Household, hotel and market waste audits for composting in Vietnam and Laos
Philip H. Byer, Chi Phuong Hoang, Thi Thuc Thuy Nguyen, Sangeeta Chopra, Virginia Maclaren and Murray Haight
Waste Management Research 2006; 24; 465
DOI: 10.1177/0734242X06068067

The online version of this article can be found at:
http://wmr.sagepub.com/cgi/content/abstract/24/5/465

Published by:
SAGE Publications
http://www.sagepublications.com

On behalf of:
ISWA
International Solid Waste Association

Additional services and information for Waste Management & Research can be found at:

Email Alerts: http://wmr.sagepub.com/cgi/alerts

Subscriptions: http://wmr.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.com/journalsPermissions.nav
Household, hotel and market waste audits for composting in Vietnam and Laos

In Da Nang and Ha Long, Vietnam and in Vientiane, Laos, there was interest by local authorities in separating and composting waste in order to reduce environmental and health problems at the local landfills and to produce a soil conditioner for local agricultural use. To assist in the planning of composting projects, three studies were carried out to estimate waste quantities and composition.

1. A 9-day audit of waste from 45 vendors in a market in Vientiane, the capital of Laos. The total quantity of waste and the quantity in each of nine categories were estimated for each of six different types of vendors.
2. A 7-day audit of waste disposed by three hotels in the tourist area of Ha Long, Vietnam. Waste quantities were estimated in total, on a per guest basis, and in three main categories: compostables, recyclables and miscellaneous.
3. A 7-day audit of waste collected from 74 households in Da Nang, the fourth largest city in Vietnam. Waste from each household was separated into compostable and non-compostable waste.

Over 60% of each waste source comprised compostable waste and this was considered significant enough to warrant further planning of composting operations.

Introduction

The South-east Asian developing countries of Vietnam and the Lao People’s Democratic Republic (Laos) face challenges in managing their urban solid waste. The primary means of disposal is through open dumps and landfills that are often poorly sited, designed and operated. Information on the quantities and composition of waste is needed in order to properly plan and design integrated waste management systems to help improve waste management practices. This paper reports on three studies, two in Vietnam and one in Laos, which were conducted to estimate waste quantities and the composition of waste at source. The types of waste examined were market waste in Vientiane, Laos; hotel waste in Ha Long, Vietnam; and household waste in Da Nang, Vietnam. In all three cities, local authorities had expressed interest in diverting organic waste from landfills by separating and composting the waste. This would reduce the environmental and health...
problems at the local landfill and produce a soil conditioner for local agricultural use. By observation, it was known that there are significant quantities of organic matter in the respective waste streams, but there were no detailed data on the quantities or make-up of the organic matter and its suitability for composting. The waste audits were therefore needed as a first step in determining the feasibility of the proposed composting projects.

There are many methodologies for quantifying and characterizing solid waste, including direct waste analysis, material flow analysis, survey analysis and empirical analysis. Each methodology has certain capabilities and limitations (SENES 1992). Direct waste analysis, which involves the examination of the actual waste stream, was used in all three of the studies. The methodology is flexible and was designed to suit the needs and constraints of each study. As in any audit, there were important constraints due to limited funding and the time available. These affected the number of waste generators that were sampled, and restricted sampling to several weeks in the summer (wet season). In Vientiane, sampling took place in the summer of 2003; the sampling in Da Nang and Ha Long occurred in the summer of 2004. All waste quantities were taken and are reported on an as-discarded (wet) basis.

This paper discusses the basic methodology and results of each study, and ends with observations on the overall results, which can be useful in planning composting projects as part of an integrated waste management system. Detailed descriptions of the methodologies, data, data analyses, and results can be found in Chopra (2004), Hoang (2005), and Nguyen (2005).

The three studies illustrate the different approaches used for undertaking waste characterization studies when the focus is on compostable waste. The market waste study in Vientiane sorted organic waste into ‘green’ or high nitrogen waste and ‘brown’ or high carbon waste. This breakdown was felt to be important because successful composting operations rely on a carbon : nitrogen (C/N) ratio between 20 : 1 and 25 : 1 or slightly higher (Hoornweg et al. 2000). The hotel waste study sorted the waste that was suitable for composting into subcategories such as fruits, vegetables, leftover food and yard waste, from which C/N ratios were calculated. However, due to time and financial constraints, the household waste study did not subdivide the organics.

The three studies also used different approaches in categorizing their waste generator samples into sub-groups. In the market waste study, the challenge was in sampling from a highly heterogeneous group of generators, and attempting to classify them into more homogeneous sub-groups according to the types of goods sold. The classification system used in the hotel study was much simpler, defining each hotel by its quality rating (4-star, 3-star, etc.). There was no need to break down the households into groups because the residential areas sampled had similar incomes and housing quality.

Market Waste in Vientiane, Lao PDR

Introduction

The Lao People’s Democratic Republic (PDR), which is bordered by Vietnam, Cambodia, Thailand and China, is one of the world’s poorest countries. Vientiane is its largest city and capital, with a population of about 600,000. Waste management in Vientiane consists primarily of regular collection and transport of waste by trucks to a landfill located 18 km outside the city. Waste picking and buying by individuals (an informal sector) who sell the material to recyclers also occurs.

A significant amount of commerce in Vientiane takes place in several markets, which sell packaged goods, foods, appliances, etc. Waste produced at the markets is picked up from the vendor stalls by ‘market cleaners’, taken to central areas within the markets, and picked up and transported to the landfill.

The research reported here was part of a larger study to assess the feasibility of composting waste from these markets.

Methodology

To estimate the quantity and composition of the market waste, an audit of waste at the Early Morning Market (EMM) next to the Thong Khankham (TKK) market, was carried out over a 9-day period during the wet season. The market consisted of 170 vendors, who were stratified into seven groups of vendors of the following types of goods: fruits and vegetables (FV); packaged goods (PG); meat, fish and eggs (MFE); food stalls (FS); noodles and blood (NB); rice and charcoal (RC), and clothing (CI).

An audit by vendor group was carried out to help identify the potential contribution of organic materials suitable for composting from each of the groups of vendors, except for clothing vendors who were few and generated essentially no compostable waste. This would allow the results of the audit to be applied at other markets. Vendors within each vendor group were expected to produce similar waste. As the number of vendors of each type that could be studied was relatively small and also depended on the willingness of vendors to participate, the sample consisted of as many vendors as would agree to participate, instead of a statistically pre-determined sample size. Table 1 lists the number of vendors of each type in the market, and the number and percentage that agreed to participate, with the lowest percentage being 21% of the fruit and vegetable vendors, and only two (but 67%) of the rice and charcoal vendors participating.

The audit was carried out during 14–20 July and 3–4 August 2003. Each day, each participating vendor was given
a labelled plastic bag in which they would place their daily waste. Since recyclables were partially or completely removed by the informal recycling sector before the waste was placed in the bags, the waste in the bags can more accurately be described as the waste collected from, rather than waste generated by, the vendors.

The quantity and composition of waste was analysed for each of the six vendor groups separately on each of the 9 days. First, each of the waste-filled plastic bags from each vendor was weighed. Each empty bag was also weighed and the amount subtracted to get an estimate of the waste contents. Then, the contents of all of the bags from vendors within each of the vendor groups were combined and sorted for compositional analysis.

Nine categories of waste were selected for the compositional analysis.

1. Green organics – fruits and vegetable scraps high in nitrogen.
2. Brown organics – fruits and vegetable scraps high in carbon and soiled paper.
3. Paper – unsoiled tissue, newspaper, cardboard, etc.
7. Metals.
8. Glass.
9. Other – textiles, rubber, string, cigarettes, candy wrappers, etc.

The auditors had a list of the types of materials that fit under each category (Chopra 2004). ‘Green’ and ‘brown’ organics and paper (categories 1, 2 and 3) can be used as feedstock to composting facilities. It is also important to know the quantities of the other waste categories (numbers 4–9 above) since they should be separated out before composting, and some could be recycled before the market waste is composted. Measuring waste streams (4) to (9) in the list above did not require significant additional work.

Results

Statistical data about the quantity of waste generated by each vendor group are presented in Table 2.

With the high moisture content of fruits and vegetables, it was not surprising that the largest quantity (by weight) of waste per vendor was from the fruit and vegetable sector. The packaged goods and the meat, fish and egg vendors produced the smallest quantities. As there was a wide range of quantities from the fruit and vegetable vendors, the standard deviation (9.92 kg/vendor per day) was greater than the average (6.49 kg/vendor per day) for this vendor group. In addition, as shown by the wide confidence interval for rice and charcoal vendors, and as only two vendors were audited, care must be taken in using the results for this vendor group.

In general, the amount of daily waste generated by a vendor did not change greatly from day to day over the 9 days (Chopra 2004). The analysis also showed that seven of the 20

---

Table 1: Audit participation by vendor group in Vientiane market.

<table>
<thead>
<tr>
<th>Vendor group</th>
<th>Number in market</th>
<th>Number in audit</th>
<th>Percentage participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits and vegetables (FV)</td>
<td>94</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Packaged goods (PG)</td>
<td>38</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Meat, fish, eggs (MFE)</td>
<td>12</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>Food stalls (FS)</td>
<td>11</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>Noodles and blood (NB)</td>
<td>7</td>
<td>4</td>
<td>57</td>
</tr>
<tr>
<td>Rice and charcoal (RC)</td>
<td>3</td>
<td>2</td>
<td>67</td>
</tr>
<tr>
<td>Clothing (Cl)</td>
<td>5</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>170</td>
<td>45</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 2: Waste quantities from vendors in each vendor group in Vientiane market [kg/vendor per day].

<table>
<thead>
<tr>
<th>Vendor group</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum–maximum</th>
<th>95% confidence interval of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits and vegetables (FV)</td>
<td>6.49</td>
<td>9.92</td>
<td>0.52–45.37</td>
<td>1.85 to 11.14</td>
</tr>
<tr>
<td>Packaged goods (PG)</td>
<td>0.59</td>
<td>0.43</td>
<td>0.15–1.37</td>
<td>0.26 to 0.92</td>
</tr>
<tr>
<td>Meat, fish, eggs (MFE)</td>
<td>0.62</td>
<td>0.33</td>
<td>0.38–1.20</td>
<td>0.21 to 1.03</td>
</tr>
<tr>
<td>Food stalls (FS)</td>
<td>2.41</td>
<td>0.84</td>
<td>1.55–3.82</td>
<td>1.37 to 3.46</td>
</tr>
<tr>
<td>Noodles and blood (NB)</td>
<td>1.41</td>
<td>0.37</td>
<td>0.88–1.70</td>
<td>0.81 to 2.0</td>
</tr>
<tr>
<td>Rice and charcoal (RC)</td>
<td>2.22</td>
<td>1.68</td>
<td>1.03–3.41</td>
<td>–12.9 to 17.4</td>
</tr>
<tr>
<td>FV-13</td>
<td>4.07</td>
<td>1.95</td>
<td>1.67–7.15</td>
<td>2.90 to 5.25</td>
</tr>
<tr>
<td>PG-7</td>
<td>0.41</td>
<td>0.25</td>
<td>0.15–0.88</td>
<td>0.17 to 0.64</td>
</tr>
</tbody>
</table>
fruit and vegetable vendors generated significantly greater or less waste than other vendors in the group because of the different types of fruits and vegetables they sold. This was not known when all of the fruit and vegetable vendors were initially put in the same sample set. To see the effect of separating fruit and vegetable vendors into sub-groups according to quantity of waste, a new sample group based only on the 13 vendors was established. The results, presented as FV-13 in Table 2, show a lower average (4.07), and much lower range (1.67 to 7.15) and standard deviation (1.95) than for the full set of 20 fruit and vegetable vendors. Similarly, two of the nine packaged goods vendors sold completely different products, which caused them to produce more (heavier) waste. With these two vendors removed, the waste quantity for the remaining seven vendors was calculated, as shown under PG-7 in Table 2. With the two large waste generators removed, the average quantity decreased by 30%, and the standard deviation by over 40%. These results show that it may be worthwhile when carrying out market waste studies to categorize the waste generators into more specific sub-groups.

The composition of the waste from each vendor-type is shown in Table 3.

Because of the nitrogen and carbon contents of the green and brown organic waste, these categories are of most importance for composting. The fruit and vegetable, food stalls and noodles and blood vendor groups generated the largest combined percentages of these waste with 98, 65 and 65%, respectively. As each fruit and vegetable vendor generated a relatively large amount of waste on average and there were many such vendors, whereas the same was not generally true for the food stall and noodles and blood vendors, the collection of waste for composting should begin with fruit and vegetable vendors.

In addition to these averages, the data showed that the range of percentage compositions of the waste from all vendor groups was quite wide for most of the categories. Other observations were: much of the paper from packaged goods vendors was soiled by food, which was included under the browns category; the high percentage of soft plastics from meat, fish and eggs vendors was primarily due to meat packaging and plastic bags for selling the goods; waste from personal purchases made by vendors could significantly affect the composition; and there was little hard plastics, metals or glass due to their prior removal for recycling.

Another developing country market waste characterization study (JICA and Kokusai Kogyu 2003) sampled a market in Phnom Penh, Cambodia in the rainy season and found that 69.3% of the waste was food waste and 10.0% was grass and wood. Although their results are similar to ours in having a very high percentage of materials suitable for composting in market waste, it is not possible to compare the two studies directly because the other study did not describe the type of market that they sampled or break down the waste generated by type of vendor.

Hotel Waste in Ha Long, Vietnam

Introduction

Ha Long City is located along the northern coast of Vietnam. With a permanent population of about 230 000, it is popular with tourists to Ha Long Bay, a UNESCO World Heritage Site. Waste from most of the city, including its numerous hotels and restaurants, is collected and transported to two landfills that are expected to reach capacity within a few years.

The research reported here was part of a pilot project on composting waste from hotels in Ha Long. For this, information was needed on the quantities and composition of waste from hotels in the city. An audit of the waste from three hotels was therefore carried out during the wet season in 2004.

Methodology

Three hotels located in Bai Chay, a part of Ha Long City that caters to tourists, were selected to participate in the study, in order to have a range of types, based on size and ratings (see Table 4). There were no 5-star or 1-star hotels in Ha Long.

The waste collection system was observed at each hotel before auditing in order to identify the sources of waste and
to design a method to gather the waste for auditing. Three general waste sources were identified: kitchens and restaurants; guest and staff rooms; and gardens. The waste from each of these sources was collected and sorted separately.

The audit was carried out over 1 week (7 consecutive days) at each hotel between 6 and 22 June 2004. The method for gathering the waste for the audit relied primarily on the existing hotel practices and infrastructure, which differed among the three hotels. At each hotel, the waste that was to be collected and disposed from each of the three sources was gathered daily at storage areas. The auditors then physically sorted the waste into three main categories (material suitable for composting, recyclables and miscellaneous) and various sub-categories, and weighed the waste in each category and sub-category. Five sub-categories of material suitable for composting were used: fruit, vegetable, leftover food, other food (e.g. egg shells) and yard (grass and leaves) waste. As each of these types of waste has its own properties, such as moisture content, pH, and C/N ratio, that can strongly influence composting processes, this breakdown provided more information than if the waste had been categorized into only ‘brown’ and ‘green’ waste. Recyclables included metals, glass, plastics and unsoiled paper.

As the staff at the hotels attempt to collect recyclables for sale and to give leftover food waste to farmers for animal feeding, the results reported here are of the waste collected from, rather than the waste generated by, the hotels. This is of particular interest as it reflects the actual amount of waste from hotels that is discharged to the environment and is currently available for composting and recycling. Estimates of the total waste generated, including all of the recyclables and leftover food waste, are also presented by Hoang (2005).

Results

Table 4 summarizes the statistical analysis of the waste quantities for each hotel during the 1-week audit period. The total amount of waste varied significantly from day to day, as shown by the ranges. This could be related to the level of activity in the hotel, such as the number of guests, as discussed below.

<table>
<thead>
<tr>
<th>Hotel rating</th>
<th>Number of rooms</th>
<th>Total daily quantities (kg/day)</th>
<th>Quantities per guest (kg/guest per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>4 Star</td>
<td>233</td>
<td>203.3</td>
<td>63.7</td>
</tr>
<tr>
<td>3 Star</td>
<td>121</td>
<td>114.3</td>
<td>20.7</td>
</tr>
<tr>
<td>2 Star</td>
<td>84</td>
<td>89.2</td>
<td>19.1</td>
</tr>
</tbody>
</table>

Note: * based on the total waste for the week divided by the total number of guests for the week, rather than the average of the daily averages.

The amount of waste was very much dependent on the number of hotel guests. To account for this, the amount of waste collected per overnight guest per day was calculated for each of the three hotels, as also shown in Table 4. Standardizing for the number of guests, the average amount of waste collected at the 4-star and 2-star hotels was similar, at approximately 0.5 kg/guest per day, whereas the 3-star hotel had somewhat less (0.43 kg/guest per day). The differences in the results between the hotels may be due to the type of guests (nationality and income) staying at each hotel, and the degree of recycling by staff as reflected in the composition analysis discussed below.

In addition to the averages over the week, the averages on each day were estimated. As shown in the right-hand two columns of Table 4, there were significant daily variations, especially at the 4-star hotel. These were the result of the daily variations in the number of overnight guests (mostly tourists) and total waste, for example, from 337 to 484 guests and 136 to 329 kg/day at the 4-star hotel. Furthermore, although there were additional visitors present at events such as workshops, the numbers of these events and their guests were not available for inclusion in the calculations. However, by observation these other guests were considered relatively insignificant. Overall, the averages for the full sampling period provide quantities that can be useful for planning a composting system in this tourist area.

These results are significantly lower than estimates for 4-star and similar for 3-star coastland hotels in Vietnam reported by Trung and Kumar (2005): namely 2.5 to 7.2 kg/guest per day at 4-star hotels, and 0.4 to 0.5 kg/guest per day at 3-star hotels; there were no estimates for coastland 2-star hotels. However, their estimates are of waste generated (i.e. including recyclables and waste sold as animal feed) rather than waste collected, and are based on a questionnaire survey and approximations by hotel staff, rather than direct measurements.

The percentage compositions of waste are shown in Table 5. Compostable materials were the largest portion of the waste stream, accounting for an average percentage of approximately 60 or 70%. Most of this was fruit and vegetable waste, as well as yard waste at the 2-star hotel (Hoang 2005). Miscellaneous waste, consisting of non-recyclable paper, non-recyclable plastics, rubber, cloth and dirt, was the next largest, with average percentages ranging from 26 to 34%. Recyclables were generally a small percentage.
The daily percentages were also calculated, with the ranges and standard deviations shown in Table 5. On a daily basis, materials suitable for composting ranged from a low of about 40 to 60% to a high of about 70 to 90% at the hotels. The reasons for these significant fluctuations in daily composition can be complex; for example, more compostable material might be produced on a particular day if more guests order meals in the hotel.

The quantities of vegetable, fruit and yard waste, together with estimates of their minimum and maximum C/N ratios were used to estimate that the overall C/N ratio of the compostable waste would be from 21 : 1 to 38 : 1, which is within the optimal range for composting.

Household Waste in Da Nang, Vietnam

Introduction
Da Nang, with a population of about 750,000, is the fourth largest city in Vietnam. Most solid waste is collected daily and taken either directly to the city’s landfill or first to one of three transfer stations and then to the landfill. An informal sector of waste pickers recycles some of the waste. A new landfill is being constructed, and the city is planning to construct a composting facility at the old landfill.

The research reported here consisted of a waste audit that as part of a pilot source separation project at households in Da Nang in order to provide advice on the composting of household waste.

Methodology
The waste audits were carried out in two residential areas of Da Nang. Each area was audited over 1 week (7 days) in June and July 2004. The two areas were selected on the basis of having houses and being on streets that are typical of residential areas of Da Nang, and having waste that is put out daily for collection. A total of 74 households (31 from ‘area 1’ and 43 from ‘area 2’) participated in the audit.

For each day of the audit, each of the 74 households was given a plastic bag for their waste for the day. These bags were labelled and collected daily and taken to the auditing area for sorting and weighing. Since the purpose of the study was to assess the possibility of composting organic solid waste, the audit focused on the quantities of compostable and non-compostable waste. To do this, each bag was weighed, the contents were separated into the compostable waste and non-compostable waste, and compostable materials were weighed. The compostable materials consisted of food and kitchen scraps (e.g. grains, vegetables, fruit, bread, tea bags and coffee grounds), leaves and plant branches (yard waste).

Results
The audit resulted in information on the total quantities of compostable and non-compostable waste collected from households. Statistical information on the quantities of waste collected from each household over the audit periods is shown in Table 6. The overall average was 2.55 kg/household per day. The quantities collected varied considerably among households, as shown by the standard deviations and ranges. In some cases, as shown by the zero minimum values in Table 6, no waste was collected from some households on one or more days because they were away. In addition, the averages on each day were calculated. These ranged from 1.91 to 3.02 kg/household per day (with standard deviation of 0.38) in area 1, and 2.43 to 2.95 kg/household per day (with stand-
ard deviation of 0.16) in area 2 (Nguyen 2005). When collection is done on a daily basis, information on the daily variability is needed to determine the capacity of the collection method.

With approximately five people per household, which was estimated from a survey of the participating households, the average amount of waste was equivalent to about 0.5 kg/capita per day. This can be compared with data published for various other cities in developing countries: 0.5 to 0.8 kg/capita per day in south and west Asian cities (International Environmental Technology Center 1996); 0.4 kg/capita per day in Bangalore and Manila (Grover & Grover 2000); 0.1 to 0.93 (average of 0.38) kg/capita per day in class 1 cities in India (Biswas et al. 2000); 0.2, 0.44 and 0.1 kg/capita per day in Bombay, Delhi and Bhiwanda, India (Ludwig et al. 2003); and 0.35 kg/capita per day in Hyderabad, India (Galab et al. 2004). However, care must be taken in making comparisons due to differences in methodologies among the studies.

The composition of this waste, as summarized in Table 7, shows that 63% of the waste is compostable and 37% is non-compostable for the combined areas. These average quantities are based on the total quantities of compostables and non-compostables from all of the households over the audit periods. Similar results were found by averaging the percentages from each household: 65 and 35% for compostables and non-compostables, respectively, for the combined areas. The results also show a relatively large standard deviation and range in the amounts generated per household.

These results are in the middle to high end of estimates of the percentage of putrescible waste in other cities in developing countries: 75% in Bangalore, 45% in Manila and 49% in Lahore (Grover & Grover 2000); 24 to 58% (average of 35%) in class 1 cities in India (Biswas et al. 2000); and 55% in Hyderabad, India (Galab et al. 2004).

### Conclusions

The three studies summarized in this paper provide important information on waste quantities and composition relevant for composting waste from markets, hotels and residential areas in cities in developing countries. In particular, the following observations were made.

1. At a market in Vientiane, Laos, fruit and vegetable vendors generated the largest quantity of waste per vendor, and 98% of their waste consisted of ‘green’ and ‘brown’ organic waste. There was great heterogeneity in the types of vendors found in the market and in the quantities and composition of waste they produced. Therefore, as with surveys of industrial waste, it is recommended that market waste characterization studies be disaggregated by type of vendor.

2. The average quantities of waste at three hotels in Ha Long, Vietnam ranged from 0.43 to 0.53 kg/guest per day. Compostables accounted for 60 to 70% of the waste and were about 13% points higher in the 4-star hotel compared to the 3- and 2-star hotels. Although the three hotels sampled showed some differences in both waste quantities and composition, it cannot be concluded yet that hotel waste characterization studies should divide hotels by quality because of the small size of the sample.

3. The average quantity of waste collected from selected residences in Da Nang, Vietnam was 2.55 kg/day per household (consisting of about five people). Of this, 63% was compostable waste. There was no attempt to determine whether these estimates varied by socio-economic characteristics.

The high percentages of compostable waste found in the market, hotel and household waste streams suggest that com-

---

Table 6: Waste quantities from Da Nang households (kg/household per day).

<table>
<thead>
<tr>
<th>Audit period and area</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum–maximum</th>
<th>95% confidence interval of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1 and Area 1</td>
<td>2.37</td>
<td>1.93</td>
<td>0.0–12.1</td>
<td>1.69 to 3.05</td>
</tr>
<tr>
<td>Week 2 and Area 2</td>
<td>2.68</td>
<td>1.68</td>
<td>0.0–9.3</td>
<td>2.18 to 3.18</td>
</tr>
<tr>
<td>Two weeks and areas</td>
<td>2.55</td>
<td>1.80</td>
<td>0.0–12.1</td>
<td>2.14 to 2.96</td>
</tr>
</tbody>
</table>

Table 7: Compostable and non-compostable waste from Da Nang households (kg/house per day).

<table>
<thead>
<tr>
<th>Audit period and area and waste type</th>
<th>Mean (std dev)</th>
<th>Standard deviation</th>
<th>Minimum–maximum</th>
<th>95% confidence interval of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1, Area 1 Compostable waste</td>
<td>1.39 (59%)</td>
<td>1.09</td>
<td>0.15–6.6</td>
<td>1.00 to 1.78</td>
</tr>
<tr>
<td>Week 1, Area 1 Non-compostable waste</td>
<td>0.97 (41%)</td>
<td>0.91</td>
<td>0.0–5.5</td>
<td>0.65 to 1.29</td>
</tr>
<tr>
<td>Week 2, Area 2 Compostable waste</td>
<td>1.75 (65%)</td>
<td>1.07</td>
<td>0.20–5.3</td>
<td>1.43 to 2.06</td>
</tr>
<tr>
<td>Week 2, Area 2 Non-compostable waste</td>
<td>0.93 (35%)</td>
<td>0.76</td>
<td>0.0–4.0</td>
<td>0.71 to 1.16</td>
</tr>
<tr>
<td>Two weeks and areas Compostable waste</td>
<td>1.60 (63%)</td>
<td>1.10</td>
<td>0.15–6.6</td>
<td>1.35 to 1.85</td>
</tr>
<tr>
<td>Two weeks and areas Non-compostable waste</td>
<td>0.95 (37%)</td>
<td>0.83</td>
<td>0.0–5.5</td>
<td>0.76 to 1.14</td>
</tr>
</tbody>
</table>
posting is a promising option for managing waste from these sources. However, understanding the composition of a waste stream is just one step of many in determining the feasibility of composting programmes. Other key factors to consider include (Hoornweg et al. 2000): the need for and the feasibility of separating waste at source in order to produce higher quality compost; the availability and cost of land for a composting site; the cost of waste transport and processing; the avoided costs of disposal; and the availability of revenue sources from selling the compost product or recovering recyclables. Waste audits contribute to the assessment of several of these factors. For example, the market waste audit revealed that the waste from fruit and vegetable vendors is almost entirely compostable and would probably produce high-quality compost without the cost and effort of source separation.

All three audits provided important information about waste quantities that can be used in making capacity and cost estimates for the collection system and the composting site. This includes information on the daily variations in waste quantities, which can be significant as shown in the hotel and household waste audits. In addition, the market and hotel waste audits illustrate how the quantities of recyclables to be disposed of depended on the extent of prior recycling by the informal sector.

Acknowledgements

The authors thank the Canadian International Development Agency (CIDA) for financial support for this project through the WASTE-ECON Program at the University of Toronto. We also thank the staff at the following organizations who contributed to the studies: National Science Council, Nabong University, and Thong Khankham Morning market in Vientiane, Lao PDR; Vietnam National Institute for Science and Technology Policy and Strategy Studies (NISTPASS); Centre for Environmental Engineering of Towns and Industrial Areas (CEETIA), Hanoi University of Technology; Saigon-Halong, Cong Doan and Tien Long hotels, and Bai Chay Urban Environmental Company in Ha Long, Vietnam; and University of Da Nang College of Technology.

References


P.H. Byer, C.P. Hoang, T.T.T. Nguyen, S. Chopra, V. Maclaren, M. Haight