal	

Day	Weather Conditions	Vendor-Type	Category	Notes	General Notes
		FS	PP	Tissue	All waste soiled by wet, ground coffee
			Metals	Condensed milk cans soiled by coffee	
			Other	Some charcoal	
7	Dry, hot, sunny day	FV		Vendor 17 – today she had separated the waste (whole banana flower is in one basket and peels are in another)	
		PG	SP	Tape	Banana flower leaves found in vendor 28 bag
		MFE	PP	Egg Cartons	
		RC	Browns	Coconut shells and banana flower leaves (maybe peels banana flower at the stall, disposing of leaves at stall and taking inside home)	
			PP	Corrugated paper	
			HP	Plastic water bottles	
			Metals	Pepsi can	
		FS	SP	Soiled by coffee	Plastic bags soiled by wet, ground coffee
			Metals	Few spoons and condensed milk cans	
8	Dry, clear, sunny day	FV	Greens	Soiled with some onion and garlic peels (due to moisture from greens)	Paper categories included pink tissue – moisture content test not done on paper because it is expected to complicate the compost pile (dyed paper)
			Others	Foam, elastic bands	
		PG	Greens	Some green beans and tomatoes	
			Browns	Come mostly from #28 (bamboo products)	
			Others	Broken ceramic dish pieces, Styrofoam, plastic crate	
		FS	Browns	Ashes found here (probably from making sticky rice)	
			AFW	Cow bones	
			Others	Elastic bands, brick, tetra pak, tape of cardboard box	
		MFE	Others	Elastic Bands	
9	Clear, slightly overcast, hot day	PG	Other	Ceramic	Learned that if a vendor is not

Day	Weather Conditions	Vendor-Type	Category	Notes	General Notes
		FS	AFW	Cow's bones	present at their location for four days, their vendor stall is taken by someone else.
			Others	Foam box soiled with coffee	
		RC	Others	Fabric and elastic bands	
		MFE	AFW	Pig's nail	

NOTES:
AFW – Animal Food Waste
PP – Paper products
HP – Hard Plastics
SP – Soft Plastics