DEVELOPMENT AND TRIAL OF A METHODOLOGY FOR THE QUANTIFICATION AND EVALUATION OF HOME COMPOSTING IN PALMERSTON NORTH, NEW ZEALAND

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Abstract

Home composting and commercial composting can be regarded as part of the Municipal Solid Waste Management system. Currently, in Palmerston North and more broadly in New Zealand, home composting plays an important, but an unquantified role in waste diversion. In Palmerston North, the quantity of organic waste diverted from landfill via home composting is not captured in the City's official 'waste assessment' or recorded in the 'waste management and minimisation plan'. Additionally, there appears to be little local social and technical data on why, who, when, what and how well home composting is practised. The aim of this study was to develop and implement a methodology for a mixed-method quantitative-qualitative study for the quantification and evaluation of home composting practices in Palmerston North. The development process for the research methodology drew upon an international literature review of scientific research, a range of municipal best practice guidelines for home composting and referenced elements of the New Zealand composting standard. The data collection for this study involved a combined telephone and door-to-door survey of 300 households (that is, approximately 1% of occupied dwellings, randomly selected from across all 15 suburbs in the City). To support the physical data collection, a novel home composting evaluation tool was also developed and trialled for empirical and quality assurance evaluation. The overall participation rate recorded in the present study (64%) was high and both data collection methods proved to be viable, yielding positive results. 36% of the households who participated in the present study were home composters which could mean that about 10,761 households in the occupied dwellings of the City practise home composting. At the time of the survey, it appears that nearly 4005 tonnes of organic waste was being treated via home composting processes. The results also indicated positive quality assurance of the home composting process and the resulting compost in the City. Whilst most of the study participants have a positive experience towards home composting, nuisance insects, rodents and odour problems were reported as issues. In terms of motivation around current and future home composting practices, a range of support options appears to be available for Councils to encourage and enhance this positive environmental practice.

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Table of Contents

List of tables

List of figures

Abbreviations and Acronyms

ACC .... Auckland City Council

CCA .... Chromated copper arsenate

CCC .... Christchurch City Council

CO_2-e .... CO_2-equivalent

C/N ratio... Carbon-nitrogen ratio

DCC.. Dundee City Council

DSEWPC............. Department of Sustainability Environment Water Population and Communities

DOS .... Department of Sanitation

GHG .... Greenhouse gases

HCET... Home composting evaluation tool

IGES..Institute for Global Environmental Strategies

LCA.. Life cycle assessment

MfE... Ministry for the Environment

MSW... Municipal Solid Waste

MSWM... Municipal Solid Waste Management

Mt..Metric tonnes

NZS4454:2005 ...... New Zealand Standard 4454:2005 - Composts, Soil Conditioners and Mulches

NZWS... New Zealand Waste Strategy

PCC.. Pembrokeshire County Council

PNCC .... Palmerston North City Council

QA .... Quality Assurance

RMA.. Resource Management Act

SES... Socio-economic status

tpa... tonnes per annum

UNDP... United Nations Development Programme

UNEP .... United Nations Environment Programme

WA .... Waste Assessment

WMA... Waste Minimisation Act

WMMP .... Waste Management and Minimisation Plan

ZWNZT... Zero Waste New Zealand Trust

1.0 Introduction/background

Each year approximately 1.3 billion metric tonnes (Mt) of solid waste is generated globally out of which organic waste forms the largest proportion (46%) (Lim, Lee, & Wu, 2016). The amount of organic waste generated in high-income and low-income countries are 28% and 64% respectively (Dai et al., 2015). Although the types of organic waste in developing countries are almost identical to that of developed countries, the quantity and magnitude vary (Bobeck, 2010). Organic waste or bio-waste is defined in the European Union legislation as ''biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants'' (Zabaleta & Rodic, 2015). The major constituents of organic waste in the municipal solid waste (MSW) stream are food waste and garden waste (Karnchanawong & Suriyanon, 2011).

The inclusion of organic waste in the general household waste for disposal into landfills can lead to the generation of greenhouse gases (GHG) (Institute for Global Environmental Strategies (IGES), 2008). It can also cause other generally recyclable resources (such as plastics, metal and paper) to be contaminated and devalued, making it more challenging to profitably recycle these resources (Hannon, 2017). The failure to separate, treat and beneficially recycle organic waste, alongside other poor land management practices has also resulted in declining organic matter and plant nutrient contents in many cropping areas around the globe (Hanc & Pliva, 2013).

Separate collection of organic waste for biological treatment has been recommended as a key tool for improving the environmental sustainability of the waste management sector (Naroznova, Møller, & Scheutz, 2016). Accordingly, biological treatment methods for organic recycling like anaerobic digestion, vermicomposting (worm farming[a]) and composting has become popular and widely-practised (Karkanias, Perkoulidis, & Moussiopoulos, 2016).

[a] Vermicomposting systems and worm farms employ similar processes and so both terms will be used interchangeably in the present study.

Composting of organic waste has been perceived to have great potential in reducing GHG emissions (Chan, Sinha, & Wang, 2010; IGES, 2008). Although emissions of nitrous oxide may occur during the composting process, studies have revealed that the quantities are negligible as compared to that from landfilling (Chan et al., 2010; IGES, 2008). Vázquez, Sen, and Soto (2015) also mention that relative to landfilling, composting systems are likely to accommodate about 50% of organic waste in the municipal waste stream, reducing GHG emissions by 40%. The biogas produced from anaerobic digestion has also been reported to reduce GHG emissions significantly when used as a biofuel for transport or directly injected into the gas distribution grid (European Union Commission, 2008). Macro and micro nutrients available in organic waste also represent an inexpensive and environmentally sound alternative to inorganic fertilisers for crop growth when organic waste is effectively recovered and recycled (such as by vermicomposting) (Gómez-Brandón & Domínguez, 2014).

Relative to commercial composting operation undertaken at a municipal level, home composting is the most frequently reported alternative for the management and treatment of organic waste at the household scale (Faverial & Sierra, 2014; Quirós et al., 2014). Given that home composting is undertaken on-site at the source of the organic waste generation before the material enters the Municipal Solid Waste Management (MSWM) system, this process has been profiled as a waste prevention approach for the management of unavoidable household food waste and garden waste (Abeliotis, Lasaridi, & Chroni, 2016). For instance, New Zealand's Ministry for the Environment (MfE/the Ministry) aims at encouraging home composting among households as a means of reducing the amount of organic waste disposed of in landfills (MfE, 2009).

Home composting is categorised under the MSWM system (normally in conjunction with commercial composting). In Palmerston North (the City), New Zealand, a key query is the quantity of organic waste diverted from landfill via home composting which is not captured in the City's waste diversion rate. Therefore, the aim of the present study was to develop and trial a methodology to quantify home composting (volume/mass) and to evaluate the process management, quality assurance (QA) and other social/behavioural parameters around home composting in Palmerston North.

1.1 Problem statement

1.1.1 Scenario description

Waste management and minimisation in New Zealand is guided by the New Zealand Waste Strategy (NZWS:2010) (refer to Section 2.1.1.1 for details on NZWS:2010). The main sectors in New Zealand that are affected by NZWS are the central government, local government (made up of Regional Councils and territorial authorities), the waste industry, businesses and communities. The functions of each of these sectors with regards to waste management and minimisation in are presented in Table 1.

Table 1 Functions of the major sectors in New Zealand with regards to waste management and minimisation. Adapted from (MfE, 2010).

Sector	Functions
Central government	• Implementation and administration of the legislative framework for waste management and minimisation. • Provision of high-level direction via NZWS to local government, business and communities on areas to focus their waste management effort. • Publishing of best practice guidelines for waste management and minimisation.
Local government (made up of Regional Councils and territorial authorities)	• Regional Councils regulate the environmental impacts of waste management facilities by granting and monitoring resource consents under the 'Resource Management Act'[b]. • In accordance with the 'Waste Minimisation Act', 2008[c] territorial authorities have a statutory responsibility to promote effective and efficient management and minimisation of waste within their district. • Territorial authorities are also required to review their 'Waste Management and Minimisation Plans' by 1st July and every six years thereafter with regards to NZWS.
Waste industry	• Increase the variety of services available and ensure that incentives/costs affect consumers in a way that influences waste reduction.

[b] New Zealand's primary environmental regulation, covering environmental protection, natural resource management, and urban planning regime (MfE, 2015).

[c] It provides a legislative framework with tools and responsibilities, and aims at encouraging waste minimisation in New Zealand, to reduce the environmental effect of waste and provide environmental, social, economic and cultural benefits (MfE, 2009; 2011).

	• Effective management and minimisation of harmful waste.
Business and communities	• Businesses are required to improve resource efficiency in the manufacture and consumption of goods and services. • Communities can help reduce waste through changed behaviours at home and at work, by supporting businesses that are reducing their impacts on the environment or by joining the community and voluntary groups.

According to MfE (2007), information on waste flows and volumes that were used to set targets during the development of NZWS:2002 (refer to Section 2.1.1.1 for more information on NZWS:2002) was incomplete. For instance, organic waste forms part of the priority waste streams in NZWS:2002 targets but there has been limited progress in measuring the quantity of organic waste diverted; particularly, through home composting. The primary reason for this lack of progress according to MfE (2007), is limited data regarding organic waste diversion. According to MfE, the inability of some territorial authorities to provide complete data sets on their waste and recycling activities makes it difficult to develop a comprehensive national picture of waste flows. They further state that improvement of data on waste is required since restricted data hampers their ability to plan suitable activities to improve waste management and minimisation. Given this point, the establishment of the true waste diversion rate in Palmerston North by means of including that derived from home composting will contribute to a better assessment of local Palmerston North City Council (PNCC/the Council) Waste Management and Minimisation Plan (WMMP) goals and the generic aims of the NZWS:2010.

Additionally, differences in survey methodology used for waste assessment (WA) was identified by MfE (2009) as one of the factors that hinder their ability to compare results over time. It is, therefore, essential to develop WA survey methodologies specific to each waste stream or treatment pathway instead of using different methodologies over time. The methodology developed and implemented in the present study can, therefore, serve as a template for conducting home composting quantification and evaluation studies in other municipalities in New Zealand (and possibly other parts of the world). This will enable the Ministry to compare results from home composting quantification and evaluation studies across the various municipalities over time.

1.1.2 Waste flow in Palmerston North

In 2011/2012, the total amount of waste generated in Palmerston North was estimated to be 108,194 tonnes per annum (tpa), out of which 44,000 tpa was disposed of in landfill (Jones & Green, 2012; Wilson, Eve, Yates, & Middleton, 2012). Table 2 provides an overview of the categories of waste assessed during 2011/2012.

Table 2 Total waste flows in Palmerston North during 2011/2012. Source: (Jones & Green, 2012; Wilson et al., 2012)

Waste type	Tonnes per annum	Percentage of the total
Landfilled waste	44,000	40%
Recycled waste	20,070	19%
Clean filled waste	25,000	23%
Composted waste	19,124	18%
Total	**108,194**	**100%**

It can be noted from Table 2 that landfilled waste formed a major component of the total waste generated in Palmerston North during 2011/2012 while composted waste formed a smaller fraction.

1.1.2.1 Composition of landfilled waste

Organic waste, comprising mainly food waste and garden waste, constituted the largest proportion of the total waste disposed of in landfill in the City (Wilson et al., 2012). Table 3 illustrates the major components of the total waste sent to landfill in Palmerston North during 2011/2012.

Table 3 Major components of landfilled waste in Palmerston North during 2011/2012. Source: (Wilson et al., 2012).

Waste component	Tonnes per annum	Percentage of the total amount
Organic waste (mainly food waste and green waste)	13,800	31.4%
Timber (construction and demolition materials, and furniture)	5,667	12.9%
Plastics	5,605	12.7%
Paper	5,119	11.6%

1.1.3 Waste minimisation in Palmerston North

As highlighted in Table 1, all territorial authorities are required by the WMA:2008 to develop WMMP. Consequently, PNCC has developed their own WMMP, which contains the Council's goals, actions and targets for waste management and minimisation in Palmerston North. One of the goals of the Council is to divert 75% of the City's waste from landfill and clean fills toward beneficial uses (Jones & Green, 2012). Currently, 59% of waste from landfill is estimated to be diverted in Palmerston North (Jones & Green, 2012).

To achieve the ambitious goal of a 75% waste diversion rate, PNCC provides and undertakes public education services and waste minimization initiatives to encourage the reduction, reuse and recycling of waste (PNCC, 2015). Concerning waste reduction in the City, the Council undertakes zero waste education programmes (PNCC, 2016b). For instance, the Awapuni Sustainable Development Centre is a Council-operated educational centre where the public is educated on how to address waste recycling. The Square Circular, a newsletter from the Council is also supplied to residents once a month. This newsletter usually has a section such as the 'green spot' which usually addresses environmental issues (PNCC, 2017). Additionally, the Council and the private-community sector provide waste collection and recycling services to households and institutions in the City. Table 4 outlines waste collection and recycling services in Palmerston North.

Table 4 Waste collection and recycling services in Palmerston North. Adapted from (PNCC, 2015; 2016a; Simmons, 2014; Wilson et al., 2012).

Service providers	Waste collection and recycling services provided
The Council	• Weekly kerbside collection of waste (in bags), co-mingled recyclables and separate glass recycling on alternate weeks for households in residential areas. • Commercial recycling and waste collection. • Green waste or garden waste drop-off at the Awapuni resource recovery centre, and the Ashhurst and Bunnythorpe transfer stations. • E-waste recycling at the Ferguson Street recycling centre.

Private waste companies	• Weekly household waste collections. • Collection of garden waste. • Commercial and industrial waste collections. • Construction and demolition waste collections. • Collection of commercial recycling. • Collection of medical waste.
Community waste and recycling organisations	• E-waste drop-off, resale and consolidation for processing. • Commercial recycling collections. • Promotion of home composting.

1.1.3.1 Organic waste management in Palmerston North

The forms of organic waste management in Palmerston North comprise landfilling, open burning[d] (mainly in rural areas), vermicomposting, commercial composting, home composting, animal feed (for example, food scraps to chickens), stockpiling and mulching. Among these processes, vermicomposting, commercial composting, home composting, animal feed and mulching usually result in the diversion of organic waste into beneficial uses.

Conversely, landfilling and incineration of organic waste result in adverse environmental impacts (see Sections 2.2.1 and 2.2.2). Stockpiling of organic waste also leads to non-beneficial use because the organic waste is either left to decompose without the intention of use in a garden or soil or is eventually collected for disposal into the landfill by the Council and private waste service providers. Figures 1, 2 and 3 illustrate some of the forms of organic waste management in Palmerston North.

[d] Also referred to as incineration.

Figure 1 Commercial composting at the Awapuni composting site (Hot Rot in-vessel composting system (left), garden waste drop-off (middle) and finished compost (right). Source: (Hannon, Hay, City Enterprises, Allen, & Simmons, 2014).

Figure 2 Home composting systems containing fresh feedstock (left) and decomposed feedstock (right)

Figure 3 Organic waste used as a garden mulch to reduce weeds in garden soil.

1.1.3.1.1 Composting in Palmerston North

Currently, PNCC does not provide an organic waste kerbside collection service. Instead, the Council offers user pays facilities at the Awapuni composting site and the Ashhurst transfer station for the disposal of garden waste (PNCC, 2011). However, there are no facilities for food waste drop-off nor collection for the general public/households in the City (PNCC, 2011). This indicates that food waste generated by households in Palmerston North is not treated via commercial composting processes at the PNCC commercial composting site.

Home composting and commercial composting can both be broadly considered as forms of organic recycling and part of the MSWM system (Figure 4). However, whilst generally similar biodegradation processes occur in both home and commercial composting, they are quite distinct biophysically. Both home composting and commercial composting may also be considered as sustainable processes because they recycle organic waste to produce organic fertilizer which could be applied to agricultural lands (see Sections 2.2.3.1.1.1.1 and 2.2.3.1.2.2 for more details). Thus, both processes are considered important for an effective organic waste management system. In the case of Palmerston North, home composting can be employed as a substitute for the treatment of food waste in the City, since the Awapuni composting site does not currently accept food waste from households.

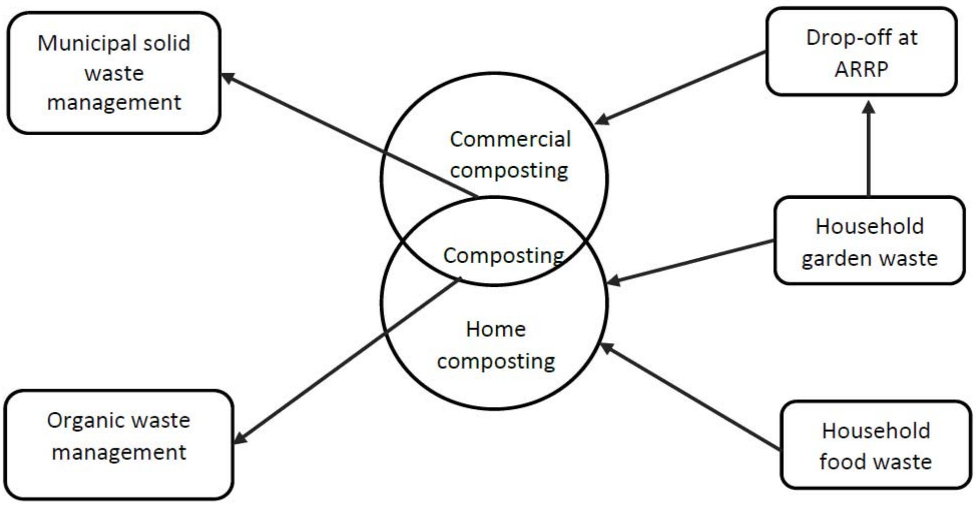

Figure 4 Pathways for the composting of household food waste and garden waste in Palmerston North. Both household garden waste and food waste are treated via home composting processes in the City. In contrast, the commercial composting site in Palmerston North accepts only household garden waste.

The Council controls 97% of commercial composting operations in Palmerston North (Wilson et al., 2012). In 2012, the amount of organic waste composted in the City was estimated to be 19,124 tpa (Table 2). This figure does not include home composting as it is currently unrecorded. It is estimated that an additional 12,639 tpa of organic waste, comprising food waste and garden waste, are potentially recyclable in Palmerston North (Jones & Green, 2012; Wilson et al., 2012). The sum of the respective amounts of currently composted and potentially recyclable organic waste indicates that a total of 31,763 tpa of organic waste can be diverted from landfill into beneficial uses in the City's gardens, soils and surrounding agricultural lands. These projections make it evident that an effective management of organic waste provides a key opportunity for the Council to reach its goal of 75% waste diversion from landfill in Palmerston North.

Currently, PNCC carries out home composting promotional activities such as the distribution of composting guides. Other initiatives include the carrying out of home composting trials in the City. An example is a trial conducted by the Behaviour Change and Education Coordinator of PNCC. This trial focused on social marketing and how to facilitate home composting by overcoming or eliminating the barriers to desired behaviour change (S. Battman, personal communication, December 20, 2016).

Although home composting leads to the diversion of organic waste into beneficial use in the City, PNCC, like other territorial authorities in New Zealand, has little information on the amount of organic waste diverted via home composting in their WA data. There exists, therefore, a need to quantify the volume of organic waste recycled through home composting and to work towards establishing the actual waste diversion rate in the City by including that from home composting. The present home composting study undertaken in Palmerston North will also aid in the exploration of the operational schemes, the awareness and attitude, and the issues faced by residents regarding home composting. It will also aid in the examination of the QA of local home composting processes and of the finished compost produced.

1.2 Research questions

a. How can a methodology for a home composting quantification and evaluation study in Palmerston North be developed and implemented to;
    - estimate the volume/mass of organic waste being diverted from landfill via home composting?

- explore the types of home composting systems and accompanying management practices?
- explore the local community awareness and attitudes around home composting processes?
- explore the issues faced by households?
- evaluate the QA of the home composting process and the final product?

b. What can the findings from implementing this home composting methodology offer to future research seeking to quantify and evaluate home composting practices in other parts of New Zealand and in other places around the world?

1.3 Objectives of the study

The key objectives of the present study are as follows:

a. Development of a methodology for a home composting quantification and evaluation study in Palmerston North to aid in the
   - estimation of the volume/mass of organic waste diverted from landfill via home composting.
   - exploration of the types of home composting systems and accompanying management practices.
   - exploration of the local community awareness and attitudes around home composting.
   - exploration of any perceived issues with home composting and conversely potential opportunities, such as for PNCC interventions to resolve issues, increase waste diversion rates and improve home composting practices.
   - evaluation of the local home composting process and final product QA (relative to what is understood internationally as good practice guidelines).

b. Once trialled, make recommendations on how the present study's methodology can be improved based on the research findings and researcher experience from its implementation in the Palmerston North context.

2.0 Literature review

2.1 Municipal solid waste management (MSWM)

Municipal solid waste management (MSWM) is any activity that is intended to reduce the harmful effects of MSW on public health and the environment (Addaney & Oppong, 2015). The goals of MSWM is to protect public health, promote environmental quality and sustainability, support economic productivity and create employment using sustainable solid waste management systems (Schübeler, Christen, & Wehrle, 1996). According to Schübeler et al., the scope of MSWM encompasses the following elements: "planning and management systems, waste generation processes and organisations, and procedures and facilities for waste handling". Generally, MSWM involves the functions of generation, source separation, storage, collection, transfer and transportation, processing and recovery, and the final disposal of waste (Das & Bhattacharyya, 2015; Puopiel, 2010).

Municipal authorities are mainly responsible for MSWM in most cities around the world (Amritha & Anilkumar, 2016). They aim at developing and implementing cost-effective and environmentally sound methods for the management of MSW generated by their residents. In many cities, especially in the developed countries, MSWM is guided by the waste hierarchy (Gharfalkar, Court, Campbell, Ali, & Hillier, 2015; Van Ewijk & Stegemann, 2016).

In the waste hierarchy, waste management options are ranked with regards to their impacts on the environment and minimization of final waste (European Environment Agency, 2009; Lazarevic, Buclet, & Brandt, 2010). Waste reduction, reuse, recycling and recovery are the most preferred options in the waste hierarchy while disposal methods like landfilling and incineration (without recovery) are considered as the least preferred options.

2.1.1 MSWM trends internationally and within New Zealand

According to the United Nations Development Programme (UNDP) (as cited by Zhu, Asnani, Zurbrügg, Anapolsky, & Mani, 2007), a survey of 151 municipal authorities across the world revealed that inadequate MSWM is the second most severe problem city dwellers face after unemployment. Characteristically, one-to-two-thirds of MSW generated in many cities is not collected and the uncollected waste is indiscriminately disposed of on streets and in drainage systems contributing to flooding, to creating breeding grounds for vectors such as rodents and insects, and the spread of disease (Hoornweg & Bhada-Tata, 2012; Zhu et al., 2007).

The collection and disposal of MSW are the major challenges confronting many developing countries while most developed countries appear to have effectively abated the problem of MSWM and are now aiming at reducing environmental pollution and increasing resource efficiency and recovery (Owusu-Sekyere, Bagah, & Quansah, 2015). Open dump sites are popular waste disposal methods in developing countries (Rozenberg; United Nations Environment Programme (UNEP), 2013). Conversely, developed countries like Austria, Belgium, Denmark, Germany, the Netherlands and Sweden have met and surpassed the targets of the European Union Landfill Directive[e] (Lim et al., 2016). Nevertheless, landfilling of MSW remains prevalent in several cities in Europe such as Naples in Italy (Rozenberg; UNEP, 2013).

Chatterjee and Mazumder (2016) explained that the challenges faced with MSWM in developing countries can be attributed to economic constraints, inadequate labour and infrastructure, unsuitable strategies and the inability to develop an effective and sustainable method for MSWM. Additionally, data on the quantity and composition of waste in developing countries is limited, making it difficult to design sound and cost-effective strategies for MSWM (Rozenberg; UNEP, 2013). Likewise, some developed countries like New Zealand, as illustrated in Section 1.1.1, face similar challenges with waste data. This, therefore, buttresses the assertion by the Ministry that the improvement of waste data is essential for developing effective and efficient waste management strategies. The present home composting study seeks to contribute towards addressing this shortfall.

[e] "The Directive requires, amongst other things, that a strategy on organic (biodegradable) waste is put in place that achieves the progressive diversion of organic (biodegradable) municipal waste from landfill" (Department for Environment Food and Rural Affairs, 2010).

2.1.1.1 MSWM in New Zealand

The main MSWM systems in New Zealand is the weekly and/or fortnightly kerbside waste collection, and the various forms of recycling collection/drop-off provided by municipal authorities, private waste companies and community waste and recycling organisations, using either waste bags, plastic crates and/or wheeled bins (MfE, 2009).

In 2002, New Zealand adopted a waste strategy (NZWS:2002) which included a generic zero waste statement and objectives (Davidson, 2011). According to MfE (as cited by Davidson, 2011), the country made considerable progress under this strategy and accompanying programme. However, there were difficulties in evaluating both progress and success in reaching the regime of NZWS:2002 targets, so the zero waste vision was replaced in the next NZWS:2010 which aimed to minimise the harm from waste and maximise resource efficiency (Davidson, 2011).

Several activities and regulatory changes have been made in the NZWS:2002-2010 period. These include the closure of sub-standard disposal facilities and the introduction of the waste levy through the implementation of the regulatory requirements of Resource Management Act (RMA) and the development of the Waste Management Act (WMA:2008) respectively (MfE, 2010). The Ministry further added that best practice guidelines, such as the use of leachate collection systems, engineered liners, and systems for recovering methane gas are being applied to effectively manage landfill disposal facilities. Although some significant improvements have been recorded in New Zealand's waste management performance, further improvement is required (MfE, 2010) (as previously discussed in Section 1.1.1).

2.2 Zero waste and organic waste management

Zero waste, a visionary system for waste management, has been offered as an alternate solution for the waste-related issues in recent years (Zaman, 2015). According to Zaman, zero waste is the most integrated approach to attaining a real sense of sustainable waste management systems. In a zero waste system, material or resource flow is circular because, at the end of life, materials are reused, repaired, sold or redistributed within the system until the optimum level of consumption is obtained (Lim et al., 2016; Zaman, 2015).

Where recycling and repair are impossible, the material may be recycled or recovered from the waste stream and used as inputs, preventing the depletion of resources and emissions into the environment (Smith, Sengupta, Takkellapati, & Lee, 2015; Zaman, 2015). Hence, materials are rarely wasted or underused in a zero waste system. Reducing material output is an attractive criterion for attaining sustainability, since material flows generally equate to waste generation in our current, mostly 'linear' (or 'take make waste') economy (MacArthur, 2013; Van Ewijk, & Stegemann, 2016).

Recycling of organic waste is a key focus and strategy of zero waste and the movement for a circular economy. With respect to the organic fraction of MSW, several countries have developed strict mandatory targets[f] and a range of management methods for addressing organic waste. The main organic waste management methods employed internationally include: source reduction, kerbside recycling, material recovery, landfilling, incineration, and composting. The following sections provide some background information on these organic waste management methods.

2.2.1 Landfilling

According to the European Union Commission (2008), landfilling of organic waste is usually regarded as the cheapest MSWM method, especially when the cost of land is low. However, landfilling as a means of organic waste management is becoming more problematic due to the decreasing availability of land alongside other environmental and social factors (Chatterjee & Mazumder, 2016). For instance, a poorly managed and unmonitored landfill site with excess organic waste is likely to result in the generation of leachate, which can contaminate groundwater, and adversely affect human and environmental health (Chatterjee & Mazumder, 2016).

Organic waste decomposition in landfills occurs anaerobically, which leads to the emission of GHG such as methane, carbon dioxide, nitrous oxide and non-methane hydrocarbons. Globally, this contributes to about 3–4% of the anthropogenic GHG

[f] The European Union Landfill Directive is an example (Alexander, 2007; European Bioplastics, 2015; Farrell & Jones, 2009; Lleó et al., 2013).

emissions regarding CO_2-equivalent (CO-e)[g] (Chan et al., 2010; Lalander, Komakech, & Vinnerås, 2015; Pembrokeshire County Council (PCC), 2007). In addition, the excessive and unnecessary landfilling of organic waste increases the total material handling load on waste collection and disposal systems, as well as emitting bad odours to surrounding environments (Hara, Furutani, Murakami, Palijon, & Yokohari, 2011).

2.2.2 Open burning and incineration

According to Smith et al. (2015), approximately 40% of MSW is openly burned worldwide which could represent up to 64% of the worldwide emissions. Karnchanawong and Suriyanon (2011) also mentioned that the incineration of garden waste results in the release of various toxic compounds such as nitrogen oxides, volatile organic compounds and carbon monoxide into the environment. The European Union Commission (2008) also reported that the environmental effects from the incineration of organic waste are mostly related to airborne emissions including GHG, and the loss of organic matter and potential nutrient resources from the soil.

Thermal incineration, a processing method for organic waste management, results in considerable volume reduction and can be used to generate and recover energy (Chatterjee & Mazumder, 2016). However, because of the high moisture content in organic waste, thermal incineration of this waste stream may require additional energy inputs to achieve drying, an external supply of oxygen, a well-equipped burning system, and suitable pollution control equipment (Chatterjee & Mazumder, 2016). Improper handling of the slag from flue gas cleaning is also likely to contaminate the environment (Rand, Haukohl, & Marxen, 2000).

2.2.3 Biological treatment methods

The most preferred option for organic waste management is biological treatment (Jensen, Møller, & Scheutz, 2016). Biological treatment processes such as composting,

[g] A term for describing different GHGs in a common unit. For any amount and type of GHG, CO2-e denotes the amount of CO_2 which would have the equivalent global warming impact (Brander, 2012).

anaerobic digestion and vermicomposting are common methods for the recycling of organic waste (Chan et al., 2010).

Anaerobic digestion systems are used to recover energy in the form of biogas (Pecorini, Baldi, Carnevale, & Corti, 2016). As compared to incineration and landfilling, a well-managed anaerobic digestion system is likely to be a low-pollution process especially when the biogas produced is effectively used to offset fossil fuel. When full costing of all normally externalised factors is considered, anaerobic digestion offers a relatively low-cost for organic waste management (Campuzano & González-Martínez, 2016).

Composting and vermicomposting have also been utilised and are reported to be less complex and more cost-effective than anaerobic digestion (Hoornweg & Bhada-Tata, 2012). The main difference between these processes is that in composting, microbes are responsible for the decomposition of organic waste whilst microbes and earthworms are involved in the decomposition process in vermicomposting (Ali et al., 2015).

Techniques employed for the composting and vermicomposting of organic waste may range from small-scale home and community-based techniques to high-tech commercial scale operations. Home composting processes may be understood as residing more towards vermicomposting than commercial composting processes on the spectrum of technology, complexity, cost and scale. For instance, in terms of sustainable food waste management options, Lleó et al. (2013) pointed out that home composting and vermicomposting have been proposed as alternative and somewhat overlapping treatment pathways (as worms will often be found in a healthy home composting system just as in vermicomposting).

Additionally, home composting as delineated by Martínez-Blanco et al. (2010) can be an effective alternative to commercial composting in low-populated urban areas. It is, therefore, useful to explore and understand these biological treatment methods in detail. The following sections provide an overview of vermicomposting and composting processes both internationally and within New Zealand.

2.2.3.1 Vermicomposting

Vermicomposting can be defined as the bio-oxidation and stabilisation of organic waste by the combined action of earthworms and microbes to produce vermicompost, a humus-like material rich in essential plant nutrients (Hanc & Pliva, 2013; Karmakar, Brahmachari, Gangopadhyay, & Choudhury, 2012). The microbes are responsible for the biochemical breakdown of organic waste, while earthworms condition the substrate and vary the biological activity (Ali et al., 2015).

Vermicomposting has been demonstrated to be an adequate technique for the treatment of diverse types of organic waste such as sewage sludge, agro-industrial waste and sludge, cattle manure, urban solid waste, paper industry waste, horticultural waste and cultivars (Gómez-Brandón & Domínguez, 2014; Lleó et al., 2013). In New Zealand, mixed pulp mill solids are treated through vermicomposting processes and are reported to record a volume reduction of between 78-85% (Quintern, Seaton, Mercer, & Millichamp, 2013).

Commercial vermicomposting operations produce two marketable products, worms and vermicompost (Karmakar et al., 2012). For instance, the Kinleith Worm Farm in New Zealand produces vermicompost as well as earthworms on a commercial scale (Quintern, 2011). It has also been shown that earthworms and their vermicompost can protect plants against several pests and diseases (Singh, Singh, Araujo, Hakimi Ibrahim, & Sulaiman, 2011).

With respect to food waste and garden waste, the Department of Urban Services in Canberra, Australia, processes food waste in covered brick units by employing vermicomposting processes (Appelhof, Webster, & Buckerfield, 1996). Some farmers in Rajasthan, India, have also built a multi-compartment system for the vermicomposting of food waste and garden waste on a commercial scale (Nagavallemma et al., 2004).

The Wellington City Council in New Zealand has also collaborated with local companies to process food waste through vermicomposting (Appelhof et al., 1996). In Palmerston North, PNCC has set up worm farms in schools (Zero Waste New Zealand Trust (ZWNZT), 2002). Over fifty schools in the Selwyn and Ashburton district in New Zealand also have worm farms where students are educated on their maintenance (ZWNZT, 2002).

2.2.3.2 Composting

Composting can be defined as “the biological decomposition of organic matter under controlled aerobic conditions to form a stable, humus-like finished product” (Farrell &

Jones, 2009). Thermophilic temperatures are developed by a diverse population of microbes due to biologically produced heat during the composting process (Hester, Harrison, Swan, Crook, & Gilbert, 2002). Composting can also take place under anaerobic conditions; however, it is not as extensively practised as aerobic composting (Lim et al., 2016).

The following parameters are essential for an effective composting process as well as good quality compost products: aeration, moisture content, carbon-nitrogen (C/N) ratio and temperature (Bardos, 2004; Fernández, Mateu, Moral, & Sole-Mauri, 2016; Lim et al., 2016). These important composting parameters are inter-related (Bardos, 2004). Proper control of input material in addition to the monitoring of composting parameters is crucial in the composting process (European Union Commission, 2008). Critical parameters which also affect the temperature, microbial population and microbial diversity within the compost pile are the pile dimensions, the particle size of the feedstock, nutrient availability, oxygen concentration, and moisture content (Bardos, 2004; Christian, Evanylo, & Pease, 2009).

Composting continues to be one of the widely-practised processes for the treatment and recycling of organic waste (González et al., 2016). According to Hoornweg and Bhada-Tata (2012), composting is becoming popular in high-income countries although the waste stream in these parts of the world contains a smaller fraction of compostables, than in low and middle-income countries. The European Union Commission (2008) also reported that in 2005, a total of 13.2Mt of compost was produced in Europe alongside 35-40Mt potentially compostable materials. Farrell and Jones (2009) also reported that 33% of the MSW generated in the USA is composted (and recycled).

From an environmental perspective, composting is regarded as one of the most suitable options for the management and treatment of organic waste (Oliveira, Oliveira, Bezerra, Silva Pereira, & Battistelle, 2016). Composting of segregated organic waste has also been reported to significantly reduce the contamination of finished composts as compared to the processing of mixed MSW (Hoornweg & Bhada-Tata, 2012). The process also eliminates pathogenic microbes and reduces odour compounds (Quirós et al., 2014).

Additionally, composting leads to the diversion of organic waste from landfills which results in the recovery and recycling of nutrients and organic matter, as the compost produced in this process can be applied to soils to promote plant growth and improve soil structure (Bong et al., 2016). Composting also promotes the consideration of organic waste as a resource, since the diversion of organic waste from MSW stream for composting results in significant volume reduction as via composting, organic waste is returned to the soil for beneficial use (Abeliotis et al., 2016).

As previously stated, composting can be undertaken on a commercial or a home scale. Although both processes require the same basic parameters (such as moisture content, aeration, temperature, C/N ratio), most of the decomposition process in home composting occurs under mesophilic temperatures (20-45 °C). The decomposition process in commercial composting, on the other hand, occurs mostly at thermophilic temperatures (above 45 °C) (Compost New Zealand, 2007a; European Bioplastics, 2015; Rynk et al., 1992). The amount of organic waste composted per site (but not necessarily collectively by all households), in the home composting scenario is also likely to be considerably smaller than in commercial composting (European Bioplastics, 2015).

As shown in Figure 4, both commercial and home composting processes present essential differences and each one may be suitable for different jurisdictions and socioeconomic situations. For instance, it may be difficult to substitute commercial composting with home composting in highly populated urban areas, due to site, hygiene and monitoring requirements (Martínez-Blanco et al., 2010). Further information about commercial and home composting processes are presented in the following sections.

2.2.3.2.1 Commercial composting

Commercial composting is also referred to as ‘centralised’, ‘industrial’ or ‘large-scale’ composting. In commercial composting processes, large-scale professional facilities are employed to enable the essential biophysical parameters for composting, rapid decomposition, proper emission control and good quality compost (Fernández et al., 2016). The forms of commercial composting include passive composting, windrow composting, aerated static pile and in-vessel composting (Rynk et al., 1992).

2.2.3.2.1.1 Commercial composting trends internationally and within New Zealand

Composting to produce soil amendments and/or the mechanical separation of organic waste at source to produce soil amendments are the most common methods for the treatment of organic waste in northern Canada, Germany, the Netherlands, Spain and France (Adhikari, Trémier, Martinez, & Barrington, 2010).

Within the UK, open air windrow systems are prevalent (Sykes, Jones, & Wildsmith, 2007). However, Sykes et al. note that, in mainland Europe, there is a shift towards large-scale in-vessel and mechanical composting plants.

In New Zealand, mechanically turned open windrow systems have been the main method for commercial composting and are reported to be easy and less problematic from input to the processing of organic waste (Compost New Zealand, 2007a). Currently, advanced technological forms of composting like in-vessel composting are being employed in New Zealand for the processing of organic waste materials which have been considered problematic and/or, difficult to process in turned windrow systems (Compost New Zealand, 2007a).

2.2.3.2.1.1.1 Benefits and drawbacks of commercial composting

Commercial composting of source-separated organic waste presents great benefits including the production of high quality and valuable compost. It also involves more specialized levels of control of the composting process parameters, such as temperature, moisture and oxygen content (Adhikari et al., 2010; Martínez-Blanco et al., 2010).

Studies which employ life cycle assessment (LCA) tools to assess the environmental impact of commercial composting, however, have revealed that commercial composting may contribute to environmental issues such as global warming, ozone depletion and eutrophication (Andersen, Boldrin, Christensen, & Scheutz, 2012; Cadena, Colón, Sánchez, Font, & Artola, 2009; Martínez-Blanco et al., 2010; Rizki, Chevakidagarn, & Danteravanich, 2015).

Commercial composting also involves an additional municipal expense with respect to the collection and transportation of organic waste, alongside associated increases in noise pollution and traffic volume (Adhikari et al., 2010; PCC, 2007). For instance, Lleó et al. (2013) report that transport energy needs for commercial composting are 18.6-fold the energy required for home composting when a comparative LCA of the two processes are performed.

2.2.3.2.2 Home composting

Home composting can be defined as the self-composting of organic waste and the application of the finished compost in a garden owned by private householders (Martínez-Blanco et al., 2010). Thus, in home composting, the householder can be recognised as the waste producer, the recycler and the end user of the finished compost products (Andersen, Boldrin, Christensen, & Scheutz, 2011). Home composting is also referred to as 'backyard', 'amateur', 'on-site', or 'small-scale' composting.

The home composting process usually involves the gradual addition of feedstock to a home composting system[h] and over time natural decomposition takes place to form the finished compost (European Bioplastics, 2015). The feedstock is sometimes referred to as 'greens and browns', where the former represents nitrogen rich wet materials and the latter, high carbon, dry materials (Schwarz & Bonhotal, 2011). The relative amount of green and brown materials required for the home composting process is referred to as the C/N ratio (refer to Table 10 for this ratio). Different types of feedstock can be combined to obtain the desired C/N ratio for higher composting efficiency. Common home composting feedstock types and their functions are presented in Table 5.

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[h] It can also be referred to as compost bin. Thus, both terms are used interchangeably in the present study.

Table 5 Feedstock treated via home composting and their respective functions. Adapted from (Auckland City Council (ACC), 2011; Ayre, 2012; Chen, Moore, & de Haro-Marti, 2012; City of Casey, n.d.; Dundee City Council (DCC), 2016; PCC, 2007; PNCC, n.d.; Rynk et al., 1992; Schwarz & Bonhotal, 2011).

Feedstock	Examples	Functions
Brown materials (rich in carbon)	Hay, straw, untreated sawdust, garden pruning, cardboard/paper, twigs, dry leaves, tree pruning, bark, wood ash, wood chippings, crushed shells.	• Provide energy for composting organisms. • Absorb excess moisture. • Enhance the structure of the compost pile. • Facilitate airflow, prevent compaction and keep the pile porous.
Green materials (rich in nitrogen)	Fruit and vegetable waste, sheep or horse, sheep, cattle, rabbit and poultry manure, egg shells, tea bags/coffee grounds, fresh grass clippings, raw uncooked kitchen scraps, weeds without seeds, seaweeds.	• Provide nutrients (proteins) and moisture for composting organisms. • Essential for reproduction in composting organisms.

2.2.3.2.2.1 Home composting systems

Home composting can be undertaken in a homemade or manufactured compost bin or simply in an open pile (Karnchanawong & Suriyanon, 2011). The bin types, whether homemade or manufactured, come in many shapes and sizes. Each type is simply designed to facilitate a naturally occurring process to ensure that the essential composting parameters are available. The main differences between homemade and manufactured home composting systems are outlined in Table 6.

Table 6 Differences between homemade and manufactured compost bins

Homemade compost bins	Manufactured compost bin
The compost pile is often uncovered.	The compost pile is usually covered.
Hatches are often absent at the bottom to access the finished compost.	Most types especially those made from plastic have hatches at the bottom to access the finished compost.
Offer a cost-effective method of home composting since the bins are made at home from materials such as wood, wire mesh, corrugated iron, bricks or scrap metals.	Manufactured by companies and are either sold directly to households by the manufacturers or through municipal authorities.

Moreover, home composting systems can either be single or multi-bin systems. The operational scheme used is, however, dependent on whether the system is homemade or manufactured, specifically with the multi-bin system. The various operational schemes employed in single and multi-bin home composting systems are outlined in Table 7.

Table 7 Single-bin and multi-bin home composting systems and the various operational schemes employed in each system

System type	Operational scheme
Single-bin system (for both homemade and manufactured compost bins)	The fresh feedstock is normally added on a daily or weekly basis to a compost bin containing partly decomposed and/or finished compost.
Homemade multi-bin system	Usually, consists of two to four compartments where the compost pile is created in one compartment and later transferred to the other compartment when the feedstock is partly decomposed or is finished.
Manufactured multi-bin system	Consists of either two, three or four layers. Each layer normally contains fresh feedstock, partly decomposed and/or matured compost respectively.

The operational schemes provided in Table 7 shows that relative to the single-bin system, fresh feedstock and finished compost are separated in the multi-bin systems.

2.2.3.2.2.1.1 Benefits and drawbacks of home composting

Encouraging and expanding participation in home composting schemes has the advantage of providing a cost-effective and sustainable approach to organic waste management via local organic recycling (Smith & Jasim, 2009). Knowledgeable and sound management practices and an effective home composting process will improve the QA of the finished compost, and provide a measure of environmental protection for the home garden (or possibly agricultural soils) receiving applications of compost (Mihai & Ingrao, 2016).

If source separation of organic waste is performed and critical parameters such as temperature and moisture content are properly monitored, home composting can also be a more practical and economically feasible option than commercial composting (Mihai & Ingrao, 2016). Table 8 presents potential benefits and drawbacks of home composting.

Table 8 Potential benefits and drawbacks of home composting. Adapted from (Abeliotis et al., 2016; Badan & Gajendra, 2005; Andersen et al., 2011; Boldrin, Andersen, Møller, Favoino, & Christensen, 2009; Colon et al., 2010; European Bioplastics, 2015; Lleó et al., 2013; Martínez-Blanco et al., 2010; Moore, 2005; Oliveira et al., 2016; Quirós et al., 2014; Tucker, Speirs, Fletcher, Edgerton, & McKechnie (2003); Vaverková, Adamcová, & Zloch, 2014; Vázquez et al., 2015).

Benefits	**Drawbacks**
Provides municipal authorities with a cost-effective method for organic waste management since organic waste is not collected and transported to commercial composting sites or landfills but is separated and treated at the source of generation.	Municipal authorities may have to provide incentives such as free or subsidised bins to ensure active participation of residents which reflect some form of financial investments.
Avoidance of major costs involved with material and energy investment in commercial composting infrastructure.	The cost of compost bins may deter households from undertaking the practice.
Home composters spend less money on waste disposal.	
Barriers to marketing waste-derived composts are of less importance to home composting since compost is produced for private use in the household's garden or soil.	
Reduces the amount of waste in the municipal waste stream since organic waste is separated at source.	The process is difficult to define and thus to measure.
Reduces the environmental effect from leachate produced from the decomposition of organic waste in landfills.	Poorly managed home composting systems can lead to leachate production.
Avoids emissions which would have been released from vehicles engaged in waste collection and transportation to commercial composting sites.	If poorly managed, direct emission of odours may occur during the process.
Direct control of the composting process and feedstock input by avoiding or reducing the addition of impurities.	Potential problems with insects and pests, which risks spreading diseases and causing a wider nuisance.
Negates the need for heavy machinery for turning and managing the compost pile thus, avoids the release of GHG from the energy used to operate this machinery in commercial composting facilities.	If poorly managed, it can lead to the emission of gaseous pollutants into the atmosphere thereby contributing to global warming.
It entails less land use.	
Production of quality compost as an organic addition for the garden or soil.	Production of heterogeneous compost.
Reduces the need for soil conditioning and the extraction or mining of peat based products.	Poorly managed home composting systems may result in a poor-quality compost which can affect soil quality or plants when applied to the garden or soil.
Avoidance of the use of inorganic fertilisers in the garden or soil.	In some countries like New Zealand, ash from 'Chromated copper arsenate' treated wood is sometimes added to the home compost pile and may result in contamination if added to a garden or soil[i].
	Many seeds and plant propagules are not pasteurised in home composting and may spread via compost application
Strengthens environmental awareness and social responsibility of householders.	Lack of willingness to participate, which means home composting is only relevant to a certain proportion of the population.
	Lack of knowledge, awareness, motivation and encouragement may result in a poor participation rate and as such may not impact on the waste diversion rate.

[i]This is also recognised as an issue in commercial composting

From Table 8, it can be observed that most of the drawbacks of home composting are associated with poor management practices. This shows that effective management and control of composting parameters are essential to ensure adequate composting process, to produce good quality compost and to reduce any harmful effects of the process and of the finished compost on the environment. It was also specified in Table 8 that the home composting process is difficult to define and, thus, measure. This may be attributed to the continuous addition of fresh feedstock to the compost pile which creates a heterogeneous and variable environment for microbes (Ermolaev, Sundberg, Pell, & Jönsson, 2014). This creates different composting processes like aerobic digestion, nitrification and denitrification, which may occur simultaneously, making it difficult to estimate parameters affecting emission sources (Ermolaev et al., 2014).

Regarding the lack of willingness to participate in the practice, lack of awareness and the attitude of householders, Smith and Jasim (2009) explained that such issues can be minimised by encouraging the willingness, knowledge and proficiency attitudes of householders through local council programs to enhance home composting practices.

The benefits and drawbacks of the home composting process provided above underpin one of the objectives of the present study, namely: to explore home composting operational schemes, to study the awareness and attitudes of composting households, to explore home composting problems, and to evaluate the QA of the home composting process and final product in Palmerston North.

3.0 Materials and method

3.1 Research project design process

The project design for the present study was made up of the following elements:

a. A literature review of previous international and New Zealand home composting and related studies.
b. A review of international and New Zealand best practice guidelines for home composting management (including an examination of relevant aspects of the New Zealand compost standard-hereafter referred to as NZS4454:2005).

c. Identification of the most relevant previous home composting studies, commonly recognised home composting best practice guidelines and insights from NZS4454:2005 for focused examination in the present study.
d. Development and implementation of an appropriate methodology for carrying out a home composting quantification and evaluation study in Palmerston North based on the assimilation and advancement of the findings from the selected previous home composting studies, international and New Zealand home composting best practice guidelines and NZS4454:2005.
e. A report on the development, field-trial and finalisation of a mixed-method home composting survey methodology which can be utilised in other jurisdictions, including a proposed home composting evaluation tool (HCET)/on-site physical assessment data collection tool.

3.1.1 Classification of literature employed in the development of the methodology

Based on the project design, the literature employed for the development of the methodology were classified under the following three headings:

a. Previous home composting studies internationally and within New Zealand.
b. International and New Zealand best practice guidelines for home composting management.
c. Compost standards.

3.1.1.1 Previous home composting studies internationally and within New Zealand

The key terms used in search of the literature on previous home composting studies were: ‘home composting’, ‘backyard composting’, ‘decentralised composting’, ‘small scale composting’, and ‘amateur composting’, in combination with the terms ‘organic waste’, ‘household organic waste’, ‘bio-waste’ and ‘biodegradable waste’. The key journals from which this literature was selected included: the Waste Management Journal, Biocycle, Journal of Waste Management and Resources, and the Resources, Conservation and Recycling Journal.

After the literature was selected, the type of home composting study was then taken into consideration. Home composting studies which were of relevance to the present study were those that

a. examined how home composting has been utilised to increase organic waste diversion from landfills.
b. explored home composting systems, practices, awareness and attitudes, and issues.
c. investigated the home composting process and compost QA.

This was done to ensure that the selected literature aligned with the objectives of the present study. Key observations from the selected previous home composting studies are presented in Table 9.

Table 9 Overview of home composting studies identified and reviewed from international and New Zealand academic peer-reviewed scientific literature and reports. As previously explained, the highlighted sections of the table represent the types of home composting studies relevant to the objectives of the present study.

Type of home composting study	Source/Location	Objective of study	Key findings relevant to the present study
Compost QA	• Barrena, Font, Gabarrell, and Sánchez (2014) • Spain	Comparison of compost QA produced from home composting and commercial composting.	• Home composting, if properly managed, can achieve the same or better level of stability than commercial composting. • To obtain good quality compost, good home composting practices are important.
Environmental impact assessment of home composting	• Quirós et al. (2014) • Spain	Comparison of two home composting units with high and low emissions to observe the impacts of the gaseous emissions of the composting process on the environmental performance of horticultural systems.	• Compost quality is highly dependent on the process management, environmental conditions, the type of feedstock, and the mixing frequency. • To guarantee a good quality product along with low emissions, the management of the home composting process plays a vital role.
Environmental impact assessment of home composting	• Adhikari et al. (2010) • Europe and Canada	Examination of on-site organic waste composting strategies using a combination of centralized composting facilities, community composting centres and home composting systems.	• To recycle a high portion of organic waste through home composting processes, the prerequisite is the participation of waste producers, i.e. households.
Compost QA	• Alexander (2007) • the UK	Examination of the effects of vessel type and turning on the resultant temperature, nutrient concentrations and physical characteristics of compost produced from home composting.	• The longer the compost is allowed to mature, the better the product. • Insulating compost vessels and providing some form of lid offer insulation and protect the pile from worst weather conditions like heavy rainfall, which can cool the temperature very quickly.

			• Vessel volume rather than type is important in generating, and to an extent, maintaining heat. • Turning vessels lead to an increase in mean temperature.
Home composting operational scheme, practices, awareness and attitudes, and issues	• Tucker et al. (2003) • the UK	Exploration of the reasons behind the positive response to a promotional offer of free/subsidised compost bins among some households in Fylde, Blackwood, Inverclyde and University of Paisley municipalities.	• The strongest motivations for home composting among the participants were the reuse of organic waste and the saving of waste and landfill space. • Home composting participation can be increased markedly through promotions. • The real problem associated with home composting appears to be that many individuals experiencing problems are not seeking to increase their knowledge and find solutions.
• Amount of organic waste recycled through home composting. • Home composting operational scheme, practices, awareness and attitudes, and issues	• Gillan, Leland Jr, Davies, and Walsh (2003) • New Zealand	Reducing kerbside waste volumes by promoting home composting.	• The presence of compost bins in the kitchen and yard serve as continuous prompts for composting behaviour. • People interested in home composting are more likely to participate in the scheme when given the means as well as the reduced cost motivation like the provision of compost bins at a reduced rate. • Provision of resources and information results in significant reduction in the volume of waste. • The lower socioeconomic status (SES) control group was more willing to increase their conservation behaviour than the higher SES group. • Income alone is an inadequate predictor of conservation behaviour when the resources needed for that behaviour are made equally available to both high and low-income areas.

• Amount of organic waste recycled through home composting • Home composting operational scheme, practices, awareness and attitudes, and issues	• Mustapha (2013) • Canada	This study is based on data from the 2011 Households and the Environment Survey (HES), which was conducted as part of the Canadian Environmental Sustainability Indicators initiative. Respondents were asked to report if they had participated in any type of composting and the methods that were used to compost either kitchen or yard waste.	• In 2011, over 61% of Canadian households had participated in some form of composting which is up by 38% points from 1994. • 40% of all households reported composting kitchen waste • 68% of households with a lawn or garden reported composting yard waste. • In 2011, 63% and 60% of Canadian households that had composted their yard waste and their kitchen waste respectively, used a kerbside collection system. The remainder used a compost bin or pile or other methods to compost. • The type of dwelling a household occupied was directly correlated to the rate of composting. • Over 50% of households in detached or single dwellings reported composting their kitchen waste, compared to 22% of households living in apartments which show that the fact that many apartment dwellers can find it difficult to compost.
• Amount of organic waste recycled through home composting • Home composting operational scheme, practices, awareness and attitudes, and issues	• Department of Sanitation (DOS) (1999) • USA	A comprehensive evaluation of the diversion potential, participation rate, and cost effectiveness of a residential home composting program.	• 92 percent of the participants reported that they were still composting eight months after receiving a bin. • A comparison of the price of waste export against the costs of a slightly simplified compost bin distribution program revealed that the latter was the best option.
• Environmental impact assessment	• Andersen et al. (2012) • Denmark	The performance of a full LCA on the home composting of organic waste.	• Home composting units performed well compared to incineration and landfilling.

of home composting			• Home composting is a good alternative for disposal of organic waste.
• Home composting operational scheme, practices, awareness and attitudes, and issues	• William, Kevin, and Roberts (2002) • USA	Identification of factors associated with household home composting behaviour.	• To encourage home composting, programs might be designed to increase the visibility of composting, and discourage the attitude that home composting requires too much effort to be worthwhile. • Communities may employ a unit pricing or "pay-as-you-throw" system for financing solid waste management, which would give a clear economic incentive for households to practice home composting.
• Environmental impact assessment of home composting • Compost QA	• Colon et al. (2010) • Spain	Preparation of a detailed inventory of energy and material resources consumed during home composting; determination of the environmental impacts associated with home composting; detection of critical stages of home composting from an environmental perspective; and assessment of the QA of the finished compost.	• The average temperature during the study period was 37.4 °C which is appropriate for the growth of microbes. • From both technical and environmental viewpoint, home composting is a suitable treatment option for organic waste such as raw fruit and vegetable waste.
Home composting operational scheme, practices, awareness and attitudes, and issues	• Miljoestyrelsen and Gies (1996) • Canada	Attainment of 80 percent home composting in single family homes.	• Analysis of the kerbside waste composition after the home composting program was set up indicated that the amount of kitchen organic waste has reduced from 283 kg/household/year to an average of 140 kg/household/year.
• Amount of organic waste recycled through home composting	• Karnchanawong and Suriyanon (2011)	A performance study of home composting using bins with different types of passive aeration.	• Temperature is the most important indicator of the efficiency of the home composting process.

• Compost QA	• Thailand		• Bins with holes around the bottom and ventilation pipe in the middle produce a higher rate of organic waste biological decomposition.
• Amount of organic waste recycled through home composting • Compost QA	• Cristoforetti, Silvestri, and Zorzi (1998) • Italy	Verification of the performance of a composter designed for family use.	• It is good practice to mix finished home compost with peat of 50 percent by volume before applying it to the soil.
Environmental impact assessment of home composting	• Martínez-Blanco et al. (2010) • Spain	Quantification of material requirements, energy consumption, gaseous and waste emissions associated with home and commercial composting; and the determination of their environmental impacts using life cycle assessment.	• The physicochemical properties of the finished composts derived from both home and commercial composting indicated that the products are stable. • As compared to home composting, commercial composting implies higher consumption of energy during the process, larger transport requirements for the organic waste collection and higher generation of waste.
Home composting operational scheme, practices, awareness and attitudes, and issues	• Karkanias et al. (2016) • Greece	Evaluation of home composting scheme in the municipality of Neapoli-Sykies.	• The prerequisites for implementing home composting schemes include public awareness which is likely to positively influence people’s behaviour. • People do not compost due to the low capacity of the compost bin, and the weather which prevents them from taking organic waste to the bin.
Home composting operational scheme, practices, awareness and attitudes, and issues	• Johnson (1995) • USA and Canada	Determination of the status and extent of national home composting education programs, and effective methods for reaching large audiences and motivating them to participate.	• A barrier to overcome in home composting schemes is residents who lack knowledge on the benefits of home composting. • Common reasons for not composting include odours, flies, rodents, and the time or effort required. • Ways of improving home composting programs include the promotion and broadcasting of the program by media

			involvement, use of demonstration sites, and the education of students on home composting.
Amount of organic waste recycled through home composting	• Anon (1996) • USA	Demonstration of the effectiveness of home composting, on-site management and source separation of organic kitchen waste and garden trimmings, with an emphasis on proven low-cost and low-technology systems.	• Audits of the components of the waste stream conducted before, during and after the pilot recorded a 33% reduction in readily compostable organics by participants.
• Home composting operational scheme, practices, awareness and attitudes, and issues Compost QA	• Faverial and Sierra (2014) • Guadeloupe	Examination of QA of finished home composts produced under tropical conditions by households in Guadeloupe; assessment of the management problems observed during composting, and evaluation of the effect of soil and climatic conditions on compost quality.	• The most frequent problem was the presence of cockroaches, ants, Scolopendra, tree roots and rodents inside the composter. • None of the participants stopped composting even though they experienced problems with the process. • Most of the end products were of suitable quality. • Although no one reported slow waste decay, five products presented waste residues and bad smells which show participants were not yet familiar with the use of the composter. • The quality of compost derived from home composting is highly dependent on parameters such as turning and wetting.
• Environmental impact assessment of home composting • Compost QA	• Ermolaev et al. (2014) • Sweden	Determination of the influence of real-life management on greenhouse gas emissions from home composts under Swedish conditions, and to assess the seasonal variations in emissions and in compost management.	• A range of home composting process parameters like moisture and temperature can significantly affect the development, efficiency and environmental emissions of home composting. • Temperatures within 40–60 °C influence methane and nitrous oxide emissions while temperatures above 60–65 °C could impede the overall decomposition rate. • pH of compost directly reveals the compost dynamics and is affected by management practices.

3.1.1.2 International and New Zealand best practice guidelines for home composting management

The implementation of international best practice and experience offers a great opportunity to accelerate waste minimisation activities and standardise best practice across New Zealand (MfE, 2007). As previously discussed in Section 1.1.3.1, home composting is an organic waste management method, commonly practised in Palmerston North, which results in diversion, recycling and beneficial use of organic waste. Home composting can, therefore, be considered as a critical waste minimisation activity for the City. An application of national and international home composting best practice guidelines to that of Palmerston North is, therefore, consistent with the recommendation offered by the Ministry.

Additionally, the comparison of a municipality's home composting practices, operational schemes and finished products with national and international best practice guidelines provides useful information which serves as a basis for making decisions when developing new home composting programs or improving existing ones.

Information from the review of international and New Zealand best practice guidelines for home composting management was, therefore conducted to enable a comparison with that of Palmerston North (Table 10). The best practise guidelines were arranged according to the commonly recognised ones from the various literature and reports examined. This part of the literature review provides a clear sense of what is broadly understood as the key elements of good home composting practice. This novel analysis illustrates the 'level of consensus' amongst the selected 'good practice guides' in terms of the number of cited references (that is, the number codes in Table 10) in relation to the key DO'S and DON'TS. This novel data was utilised to inform and shape the research methodology in terms of both, the survey questionnaire and the on-site evaluation tool.

Table 10 International and New Zealand best practice guidelines for home composting management. Adapted from (ACC, 2011 **(1)**; Asia/Pacific Cultural Centre for UNESCO, n.d.; **(2)**; Ayre, 2012; **(3)**; Chartered Institute of Environmental Health, 2009 **(4)**; Chen et al., 2012 **(5)**; Christchurch City Council (CCC), 2014 **(6)**; City Of Casey, n.d. **(7)**; DCC, 2016 **(8)**; PNCC, n.d.; **(9)**; PCC, 2007 (10); Pears, 2009 (**11)**; Rynk et al., 1992 **(12)**;University of Illinois Extension, 2016) **(13).**

Dos	International and New Zealand best practices guidelines for home composting management	References
	The optimum moisture content for the compost pile should be between 50 and 60%. Water can be added to the pile when needed.	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
	Mixing/turning of the compost pile is crucial for aeration, rapid decomposition, removal of excess heat and addition of moisture to the pile.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13
	A C/N ratio of 25-30 to 1 that is, 25-30 parts carbon to 1-part nitrogen (more green materials and less brown materials) is essential.	1, 3, 4, 6, 7, 8, 9, 10, 11, 13
	Shredding/size reduction of large feedstock (that is to make partial size distribution more uniform) before home composting is vital for rapid and sustained decomposition.	1, 3, 4, 8, 10, 11, 13
	Feedstock should be layered thinly and uniformly when starting a new pile.	1, 6, 7, 8, 10, 11, 13
	It is essential to have a sturdy and enclosed home composting system, or piles on the ground can be covered with underfelt, tarpaulin or plastic sheet.	1, 6, 7, 9, 10, 11, 13
	Physical characteristics of good quality finished home compost include dark brown to black colour, earthy smell and crumbly texture.	1, 2, 3, 6, 7, 10, 11
	Bulking agents (dry brown materials) can be added to saturated, smelly or slimy pile as well as to increase porosity.	1, 3, 5, 8, 10, 13,
	Home composting systems should be sited proximally with good access to the house and a water source, sheltered and on a level area with good drainage.	1, 2, 6, 8, 9, 13
	It can take between 2-18 months to obtain finished compost depending on the operational scheme, turning rate, type of feedstock, and time of the year. Decomposition is, however, more rapid in summer than winter due to excessive heat which accelerates decomposition.	1, 6, 7, 8, 9, 10
	The home compost pile formation or process should be started with a dry base of twigs to support good base for aeration and drainage.	1, 6, 7, 9, 10,
	It may be necessary to raise enclosed home composting systems on a few bricks, wire mesh or chicken wire.	1, 4, 6, 7, 13
	The recommended pile dimension is at least 1m high x 1m wide x 1m deep. This helps to form the critical mass to retain moisture content and temperature.	1, 5, 6, 7, 13

	Food waste is to be buried in the centre of the pile, during turning or covered with more brown materials in case there is an abundance of insects or pests.	1, 3, 6, 13
	The optimum compost pile temperature should be in the range of 30 to 60°C.	1, 7, 9, 13
	A small amount of soil can be added halfway through the layers to encourage microbial activities and prevent insects.	6, 8, 11, 13,
	More green materials can be added to a slow or ineffective compost pile, to revitalise the process.	1, 3, 10, 13
	A small amount of lawn clippings should be added as the addition of a larger amount can prevent the pile from composting well.	1, 6, 7
	Compost activators or accelerators can be added to the compost pile to speed up the natural breakdown process.	1, 8
	Lime and untreated wood ash can be sprinkled on the pile to balance pH, reduce smell and fruit flies.	1
	Coarse finished compost should be sieved through chicken netting before use and the coarse material returned to the pile for further composting.	6
	Pest control mechanisms include regular inspection within and around the compost pile for the presence of burrows of rodents.	4
Don'ts	Input: Meat, fish and bones should not be added because they may not break down in the composting time frame and may attract vermin.	1, 4, 7, 8, 9, 10, 11, 13
	Input: Cat, dog and human faeces should not be added as they can generate odour and may contain and transmit parasites and diseases.	1, 4, 7, 8, 9, 10, 11
	Input: Diseased plants, large woods, treated wood, invasive weeds, fertilisers and general toxic material should not be added since they may be saturated with harmful chemicals.	1, 6, 7, 8, 9, 10,11
	Input: Baked, cooked and processed foods, beer and sugary or carbonated drinks should not be added to the compost pile as they attract vermin and insects (such as ants).	4, 6, 7, 9, 10, 11
	Input: Oils, fats and dairy should be avoided as the fats and oils cover the ingredients and smother the bacteria, and are also unable to break down.	1, 4, 6, 9, 10, 11
	Input: Coal ash, disposable nappies, used tissues and bamboo should not be added to the pile.	1, 4, 10, 11
	Home composting systems should not be sited in an area where water will pool and risk becoming stagnant causing bad odour.	5, 8, 11, 13
	Home composting systems should not be sited under direct sunlight and areas exposed to strong winds to prevent drying and cooling of the pile.	9, 13
	Input: Citrus, onions and garlic should not be composted due to their strong smell inhibiting the bacteria around it.	7

3.1.1.3 Compost standards

Compost standards seek to provide safety for consumers as well as a template for compost operators to attain safe, hygienic, efficient and environmentally compliant operations (Compost New Zealand, 2007a). Nevertheless, standards are by nature voluntary and are designed to encourage and guide operational quality. In a general sense, standards offer a foundation for establishing consistent and satisfactory minimum levels of quality operations, safety and reliability (Compost New Zealand, 2007a).

Most compost standards internationally and in New Zealand are not designed to be applied to home composting operations (Ontario Ministry of the Environment, 2012; Compost New Zealand, 2007b; Standards Australia Committee, 2003; Standards New Zealand, 2005). Due to this focus on commercial composting, there appears to be a lack of applicable standards by which home composting processes can be evaluated for process and finished product QA. However, as previously stated, decomposition, be it in commercial or home composting contexts, is a generic and broadly similar biological process.

Commercial composting standards, therefore, offer a reference point and 'degree of relevance' for evaluating home composting processes and product QA. However, this degree of relevance must not be interpreted as a direct correlation. Additionally, due caution, knowledge and experience have been exercised in drawing on commercial composting standards for the evaluation of the QA of home composting processes and product. A carefully considered application and adaptation of some of the key principles and practices outlined in compost standards to the context of home composting can also offer a scientific and technical basis for evaluating the QA of the home composting process and finished compost.

In New Zealand, commercial composting operations can secure accreditation by complying with NZS4454:2005. NZS4454:2005 establishes the chemical, physical and biological quality standards for the products derived from composting processes. It also outlines the pathway (general requirements and operational best practices) through which producers can achieve the guidelines it provides.

In addition, NZS4454:2005 defines compositional and compliance requirements, sampling methods for composts, soil conditioners and mulches, alongside testing methods for determining parameters such as pH, moisture content and electrical conductivity of composts, soil conditioners and mulches. A summary of the key provisions of NZS4454:2005 is illustrated in Figure 5.

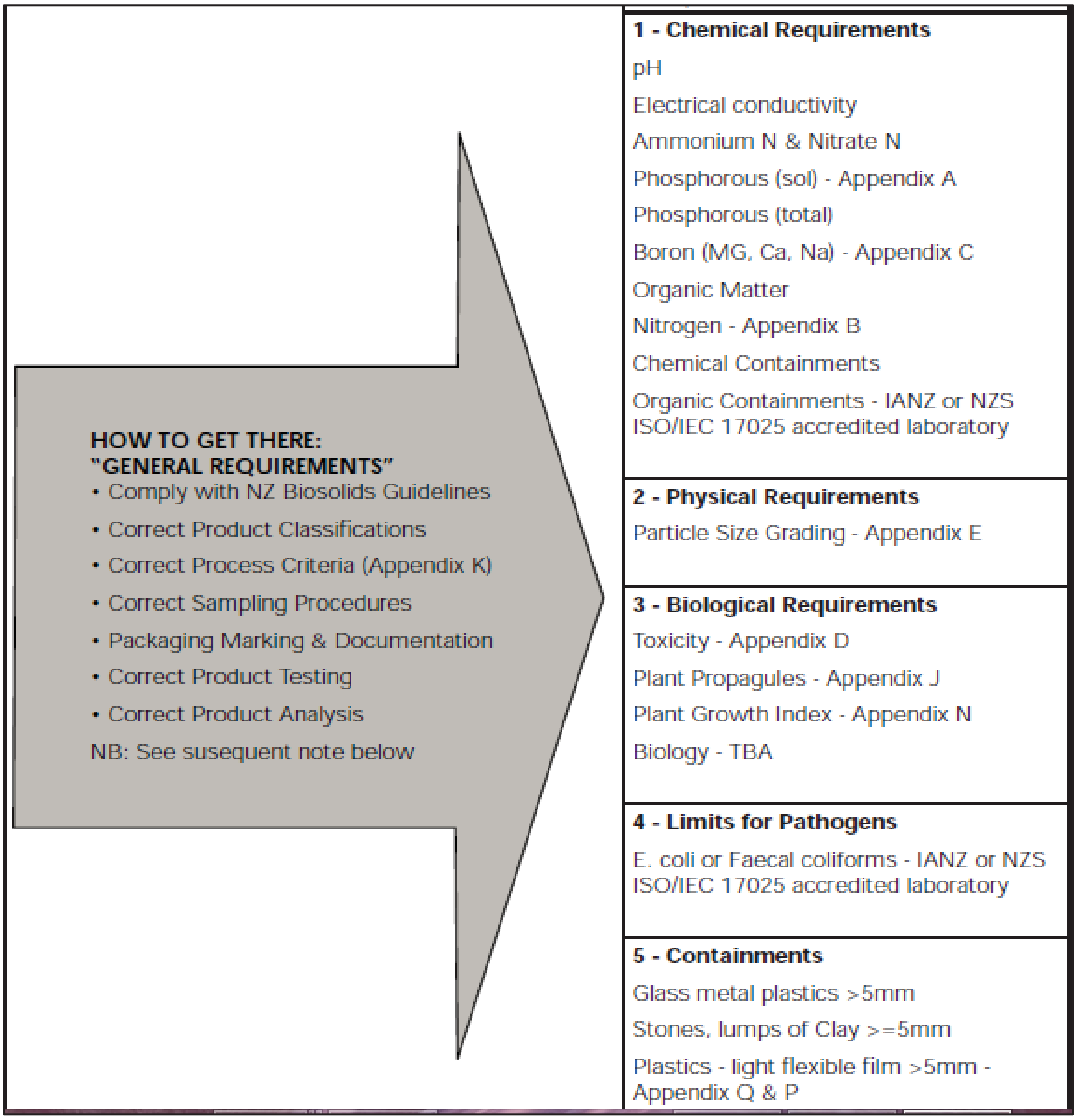

Figure 5 A graphical overview of the key provisions of NZS4454:2005. Source: (Compost New Zealand, 2007b)

The categories outlined in Figure 5, aid commercial composting operators in undertaking best management practices as well as in ensuring that essential composting parameters are available to derive compost, which does not present any hazardous effects to the environment or to public health when applied to agricultural land or to the soil.

3.1.2 Development of a methodology for conducting a home composting quantification and evaluation study in Palmerston North

The findings from the reviews of previous home composting studies, international and New Zealand home composting best practice guidelines, and the insights gained from the examination of NZS4454:2005 were grouped under the following two headings to develop a methodology for conducting a home composting quantification and evaluation study in Palmerston North.

a. Methods employed for data collection in previous home composting studies.
b. Home composting evaluation/QA tools.

3.1.2.1 Methods employed for data collection in previous home composting studies

The methods employed for data collection in some of the previous home composting studies are summarised in Table 11. This was done to aid in the selection of a data collection method that is cost-effective, less time-consuming and will yield a reasonably high response rate in the present study.

Table 11 Survey methods employed for data collection in selected previous home composting studies. The highlighted sections of the table mostly correlate with the objectives and scope of the present study.

Selected study	Survey method	Sampling pool	Response rate (%)	Objectives of study / Subject questions
Tucker et al. (2003)	• Door-to-door survey • Postal survey	849 households (200 in Fylde, 228 in Blackwood, 327 in Inverclyde and 94 in University of Paisley)	57.8	• Main reasons for taking up promotional bins. • Important ratings of several factors in a home composting decision.
Gillan et al. (2003)	• Door-to-door survey	196 households (102 in a high SES area and 94 in a lower SES area.	26.5	• The agent responsible for rubbish collection. • Interest in buying a promotional compost bin.
DOS (1999)	• Postal survey • Telephone survey • Door-to-door survey	116 households	9.4	• Willingness to volunteer in the study • Reasons for not home composting. • Recycling and waste management attitudes.
Johnson(1995)	• Door-to-door survey	1292 households (725 were bin owners for a specific period, 127 households with newly placed compost bins and 440 participants that had already been interviewed but relayed operational problems during the first visit).	65.9	• Continued or possible participation in the home composting scheme. • Satisfaction with the amount of compost produced. • Issues and motivation to continue home composting.
Anon (1996)	• Email	539 households	46	• Onsite yard trimming management method. • Effectiveness ratings for home composting program elements. • Barriers to expanding home composting participation. • Suggestions for implementing new home composting programs and/or improving existing ones.

It can be observed from Table 11 that most of the previous home composting studies which employed door-to-door survey or combined door-to-door survey with other data collection methods, obtained a reasonably high response rate. A door-to-door survey is usually a form of a personal/face-to-face interview. Although this form of data collection method is effective and robust, it is relatively time and cost-intensive (Fowler, 2014) which may prove prohibitive in the present study context. Considering the scope of the present study, and the time and resources available, employing a door-to-door survey as a single method of data collection was not feasible. It was, therefore, considered essential to combine the door-to-door survey with other data collection methods.

The combination of two or more data collection methods for survey research has been reported to improve overall response rate and result in strong data (Christian, Dillman, & Smyth, 2008; Fowler, 2014). For instance, it can be observed from Table 11 that a combination of door-to-door survey and telephone/postal/mail survey were successfully utilised to collect data in the previous home composting studies. According to Fowler (2014), a combination of door-to-door, telephone, postal and email data collection methods is likely to be a cost-effective approach and can also result in a high response rate.

Regarding the use of telephone surveys, the increasing number of telemarketing, answering machines and caller identification systems has enabled potential respondents to employ gatekeeper technologies to screen calls, specifically calls from unknown numbers (Bonnel & Le Nir, 1998; Hollier, Pettigrew, Slevin, Strickland, & Minto, 2016; Lipps & Pekari, 2016; Rocheleau et al., 2012). In New Zealand, for instance, most of the calls from the telecommunication companies are outsourced to India which has resulted in a generally negative reaction of New Zealanders to overseas-sounding voices over the telephone. This may affect the response rate when telephone survey is employed as a data collection method.

Nevertheless, as a time and cost-effective method of data collection, telephone surveys can contribute to representativeness by enabling a larger sample size to be studied which may avert any possible low response rate. Telephone surveys in comparison with door-to-door personal interviews are also less time-consuming and yet can produce high-quality data (Díaz de Rada, 2011; Fowler, 2014; Nardi, 2014). There is also the potential of collecting data easily and quickly from a geographically dispersed sample, including those in remote rural areas (Boland, Sweeney, Scallan, Harrington, & Staines, 2006). Telephone surveys have, therefore, been proposed as being quicker than personal interviews of comparable sizes (Fowler, 2014).

Postal survey as a mode of data collection has been reported to be effective for general population surveys (Fowler, 2014). However, according to Fowler, to obtain a high response rate, small incentives and extensive and appropriate follow-up procedures may be required. Additionally, a high cost can be incurred from the cost of postage as well as clerical time for mailing. The use of postal survey as a mode of data collection was, therefore, considered time-consuming and costly in the present study context.

Email surveys, as explained by Fowler (2014), involve shorter data collection periods. They, however, require repeated contacts and reminders to maximise response rates (Fowler, 2014) which were anticipated to have an impact on the cost, time and resources involved in the present study. In addition, email surveys are restricted to samples of internet users and may require a comprehensive address list which is mostly unavailable for the general population (De Vaus, 2014; Fowler, 2014; Lipps & Pekari, 2016). Sending emails with study questionnaires may also result in spamming which can result in low response rate as well as poor quality data (De Vaus, 2014) in the present study.

According to Fowler (2014), in comparison to personal interviews and telephone surveys, postal and email surveys have the disadvantage of the interviewer not being involved in the data collection process. This was deemed unfavourable for the present study context because, in order to achieve the overall objectives of the present study, the involvement of the researcher was paramount in the data collection process.

Based on the potential limitations that postal and email survey methods could impose on the present study when employed, a combination of a telephone survey and door-to-door survey methods was employed. A large percentage of the study sample was, however, contacted through a telephone survey (Table 14) because, as previously discussed, telephone survey is less time-consuming.

A self-selection method (that is, by public appeal offered via a local newspaper article about the present study) was also proposed as an additional data collection method. According to Fowler (2014), a self-selected sample is produced when a researcher passively relies on people to volunteer to participate in the study. Any sample that is based on volunteering or self-selection will violate the standard that gives every member of the sampling frame the chance for selection (Fowler, 2014). Therefore, any data from such method does not present a statistically representative sample selection process and must be treated separately.

However, in spite of the limitation posed by self-selected research participants, additional data from this source may be of some benefit in the present study context. In case the data obtained from the combined telephone and door-to-door survey were too small for a significant data analysis of the volume of organic waste diverted from landfill and for the evaluation of the QA of the process and compost in the City.

Data obtained from this data collection method was, however, managed carefully and ring-fenced for separate treatment and consideration from that of the combined telephone and door-to-door survey data.

3.1.2.2 Proposed 'Home Composting Evaluation Tool' (HCET)/on-site physical assessment data collection tool

Undertaking observation and evaluation aid our understanding of how a service or a programme is functioning by enabling the identification of opportunities for improvement (Department of Sustainability Environment Water Population and Communities (DSEWPC), 2012). For instance, an observation and evaluation of the home composting process and finished compost in Palmerston North will provide an understanding of the QA of the process and finished compost. Additionally, it will allow for the identification of necessary improvements. The following sections provide information on how the proposed HCET/on-site physical assessment data collection tool was developed.

3.1.2.2.1 Findings from the review of international and New Zealand home composting best practice guidelines

Commonly recognised 'priority parameters' identified by charting the 'levels of consensus' amongst home composting best practice guideline literature, as addressed by the various authors in Table 10 are presented in Table 12.

Table 12 Common home composting best practice guidelines collated from a review of international and New Zealand best practice guidelines for home composting management

Parameters	Key observations
Location/siting of the home composting system	Important considerations include proximity to the house, neighbours, back door, kitchen and garden; nearness to a water source; visual appeal; accessibility during the various weather conditions; no evidence of stagnant water and water pooling; sheltered; located on a level area with good drainage; unexposed to direct sunlight and wind.
Design/construction of the home composting system	The home composting system should be sturdy, have a cover or be elevated on bricks/wire mesh.
Essential management practices	• Shredding increases the surface area of feedstock for effective microbial decomposition. • Layering helps to achieve the required proportions of green and brown materials (thereby producing the required C/N ratio). • Mixing/turning promotes aeration. • The addition of bulking agents or amendments enables the adjustment of the porosity and smell of the pile. • Covering of food waste prevents the attraction of pests, and reduces the smell.
Process parameters	Control and monitoring of process parameters are necessary to ensure an effective process and good quality compost. The parameters include: • Moisture content (50-60%). • C/N ratio (25-30 to 1). • Temperature (30-60°C). • Pile dimension (1m high x 1m wide x 1m deep). • Timeframe (>2 <18 months).

Materials to be excluded from the compost pile	The addition of the following materials to the compost pile may result in home composting problems such as the attraction of pests, emission of bad odours and slow home composting process: • Baked, cooked and processed foods. • Beer and carbonated drinks • Cat, dog and human faeces. • Oils, fats and dairy. • Meat, fish and bones. • Grass, diseased plants, large and treated wood. • Tins, glass and plastics. • Invasive weeds, fertilisers and general toxic material. • Coal ash, disposable nappies, used tissues. • Bamboo, flax and cabbage tree leaves. • Large amounts of lawn clippings.
Common home composting problems	Aside the addition of the wrong feedstock types, home composting problems can also be caused by poor control and monitoring of essential home composting parameters. Home composting problems comprise: • Non-decomposing pile. • Smelly pile. • Slimy pile due to high moisture content • Saturated or dry pile. • The presence of insects, rodents or pests. • Overheated or under-heated pile.
Physical characteristics of finished compost	A matured compost normally has a dark brown to black colour, an earthy smell, a crumbly texture with no recognisable feedstock.

3.1.2.2.2 Insights from NZS4454:2005

The sampling methods provided by NZS4454:2005 for obtaining a representative sample and for collecting samples from representative locations of a compost pile was considered relevant to the present study (refer to Section 3.1.4.1.5.1). Additionally, testing methods provided by NZS4454:2005 for determining the temperature and the moisture content of compost was applicable to the context of the present study.

3.1.2.2.3 Findings from selected home composting studies that assessed compost QA

The findings from the previous home composting studies which assessed compost QA are presented in Table 13. The common parameters analysed in the selected studies formed part of the parameters that were assessed in the present study for the evaluation of the home composting process and final product QA in Palmerston North.

Table 13 Parameters analysed in selected compost QA studies. The highlighted boxes indicate the common parameters analysed in these studies. pH, moisture content, C/N ratio and temperature were the most common parameters analysed and therefore, formed part of the parameters that were assessed for the evaluation of the home composting process and final product QA in Palmerston North.

Study	Moisture content	Organic matter content	Heavy metals content	C/N ratio	Temperature	pH	Electrical conductivity
Barrena et al. (2014)	✓	✓	✓	✓		✓	✓
Alexander (2007)				✓	✓	✓	✓
Colon et al. (2010)	✓	✓				✓	
Karnchanawong and Suriyanon (2011)				✓	✓		
Cristoforetti et al. (1998)	✓		✓	✓		✓	
Ermolaev et al. (2014)	✓				✓	✓	

3.1.2.3 Development of the proposed 'Home Composting Evaluation Tool' HCET/on-site physical assessment data collection tool

From the findings outlined in the previous sections, the following parameters were considered essential for undertaking a home composting QA evaluation in Palmerston North.

a. Physicochemical properties- temperature, moisture content and pH.
b. Process management- inputs/feedstock, shredding, blending/amendment, mixing/turning.
c. Physical characteristics (colour, smell and texture) of finished compost.
d. Siting, design and construction of the home composting system.

Subsequently, a proposed HCET/on-site physical assessment data collection tool was developed using the parameters listed above (refer to Appendix B). The tool aided in the evaluation and recording of observations and measurements made on home composting systems, process and finished products regarding the aforementioned parameters.

3.1.3 Methodology for a home composting quantification and evaluation study in Palmerston North

3.1.3.1 Development of the survey sample

The following sections outline the design parameters which were chosen to develop the survey sample of the present study. As discussed by De Vaus (2014), Fowler (2014) and Nardi (2014), these parameters were chosen to

a. seek results which can be reasonably generalised for the targeted population.
b. obtain a randomly selected sample.
c. obtain a representative sample.
d. obtain a statistically valid sample size.

3.1.3.1.1 Sampling frame

The sampling frame for the present study was the occupied dwellings in Palmerston North, as these households are where the activity of home composting takes place. There are fifteen suburbs in the City. Each suburb is unique and has distinct socioeconomic and demographic characteristics. Collectively the suburbs reflect the overall diversity and characteristics of the City. All fifteen suburbs were therefore included in the present study to ensure that the chosen sample was representative across the varying SES associated with the respective suburbs.

3.1.3.1.2 Sampling methods

Probability sampling methods comprising stratified random sampling, simple random sampling and systematic random sampling were employed in the present study. These were used because probability sampling methods are known to contribute to the representativeness, and validity of data collected (Lavrakas, 1993). The aforementioned characteristics of probability sampling methods also corresponded with the aims for choosing the design parameters for the survey sample. Figure 6 shows a graphical presentation of how the study sample for the present study was developed using probability sampling methods.

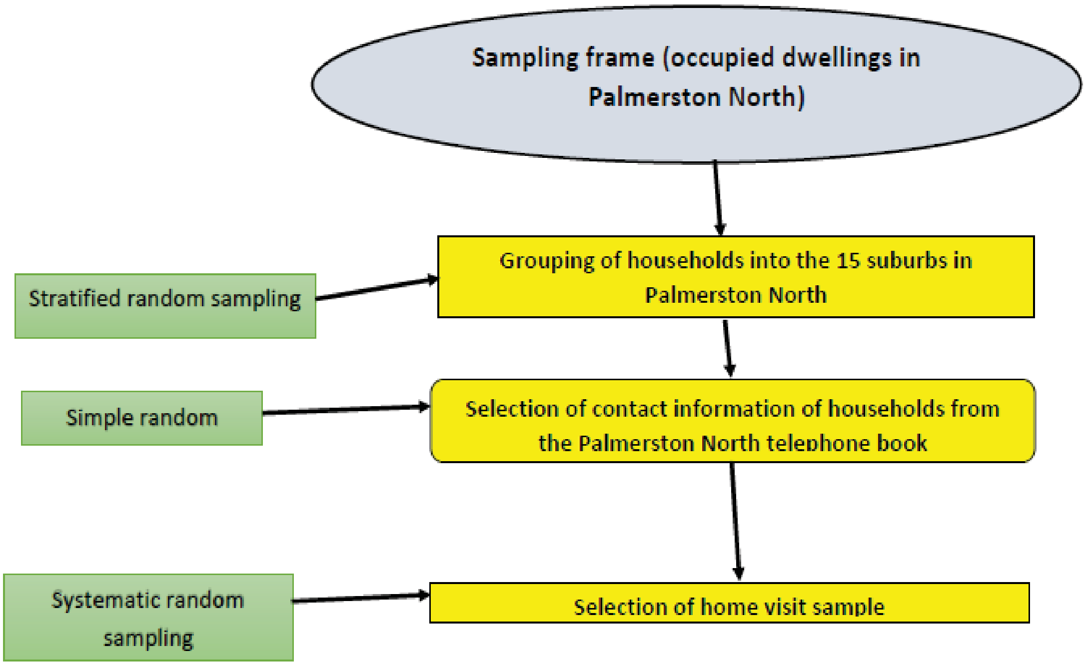

Figure 6 A graphical presentation of how the study sample for the present study was developed using probability sampling methods (stratified, simple and systematic random sampling methods)

3.1.3.1.3 Sample size

The targeted (final participating) sample size for the present study was 300 households which represented approximately 1% of the 29,892 occupied dwellings in Palmerston North (Statistics New Zealand, 2013). It was also equivalent to about 20 households per suburb. As a result of limited data on the number of households per suburb in the City, the 20 households per suburb were chosen on the assumption that the number of households in each suburb is almost similar.

As discussed by Lavrakas (1993), the sampling pool[j] needs to be larger than the targeted final sample size to mitigate the challenge of non-participation (that is when people are approached to participate in the present study). Therefore, a total of 600 contact lists

[j] The set of elements chosen from a sampling frame in which all may or may not be used in completing data collection for a given survey research (Lavrakas, 1993).

was generated using a simple random sampling method (Figure 6) to allow for households that may choose not to participate in the study as well as households that will be unavailable at the time of data collection. Table 14 shows a breakdown of the sampling pool and the targeted final sample size, split according to a combination of the two selected data collection methods.

Table 14 A breakdown of the sampling pool and targeted final sample size for the present study. The total sampling pool was 600. The contact list for the door-to-door survey was 60 households (that is, 10% of the total sampling pool) and the remaining 90% (540) was used for the telephone survey.

Method of data collection	Sample size	
	Sampling pool	Targeted final sample size
Telephone survey	540	270
Face-to-face interview	60	30
Total	**600**	**300**

3.1.3.1.4 Sample selection

A hand-drawn directory sampling method as described by Lavrakas (1993) was employed to randomly select the sampling pool from the Palmerston North telephone directory. This method was employed because telephone book-based samples are reported to be the most comprehensive and feasible way of sampling the general population (Fowler, 2014). Additionally, the use of the telephone book as the source document from which the sampling pool is selected has the advantage of easy availability and use (Lepkowski et al., 2007).

Prior to utilising the telephone book to identify contacts, the street names of each suburb were established from a combination of data obtained from PNCC and the New Zealand Post. This background information allowed any given contact randomly selected from the telephone book to be allocated to the correct suburb. The random contact selection from the telephone book listing can be identified by the following random selection method provided in Figure 7.

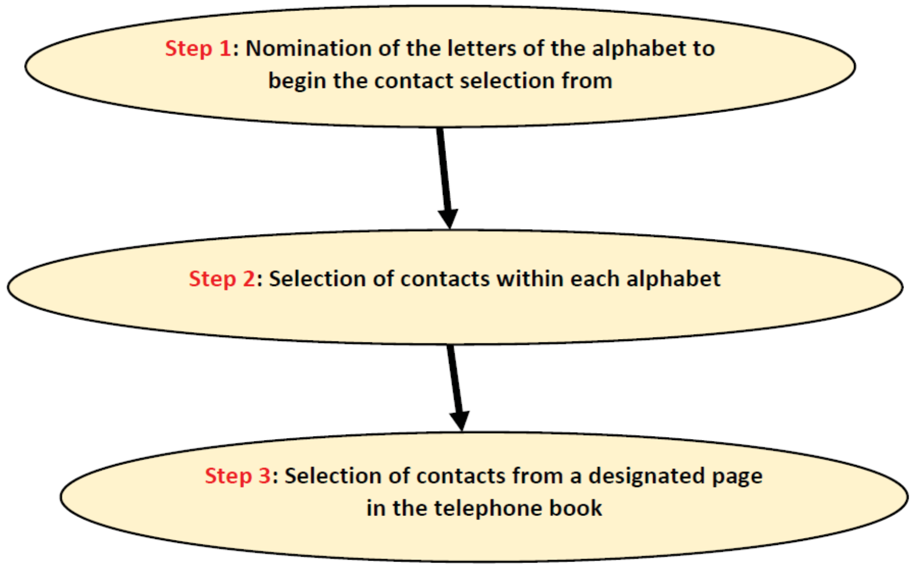

Figure 7 Steps taken in the present study for random contact selection from the telephone book

A description of the steps outlined in Figure 7 is as follows;

- Step 1: Numbers were allocated to the letters of the alphabet, that is from 1 to 26. For instance, A=1, E=5 and Z=26. Random numbers were then generated by setting 1 and 26 as the minimum and maximum numbers respectively. The letters of the alphabet were changed after every 10 minutes using the generated random numbers.

- Step 2: The page numbers of the pages in which each letter of the alphabet appeared in the telephone book were used to generate random numbers to determine where to start contact selection within each letter of the alphabet.

- Step 3: A 30cm ruler (which provides a fixed parameter) was employed to select contact information from designated pages[k] in the telephone book. Random numbers were generated by setting 1 as the minimum number and 30 as the maximum number. The generated numbers were then used for the selection of contacts from each page by placing the 30cm rule vertically on the designated page and selecting the contact lists that appeared on/around the designated number.

[k] A page that has already been selected in step 1

An illustration of how contact information was selected from designated pages in the telephone book with the 30cm ruler is shown in Figure 8.

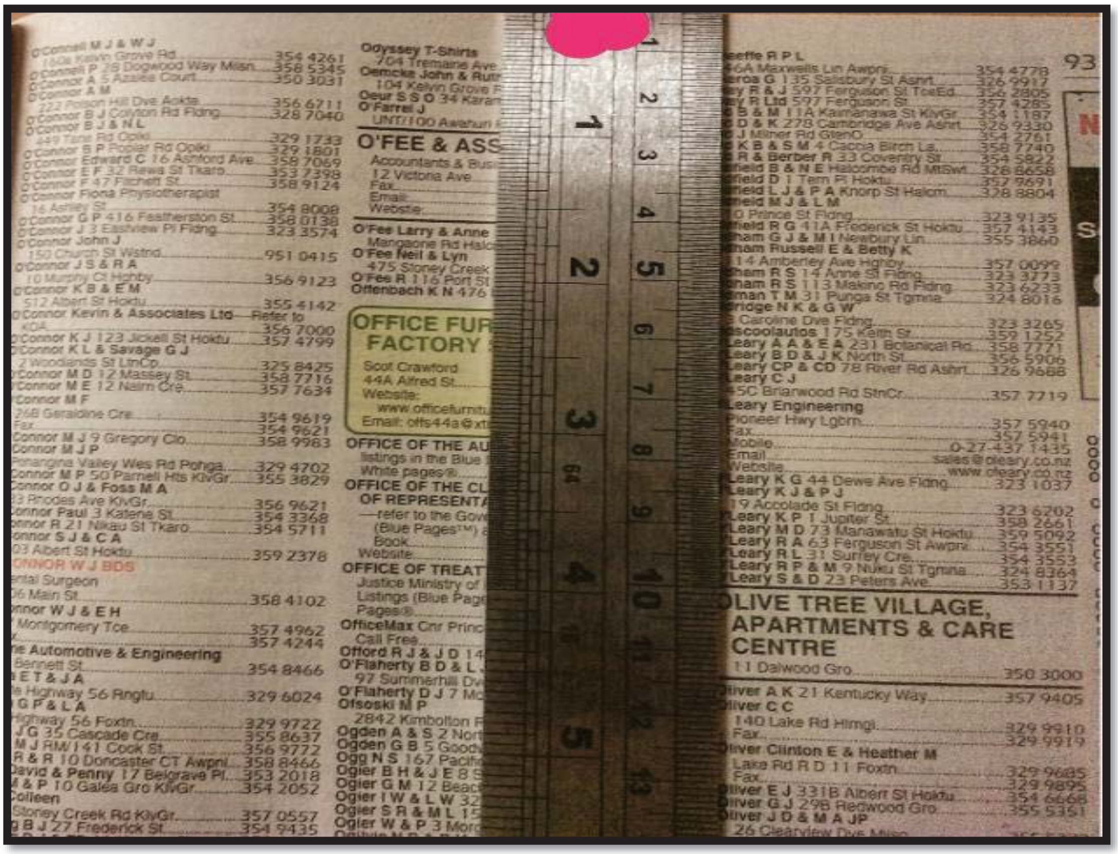

Figure 8 An illustration of how households' contact information was selected from designated pages in the telephone book. In this case, the household contact that falls on the 1cm mark was selected (that is, O'Connell and Okeeffe) to form part of the list. Odyssey T-shirts was not selected because it was a commercial contact.

The selected household contacts' information (name and telephone numbers) were assigned to their respective suburbs using the addresses (street names and street numbers) provided in the telephone book. The random selection of contacts continued until the full requirement of contact lists for all the 15 suburbs had been completed. This enabled the completion of the full city-wide socio-economic/suburb representative contact list.

Table 15 presents the proportion of sample size per suburb based on the 600 randomly selected contacts. As previously stated in Section 3.1.3.1.3, an assumption was made that the number of households per suburb was approximately equal when the sample size was being developed. 20 households per suburb were, therefore, chosen to obtain a representative sample. However, the random contact selection method employed revealed that there is disproportionality among the 15 suburbs in the City with respect to the number of households. For example, as many as 84 households were recorded on the 600-household contact list for Hokohwitu while Longburn recorded 6 households (Table 15).

Table 15 Proportionality distribution across the fifteen suburbs in Palmerston North used in the present study

Suburbs	Total sampling pool per suburb (that is, approximately 2% of the 29,892 occupied dwellings in Palmerston North)	Percentage of the total sampling pool per suburb (rounded)	Telephone survey		Door-to-door survey	
			Proportion of total sampling pool per suburb (rounded)	Targeted final sample size per suburb	Proportion of total sampling pool per suburb (rounded)	Targeted final sample size per suburb
Aokautere	18	3	16	8	2	1
Highbury	46	8	41	21	5	2
Milson	52	9	47	23	5	2
Terrace End	41	7	37	18	4	2
Awapuni	58	10	52	26	6	3
Hokowhitu	84	14	76	38	8	4
Pnth[l] Central	56	9	50	25	6	3
Westbrook	20	3	18	9	2	1
Cloverlea	20	3	18	9	2	1
Kelvin Grove	43	7	39	19	4	2
Roslyn	41	7	37	18	4	2
West End	39	7	35	18	4	2
Fitzherbert	23	4	21	10	2	1
Longburn	6	1	5	3	1	1
Takaro	53	9	48	24	5	3
Total	**600**	**100**	**540[m]**	**270**	**60[n]**	**30**

[l] Palmerston North

[m] The telephone survey sample pool was set at 90% of the total (that is, 540 for a target of 270)

[n] The door-to-door survey sample was set at 10% (that is, 60 for a target of 30).

3.1.4. Data to be collected in the present study

3.1.4.1 Exploration of home composting operational schemes, awareness and attitude, and problems

Reviews of the previous home composting studies which explored home composting operational schemes, awareness and attitudes, and issues (Table 9) show that people seem to lack knowledge regarding the implementation of the home composting process. Furthermore, the studies revealed that this lack of knowledge has resulted in low participation rates in home composting programmes. The studies, however, revealed that people interested in home composting were more likely to undertake the practice when given the means to do so. Based on these observations, data on home composting operational schemes (home composting systems and management practices), awareness and attitude, and problems were collected using questionnaires (Appendix A). The results obtained were then analysed to establish the major home composting operational schemes, awareness and attitudes, and problems faced by home composters in Palmerston North.

The previous studies also indicated that to close the gap and correct any misconceptions and problems faced with home composting, municipal authorities can undertake initiatives such as composting workshops where people can learn about or improve upon home composting practices. They also revealed that these authorities seem to have the means to provide compost bins at reduced prices to households. Therefore, in the present study, home composters were assessed concerning their potential motivation to continue home composting or do more home composting, whereas non-home composters were examined with regards to how they may be motivated to start home composting. Based on the most common responses/suggestions offered, recommendations were made to PNCC on initiatives they might undertake to encourage as well as to improve home composting practices in Palmerston North.

3.1.4.2 Home composting QA evaluation

A five-point rating scale ranging from 1 (“very poor”) to 5 (“very good”) was employed in the proposed HCET/on-site physical data assessment tool (Appendix B) to evaluate the home composting process and the finished compost of home composters in the present study. The average scores per sub-parameter were then found to determine the average score for the main parameters. To estimate the overall score, termed the "final home composting evaluation score", the averages for each parameter was found. The specific methodology that was utilised for the QA evaluation of the home composting process and for the finished compost using the proposed HCET/on-site physical data assessment tool is outlined in the following sections.

3.1.4.2.1 Temperature

Temperature provides one simple overall QA metric which is quick and easy to measure (Compost New Zealand, 2007b; Karnchanawong & Suriyanon, 2011; Li, Lu, Ren, & He, 2013), and as such, suits the context of the present study. This measure also formed part of the common parameters analysed in the previous home composting studies outlined in Table 13. By following the procedure provided by NZS4454:2005, the temperatures of active composting processes were recorded with a temperature probe.

Firstly, the ambient temperature was recorded. Afterwards, the probe was inserted in the centre of the compost pile and the temperature reading was recorded after one minute. The temperature recordings were then compared against the guidelines provided by NZS445:2005 and other good practices identified in the literature.

The temperature probe was inserted in the centre of the pile because the ends of the home composting system are mostly cooler due to the availability of higher surface area for heat loss (Recycled Organics Unit (ROU), 2003). The temperature probe was also kept away from direct sunlight specifically on sunny days to avoid heating which could possibly affect temperature readings.

3.1.4.2.2 Moisture content

Moisture content was also part of the common compost QA parameters assessed in the previous home composting studies that evaluated compost QA (Table 13). As stated previously, the testing method for moisture content provided by NZS4454:2005 was adopted by the present study. NZS4454:2005 (as cited by ROU, 2003) reports on two methods for moisture content evaluation. One is a quick field based visual evaluation referred to as the squeeze-test and the other is an empirically accurate laboratory-based method. Both methods were utilised as part of the home composting QA evaluation in the present study. The squeeze-test method was employed for an on-site moisture content evaluation of compost piles and was conducted as follows:

a. A sub-sample of partly-decomposed or finished compost was placed in the palm.
b. The palm was closed and the sample was squeezed firmly.
c. The structure of the sample was then evaluated and recorded on the proposed HCET/on-site physical data assessment tool; samples which crumbled with light pressure indicated the availability of adequate moisture while those which either got deformed, stuck together when the pressure was applied, or released water, showed high moisture content.

Compost samples were then collected and taken to the laboratory for comparative moisture content analysis. The moisture contents of the compost samples were determined by employing the following procedure by NZS4454:2005 (Standards New Zealand, 2005):

a. The weight of an empty aluminium foil was determined **(w_1).**
b. The combined weight of the wet sample and the aluminium foil was determined **(w_2).**
c. The samples were then pre-dried in an oven set at 70° C for approximately 24 hours (this was done to reduce the smell of the samples).
d. The samples were further dried in an oven set at 105°C for nearly 12 hours.
e. The combined weight of the dried sample and the aluminium foil were then determined **(w_3).**
f. The moisture content (expressed as a percentage) was calculated by using the following formula: **$((w_2 - w_3)/(w_2 - w_1)) \times 100\%$**

The analyses were carried out in duplicates and the average moisture content of each sample was subsequently determined. The values obtained were compared against good practice figures such as the one provided by NZS4454:2005 and other good practice results from the literature. Figure 9 presents a pictorial description of some of the procedures employed in the present study to determine the moisture contents of the compost samples.

a b c d

Figure 9 Pictorial illustration of some of the procedure employed in the present study to determine the moisture content of compost samples; (a) determination of the wet weight of samples; (b) weighed wet samples; (c) preheating process to reduce the smell of samples; (d) samples in an oven set at 105°C.

3.1.4.2.3 pH

pH formed part of the common parameters analysed in the previous home composting studies to assess compost QA (Table 13). In the present study, a soil test pH procedure was adapted to analyse the pH of compost samples. The test can be identified by the procedure outlined below:

a. Approximately 30g each of compost samples were obtained and placed in conical flasks.
b. 75ml of ionised water was added to the samples (ratio 1:2.5).
c. The suspensions were then agitated and left for approximately 12 hours before measuring the pH with a glass electrode membrane.

The compost samples collected were either fresh, semi-matured or matured. Therefore, the results obtained were compared to establish the differences in pH values between fresh feedstock, semi-matured feedstock and matured compost (Appendix G). The values obtained for each category were then compared with pH values provided by NZS4554:2005 and other good practice results.

3.1.4.1.4 Observation of home composting processes and finished product

Observations were made as to the physical appearance of

a. the home composting system/pile (siting, design and construction),

b. the home composting process management (inputs/feedstock, shredding, blending/amendment, mixing/turning, presence of pests and covering), and
c. the finished compost quality (colour, texture, smell[o]).

Evaluation of these parameters was guided by the guidelines provided in Appendix C. Accordingly, each parameter was scored based on the observations made to assess the home composting process and product QA of the study participants. A photographic illustration of the system type and construction was also performed.

3.1.4.1.5 Methodology for the quantification of the volume and mass of organic waste diverted from landfill via home composting

The step-by-step method employed to quantify the volume and mass of organic waste diverted from landfill via home composting in Palmerston North is illustrated in Figure 10.

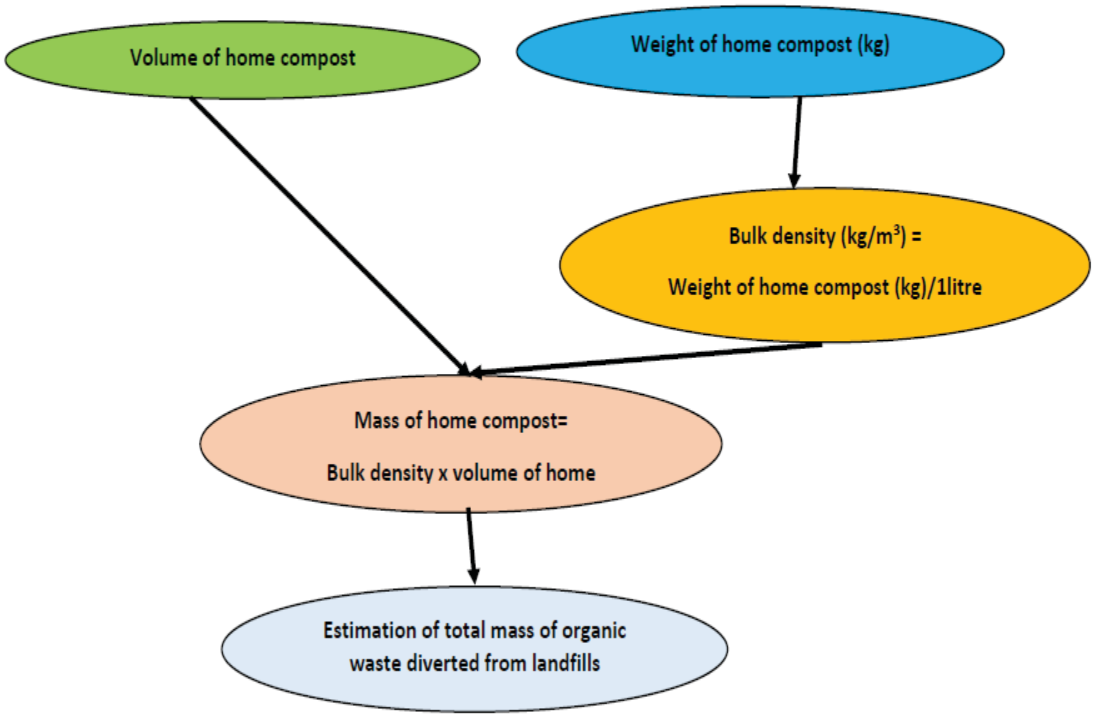

Figure 10 Step-by-step methodology for the quantification of the volume and mass of organic waste diverted from landfill via home composting in Palmerston North

[o] To get a reasonably accurate smell of the compost pile/finished compost, the pile was dug up before assessing the smell.

The method employed to quantify the volume of organic waste (Figure 10) was based on the home composting system (that is single or multi-bin system) and the shape of the compost bin used by study participants. Thus, the shape and type of home composting systems were identified as part of the data collection process to establish the various measurements (width, height, length and radius) and the volume formulae necessary for calculating the volume of different home composting system types. Figure 11 illustrates a range of compost bin shapes that were anticipated to be encountered in the present study.

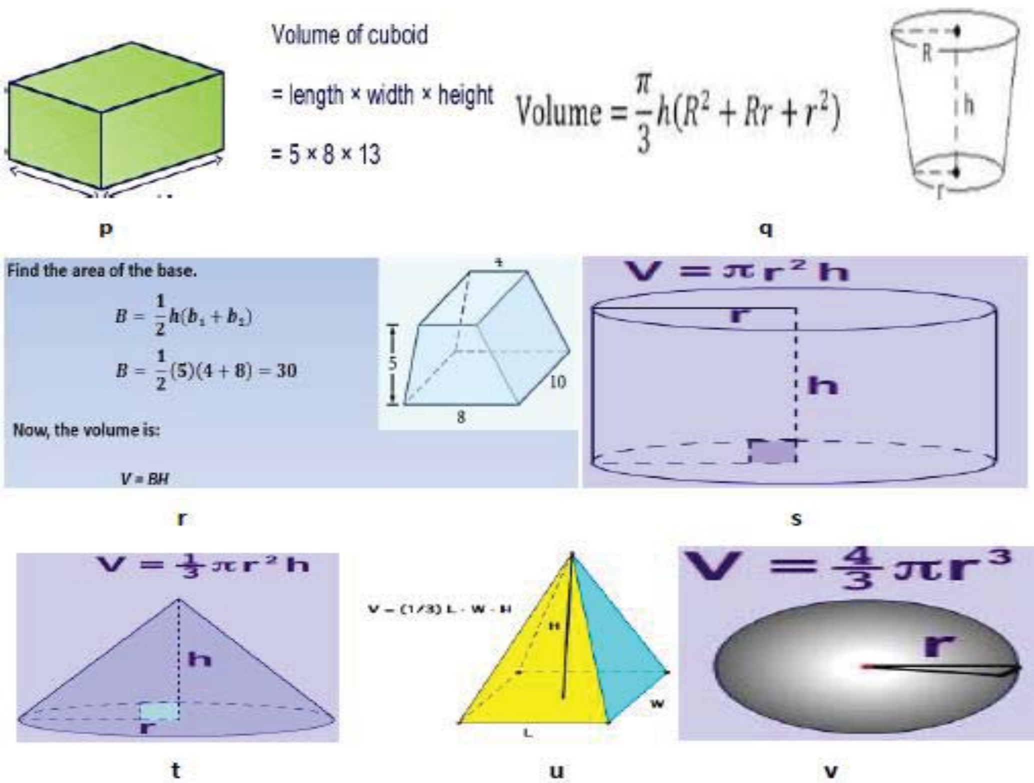

Figure 11 A range of possible formulae for calculating the volume of differing home composting system types anticipated to be encountered in the present study; cuboid (p), frustum (q), trapezoidal prism (r), cylinder (s), cone (t), pyramid (u), sphere (v)

The measurements appropriate to the identified home composting system were then taken. An illustration of how the volume measurements were performed can be found in Figure 12.

Figure 12 Photographic illustration of volume measurements of a wooden box compost bin during data collection in the present study

3.1.4.1.5.1 Collection of compost samples

Following the sampling method provided by NZS4454:2005, representative samples of finished compost (and/or fresh and partly decomposed samples) were also collected into a two-litre fixed-volume container. This was done by collecting several sub-samples from different, representative locations of the compost pile[p] using a digging fork. The samples were then bagged, labelled and brought to the laboratory to determine the weight and bulk density.

3.1.4.1.5.2 Determination of the bulk density and mass of compost samples

In the laboratory, a one-litre sample was obtained from the two-litre samples[q] collected on-site by pouring the samples into a one-litre beaker. The weight of the sample and the beaker was then determined to establish the bulk density of the samples (refer to Figure 10). Using the values for the previously calculated home composting system volume and that of the bulk density, the mass of the samples was estimated. An estimate of the total

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[p] In the case of households with multi-bin systems, two-litre samples were taken from each of their composting systems to estimate the average bulk density/volume/mass of that household.

[q] A two-litre sample was collected on-site instead of the one-litre desired sample to allow for enough sample from which an accurate sample of the desired amount can be obtained.

mass of organic waste (tonnes) diverted from landfill via home composting was then derived.

3.1.4.1.5.3 Comparison of the physicochemical properties of home compost sample with commercially produced PNCC compost sample

As part of evaluating the QA of the home compost produced in Palmerston North, an analytical test was conducted on home compost samples collected in the present study as well as on commercial compost produced at the Awapuni composting site by PNCC. The tests were carried out in duplicates. The mean values of the test results were compared against each other. They were also compared with the guidelines provided by NZS4454:2005 and other good practise results from the literature.

Prior to the test, the matured compost samples collected in the present study were thoroughly mixed and aggregated into one sample. Water was then sprinkled on the sample. Both the home and commercial composts were then sieved with a 5mm sieve and sent to the PNCC laboratory to conduct the analytical test (Figure 13).

Figure 13 Sieved aggregated home compost samples for the analytical test

3.1.4.1.6 Improvement of the current methodology for future home composting quantification and evaluation studies

Using the results, observations and recognized limitations of the present study, the current methodology was improved upon. These improvements included an amendment of the survey questionnaire. Recommendations were also provided to assist with future home composting quantification and evaluation studies, both internationally and within New Zealand.

3.1.5 Methods for data collection

3.1.5.1 Pilot-testing of survey questionnaire

According to Nardi (2014), pilot-testing a survey questionnaire is an important technique to assess whether the chosen questionnaire flows, whether the wording of the questions is sufficiently clear, and whether it is likely that the survey will take a reasonable time to complete. Accordingly, the survey questionnaire for the present study was pilot-tested. Five potential participants in the present study were employed in the pilot-test.

3.1.5.2 Telephone survey

Lavrakas (1993) observed that although each area has its specific localised patterns of when residents are more likely to be or not be at home, the best time to reach most potential respondents for a telephone survey of the public is usually Sundays, and Tuesdays through to Thursday evenings, and Saturday afternoons. Lavrakas added that Friday and Saturday evenings are the least productive. So, for the present study, these most ‘optimal’ time periods were utilised. Additionally, due to the finite window for data collection in the present study, a pragmatic approach of conducting data collection during the available time for the researcher was employed. Discussions with some locals of Palmerston North were also made to determine the times of the day people are likely to be at home. Table 16 presents the schedule employed for the telephone survey.

Table 16 Schedule for the telephone survey. Calling was done throughout the seven days of the week, however, the time for weekdays varied from that of weekends because, according to some residents in Palmerston North, most households pick up their children from school and prepare/take dinner between 4 pm and 6.30pm on weekdays.

Day of the week	Time
Weekday (Monday to Friday)	9am-4pm and 6:30pm-8pm
Weekend (Sunday and Saturday)	9am-8pm

3.1.5.2.1 Interviewers employed for the telephone survey

Several studies have reported the impact interviewers have on the participation and refusal rates in telephone surveys. Japec (2008) demonstrated that an interviewer's attributes, such as age, gender, education, experience, personal style, self-esteem, and religiosity, form part of the interview setting. Japec further explained that these attributes will influence how an interviewer perceives an interview. For instance, an anxious interviewer might be afraid that the respondent will hang-up, thus may speed through the interview making it difficult for the respondent to fully understand the questions (Japec, 2008). Similarly, Dijkstra and Smit (as cited by Bonnel & Le Nir, 1998) studied the causes of refusal to participate in surveys which also revealed that the interviewers played a vital role in determining the refusal rate. Groves and Couper (as cited by Japec, 2008) also studied the influence of interviewers on participation rate in telephone surveys.

Building on the highlights from the above-mentioned studies, two interviewers with different ethnic background, age and interviewing skills were employed to conduct the telephone survey in the present study. Interviewer one (the primary researcher) was a young Ghanaian with no telephonic interviewing skills while Interviewer two was older, a native of Palmerston North and a skilled technician. These interviewers were used to enable an exploration of the differences in participation and refusal rates that could result from using interviewers with different attributes. The two interviewers were also used to ensure that the data collection was conducted within a short period.

3.1.5.3 Door-to-door survey

Using a systematic random sampling method, every 10th household in the 600-generated contact list from all the fifteen suburbs was contacted by means of the door-to-door survey method (refer to Figure 6). To ensure that data was collected in a time and cost-effective approach, door-to-door surveys were conducted on the days the home visits were done. Necessary precautions taken during the door-to-door surveys are as follows:

a. Identification card(s) were taken along to aid easy identification of interviewer(s).

b. For safety purposes, two people undertook each survey.

3.1.5.4 Home visits

By employing a systematic random sampling method (refer to Figure 6), every fifth respondent in the telephone survey from each suburb that undertakes home composting was asked for a home visit. A total of 30 contacts from the telephone and door-to-door survey was targeted for the home visits. These participants were employed for the home composting process and finished compost QA evaluation in the present study. Compost samples were also collected from their compost piles for laboratory analyses.

To ensure that home visits were conducted in a time and cost-effective approach, appointments were made with the telephone survey respondents (who agreed to a home visit) prior to each visit. On the other hand, the door-to-door survey participants were asked if the physical observation and subsequent compost sample collection could be carried out at the end of each interview section. Additionally, the following preparations were made before proceeding on the home visit (and door to door survey).

a. With the aid of the Palmerston North map and participants' contact addresses, the participants were classified into smaller groups based on their proximity to each other. For example, households on the same street, on streets closer to each other or in the same suburb were each put in the same group.
b. A checklist of the apparatus required for the survey was made and this checklist was run through before each visit to ensure that the relevant items were all taken along (Figure 14).
c. The proposed HCET/on-site physical assessment data collection tool and the accompanying guidelines were read thoroughly and systematically to get a comprehensive understanding of the necessary steps by which the data would be collected.

Figure 14 Apparatus for the collection of compost samples during home visits in the present study. They comprised: temperature probe, two-litre fixed container, zip-lock bags, digging fork, white marker board, camera, gloves, tape measure, identification card)

3.1.5.4.1 Step-by-step procedure for home visits

The following procedure displays the step-by-step methodology employed during the home visits (with the aid of the proposed HCET/on-site physical assessment data collection tool):

a. The start time was recorded.
b. A board labelled with the sample identification number was placed in front of the compost bin/open pile and a photograph of the system was taken.
c. Volume measurements of the compost bin/open pile were then taken.
d. The temperature readings were taken and recorded.
e. The home composting system, process and finished product were visually observed and evaluated using the evaluation tool (reference was made to the accompanying guidelines where necessary).
f. With the aid of the digging fork, the compost pile was dug up and a representative two-litre sample was taken from different sections of the pile. The sample was then poured into a labelled zip lock bag and sealed.
g. The smell of the compost pile was examined and evaluated.
h. An on-site moisture squeeze-test was conducted.

i. The labelled board was placed in the home composting system and photographs of the compost pile/finished compost was taken (Figure 15).
j. The end time was recorded.
k. The compost pile was tidied up and a checklist of the apparatus was conducted to make sure that nothing was left behind.

Figure 15 Photographic illustration of compost pile/finished compost examined during home visits in the present study

3.1.5.5 Self-selection sampling of home composters in Palmerston North

As discussed in Section 3.1.2.1, a self-selection sampling method was also employed in the present study given that only 20 out of the 30 contacts targeted agreed to a home visit. The data obtained was, therefore, too small for a significant data analysis to attain the objectives of the present study. Consequently, households were approached through a door-to-door approach instead of the local newspaper article (because of time constraint). Households who undertake home composting were asked to voluntarily participate in the study. This group of households are termed voluntary participants in the present study. A total of 7 households voluntarily agreed to participate in the study.

3.1.6 Data Analysis

Statistical analysis was performed using SPSS software. The participation rates, home composting practices, operational schemes, issues and motivation of the study participants were analysed using descriptive statistics. The analysis was carried out at 0.05% level of significance. The results obtained from the data analysis were then presented in tables and graphs using Microsoft Excel 2016. The results are provided in the following sections.

4.0 Results

4.1 Willingness to participate in the study

The participation and refusal rates in the telephone survey are presented in Table 17. Out of the 270 contacts in the telephone survey, 64% agreed to participate in the study while 36% declined participation.

Table 17 Participation and refusal rates among the 270 contacts approached via telephone survey

Willingness to participate in the study	Frequency	Percent
Yes to participation	173	64%
No to participation	97	36%
Total	**270**	**100%**

In the door-to-door survey, 19 (63%) out of the 30 contacts approached agreed to participate in the study as opposed to 11 (37%) who declined participation (Table 18).

Table 18 Participation and refusal rates among the 30 contacts approached via door-to-door survey

Willingness to participate in the study	Frequency	Percent
Yes to participation	19	63%
No to participation	11	37%
Total	**30**	**100%**

The participation and refusal rates recorded in the telephone and door-to-door survey were combined to determine the overall participation and refusal rates among the total number of 300 contacts (Figure 16).

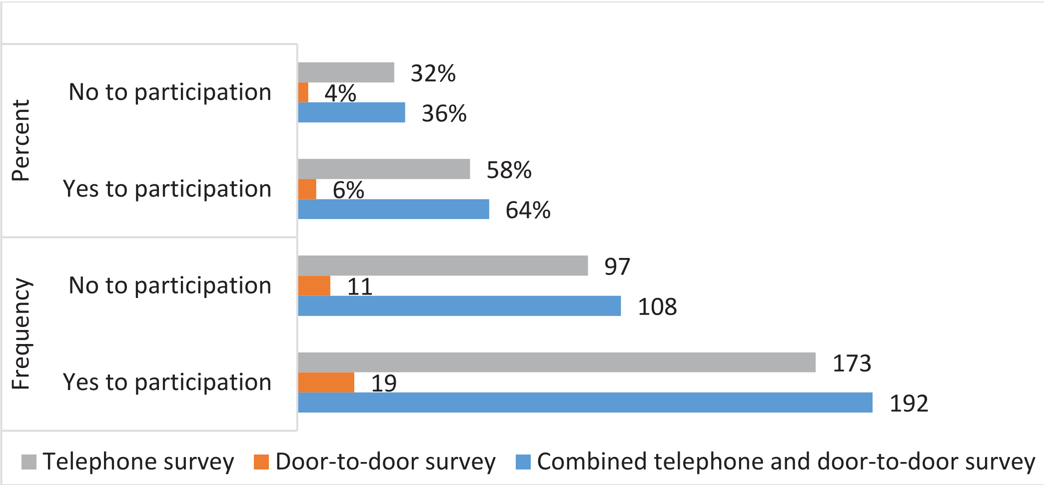

Figure 16 A graphic illustration of the individual (telephone and door-to-door survey) rate as well as the combined overall participation and refusal rates in the present study

An overall participation number of 192 (that is, 173 from the telephone survey and 19 from the door-to-door survey) was reached representing 64% of the total number of 300 contacts. The overall refusal number was 108 (that is, 97 from the telephone survey and 11 from the door-to-door survey) representing 36% of the total number of 300 contacts.

4.1.1 Participation and refusal rates recorded by each of the two interviewers in the telephone survey

As previously cited in Section 3.1.5.2.1, two interviewers were employed to conduct the telephone survey, whereas the door-to-door survey was mainly conducted by interviewer one[r]. Table 19 illustrates the quite different responses, in terms of participation and refusal rates, recorded by each of the two interviewers.

Table 19 Participation and refusal rates recorded by each of the two interviewers in the telephone survey

Willingness to participate in the study	Interviewer one (frequency)	Interviewer one (percent)	Interviewer two (frequency)	Interviewer two (percent)
Yes to participation	46	33%	127	97%
No to participation	93	67%	4	3%
Total	**139**	**100%**	**131**	**100%**

[r]Interviewer two acted as an escort as part of ethical considerations as well as to ensure the safety of the interviewer.

4.2 Reasons for declining to participate in the study

The reasons offered for declining to participate in the telephone survey are outlined in Figure 17. Among the 97 contacts who said no to participation in the telephone survey, the major reasons that emerged were: 'not a good time' (28%), 'busy' (23%) and *"not interested"* (20%). It is worthwhile to note that italicised text within quote marks, in this and subsequent sections, are direct quotations from the 'OTHER' section of the survey questionnaire (refer to Appendix A), that is, those responses which were not originally listed on the survey questionnaire.

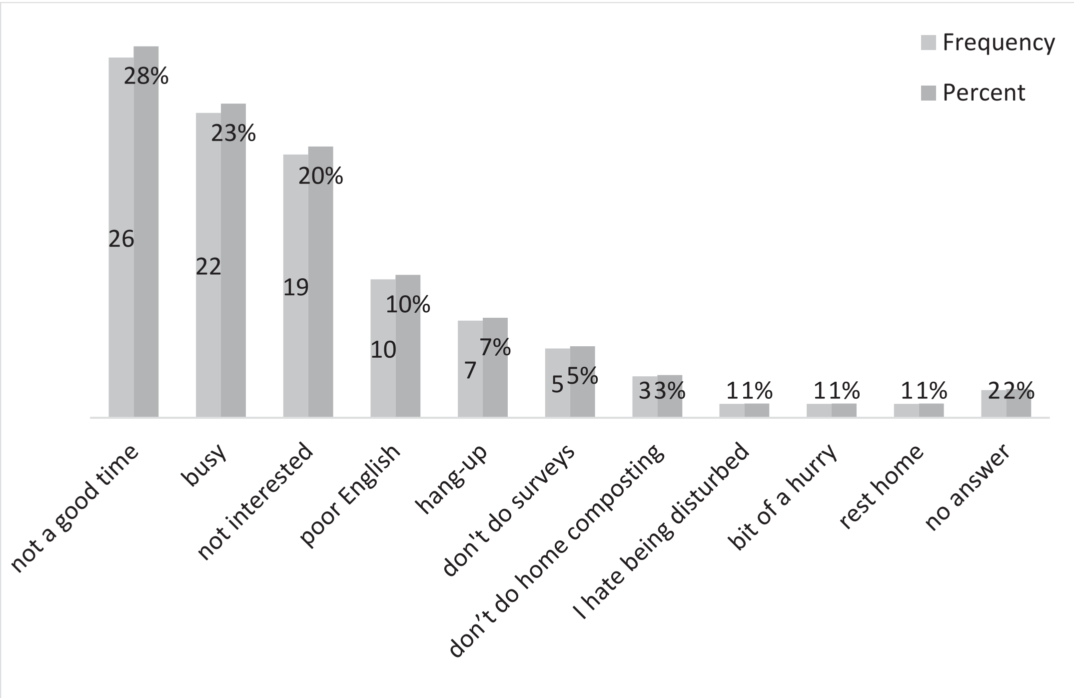

Figure 17 Reasons for refusing to participate in the telephone survey

The reasons given for not participating in the door-to-door survey are presented in Figure 18. Among the eleven contacts who responded no to participation, six (55%) stated that they 'do not do home composting' representing the largest proportion of the responses given. The quite different rationales for refusal are interesting and highlight the value of utilising two different survey approaches as this detailed/textural layer of information might not otherwise have been apparent.

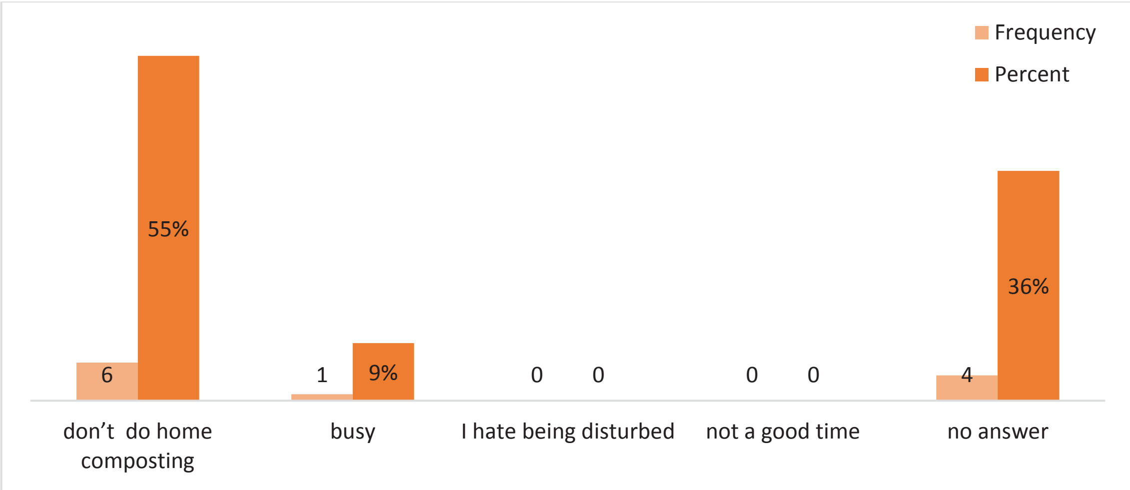

Figure 18 Reasons for refusing to participate in the door-to-door survey

Combining the separate survey results serves to relativize the two sample sizes of each data set. The collective overall reasons for refusing to participate in the study obtained from the combined telephone and door-to-door survey are presented in Figure 19. Among the total number of 108 contacts who said no to participation, the major reasons recorded were: 'not a good time' (24%) and 'busy' (21%). 'OTHER' included *"not interested"* (18%), *"hang-up"* (6%), "*poor English*" (9%), "*bit of a hurry*" (1%) and "*in a rest home*" (1%).

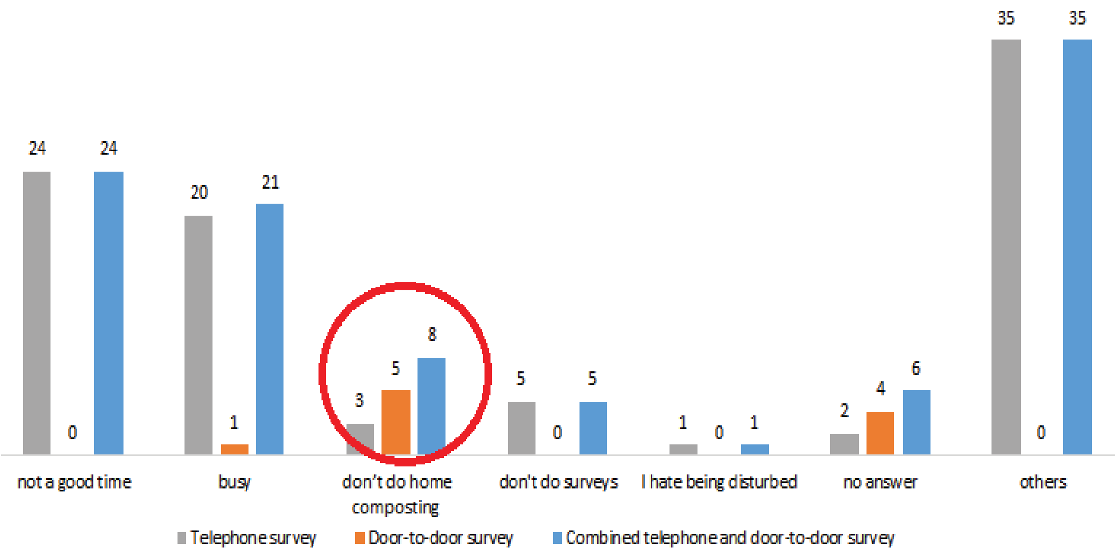

Figure 19 Overall reasons for refusing to participate in the study. The proportion of the contacts who gave the reason, 'don't do home composting' (the bars with a red circle) should have formed part of the number of non-home composters and have been addressed in Section 4.3.1.

These combined overall results also serve to illustrate the importance of relative sample size in decreasing the respective differences which may be picked up in the two individual survey methodologies. The critical importance and handling of the incidence of 'don't do home composting' as a reason for non-participation are explored in subsequent sections.

4.3 Proportion of home composters and non-home composters

The combined proportions of home composters and non-home composters in the present study are presented in Figure 20. Home composters formed 72 (37%) of the total number of 192 participants in the combined telephone and door-to-door survey. Non-home composters, on the other hand, formed 120 (63%) out of the 192 contacts.

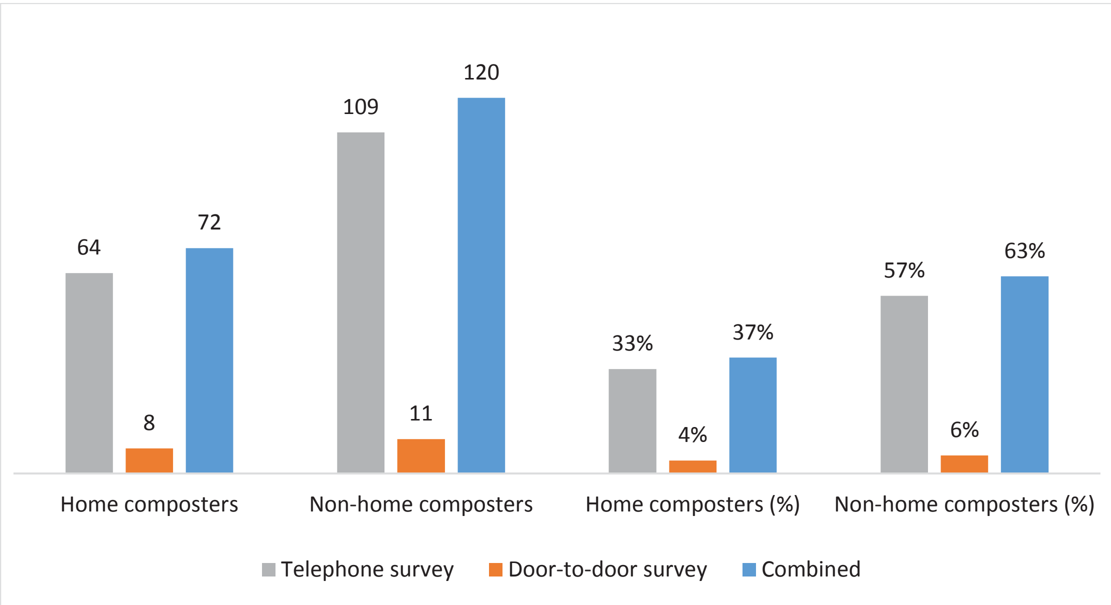

Figure 20 Overall proportion of home composters and non-home composters in the study

4.3.1 The adjusted actual proportion of home composters and non-home composters in the present study

The reason, "don't do home composting" was recorded for 8% (9) of the total number of 108 contacts who declined to participate in the study (refer to the bars with a red circle in Figure 19). Ideally, this proportion of refusals should have formed part of the proportion of non-home composters recorded. In response to the minor glitch that was discovered in the research methodology, the researcher determined that it was reasonable to make a transparent adjustment to the proportion of non-home composters recorded by including these with those who agreed to participate in the study. The non-composting percentage was, therefore, adjusted to obtain a new non-composting total of 129, which equated to 64% of the total survey sample (Figure 21).

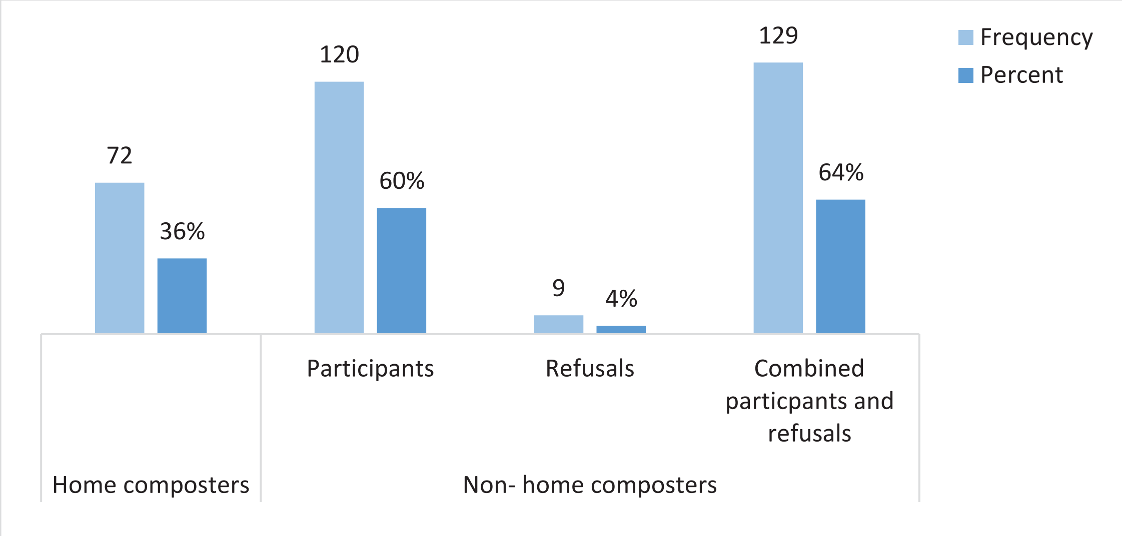

Figure 21 The adjusted actual final proportion of home composters and non-home composters in the present study

Based on the percentages of home composters (64%) and non-home composters (36%) recorded in the present study, it was projected that about 10,761 households of the 29,892 occupied dwellings of Palmerston North were home composters while the remaining 19,131 were non-home composters. Without any strong preconception, the combined overall estimate of 10,761 home composters in the occupied dwellings of Palmerston North appeared to be high. This is because having over a third of the occupied dwellings in the City practice home composting appears as a positive outcome for this waste management practice.

4.3.2 Number of years of home composting practice

Figure 22 illustrates the number of years of home composting practised among the total number of 72 home composters. The most frequent years were: 1-5 years, 6-10 years and 21-25 years. The “OTHER” category included *“not sure”* (1.5%) and *“forever”* (1.5%). The number of years of home composting practice was further categorised into three groups namely: ‘least-experienced/new home composters’, ‘medium-experienced’ and ‘highly-experienced’. This was done to determine the relationship between the number of years of home composting practice and experience level (see Section 5.3 for more details).

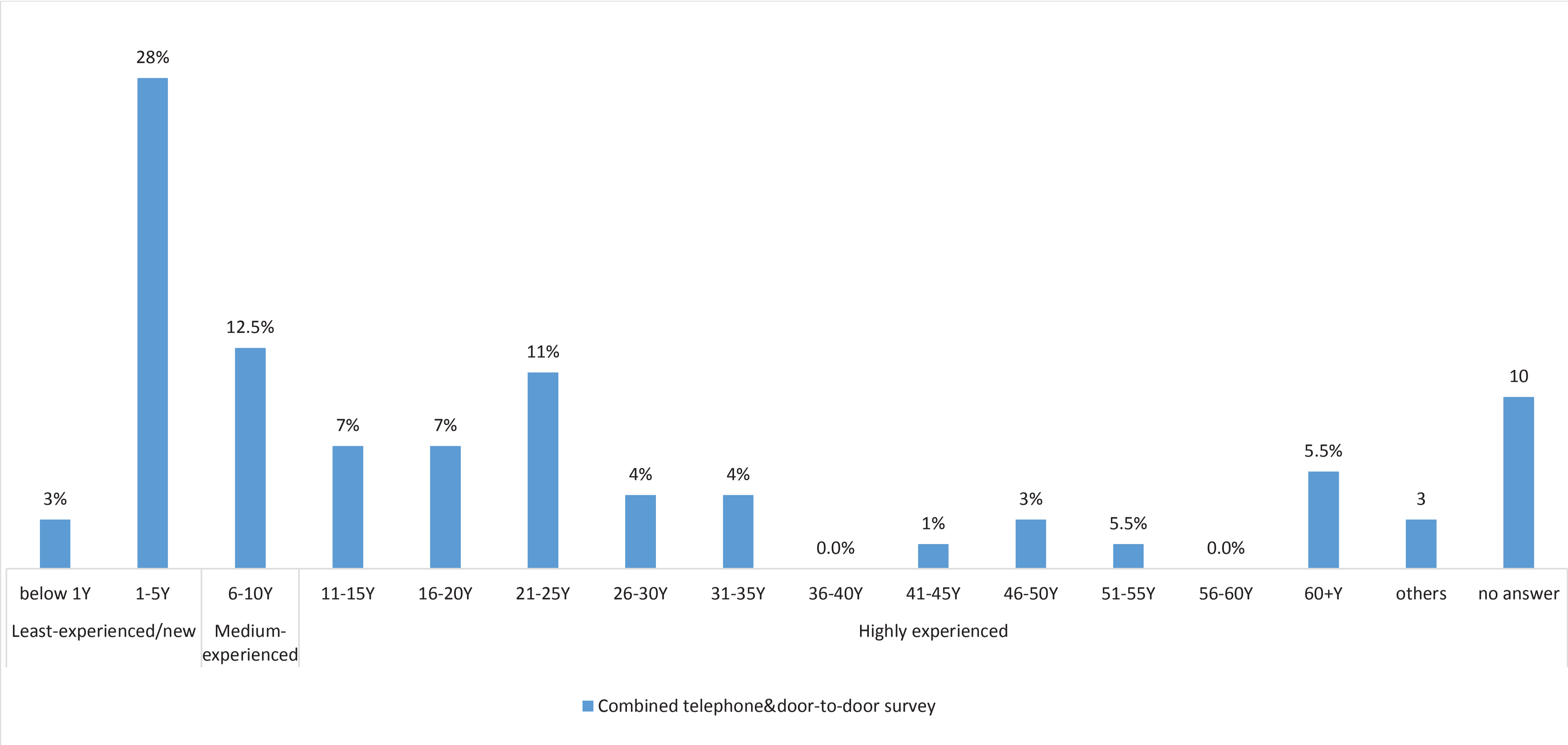

Figure 22 Number of years of home composting practice among the home composters in the combined telephone and door-to-door survey

This spectrum of answers to the ‘how long have you been home composting’ question shows that nearly a third (31%) of composting households can be considered, based upon the selected bracketing model of less than five years, as relatively new and least-experienced composters. Additionally, this data shows that an even larger group (43%) have been home composting for more than 10 years and can be considered experienced composters.

4.4 Reasons given by the home composters for practising home composting

Table 20 outlines the reasons given by the home composters for practising home composting. It is important to note that in this style of questioning, respondents were enabled, if they chose, to provide multiple answers. Therefore, some of the respondents gave multiple overlapping reasons for practising home composting, thus a total of 372 reasons were recorded among the 72 home composters. The major reasons for home composting included: ‘to reduce organic waste’ (13%), ‘compost can be used as soil amendment’ (12%), ‘to save dustbin space’ (9%) and ‘use of organic waste’ (9%). As previously stated in Section 4.2, this question also employed the strategy of utilising a combination of reasonably expected tick-box answers alongside an ‘OTHER’ category to collect the participants’ own responses and ‘voices’.

Table 20 Overall reasons given by the home composters for practising home composting

Reasons	Frequency			Percent (combined telephone and door-to-door survey)
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
reduce organic waste	45	3	48	12.9
soil amendment	38	6	44	11.8
save dustbin space	34	1	35	9.4
use organic waste	31	2	33	8.9
reduce harmful effect on environment	28	3	31	8.3
saves money on waste disposal cost	28	1	29	7.8
cheaper than buying commercial compost	28	1	29	7.8
grow and eat healthier produce	28	1	29	7.8
saves landfill	25	2	27	7.3
save money on fertiliser	21	0	21	5.6
save money on seed raising mix	18	0	18	4.8
teach children	16	0	16	4.3
curiosity	3	0	3	0.8
"convenient"	2	0	2	0.5
free bins	1	0	1	0.3
"something I have always done"	1	0	1	0.3
"a bit of green"	1	0	1	0.3
"brought up to do it"	1	0	1	0.3
"cultural"	1	0	1	0.3
"like organic matter"	1	0	1	0.3
"mother always composted"	0	1	1	0.3
peer pressure	0	0	0	0.0
subsidised bins	0	0	0	0.0
offered by the council	0	0	0	0.0
help council home composting program(s)	0	0	0	0.0
Total	**351**	**21**	**372**	**100**

4.4.1 Categorisation of the reasons for practising home composting in the present study

The reasons for home composting offered in the present study were further categorised by adopting the categories employed in the home composting study by Tucker et al. (2003). The categories included: "environmental", "economic", "gardening/agricultural" and "others". The categorised reasons for practising home composting in the present study are provided in Table 21. Most of the major reasons for home composting (Table 20), fell under the environmental, economic and gardening/agricultural categories and are highlighted in red.

Table 21 Categorisation of the reasons for practising home composting in the present study. Adapted from (Tucker et al., 2003).

Categories	Reasons
Environmental	saves landfill space
	reduce harmful effect on environment
	reduce organic waste
	use organic waste
Economic	saves money on waste disposal cost
	free bins
	subsidised bins
	save money on fertiliser
	save money on seed raising mix
	save dustbin space
	cheaper than buying commercial compost
Gardening/agricultural	grow and eat healthier produce
	soil amendment
Social	peer pressure
	curiosity
	teach children
	offered by the council
	help council home composting programme
Others	*"something I have always done"*
	"a bit of green"
	"brought up to do it"
	"convenient"
	"cultural"
	"like organic matter"
	"mother always composted"

4.5 Exploring the reasons given by the non-home composters for not practising home composting

The non-home composters were asked to offer reasons for not practising home composting. Similar to Section 4.4, some of the non-home composters gave multiple reasons for not composting. It is, however, of importance to note that no tick-boxes were provided for this question (refer to question 3b in Appendix A). Therefore, all the answers provided to this question reflect the voices of the participants. Table 22 shows the overall reasons given by the non-home composters for not practising home composting. The most frequent reasons given by the non-home composters were: *"I live in a rental" (9%), "I have a small section" (9%), "I do not own a garden" (7%), "I have stopped home composting" (7%)* and *"old age" (7%)*.

Table 22 Overall reasons given by the non-home composters for not practising home composting

Reasons	**Frequency**			**Percent (combined telephone and door-to-door survey)**
	Telephone survey	**Door-to-door survey**	**Combined telephone and door-to-door survey**	
"I live in a rental"	15	0	15	9%
"I have a small section"	14	1	15	9%
"do not own a garden"	12	1	13	7%
"old age"	12	0	12	7%
"have stopped home composting"	9	3	12	7%
"find the rubbish bin/landfill more convenient"	9	0	9	5%
"have no time"	9	1	10	6%
"lives alone"	9	0	9	5%
"have a waste disposal unit/insinkerator"	7	0	7	4%
"much effort is required"	5	1	6	3%
"health-related issues"	5	0	5	3%
"use organic waste as animal feed"	2	2	4	2%
"less garden waste"	3	0	3	2%
"green waste bin"	3	0	3	2%
"no knowledge"	4	0	4	2%
"haven't got around to it, but intend to"	3	0	3	2%
"have a commercial lawnmower"	2	2	4	2%
"can't be bothered"	3	0	3	2%
"don't have green fingers"	3	0	3	2%
"doesn't interest me"	2	1	3	2%
"easy care garden"	2	0	2	1%
"have a gardener"	2	0	2	1%
"produce less compost"	2	0	2	1%

"does on-farm composting"	2	0	2	1%
"" have a worm-farm"	2	0	2	1%
"have moved places"	0	2	2	1%
"don't have equipment"	2	0	2	1%
"mulch mowing"	1	0	1	1%
"never thought about it"	1	0	1	1%
"doesn't want to attract flies and insects"	1	0	1	1%
"I plant on top of the organic waste"	1	0	1	1%
"lives in a retirement village"	1	0	1	1%
"organic waste is stockpiled at backyard"	1	0	1	1%
"it is more convenient to buy compost"	1	0	1	1%
"haven't thought about it"	1	0	1	1%
"too lazy"	0	1	1	1%
"not interested anymore"	0	1	1	1%
"I have dogs"	0	1	1	1%
"there are no incentives"	1	0	1	1%
"own a small garden"	1	0	1	1%
"no reason"	2	0	2	1%
no answer	3	0	3	2%
Total	**158**	**17**	**175**	**100%**

4.6 Home composting systems identified in the present study

The complete spectrum of the types of home composting systems identified in the present study is shown in Table 23. 'Manufactured plastic bins' represented a significant majority of the system types reported. Below this, 'open pile' and 'wooden box' composting systems were also identified as relatively common types of home composting system used by the home composters in the present study.

Table 23 Types of home composting systems encountered in the present study and the proportion of home composters who use these identified home composting system types

Types	Frequency			Percent (combined telephone and door-to-door survey
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
manufactured plastic bin	39	6	45	63%
open pile	7	1	8	11%
wooden box	7	0	7	10%
wire fence	1	1	2	3%
concrete brick	2	0	2	3%
ground/soil incorporation	2	0	2	3%
corrugated iron	1	0	1	1%
roller bin	2	0	2	2%
bokashi system	0	0	0	0
hungry bin	0	0	0	0
home-made from scraps	0	0	0	0
bio stack	0	0	0	0
tumbleweed	0	0	0	0
cone composter	0	0	0	0
no answer	3	0	3	4%
Total	**64**	**8**	**72**	**100%**

The following photographs are some illustrations of the types of home composting systems identified in the present study (see Figures 23 and 24).

Figure 23 Some types of homemade home composting systems identified in the present study; wooden box (a); wire fence (b); open pile (c); box made from scrap metal and wood (d)

Figure 24 Some types of manufactured compost bins identified in the present study; Eco-design (e); Firth (f); Garden Mate (g); Earthmaker (h); Composta (i); Sherlock Melb (j)

The forms of single-bin and multi-bin systems used by the survey participants were also explored. The proportion of single-bin versus multi-bin systems recorded in the combined telephone and door-to-door survey are presented in Figure 25. Two-bin systems formed the largest proportion. It should be noted that the high rate of non-response may indicate that the participants were confused by this question, do not understand composting system technicalities and/or may not have known how to correctly address the question.

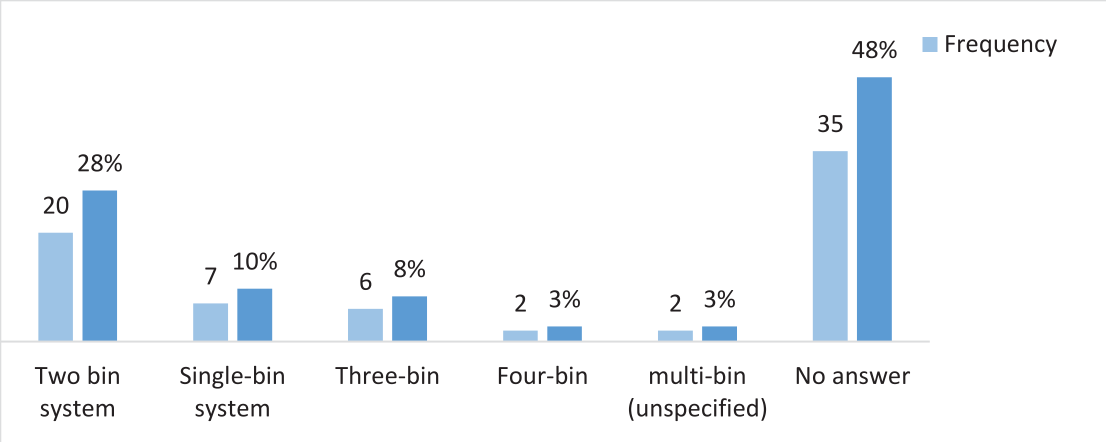

Figure 25 Proportion of single-bin and multi-bin systems identified in the present study

A pictorial illustration of some forms of single and multi-bin systems encountered in the present study are shown in Figure 26.

Figure 26 Single-bin and multi-bin systems identified in the present study; manufactured single-bin system (left), homemade two-bin system(middle) and manufactured three-bin system (right)

4.7 The range of feedstock/organic waste inputs for home composting identified in the present study

The feedstock types identified in the present study are presented in Table 24. Eight major feedstock types emerged which included: fruit and vegetable peelings, food waste, grass clippings, leaves, garden pruning, tea and coffee grounds, eggshells and garden weeds. 'OTHER' included: *"newspaper", "branches"* and *"straw"*. It should also be noted that this question was structured to allow for multiple answers. It can, therefore, be observed from Table 24 that a total of 404 feedstock types were recorded amongst the 72 home composters. This also indicated that some of the home composters composted more than one feedstock type.

Table 24 Feedstock types composted by the home composters in the combined telephone and door-to-door survey

Feedstock types		Frequency			Percent (combined telephone and door-to-door survey)
		Telephone survey	Door-to-door survey	Combined telephone and door-to-door	
Green materials	Fruit and vegetable peelings	52	6	58	14
	food waste	50	5	55	14
	grass clippings	45	8	53	13
	tea bags/coffee grounds	39	4	43	11
	eggshells	37	6	43	11
	garden weeds	31	7	38	9
	manures	4	2	6	1
	sea weed	1	2	3	1
Brown materials	leaves	39	6	45	11
	garden pruning	36	4	40	10
	sawdust/wood shavings	11	1	12	3
Other[s]	branches	0	1	1	0
	newspaper	1	5	6	1
	straw	0	1	1	0
Total		**346**	**58**	**404**	**100**

4.7.1 Number of feedstock intake per the three most common home composting systems identified in the present study

The analysis in this section examines if any of the three most common home composting system types identified in the present study was being used to manage a different and/or a wider range of material inputs (in other words, which home composting system offers the most flexibility for managing a wide range of material inputs). The number of

[s] Ideally, the feedstock types recorded under this category should have formed part of the brown materials. They were, however, grouped under the 'OTHER' category because they were not originally listed on the study questionnaire.

the eight major feedstock types composted by the users of the three most common home composting systems are presented in Figure 27.

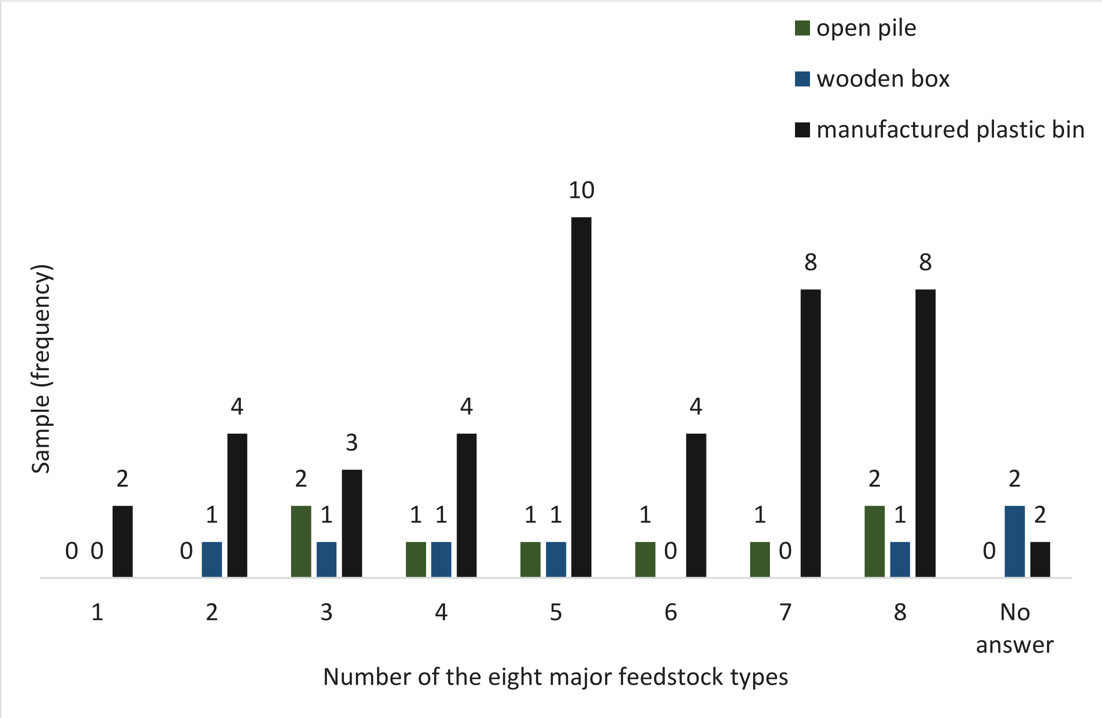

Figure 27 Number of feedstock intake per the three common home composting systems

It can be observed from Figure 27 that out of the total number of 60 users of the three most common home composting systems outlined in Table 23, 30 manufactured plastic bin users compost five-eight of the major feedstock. On the other hand, only five open pile users and two wooden box users composted five-eight of the major feedstock types. These findings show that the relative to the open pile and wooden box users, a larger proportion of the manufactured plastic bin users compost a variety of feedstock/organic waste.

4.7.2 Materials excluded from the compost pile by the home composters

The material types excluded from the compost pile by the home composters are outlined in Table 25. Major exclusions comprised: beer and carbonated drinks, cat and dog manure, and large and treated wood. 'OTHER' included: *"citrus"*, *"corn cobs"*, *"onion"*, *"pumpkin seeds"*, *"tree branches"*, *"twig"*, *"weeds"*, *"bark"* and *"treated sawdust"*. It is worthwhile to note that some of the home composters excluded more than one of the materials from their compost pile, representing a total of 360 recorded for the 72 home composters.

Table 25 Materials excluded from the compost pile by the home composters in the present study

Materials	Frequency			Percent (combined telephone and door-to-door survey)
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
beer and carbonated drinks	45	2	47	13%
cat and dog manure	45	2	47	13%
large and treated wood	43	2	45	13%
meat, fish and bones	42	2	44	12%
oils and fats	40	2	42	12%
dairy products	40	2	42	12%
diseased plants	36	2	38	11%
cooked and processed food	36	2	38	11%
other	15	2	17	5%
Total	**342**	**18**	**360**	**100%**

4.7.3 Use of the commercial composting site and/or landfill by the home composters

The home composters were also asked if they send any of their organic waste to the commercial composting site and/or the landfill. This was to determine if the home composters also utilise the commercial composting site for the management of their organic waste. It was also to determine if they use the landfill, as this method of organic waste management, discussed in Section 2.2.1, does not lead to beneficial use. This data, therefore, enabled the recommendation of strategies which PNCC could put into place to increase waste diversion from landfill in the City (see Section 5.6.1.3).

The responses provided by the home composters are shown in Figure 28. Of the total number of 72 home composters in the present study, 19% stated that they also send a portion of their organic waste to the commercial composting site and/or the landfill site.

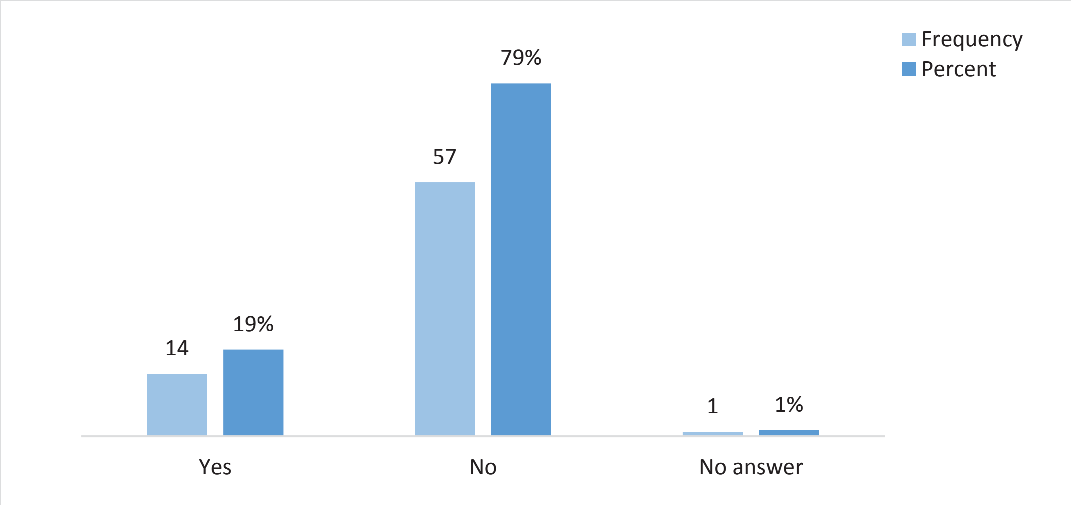

Figure 28 Use of commercial composting site/landfill by the home composters in the present study. Only a small proportion of the home composters also use the commercial composting site/landfill.

This information indicates that for approximately 80% of the home composters, home composting seems to meet all their organic recycling needs. However, approximately 20% of home composters could still benefit from some form of further organic recycling system intervention (see Section 5.6.1.3 for more details).

Organic waste types sent to the commercial composting site and/or landfill by the 14 home composters included garden waste and tree branches (Figure 29).

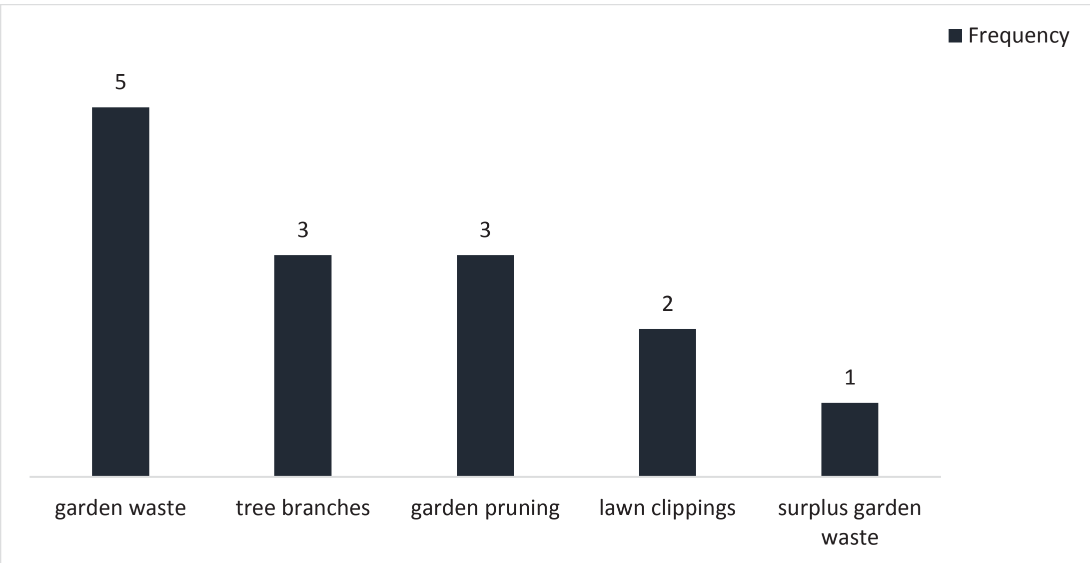

Figure 29 Material types sent to the commercial composting site/landfill by the home composters in the present study

4.8 Management practices undertaken by the home composters in the present study

Table 26 outlines the reported management practices undertaken by the home composters in the present study. Some of the home composters also gave multiple answers to this question, which indicates that they undertook more than one management practice. Overall, 32 home composters stated that they mix/turn their compost pile while only nine stated that they remove unwanted material from their piles.

Table 26 Home composting management practices undertaken by the home composters in the present study

Management practices	Frequency			Percent (combined telephone and door-to-door survey)
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
mixing/turning	29	3	32	30%
addition of soil	20	4	24	22%
watering	21	2	23	21%
addition of compost starters	17	3	20	19%
removal of unwanted material from the pile	8	1	9	8%
Total	**95**	**13**	**108**	**100%**

4.8.1 Mixing/turning practices among the home composters

A further exploration of the proportion of home composters who responded “yes” or “no” to mixing/turning of the compost pile was performed. This was undertaken because mixing/turning is a key home composting management practice, and was reported by a large proportion of the home composters in the present study. Of the 72 home composters, 44% stated that they mix/turn their compost pile as opposed to 56% who responded that they do not mix/turn their piles (Figure 30).

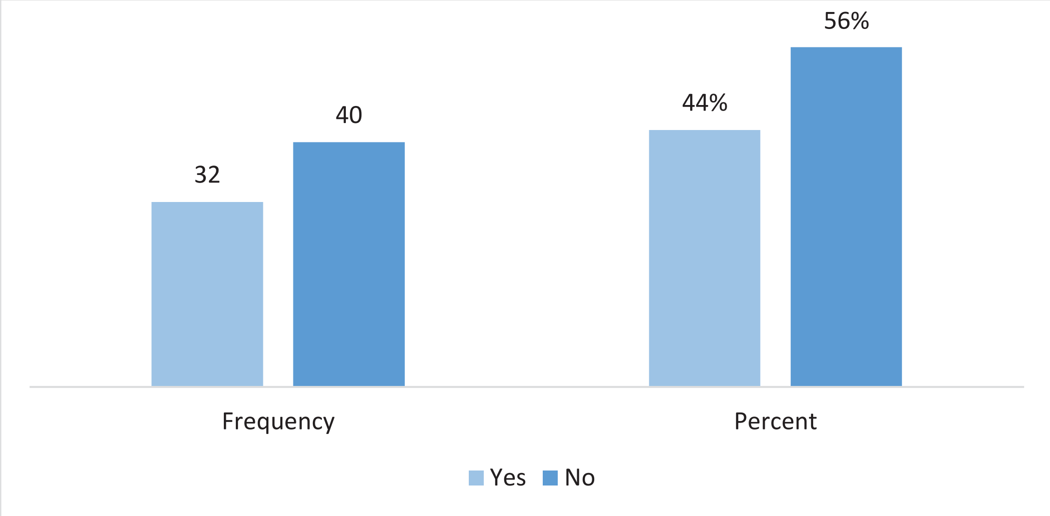

Figure 30 Proportion of home composters who responded "yes" and "no" to mixing/turning of their compost pile in the combined telephone and door-to-door survey.

4.8.2 Relationship between mixing/turning practices and home composting systems

The relationship between mixing/turning practices and the three most common home composting systems identified in the present study was also explored (Figure 31). Out of the 32 home composters who responded "yes" to mixing/turning of their compost pile, 15 were manufactured plastic bin users. In contrast, 25 manufactured plastic bin users responded "no" to mixing/turning of the pile, forming the largest proportion of the 40 home composters who responded no to mixing/turning of their piles.

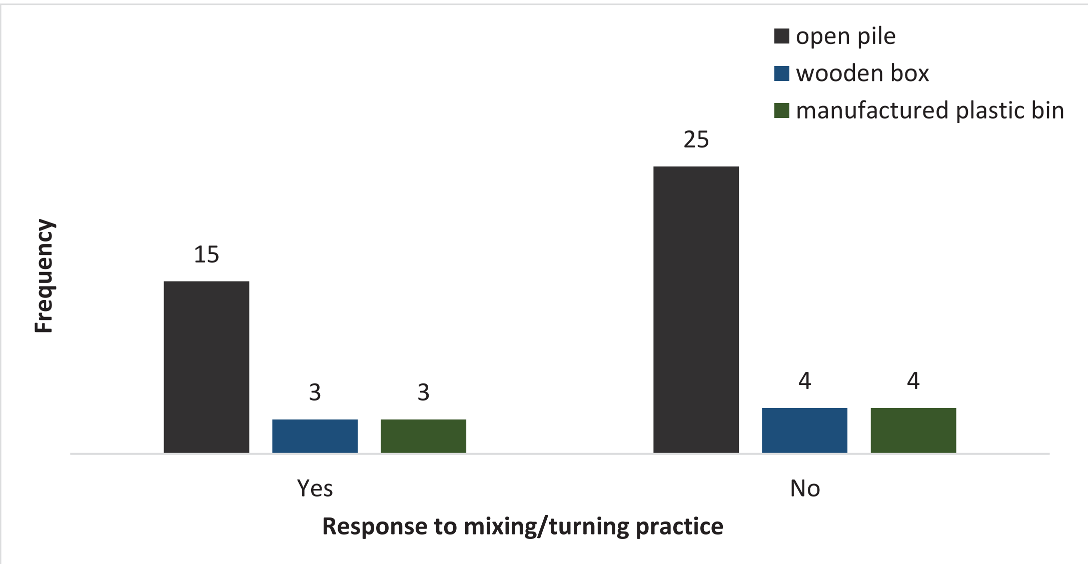

Figure 31 Relationship between mixing/turning practices and the three most common home composting systems identified in the present study

4.9 Home composting problems reported by the home composters in the present study

Home composting problems faced by the home composters were assessed to establish potential PNCC interventions to reduce problems, as well as to increase home composting participation rate. Table 27 outlines the home composting problems reported by the home composters in the present study. Among the 72 home composters, 38 stated that they have no problems with home composting, while the remaining 34 home composters reported either one or multiple problems with home composting.

Table 27 Home composting problems reported by the home composters in the present study

Home composting problems	Frequency			Percent (combined telephone and door-to-door survey)
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
none	33	5	38	29%
insects	13	0	13	10%
flies	11	0	11	8%
rodents	10	1	11	8%
bad smell	7	0	7	5%
cats/dogs	7	0	7	5%
requires lots of space	5	0	5	4%
bin/system too small	5	0	5	4%
price of composting bins	4	0	4	3%
slow process	4	0	4	3%
compost pile is too dry	4	0	4	3%
time-consuming	3	0	3	2%
much effort required	3	0	3	2%
weed growth in compost	3	0	3	2%
smelly/slimy/low compost	3	0	3	2%
compost pile does not heat up	3	0	3	2%
lack of incentives	2	0	2	2%
lack of info/know-how	2	0	2	2%
other	1	2	3	2%
Total	**123**	**8**	**131**	**100%**

The most frequent problems identified among the 34 home composters who reported problems are shown in Figure 32. They included: nuisance insects (10%), flies (8%) and rodents (8%).

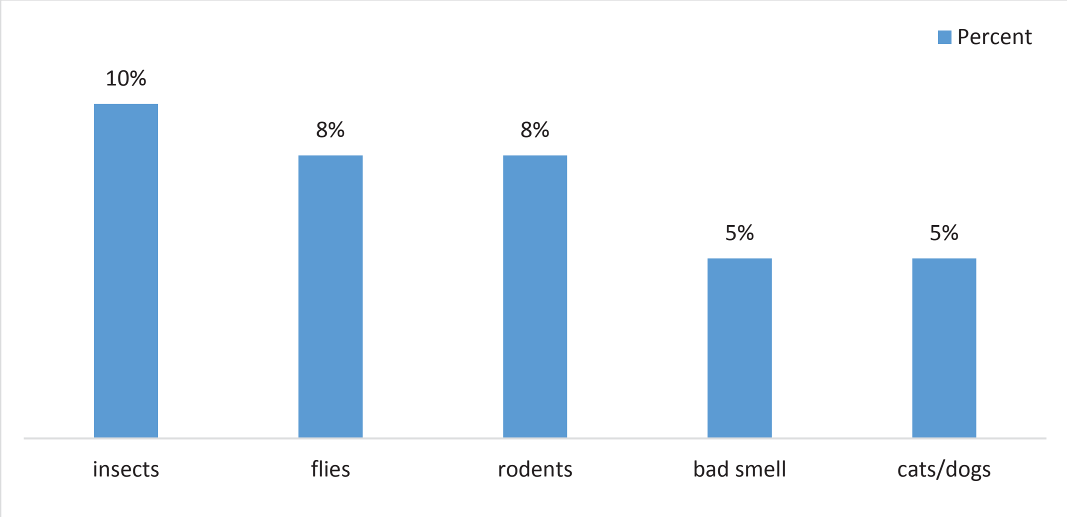

Figure 32 Major home composting problems identified by the home composters in the present study

4.9.1 Number of home composting problems chosen per home composter

Figure 33 shows the number of home composting problems identified per home composter. Among the home composters who mentioned that they have problems, 17% reported one problem representing the largest proportion of the number of home composting problems reported.

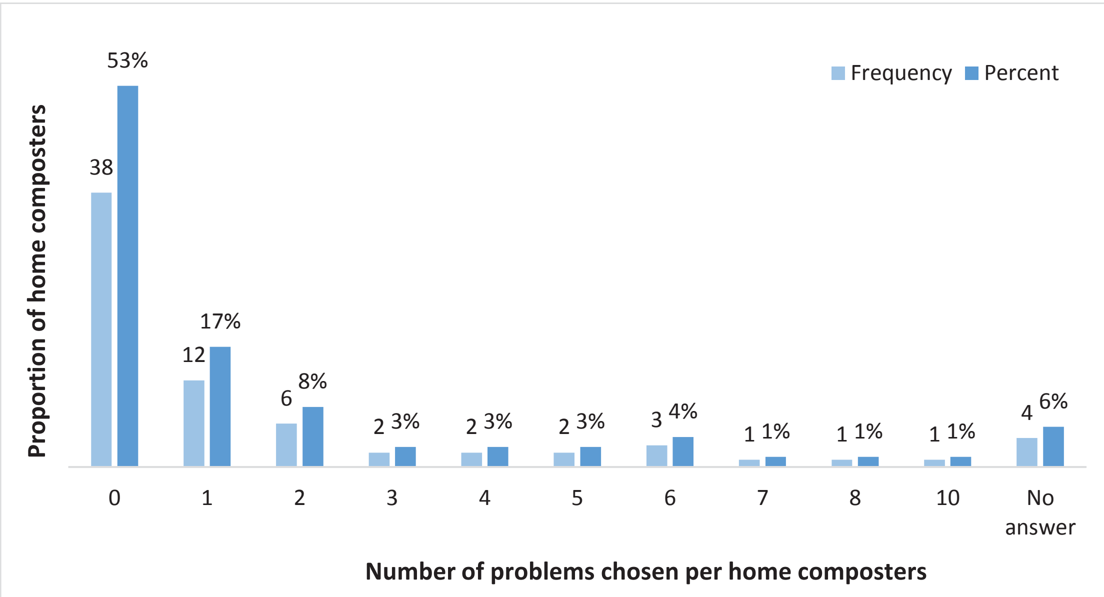

Figure 33 Number of home composting problems chosen per home composter in the combined telephone and door-to-door survey

4.9.1.1 The number of home composting problems identified by the users of the three most common home composting system

The number of home composting problems identified by the users of the three most common home composting systems was also explored to determine if users of any particular system experienced more or less problems (Figure 34). Of the total number of 38 home composters who stated that they have no problems with home composting, the largest proportion was 22 manufactured plastic bin users.

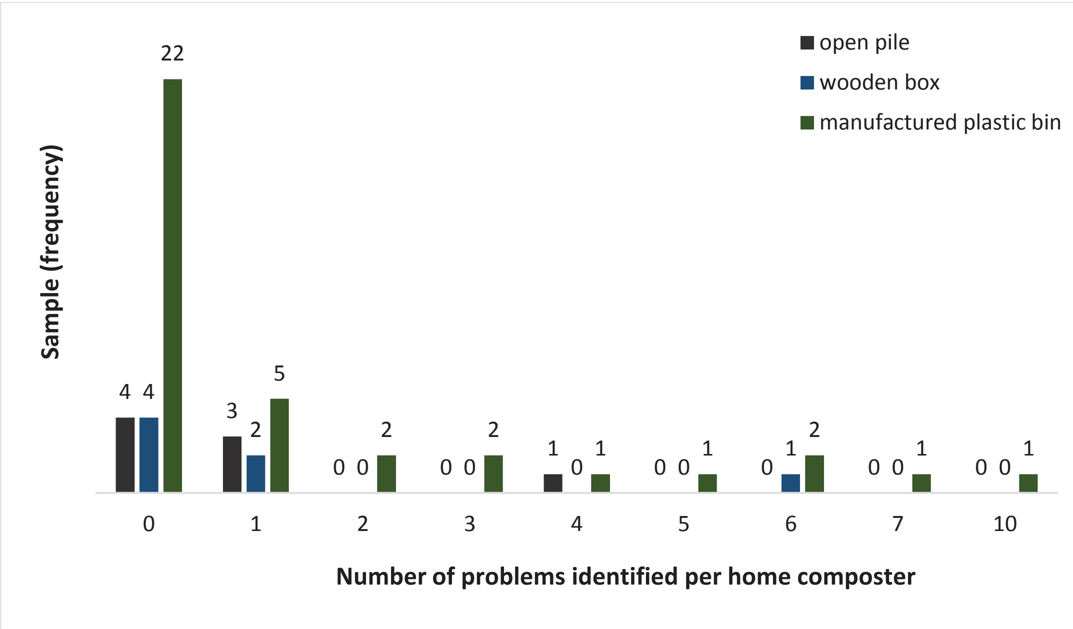

Figure 34 Number of home composting problems selected by users of the three most common home composting systems identified in the present study

4.10 Potential motivation to start home composting

The non-home composters were asked to state what would motivate them to start practising home composting. This was carried out to aid in the identification of possible strategies, by which home composting practises can be increased in Palmerston North. The responses offered by the non-home composters are presented in Table 28. It is worthwhile to mention that this question also employed the multiple answer technique. A large proportion (55%) of the home composters stated that nothing would motivate them to start home composting. Conversely, help from the Council, provision of larger compost bins and home composting workshops were the most common motivations mentioned.

Table 28 Potential motivations to start home composting given by the non-home composters

Motivation	Frequency			Percent (combined telephone and door-to-door survey)
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
nothing	70	1	71	55%
help from PNCC	8	0	8	6%
workshops	8	0	8	6%
"free/subsidised composting bins	12	0	12	9%
"leaflet drop to encourage people"	2	0	2	2%
"more garden waste"	1	0	1	1%
"equipment from PNCC"	1	0	1	1%
"garden"	1	0	1	1%
"if had a bigger section"	1	0	1	1%
"owned my own home"	1	0	1	1%
"recycling scheme by PNCC"	1	0	1	1%
"when I get a job"	1	0	1	1%
no answer	20	0	20	16%
Total	**127**	**1**	**128**	**100%**

4.10.1 Potential motivation to continue/do more home composting

Likewise, the home composters were also assessed on ways by which they could be motivated to continue or to do more home composting. The answers offered to this question were also important to the Council's policy and planning around home composting. The various motivations suggested by the home composters are outlined in Table 29. A large percentage (46%) stated that nothing will motivate them to continue/do more home composting. Common motivations recorded, however, included: provision of free/subsidised bins, provision of larger bins, and help from PNCC.

Table 29 Potential motivations to continue/do more home composting among the home composters

Motivation	Frequency			Percent (combined telephone and door-to-door survey)
	Telephone survey	Door-to-door survey	Combined telephone and door-to-door survey	
nothing	38	3	41	46%
free/subsidised composting bins	8	1	9	10%
provision of larger composting bins	7	0	7	8%
help from PNCC	5	1	6	7%
"more garden waste"	2	1	3	3%
workshops	1	1	2	2%
"be at home"	1	0	1	1%
"best thing to do"	1	0	1	1%
"bigger garden"	1	0	1	1%
"equipment from PNCC"	1	0	1	1%
"garden"	1	0	1	1%
"management of weeds"	1	0	1	1%
"more bins"	1	0	1	1%
"much awareness"	1	0	1	1%
"small bins for small sections"	1	0	1	1%
"get rid of waste"	0	1	1	1%
"more information"	0	1	1	1%
"more time"	0	1	1	1%
no answer	10	0	10	11%
Total	**80**	**10**	**90**	**100%**

4.11 Estimating the volume and mass of organic waste diverted from landfill via home composting

As already stated in Section 3.1.5.4, 30 contacts from the telephone and door-to-door survey were initially targeted for the home visit. However, only 20 contacts were available at the time of the home visit. One of the contacts (450) was also excluded from the volume/mass estimation because the feedstock were mainly large tree branches. Consequently, nineteen contacts from the telephone and door-to-door survey were employed. To broaden the data set for the quantification of organic waste as well as the QA evaluation of the home composting process and products, seven households were voluntarily asked to participate in the study. However, as already explained in Section

3.1.2.1, the result obtained for the telephone and door-to-door survey participants was separated from that of the voluntary participants.

Figure 35 illustrates the total average volume of organic waste diverted from landfill by the telephone and door-to-door survey participants, and the voluntary participants Calculations leading to these projections can be found in Appendices D and E.

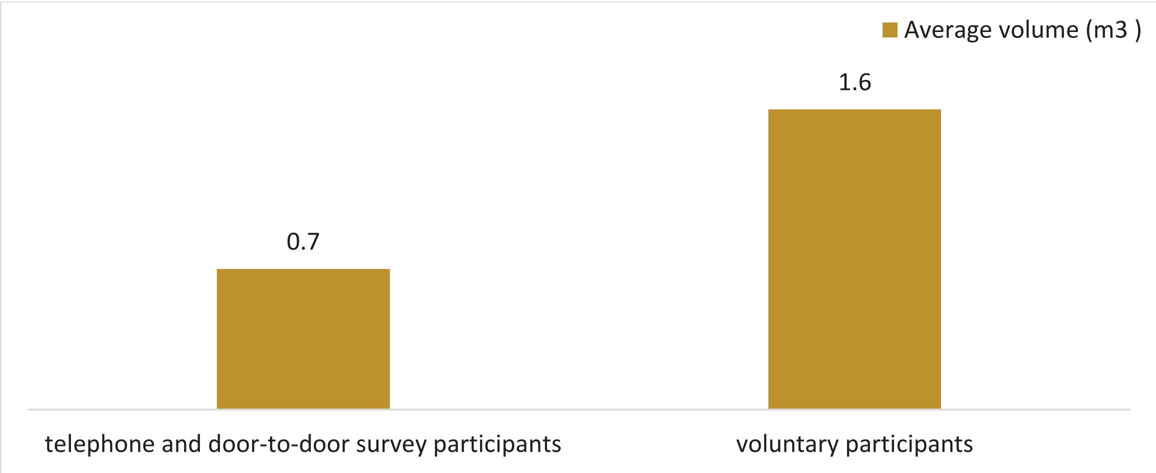

Figure 35 Total average volume of organic waste diverted from the landfill via home composting in Palmerston North (at the time of the present data collection)

Figure 36 illustrates the total average mass of organic waste diverted from landfill by the telephone and door-to-door survey participants, and that of the voluntary participants. Calculations leading to these projections can also be found in Appendices D and E.

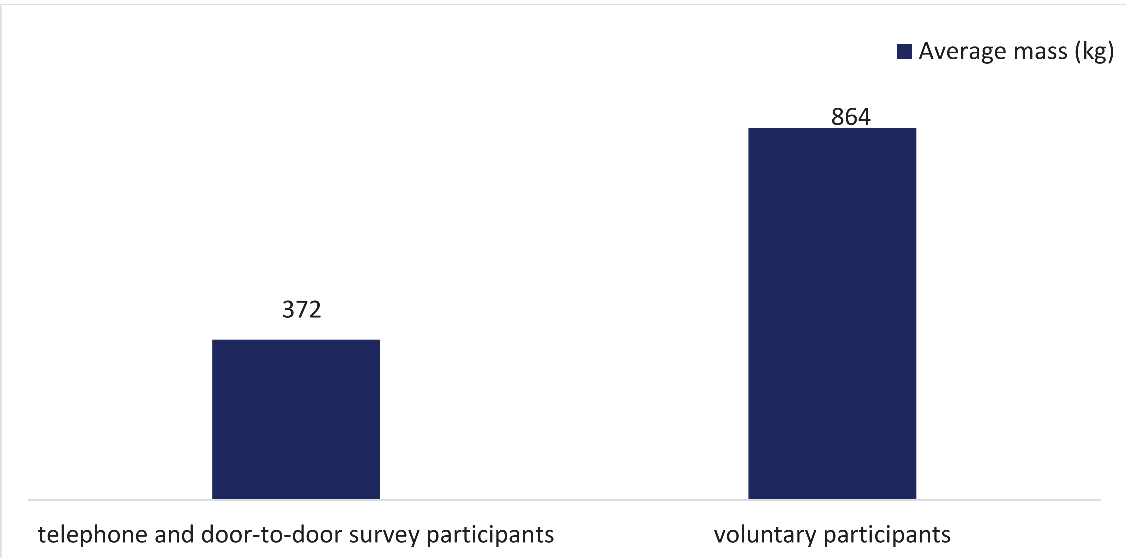

Figure 36 Total average mass of organic waste diverted from landfill via home composting in Palmerston North (at the time of the present data collection)

4.12 Physicochemical analysis of the compost samples collected during the home visit

This section provides information on the physicochemical analysis conducted on the compost samples collected during the home visit. A total of 22 and 13 compost samples were collected from the telephone and door-to-door survey participants, and the voluntary participants respectively. The number of compost samples collected was more than the nineteen telephone and door-to-door survey participants and seven voluntary participants because as already highlighted, some of the home composters had multi-bin systems. Compost samples were, therefore, collected from each system, for instance, samples 5, 74 and 117 (Table 30), to establish a representative QA of the compost samples (and home composting process) for that household.

Tables 30 outlines the results of the physicochemical analysis conducted on the compost samples collected from the telephone and door-to-door survey participants, and the voluntary participants in the home visits. The pH values for the compost samples from both the telephone and door-to-door survey participants and the voluntary participants were within the 5.0-8.5 range provided by NZS4454:2005 except for nine samples (those highlighted in red in Table 30). The average moisture content values were also mostly above the guidelines provided by NZS4454:2005. Regarding the temperature readings, the process temperatures were mostly in the mesophilic range.

Table 30 Physicochemical properties of compost samples collected from the telephone and door-to-door survey participants in the home visits. The values highlighted in red were not within the respective limits while those in green denote average moisture content values greater than 68%.

Sample ID		Average moisture content (40-60%[t])	pH (5.0 - 8.5[u])	Ambient temperature	Process temperature (45-65°C[v])
Sample	10	72.8	9.6	23.2	23.2
	20	58	6.8	24	18
	74A	56.9	7.6	18.6	22.7
	74B	76.6	9.6	18.4	20.9
	74C	49.4	7.6	18.7	18
	117A	55.4	9.8	17	19.1
	117B	67.0	7	20	19.8
	136	54.1	8.1	17	19.1
	159	77.6	7.8	22.3	20.4
	170	61.2	8.8	27.4	18.4
	172	73.4	7.4	23	23
	180	79.8	4.8	20.6	23
	220	66.3	8.8	23.7	31.1
	270	55.3	8.3	20	25.9
	340	66.4	8.4	20.6	19.8
	361	69.9	7.6	23.4	53
	384	71.4	8.6	19.4	20.6
	443	61.3	7.3	25	22.4
	481	68.3	7.7	27	18.6
	486	54.4	8.4	20.4	20.4
	493	65.9	6.5	23	22.6
	589	58.3	7.8	21.7	20.9
Voluntary participant	1	43.76	7	18.6	27.2
	2A	74.61	9.5	18.4	30.6
	2B	50.01	8.2	19	20.4
	3A	49.31	7.3	18.4	18
	3B	68.98	8.3	18.7	17.6
	4	46.77	8.5	23.7	21
	5A	68.64	7.7	26.6	18.4
	5B	50.76	9.3	24.6	25.5
	5C	67.02	8.3	24	18.1
	5D	77.25	8.4	28	24.4
	6A	59.27	6.2	24	22.7
	6B	56.79	6.6	22.7	17.4
	7	52.03	8	26	36.7

[t] Compost quality standards referenced from literature (Cristoforetti et al., 1998; Ermolaev et al., 2014; López, Soliva, Martínez-Farré)

[u] Guidelines provided by NZS4454:2005

[v] Guidelines provided by NZS4454:2005

The temperature profile of the compost samples is shown in Figure 37. The ambient and process temperatures showed similar profiles with most of the process temperatures peaking slightly above the ambient temperatures. The ambient and process temperatures were recorded to establish the effects of the ambient temperature on the process temperature and on the composting process (see Section 5.8 for more information).

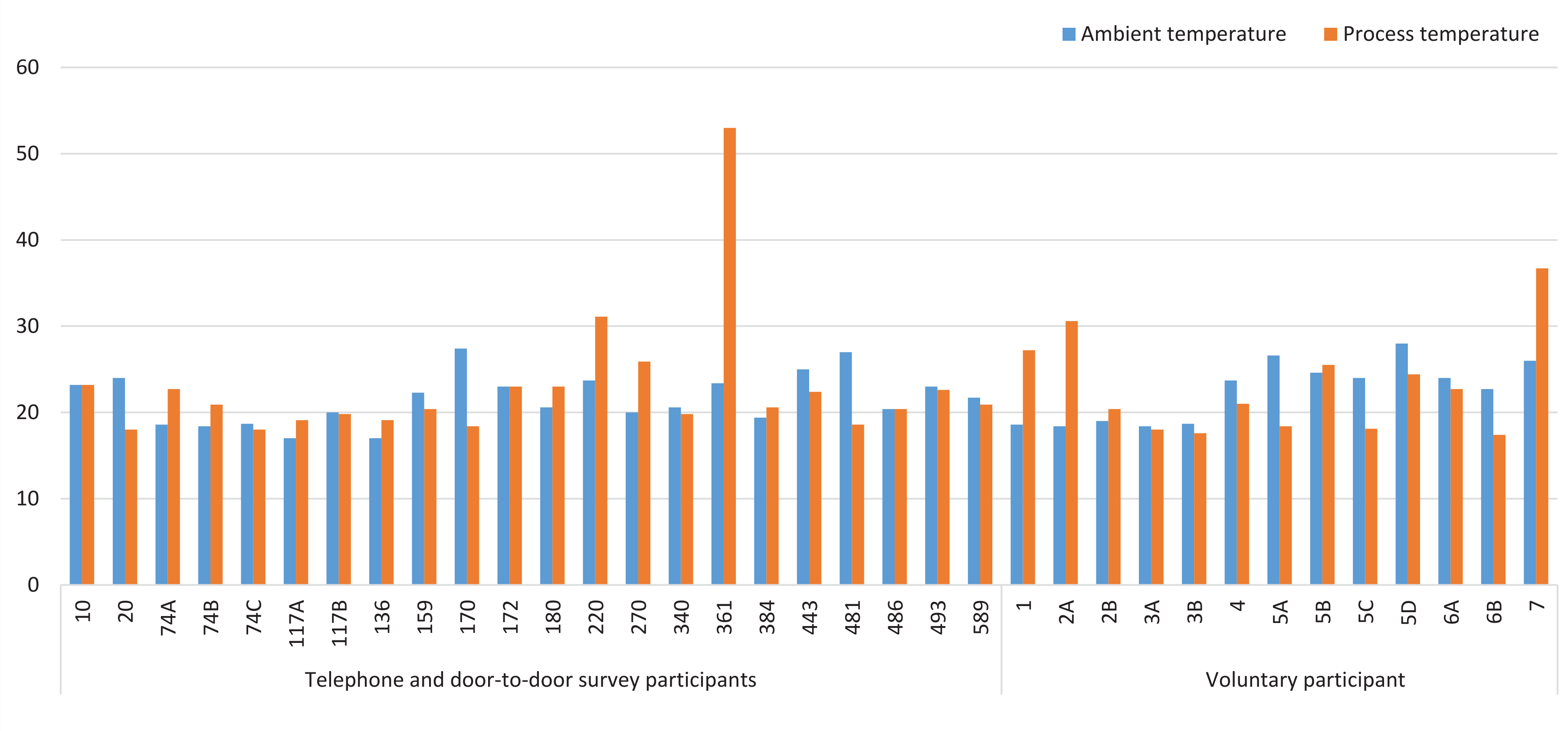

Figure 37 Temperature profile of the compost samples collected in the present study

4.12.1 Analytical results for matured home compost samples from the present study and commercially produced PNCC compost

Table 31 presents the results of the analytical test conducted on the aggregated matured home compost sample from the present study and that of PNCC commercial compost. It also shows the compost quality guidelines provided by NZS4454:2005. In order to determine the points of difference between the values for the physicochemical properties recorded for the home compost and the commercial compost, the values recorded for the commercial compost were used as a reference. This is because more information is available for commercial compost than for home compost.

Table 31 Analytical results for the aggregated matured home compost sample from the present study and commercially-produced PNCC compost. The commercial compost was used as a reference to assess the point of difference between the values of the physicochemical properties recorded because more information is available for commercial compost than for home compost.

Test	Units	Home compost	Commercial compost	Point of difference between home compost and commercial compost (ref. commercial compost)	Guideline NZS4454:2005
'Total' Sulphur	%	0.27	0.24	±0.03	-
'Total' Sulphur	mg/kg	2660	2355	±305	-
pH	pH Units	7.2	8	±0.8	5.0 - 8.5
Electrical conductivity	mS/cm	7.2	4.3	±2.9	-
Total Carbon	%	20.9	19.6	±1.3	-
Total Nitrogen	%	1.98	1.61	±0.37	Greater than 0.6
C/N Ratio	-	10.6	12	±1.4	-
Organic Matter	%	36	33.8	±2.2	Greater than 25
Dry Matter	%	60.9	51	±9.9	-
'Total' Phosphorus	%	0.6	0.41	±0.19	Greater than 0.1
'Total' Phosphorus	mg/kg	6015	4100	±1915	-
'Total' Potassium	%	1.09	1.08	±0.01	-
'Total' Potassium	mg/kg	10910	10725	±185	-
'Total' Calcium	%	3.8	2.5	±1.3	-
'Total' Calcium	mg/kg	38200	25150	±13050	-
'Total' Magnesium	%	0.4	0.38	±0.02	-
'Total' Magnesium	mg/kg	3935	3730	±205	-
'Total' Sodium	%	0.15	0.18	±0.03	-
'Total' Sodium	mg/kg	1548	1731	±183	-
'Total' Iron	mg/kg	9600	8750	±850	-
'Total' Manganese	mg/kg	480	365	±115	-
'Total' Zinc	mg/kg	280	225	±55	Less than 600
'Total' Copper	mg/kg	45	49	±4	Less than 300
'Total' Boron	mg/kg	37	24	±13	Less than 200
'Total' Chromium	mg/kg	15.6	34.5	±18.9	Less than 600
'Total' Arsenic	mg/kg	8.6	22	±13.4	Less than 20
'Total' Lead	mg/kg	44	103	±59	Less than 250
'Total' Nickel	mg/kg	10.6	7.4	±3.2	Less than 60
'Total' Mercury	mg/kg	<0.1	<0.11	±0.01	Less than 2
'Total' Cadmium	mg/kg	0.52	0.4	±0.12	Less than 3

5.0 Discussion

Discussions of the results of the present study are provided in the following sections.

5.1 Participation and refusal rates in the present study

Relatively high participation rates were attained in the telephone survey (Table 17) and the door-to-door survey (Table 18) which together resulted in an overall high participation rate in the present study (Figure 16). The respectively high participation rates recorded indicated that the design and implementation of the survey methodology for the present study was sound. It also represented a positive result in terms of a return on the time invested in the preparation/pilot-testing of the survey methodology. Additionally, it established a solid foundation in terms of a workable volume of data which enhances the overall viability of the present study.

The overall high participation rate recorded also validates the use of a combination of telephone and door-to-door survey methods. Additionally, this result appears to confirm the reports by Christian et al. (2008) and Fowler (2014) that the combination of two or more data collection methods for survey research was a sound approach which could yield a high participation rate.

In as much as a high participation rate is a positive result, the strategic methodology employed to select the two survey methods which were utilised in the present study has been shown to be sound and may have accounted for the high participation rates. This is because the process of reviewing the survey methods used in previous home composting studies (Table 11) included evaluating the pros and cons of the broad suite of survey methods and techniques (refer to Section 3.1.2.1). Ultimately, for the present study, the telephone and door-to-door surveys were specifically selected as the most appropriate survey methodologies for achieving a high participation rate, alongside providing for other critical research considerations. Subsequently, in practice, undertaking a combination of telephone and door-to-door surveys has not only proved viable, both in recording high individual and combined participation rates, but also in terms of overall high utility and feasibility as a data collection method suitable for this context.

The overall participation rate of 64% achieved for the 300 contacts employed in the present study was comparable to the 57.8% reached for 849 households by Tucker et al. (2003) in the UK (Table 11). Tucker et al. employed a combination of door-to-door and postal survey. This suggests that in general combining two methodologies can be a successful approach. However, because the home composting study by DOS (1999) in the USA, which combined door-to-door, telephone and postal surveys, yielded a lower participation rate of 9.4% of the total number of 116 households employed (Table 11), this general principle may not always hold true. Therefore, this contrast illustrates the importance of not just combining methodologies but ensuring that the combination is compatible with the specific context.

5.1.1 The use of two interviewers in this survey research context: exploring variation in participation and refusal rates

Primarily, the strategy of using two interviewers to undertake the telephone survey enabled the survey data collection phase to be completed within a short period. The choice to use two interviewers also enabled the 'influence of interviewers' on the survey process to be examined. A large difference in participation rate was recorded between the two interviewers. It was observed that interviewer one recorded a much lower participation rate (Table 19).

As previously discussed in Section 3.1.2.1, there can be issues with telemarketing and outsourcing of teleservices to overseas call centres, which can result in potential respondents in telephone surveys declining to engage with unfamiliar sounding voices. Therefore, it was likely that one of the reasons for the large difference in participation rate noted between the two interviewers was the foreign-sounding voice of interviewer one as compared to interviewer two, who is a native of the City. Interviewer one was also new to telephone surveys and outside of the pilot-testing process, and had no prior formal training. The resulting inexperience with telephone survey may have also played a role in the high refusal rate recorded by interviewer one relative to interviewer two, who is an experienced research technician.

From these findings, it could be deduced that both the choice to utilise two (or more) interviewers and the selection of the individual interviewers conducting the survey is important. These choices influence the attainment of a positive rapport when introducing the research survey to potential participants, and achieving a high participation rate. This finding appears to confirm the reported experiences from previous studies (Section 3.1.5.2.1) that the interviewers conducting a telephone survey can have an impact on the participation and refusal rates. This finding also supports the research design choices and tactical decisions involved in implementing the survey.

5.2 Reasons offered for declining to participate in the study

The reported combined overall rationales for non-participation (Figure 19) were not unexpected and, relative to the high participation rate, do not appear to be indicative of any major issues. It is likely that that the sense of business and time will always be a potential issue, irrespective of the time of contacting and soliciting the engagement of potential participants.

Japec (2009) observed that several factors will influence a respondent's decision to participate in a survey or not. Japec reported factors comprising 'interest in the survey topic' and the 'timing of the call attempt'. Lavrakas (1993) also mentioned that in a telephone survey, people often respond that they are 'not interested', 'do not have time', or 'do not do surveys', and sometimes simply 'hang-up without any response'. The reasons, as outlined by Lavrakas account for about 40%, 20%, 10%, and 10% respectively of all reported refusals. As outlined in Figure 19, there is a degree of similarity (although somewhat lower) in the results recorded in the present study and what was reported by Lavrakas (1993). Additionally, only a small percentage (20%) of the survey participants expressed a lack of interest in the telephone survey, which was also lower than the 40% reported by Lavrakas (1993). The lower percentages attained in the present study could be due to the design of the methodology, specifically the days and times the calls were made (Table 16).

5.2.1 The critical issue of 'don't do home composting' as a reason for non-participation in the survey

As already highlighted in Section 4.3.1, "I don't do home composting" accounted for 8% of the overall reasons for refusal to participate in the present study. Since these potential participants refused to participate, and in effect exited the study at this point, question two ('do you do home composting?') was not needed to be specifically asked. The net result is that the true non-composting percentage was affected as this percentage of the sample was not captured in the proportion of non-home composters. This unintended consequence is likely to have resulted from adhering to the strict ethical criteria which required the interviewers to introduce the survey topic at the first point of contact (see introduction statement in Appendix A). This disclosure of information provided an unintentional excuse for self-exclusion. This was not helpful in maintaining the rigour around the critical question designed to establish the percentage of occupied dwellings in Palmerston North who are home composters versus those who are non-home composters.

The researcher, therefore, decided that making a transparent adjustment based upon this unintended consequence was warranted as part of the analysis of the results. Subsequently, the proportion of non-home composters among the refusals was added to those among the participants to reflect the true proportion of non-home composters in the present study. This was done to enable a reasonably accurate projection of the respective percentage of home composters and non-home composters in the occupied dwellings of Palmerston North. This 'percentage of households who home compost' is a critical figure required to quantify the amount of organic waste diverted from landfill, via home composting in the City (see Section 5.7 for more details).

In future, because establishing the household home composting percentage is critical to estimating the total home composting volumes in the City, this issue needs to be addressed in the overall design of this type of study. One option to resolve this issue would be to undertake an entirely anonymous 'pre-survey stage' asking just a single question: 'Do you do home composting?' to establish the citywide home composting percentage. Since such an approach is less likely to trigger the requirement for ethics approval, it may be undertaken independently with a separate introductory wording, but be designed to be integrated in a way that maintains the overall integrity of the research process. Additionally, a quick single question survey would enable the sample size to be increased, that is beyond the current 1% of occupied dwellings in the City. An increase in the sample size would greatly increase the rigour of the critical subsequent 'total citywide organic waste volume/mass' calculation.

5.3 Number of years that home composting has been practised and experience level

The review of previous home composting studies (Table 9) revealed that these studies provided limited information on how long the home composters have practised home composting, and its impacts on the process and finished products. Therefore, in the present study, the number of years that home composting had been practised by home composters was explored as an indication of experience levels, and possible knowledge and competence.

Adding together the medium and highly-experienced composters revealed that about 56% of the home composters in the present study have been undertaking the practice for more than 5 years (Figure 22), which can be considered a reasonably high level of experience. Multiplying the estimated number of 10,761 home composters by the 56% of medium and highly-experienced composters shows that around 6026 home composters in the occupied dwellings of the City may have been composting for more than 5 years and could be considered as experienced home composters. The importance of having a large proportion of experienced home composters in the City is explored in subsequent sections.

5.4 Home composting awareness and attitude

5.4.1 The reasons offered by the home composters for practising home composting

As illustrated in Table 21, the major reasons given by the home composters for composting fell under the environmental, gardening/agricultural and economic categories. Several factors may have accounted for a large proportion of home composters offering their reasons for composting in these categories. These factors include the promotional activities and waste minimisation initiatives undertaken by the Council and compost bin manufacturers, which may have shaped local perspective on home composting. An example of the former is the composting guide provided by the PNCC, which outlines the benefits of home composting. The benefits outlined by the composting guide are mostly related to the environment, cost, and gardening. Therefore, through these mechanisms, the households may have become aware of the importance of practising home composting, which reflected in their reasons for taking up home composting.

Manufacturers of compost bins also publish advertising information on the importance of home composting on their websites. A typical example is the Earthmaker bin manufacturer's website (Earthmaker, n.d). Other locally available environmental publications (such as the 'Square Circular'), zero waste education programme (as discussed in Section 1.1.3) and initiatives of environmental organisations like the Environment Network Manawatu[w] may have also encouraged households in the City to become more aware of the importance of composting as part of demonstrating environmental responsibility.

5.4.2 The reasons offered by the non-home composters for not practising home composting

Most of the non-home composters couched their reasons for not composting in their dwelling type, which is living in rental accommodation or having small sections (Table 22). This result was comparable to the study carried out by Mustapha (2013) in Canada where over 50% of households in detached or single dwellings stated that they compost their kitchen waste, as compared to 22% of households living in apartments. In New Zealand, living in apartments/rental accommodation usually correlates to not having a garden (J. Hannon, personal communication, May 18, 2017). Concerning this issue in New Zealand, it can be observed from Table 22 that "no garden" formed a second common reason for not composting. Tucker et al. (2003) also stated that gardening interest, gardening activity, and garden size are highly connected with home composting behaviour, which might explain why a substantial proportion of the non-home composters couched their reasons for not composting in not owning a garden.

Additionally, 'old age' and 'health' formed part of the most frequent reasons offered for not composting (Table 22). Although these group of non-home composters were not assessed on how they manage their organic waste, the establishment of a kerbside

[w] A coordinating organisation and network that encourages and fosters environmental initiatives.

organic collection/food waste drop-off facility in the City could be a possible method to encourage them to divert their organic waste into beneficial uses. This is because the organic waste collected by kerbside services will eventually be composted at the commercial composting site, rather than ending up in the household rubbish bag/bin and going to landfill.

In addition, the non-home composters who mentioned that they find it more convenient to dispose of their organic waste in the rubbish bin for landfill (Table 22) can potentially be encouraged by future PNCC educational/promotional materials/media to send their organic waste to the commercial composting site. However, it may be that they do not have vehicles or find it expensive to hire a vehicle/trailer to drop-off their garden waste at the commercial composting site. This is because the fees charged at the site depend on the vehicle/trailer type conveying the organic waste material (PNCC, 2016a). Whilst pricing incentives do exist to encourage organic recycling, possibly these can be re-examined and revised to be more effective. However, even if cost-conscious members of the community are encouraged and incentivised to send their garden waste to the commercial composting site, they may continue to dispose of their food waste in the rubbish bags for the landfill. This is because as stated earlier in Section 1.1.3.1.1, the commercial composting site does not accept food waste. These service and infrastructural issues appear to be a clear barrier to increasing PNCC organic waste diversion from landfill. The current absence of a general food waste composting capacity links to the absence of a kerbside organic collection (or other alternative community-based food waste drop-off facility) offered by PNCC. Such factors could also be a possible reason why some members of the community find the use of the rubbish bin/landfill convenient for the disposal of organic waste.

Another reason for non-composting that emerged was that it was more convenient to buy commercial compost. A possible reason for this may be the combination of people living in small sections, but owning and being interested in gardens. It may be that, in such situations, people assume that home composting will require too much space, therefore, it is more convenient to buy commercial compost. In contrast to this perception, during the home visits, it was discovered that some home composters lived in small sections but still composted. It could, therefore, be a mere perception that practising home composting on small sections is impossible. Moreover, some compost bins are now advertised as being specifically designed for small sections which allow home composting in small spaces (Rynk & Colt, 1997).

Based on the various reasons given by the non-home composters for not composting, it appears that there is an opportunity for PNCC to establish a kerbside organic collection/food waste drop-off facility in the City, which would allow composting of organic waste on a commercial scale. Such a programme will lead to a significant increase in the waste diversion rate of the City. However, any future intervention through PNCC organic recycling programme will need to reconcile factors such as the relative convenience and cost, as well as other behavioural, educational and attitudinal considerations.

5.5 Home composting operational schemes and accompanying management practices

5.5.1 Home composting systems

A wide range of home composting systems utilised by the home composters was identified, photographed and catalogued in the present study. This image database provides a strong body of background information to assist in the understanding of how composting is practised by local householders. When examined by an expert eye with considerable experience and understanding of composting technicalities, this photographic database (refer to Figures 23 and 24) provides a rich field of information which strengthens the qualitative and quantitative data which emerged from the present study.

The present study was able to establish the clear popularity and uptake of the manufactured plastic option (Table 23). The main brands of manufactured plastic bins utilised by the home composters were also established (Figure 24). Possible reasons for the large proportion of home composters using manufactured plastic bins could be related to the perception that these bin types are easier to use and better for home composting. According to Karnchanawong and Suriyanon (2011), commercially manufactured bins enable the compost pile to retain heat and moisture and are tidier to operate. The design of the manufactured plastic bin offers a greater degree of material containment, which helps prevent odour, the attraction of flies and other nuisance pests and insects. Additionally, the strong, (often) plastic, lightweight, and portable structure of manufactured compost bins potentially offer greater ease of operation for home composting. Moreover, manufactured plastic bins like Garden Mate are normally vented which allows for increased aeration and a quicker composting process (McDowell & Clark-McDowell, 1998). Manufactured plastic bin types like Perroplass can also aerate the compost pile naturally, and according to the manufacturer, do not require turning (Mitre 10, n.d.).

As previously discussed as part of the literature review in Section 2.2.3.1.2.1, commercially manufactured compost bins usually have hatches at the bottom to access the finished composts. According to PCC (2007), it may be difficult to harvest the compost via the hatch, however, the hatch systems provide a useful mechanism to check on the progress of the compost pile at the bottom of the bin. During the home visits, it was found that these hatches were present in most of the manufactured plastic bins. Contrary to what was reported by PCC (2007), it was observed that the hatches were utilised by the home composters to harvest their finished compost. Thus, in reality, the presence of the hatches at the bottom of the manufactured plastic bins do offer an ease of access to the finished compost.

Another possible reason for the popularity of manufactured plastic bins could be the assistance offered in, for example, the user manual and the composting guide supplied by the manufacturers at the time of sale of the compost bin. These materials enable users to maximize the benefits from using their bin and from home composting. In contrast to using these accompanying composting guides, home composters who use homemade composting systems such as ‘open pile’ and ‘wooden box systems’ mostly rely on their own background knowledge.

An exploration of the single-bin and multi-bin system types used by the home composters also revealed that the two-bin system was operated by most of the home composters (Figure 26). One of the reasons for its use among a large proportion of the home composters could be associated with its layered structure. This is because as outlined in Table 7, the layered structure of the multi-bin systems allows fresh feedstock and decomposed materials to be separated from each other as opposed to the single-bin systems where they are often mixed together resulting in a slow decomposition process.

5.5.2 Feedstock/organic waste inputs and general exclusions

A wide range of organic waste material was identified as being feedstock/inputs in the surveyed home composting systems in the present study (Table 24). Importantly, it was discovered that compared with the open pile and wooden box users, a larger proportion of the manufactured plastic bin users composted 5-8 of the eight major feedstock types (Figure 27). This could mean that compared to the open pile and wooden box, home composters consider manufactured plastic bins to be appropriate for composting a variety of feedstock types. This perception may be attributed to the features and the design of the manufactured plastic bins outlined in Section 5.5.1. It could also be related to perceptions created by marketing and promotional information resources. This point represents a future research opportunity to explore more deeply how users perceive and use their home composting systems. Such information will assist the Council's planning and design of future commercial compost bins.

In the present study, the home composters were also asked about the material types they exclude from their compost pile (Table 25). The materials reported by the home composters in the present study also formed part of the general exclusions outlined in Table 10. As previously highlighted in Table 10, materials like cooked and processed food, cat and dog manure, dairy products, meat, fish and bones are considered unfavourable for the composting process, since they cause most of the home composting problems such as nuisance flies, pests and odour.

Due to the high temperatures at which commercial composting is done relative to home composting, material like diseased plants and large plants can be sent off to the commercial composting site rather than the landfill. Thus, as already shown in Figure 4, home composting and commercial composting are compatible and both may potentially be required for effective treatment of the complete spectrum of organic waste types, which can be diverted from landfill in Palmerston North.

5.5.2.1 Use of commercial composting site/landfill by home composters

A small fraction of the home composters also takes a portion of their organic waste such as tree branches, garden waste and surplus garden waste to the commercial composting site/landfill (Figures 28 and 29). This finding revealed that aside from home composting, a proportion of the home composters in the City also use the commercial composting site. Figure 29 also represents interesting information, specifically because all the recorded material types can be easily recycled through composting. Where these materials are reported as going to the commercial composting site, it indicates a positive contribution to the Council's WMMP goals of 75% waste diversion. However, this is also possibly an indication that further organic waste collection systems may be of advantage to home composters. Where these materials are going to the landfill, it is a clear opportunity for some form of programme to increase organic waste diversion from landfill.

As described in Figure 4, both home composting and commercial composting are forms of composting and generally, MSWM methods, which lead to the diversion of organic waste into beneficial uses, such as returning organic matter and nutrients to and enhancing the biology of local soils. Moreover, as outlined in Figure 22, a substantial number of the home composters have been composting for more than 10 years (some for as long as 60+ years) and can be considered experienced composters. However, a portion of them reported that they also use the commercial composting site. This factor appears to confirm a degree of 'unmet need' for services in this sphere and points to the need and compatibility of both home and commercial composting to effectively manage a larger proportion of the organic waste in the City.

5.5.3 Home composting management practices

The reported home composting management practices (Table 26) are reasonably consistent with the general pattern of recommendations, identified in the review of best practise guidelines, outlined in Table 10. Although the proportion of home composters in the present study who undertake these management practices was quite low, it supported the finding that most of the home composters are experienced composters. It was likely that the highly-experienced level/extended number of years of composting correlated with the home composters being knowledgeable about undertaking best management practices to ensure a good quality process and product.

Although mixing/turning formed the main management practice, a substantial proportion of the home composters stated that they do not mix/turn their piles (Figure 30). Furthermore, a large proportion of the home composters who stated that they do not mix/turn their piles were manufactured plastic bin users (Figure 31). This result could also be attributed to marketing promotions around the 'supposedly' naturally aerating nature of the manufactured plastic bins which, according to the manufacturers' marketing literature, remove the need for mechanical turning.

Regarding the addition of soil to the compost pile, it can potentially introduce seeds into the compost pile. However, a small amount of soil in the pile prevents nuisance flies, especially when it is used to cover the fresh feedstock (CCC, 2014; Pears, 2009). Additionally, as shown in Table 10, the soil encourages microbial activities in the compost pile.

Regarding the removal of unwanted material from the pile, only a small fraction of the home composters stated that they undertake this practice (Table 26). These materials included problem weeds, such as oxalis (Appendix F). This relatively low proportion recorded could be related to the exclusion of most of the materials outlined in Table 25 from the compost pile, since the exclusion of these material types from the compost pile reduces the need to remove unwanted material from the pile.

5.6 Home composting problems

The reason for the large proportion of home composters responding that they have no problems (refer to Table 27) could be due to their experience level. This is because, as already highlighted, a large proportion of the surveyed home composters can be considered experienced as they have undertaken the practice for an extended number of years. It can, therefore, be inferred that they have gained a high degree of mastery of the process and therefore, either innately embody or directly follow the best practise guidelines to obtain an effective process, which reduces problems.

In the home composting study conducted by Faverial and Sierra (2014) in Guadeloupe, the major problems reported by the home composters were the presence of insects, such as cockroaches and ants, and rodents. Home composting problems identified in the work of Johnson (1995) in the USA and Canada also included odour, flies and rodents. These home composting problems, in the previous international studies, are comparable to what was recorded in the present study (Figure 32), although in a different geographical location and time. Possible methods for resolving home composting problems can be found in Section 5.6.1.1.

As highlighted in Table 10, problems with insects, rodents, cats and dogs, and odour are usually caused or exacerbated by the addition of what is commonly advised as material recommended for exclusion, such as cooked and processed food, and cat and dog faeces to the compost pile. However, most of the home composters in the present study stated that they do not add these materials to their compost pile (Table 25). Additionally, it can be observed that relative to the number of home composters who stated that they have no problems, only a small fraction reported these types of problems.

It is, however, important to note that the 'excluded' materials are still classified as organic waste. Technically, these material types can be diverted from landfill into beneficial use by being treated (in more advanced composting systems). This then points to the reality that, in any given municipal setting, home composting as MSWM method will offer only a partial solution to the broad spectrum of possible organic waste types. Thus, there is a need to employ both home composting and commercial composting for the management of organic waste in Palmerston North.

5.6.1 Potential motivation for home composting offered by the surveyed home composters and non-home composters

Based on the percentage of the proportion of home composters who stated that nothing will motivate them to start home composting (Table 28), it was projected that about 10,522 of the total number of 19,131 non-home composters in the occupied dwellings of the City may never practise home composting. A large proportion of the home composters also stated that nothing will motivate them to continue/do more home composting (Table 29). The following sections provide information on ways home composting problems could be resolved and how households in the City could be motivated to start or continue home composting.

5.6.1.1 Resolving issues with home composting in Palmerston North

Home composters who experience problems can potentially become drop-outs from the practice (Tucker et al., 2003). Facilitating the right help and getting home composters to utilise it will, therefore, be important in sustaining ongoing participation in home composting (Tucker et al., 2003). The Council has the opportunity to intensify home composting education and awareness in the City with the objective that such an initiative will be especially relevant to the "least-experienced/new home composters". As outlined in Table 29, such initiatives might include home composting workshops where people can attend to gain more knowledge on how to effectively undertake the practice.

The option of providing free/subsidised and/or larger composting bins also formed part of the potential motivation to continue or do more home composting among the home composters (Table 29). In the event that PNCC or any given Council aims at sponsoring/supplying compost bins as part of their initiatives to encourage participation, they may consider the findings from the present study which have explored the types of manufactured plastic bins utilised by home composters. Equally, this initial information could be built upon by future or follow-on studies to explore why users are making the purchase they do and/or more details around how satisfied various composting bin users really are. These studies will be of value because it was observed that a greater proportion of the home composters, who stated that they have no problems with home composting were manufactured plastic bin users (Figure 34). Additionally, the provision of these bin types to home composters will have the potential to reduce a financial barrier to home composting that is, for example, the money spent on compost bins.

5.6.1.2 Increasing home composting practice in Palmerston North

Although 56% of the home composters surveyed in the present study have composted for a substantial number of years, about two-thirds of the occupied dwellings in the City were non-home composters out of which approximately 10,522 may never practise home composting. Subtracting the number of non-home composters who may never practise home composting from the estimated number of 19,131 non-home composters, it appears that about 8,609 non-home composters in the occupied dwellings of the City could potentially be motivated to start home composting. This group of potential home composters was referred to as 'latent' composters by Tucker et al. (2003).

Potentially, the number of current home composters plus the latent composters will ultimately determine the levels of home composting participation that might be realistically achieved in a population (Tucker et al., 2003). Thus, from the results of the present study, the level of home composting participation among households in the occupied dwellings of the City can be increased, if the significant group of latent composters are recruited into the practice. The sum of the estimated numbers of 10,761 current home composters and the approximate 8,609 latent composters indicates that potentially 19,370 home composters may be further supported and/or recruited in Palmerston North. This number represents more than half of the total number of 29,892 occupied dwellings in the City. This finding is quite significant and, therefore, presents an opportunity for PNCC. This research encourages further exploration of recruitment models to facilitate a substantial increase in the number of new home composters. There also appears to be an opportunity for initiating a Council-backed home composting recruitment programme, as well as improving promotional activities to create a positive awareness and improved QA around the practice.

Because the vast majority of the time, effort and cost in home composting are funded directly by the householder, the recruitment of non-home composters into home composting programmes is considered vital for cost-effective municipal strategic waste management planning (Tucker et al., 2003). Faverial and Sierra (2014) also explained that the active participation of a significant proportion of the population in home composting programmes has a positive effect on the municipal waste diversion rate and other strategic objectives. Therefore, increasing the number of potential home composters and encouraging them to continue undertaking the practice will also support PNCC in achieving its 75% waste diversion rate in Palmerston North.

5.6.1.3 Establishment of a kerbside organic collection/food waste drop-off facility in Palmerston North

As previously discussed, it is likely that not everyone in Palmerston North will practise home composting and/or take their garden waste to the commercial composting site. The introduction of the following options may, therefore, reduce the amount of organic waste in landfill:

a. kerbside organic collection/food waste drop-off facility for the collection of organic waste from home (and/or commercial sources).
b. expansion of PNCC commercial organic waste collection services alongside further encouragement of home composting practices.

The first step in establishing a kerbside organic collection/food waste drop-off facility and/or an expanded organic recycling system for the City may include conducting trials and surveys in the City, as were undertaken in the Timaru District (Gallagher & Clarke, 2013). This will aid in the assessment of public opinion about the programme as well as to build up support for new organic recycling programme development. It is recognised that inadequate public consultation and failure to identify and resolve issues early may result in programme failure.

The food and garden organics best practice collection manual by DSEWPC in Australia may also serve as a guideline for PNCC on how to implement a future kerbside organic collection in the City. This manual tackles each phase of the process in the consideration, planning and operation stages of an organic waste collection programme, from exploring the suitable type of systems to adopt, through to public communication and education and constant monitoring and evaluation of the programme performance (DSEWPC, 2012). A trial for a planned new organics collection service in Auckland is also being conducted by the Auckland City Council (ACC). As part of the trial, ACC has published a brochure to guide participants on materials to put in their organic waste bins, and when to put their bins out for collection (ACC, n.d.). This initiative by ACC might also provide a local New Zealand example of good practice for PNCC.

Aside from encouraging residents to participate in the diversion of organic waste into beneficial uses in the City, the programme will greatly aid the Council in achieving its aim of 75% waste diversion from landfills. The programme may, however, present some disadvantages. The pros and cons of establishing a kerbside organic collection/food waste drop-off facility in the City are outlined in the following sections.

5.6.1.3.1 Pros

A kerbside organic collection/food waste drop-off facility in Palmerston North will possibly reduce the disposal of organic waste in rubbish bins for landfills. It also implies potentially fewer home-based problems with nuisance insects, pests and odours, as the organic waste will be composted off-site at the commercial composting site.
Additionally, residents who are currently not home composting (or dropping off their organic waste at the Council's commercial composting site) will be able to participate in this user-friendly organic recycling programme option. They will also be contributing to waste minimisation activities in the City, as the collected organic waste will be composted at the commercial composting site and not disposed of in landfills.

5.6.1.3.2 Cons

The intention of home composting is to offer a flexible and cost-effective approach to organic waste management and to enable sustainable recycling for individual homeowners (Andersen et al., 2011). This is because home composting removes the cost of transporting organic waste to the commercial composting site, as well as any organic waste disposal cost paid by residents (refer to Table 8). Therefore, a new kerbside organic collection/food waste drop-off programme in the City presents an additional cost to PNCC ratepayers. Unlike home composting, where the organic waste is separated and composted at the source of generation, the collection and eventual composting of the organic waste at the commercial composting site will incur costs as it will require vehicles and additional infrastructure. Additionally, households may have to pay involuntary participation fees (included in rates) for the collection of their organic waste (even if they choose not to use this service) and at the drop-off facility.

In addition, new developments such as a kerbside organic collection/food waste drop-off programme may contain substitution effects. It may both reduce home composting rates and potentially remove the possibility of recruiting the latent composters into home composting since they are likely to opt to participate in the new programmes.

Additionally, the home composters identified in the present study as new/inexperienced and/or are facing various problems with home composting might abandon this practice to patronise the kerbside organic waste collection/food waste drop-off facility. This potentially unintended consequence may undermine what would otherwise become a future population of highly experienced and highly committed home composters.

5.7 Quantity of organic waste diverted from landfill via home composting in Palmerston North

Directly measuring the participation rate in the present study enabled an extrapolation of the diversion potential of home composting from the occupied dwellings in the City. Multiplying the estimated 10,761 home composters by the average mass of 372.2kg of compost samples (Figure 36) showed that at the time of data collection in the present study, around 4005 tonnes of organic waste was being diverted from landfill via home composting by the occupied dwellings in the City.

As already explained in Section 3.1.2.1, the results from self-selected or voluntary participants potentially present some form of bias since the resulting data from the self-selected sample is not representative of the occupied dwellings of the City. Therefore, in the estimation of the quantity of organic waste diverted from landfill, only the average mass obtained from the statistically representative sample (that is the telephone and door-to-door survey participants) was used. Relative to that of the voluntary participants, the result from this group was a statistically valid representation of the suburbs which reflects the diverse socioeconomic characteristics of the City.

5.8 Home composting QA evaluation in Palmerston North

With respect to the physicochemical properties of the composts samples, the results from the telephone and door-to-door survey participants, and that of the voluntary participants were combined. This is because, relative to the estimation of the quantity of organic waste diverted from the landfill, a statistical representation of the City was to some extent irrelevant to the QA evaluation of the compost samples. They were, therefore, combined to obtain a larger data set.

The process temperature readings recorded in the present study were mostly lower than the optimum commercial composting temperature (45–65°C) outlined by

NZS4454:2005 (Table 30). However, positive evidence of satisfactory mesophilic type of organic waste decomposition was found in most of the examined home compost piles. The relatively low temperatures recorded may be attributed to the equivalent low ambient temperatures recorded (Chan et al., 2010; Faverial & Sierra, 2014; Lim et al., 2016). Relatively low temperatures have also been reported to be characteristic of home composting processes because the volume of the decomposing material is too low and/or the insulating top layer is too thin for significant heat retention, and, therefore, rapid heat loss or thermal transfer from the pile occurs (Lim et al., 2016). Reaching and retaining the commercially optimum temperature in home composting may simply not be feasible under typical New Zealand home composting conditions due to the generically much smaller size of the compost pile, compared with that of commercial composting scenarios (Chan et al., 2010).

Other authors have also reported temperatures below the thermophilic range in home composting (Ermolaev et al., 2014; Faverial & Sierra, 2014; Smith & Jasim, 2009; Vázquez et al., 2015). Therefore, the temperature readings recorded in the present study can be considered, if not ideal, to be appropriate for home composting. The temperature recorded for one of the samples was, however, 53°C (Figure 37) which showed that home composting processes can also reach high thermophilic temperatures. An interesting expansion on this study would be to examine temperature profiles over time in a range of home composting scenarios since this is typical in QA monitoring in a commercial composting context.

High temperatures in composting have been reported to be crucial for pathogen reduction, the killing of weed seeds, and sanitization of organic waste (Lim et al., 2016). It can be observed from Table 25 that most of the home composters left out materials such as diseased plants, weeds and treated wood, which were considered unfavourable for the home composting process. The exclusion of these materials from the compost pile, therefore, reduced the reliance on the pasteurising effect of composting at high thermophilic temperatures. This is because if the material being composted is not diseased and does not contain seeds and plant propagules, high temperatures may not be required (Alexander, 2007; Dickson, Richard, & Kozlowski, n.d). Additionally, the relatively long residence time of the feedstock in compost bins allows the natural decay of pathogens to occur in home composting (Colon et al., 2010).

The overall pH of fresh feedstock, semi-matured and matured compost samples were almost neutral to slightly alkaline, except for five samples which were slightly acidic with pH values of 4.8-6.8 (Table 30). Only one matured compost sample was neutral while the remaining samples were slightly alkaline and typical of mature compost (refer to Appendices G and H for information on matured compost samples). These values can be considered favourable for the composting process and produce a quality finished compost (Vázquez et al., 2015).

Additionally, it can be observed in Table 30, that most of the pH values and their corresponding temperatures were above 6.0 and below 40 °C respectively. These values appeared to be broadly suitable for the anticipated mesophyllic decomposition of the feedstock. This is because a combination of a pH below 6.0 and temperatures above 40 °C has been reported to seriously inhibit[x] degradation during composting (Sundberg et al., 2011).

Regarding the average moisture content values recorded, none of the values was below 40%, while seven samples had values slightly above 60% (these values are highlighted in green in Table 30). Samples with average moisture content values greater than 68% (these values are highlighted in red in Table 30) were considered too high (Li et al., 2013; Vázquez et al., 2015). Andersen et al. (2011) recommended that the moisture content of finished compost should be below 50% to keep the handling, transportation and application feasible. This was, however, not considered a major issue in the present study, since the compost produced was used directly in the garden of the home composters (Andersen et al., 2011; Tatàno, Pagliaro, Di Giovanni, Floriani, & Mangani, 2015).

The relatively low temperatures recorded were also related to the high moisture contents recorded in some of the samples. This is because high moisture content has been reported to indirectly limit the internal temperature increase, due to both a

[x] NB: albeit this appears at odds with the thermophilic construction reflected in NZS4454:2005.

reduction in air-filled pores, and a lower total dry mass of the pile, which is considered unfavourable for heat retention (Bardos, 2004; Christian et al., 2009; Lleó et al., 2013; Tatàno et al., 2015). Conversely, high composting temperatures can be associated with driving off moisture as steam and drying out. It may be interesting in any such future research to examine the relationship between local rainfall patterns/peak episodes and seasonal ambient temperatures both of which may influence moisture content in the home compost, depending on bin type and compost management practice.

Furthermore, a large proportion of the home composters reported that they compost in manufactured plastic bins (Table 23) and these compost bin types are normally, by design, enclosed. Therefore, the high moisture contents could be due to the identified high utilisation level of these enclosed plastic bin types (Lleó et al., 2013) for home composting. The relatively high amount of food waste composted (Table 24) in a home composting versus commercial composting scenario (as is the case of Palmerston North) may also be a possible reason for the high moisture content values recorded. This is because food waste has a high moisture content (Li et al., 2013). To avoid limitations such as anaerobic conditions due to high moisture content, the home composters could be advised in any future PNCC home composting promotion/intervention to add brown material to their compost piles to bring down the moisture levels to less than 60% to enhance the air porosity via free air spaces (Kumar, Jayaram, & Somashekar, 2009). In future research, it would be good to explore in more detail positive and negative correlations between system type, home composting management practices and QA parameters over time.

5.8.1 Comparison between home compost from the present study and commercial compost from PNCC

Generally, there was a slight difference between the compost quality values obtained from the home compost and the commercial compost. The mean values of properties such as organic matter content and nitrogen content of the home compost and commercial compost were both within the guidelines proposed by NZS4454:2005 (Table 31). Additionally, the mean pH value of the home compost was almost neutral (7.2), while that of the commercial compost was slightly alkaline (8.0). These were also within the range (5.0–8.5) provided by NZS4454:2005.

The average C/N ratios were 10.6 and 12 for the home compost and commercial compost respectively (Table 31). Both C/N ratio values were less than 20. As explained by Karnchanawong and Suriyanon (2011) and Vázquez et al. (2015), this indicated that the feedstock used in both composts was stabilized and matured. The carbon, nitrogen and sulphur content in the home compost were, however, generally higher than that of the commercial compost. This might be explained by the relatively high use of soft plant tissues with higher potential nutrient value, as feedstock in a home composting scenario plus the relative exclusion of nonshreddable woody plant with characteristically low nutrient content (Smith & Jasim 2009).

Both composts contained significantly lower heavy metal content than the standard levels prescribed by NZS4454:2005, indicating an extremely low presence of heavy metals (Lleó et al., 2013). The total arsenic level of the commercial compost was, however, slightly above the limit proposed by NZS4554:2005. Sources of arsenic may include the composting of feedstock contaminated with shredded Chromated Copper Arsenate (CCA) treated timber or the addition, to the organic waste, of ashes derived from the burning of CCA-treated wood.

It was also discovered that the heavy metal content in the home compost was generally lower than that of the commercial compost (Table 31). One of the benefits of home composting is that it allows more specific control of the composting process and the organic material treated by the householder (Table 8). Thus, the careful selection of feedstock types in home composting may be responsible for the lower concentrations of heavy metals recorded (Faverial & Sierra, 2014; Lleó et al., 2013; Martínez-Blanco et al., 2010).

Additionally, the possible, but in this case unquantified, addition of cattle manure (Table 24) to the home compost pile could also be a reason for the lower levels of heavy metals recorded. This is because, with the addition of an appropriate amount of cattle manure, available heavy metal content could be significantly reduced, due to enhanced humification (Lim et al., 2016). An addition of lime to the home compost pile could also be a reason for the low heavy metals contents recorded. This is because the addition of lime to the compost pile has been proven to significantly aid in the reduction of the heavy metal bioavailability during the composting process (Lim et al., 2016).

The electronic conductivity indicative of the overall salinity of the substrate (Vázquez et al., 2015) was higher in the home compost than the commercial compost, with a mean value of 7.2 mS/cm. This indicated a relatively high salt content. This result may be due to the high degree of decomposition, by virtue of the relatively long production cycles of organic materials, which leads to the accumulation of various water-soluble salts (Barrena et al., 2014). It may also be due to the food waste component in the home compost pile relative to the commercial composting pile because food waste has been reported to contain high salt content (Li et al., 2013; Vázquez et al., 2015).

From the analytical results presented in Table 31 and the discussions presented above, it was inferred that both the home compost and commercial compost were of good quality, that is; they were stable, mature and had a low heavy metal content. This is because, despite the differences between the mean values of their physicochemical properties, most of the values were within the guidelines proposed by NZS4454:2005 and the referenced literature. Accordingly, they were both considered suitable for use as a soil amendment and as an inorganic fertilizer substitute.

5.9 Home composting processes and finished composts evaluation scores

The observations made on the home composting processes and finished composts during the home visits and their corresponding evaluation scores are provided in Appendices I and J. The "final evaluation score" obtained for the 19 telephone and door-to-door survey participants involved in the home visit was 4 ("good"). Additionally, the average score for the parameters used in evaluating the home composting processes and finished composts were mostly above the average score of 3. This could mean that the home composting processes and finished composts of the occupied dwellings in Palmerston North were of reasonably good quality.

It should be noted that data on the voluntary participants were not included in the QA evaluation because as previously discussed, the data obtained from these participants were not statistically representative of the different SES of the City. Thus, that of the telephone and door-to-door survey participants was employed, since this data was statistically representative of the varying SES of the occupied dwellings in the City.

Some of the responses given by the participants in the survey and the observations made during the home visits were also explored to determine the relationship between the findings from the survey, the home visits and the high final evaluation score recorded.

5.10 Self-report versus home composting QA observation

As previously highlighted, mixing/turning of the compost pile formed the most common management practice reported in the survey. At the time of home visits, it was also observed that most of the compost bins were of suitable heights and had large top openings which provided ease for mixing/turning the pile. This was reflected in the average score of 4.1 (“good”) recorded for mixing/turning (Appendix J).

Thus, as discussed in Section 5.5.1, the features and design of the compost bins (mostly manufactured plastic bins) could be attributed to the reason why mixing/turning was the most common home composting management practice.

With respect to the feedstock/input types, most of the home composters reported that they do not put material like cooked and processed foods, and meat and bones in their compost pile (Table 25). During the home visits, it was also observed that a large proportion of the compost piles were free from most of these general exclusions. An average score of 4.6 (“good”) was, therefore, recorded for contamination (Appendix J).

Based on these responses in the survey and observations made during the home visits, it was inferred that the responses provided by the home composters in the survey appeared to be consistent with the observations made in the home visits.

Recommendations on how the methodology employed in the present study can be improved are provided in the following section.

5.11 Key recommendations on how the current methodology can be improved for future studies

The present study was more than filling the gap in home composting data locally in Palmerston North but was also more broadly about developing an enhanced methodology relevant to other home composting quantification and evaluation studies, internationally and within New Zealand. One of the main tools that aided in realising this aim, was the survey questionnaire (Appendix A) and the proposed HCET (Appendix B). The benefits derived from using these tools are outlined as follows:

a. They provided an accurate, quick and efficient way of data collection.
b. They facilitated the use of a large sample size, which reasonably strengthened the projection of the results for the entire number of occupied dwelling in the City.
c. Specifically, the survey questionnaire enabled the use of two interviewers in the telephone survey because it provided a guideline for conducting the interviews uniformly.
d. The survey questionnaire also provided the opportunity to strengthen future studies, since the use of tick boxes and the "OTHER" category provided mechanisms for revising and improving the data sheets, specifically, to exclude the less frequent responses and replace them with the most frequent ones and those from the "OTHER" category.

Basically, the study questionnaire employed in the present study enabled a final revision (based on actual research practice rather than theory) of the datasheet, which can be offered to future researchers undertaking this type of data collection. As a result of this research, and based upon the importance of home composting as a municipal waste management practice, the researcher advocates further studies on home composting. Additionally, it is anticipated that the novel contribution offered in the form of the results and revised final versions of the survey questionnaire and HCET datasheets will support and improve future research in this sphere. The amended survey questionnaire can be found in Appendix K.

The following sections provide discussion and potential directions that may be useful for future home composting evaluation and quantification studies, internationally and within New Zealand, based on the findings and recognised limitations of the present study.

5.11.1 Comparison of the responses given in the telephone survey and door-to-door survey

Some of the responses given in the telephone and door-to-door survey were explored to determine possible similarities and differences in the responses given. In the telephone survey, the reasons given for not participating in the study were mostly related to time, business and lack of interest (Figure 17), while that of the door-to-door survey was because they do not practise home composting (Figure 18). These results could mean that in contrast to telephone surveys, people are less likely to respond that they are busy, or not interested in the study when approached at the door. However, some of the telephone survey participants also responded that they do not do home composting although the number (three) recorded was smaller than the six recorded for the door-to-door survey.

The most frequent reasons given for practising home composting in both the telephone and door-to-door survey were related to the environment, gardening/agriculture and cost (Table 21). Additionally, the most frequent reasons given in both survey methods featured in the reasons for not composting in the combined telephone and door-to-door survey (Table 20). These results revealed what was regarded as a relatively insignificant difference in the responses given in both survey methods.

From the observations provided above, it was inferred that a combination of telephone and door-to-door survey provides the ability to obtain a balance between responses, resulting in reasonable quality/strong data.

5.11.2 Choice of interviewers

Although the interviewers in the present study were from different cultural backgrounds and age, generally, there was little variation between the interviewers in the responses given to the questions. This was reflected in the data entry because it was done with ease by interviewer one.

According to Japec (2008), many different tasks are undertaken by interviewers which comprise gaining cooperation from the samples, persuading reluctant people and motivating respondents during the interview session. These tasks require different skills, and interviewers’ skills vary (Japec, 2008). Therefore, it is suggested that a variety of people, with different attributes, could be used as interviewers in future studies. A variety of people may enable the survey to be conducted in a shorter time frame (as in the present study), and provide a variety of voices, which could create a balance in the responses given by the participants. However, due to the differences that may arise from how each interviewer conducts the survey, a group of four interviewers appears to be optimal in this context, as this number is practical and likely to offset the differences in the responses.

5.11.3 Identification of the proportion of home composters and non-home composters

As previously discussed, some of the non-home composters were recorded among those who refused to participate in the study. Therefore, the proportion of home composters and non-home composters in the present study was adjusted. To prevent future occurrences, it is recommended that 'question 2' should come before 'question 1' in future studies (refer to Appendix K).

Alternatively, 3-4% of the population can be sampled instead of the 1% used in the present study and asked the simple question, "do you practise home composting?". This is because, the larger the number of people who answer this question, the more likelihood that a robust representation of the proportion of home composters and non-home composters among the entire population will be achieved.

5.11.4 Exploration of single-bin and multi-bin systems used by home composters

In the present study, the idea was to establish the type of compost bin and the corresponding system type (that is, single and multi-bin system) used per home composter. However, as previously stated in Section 4.6, a high rate of non-response was recorded for this question. Therefore, it is recommended that in future studies, 'question 5' should be separated to cater for the type of compost bin and the system type (single versus multi-bin systems) as illustrated in Appendix K.

5.11.5 Estimation of the diversion potential of home composting

A possible criticism of the present study is that the data for the quantity of organic waste diverted via home composting was cross-sectional data since the data was collected at a single point in time, due to time and resource constraints. Therefore, the estimated quantity of organic waste obtained in the present study could not be compared to the Council's WA data and other reported data, since these data were mostly collected through a longitudinal survey[y], mostly over a year. It is, therefore, suggested that in future studies, a longitudinal survey could be employed to enable the estimation of organic waste diverted via home composting in 'tonnes per annum'.

6.0 Conclusion

The present study developed and trialled a methodology to quantify and evaluate the home composting processes and finished composts in Palmerston North, New Zealand. To achieve this, a mixed-method quantitative and qualitative approach, using combined telephone and door-to-door surveys, were employed to survey 300 households, representing approximately 1% of the occupied dwellings of the City. The sample households, which were surveyed by each of the two survey methods were randomly selected and were statistically representative of all the suburbs to reflect the socioeconomic variation of the City. Observational and physical data were also collected from the actual home composting system of 19 sample households, and seven households who voluntarily participated in the study.

The methodology was developed by a review of previous home composting studies reported in the literature, international and New Zealand home composting best practise guidelines, as well as insights from the New Zealand Composting Standard[z] (NZS4454:2005). The research methodology was designed to be appropriate within the constraints of the research level and timeframe. Additionally, it was implemented in accordance with the University's ethic's guidance/application/approval process. The

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[y] A survey employed to collects data from the same sample elements on multiple occasions over time (Lynn, 2009).

[z] NB: Although this was designed for the commercial composting setting there are several areas of general bio-physical and technical relevance to the home composting configuration.

large and diverse body of resulting data was also analysed and reported in a manner consistent with the approach and standard demonstrated in the review of scientific literature, which generally informed this project.

In order to support the accuracy and completeness of the extensive data collection, which was undertaken in a short timeframe, two novel data sheets were developed. Firstly, in balancing the need for time and information efficiency, a survey questionnaire was employed which combined tick-boxes (reflecting expectations generated from literature review) and open answer frames to gather 'OTHER' information and to reflect the participants' voice. Secondly, a 'home composting evaluation tool' was formulated into datasheet/interpretative guidance for the onsite collection of physical data relating to the 'quality assurance' of the home composting process and finished products. Overall, the qualitative-quantitative mixed methods approach encompassing both a multiple survey approach and physical data collection was developed and revised through iterations as a result of the literature review, consultative workshop, pilot-testing cycles and final revision based upon use in research practice.

The resulting learning experiences and information resources have been captured in this thesis and presented as a research outcome offered in support of future home composting survey research. Internationally, home composting represents an important aspect of 'municipal solid waste management'. The present study supports the view that there is significant opportunity to improve the collective understanding of this practice through better data in order to enhance recruitment, participation, management practices and the 'quality assurance' of final products.

6.1 The survey findings and observations from home composting practices and end products in Palmerston North:

The participation and refusal rates recorded in the present study indicated that a combination of telephone and door-to-door survey was a viable collective methodology, which produces a high participation rate and an extensive and representative data set. It was also observed that the use of a variety of interviewers in the telephone survey supported the objectives of efficient data collection, positive participation rates and balanced responses given by the participants.

Regarding the proportion of home composters and non-home composters in the occupied dwellings of Palmerston North, the present study recorded a proportion of 36% home composters and 64% non-home composters. Based on these percentages, it was projected that approximately 10,761 and 19,131 out of the 29,892 occupied dwellings in the City are home composters and non-home composters respectively. The combined overall estimated proportion of home composters in the occupied dwellings of Palmerston North appeared to be high. Having over a third of the occupied dwellings of Palmerston North practising home composting was an encouraging outcome for this positive organic waste management method.

In contrast to 38 home composters (29%), who stated that they have no problems with home composting, a small proportion reported problems with nuisance insects (10%), flies (8%), rodents (8%), cats/dogs (5%) and odour (5%). Possible methods for resolving problems with home composting, as well as motivating and increasing participation in home composting in the City have been suggested. This included the supply of the compost bin types identified in the present study.

In terms of increasing home composting participation in the City, the present study identified that approximately 10,522 out of the estimated 19,131 non-home composters in the occupied dwellings of the City may never undertake the practice. However, it was observed that home composting practise in the City will increase if the current home composters and the latent composters are further motivated. It is, therefore, suggested that the Council could intervene to promote home composting. The Council could also explore future/further interventions/initiatives to achieve this. For example, through the distribution of free/subsidised bins and offering workshops to avoid 'drop-out' by the current home composters, as well as to recruit the latent composters into the practice.

The physicochemical properties of the compost collected in the present study were also assessed in relation to the NZS4454:2005 guidelines and other good practice guidance offered in scientific literature. The results from the physicochemical analysis indicated that finished composts produced by the home composters in the occupied dwellings of the City were positive in terms of accepted parameters of 'quality assurance'.

A comparison of the physicochemical properties of matured home compost samples collected in the present study and commercially-produced PNCC compost was also conducted[aa]. The results from the analytical test demonstrated that the physicochemical properties, such as organic matter content, electrical conductivity, and heavy metal content of the home compost, were similar to or better than that of the commercial compost. This revealed that finished compost of good 'quality assurance' can be derived from organic waste using both home composting and commercial composting in Palmerston North.

Accordingly, the integration of home composting and commercial composting appears to be a more effective overall approach than employing home composting or commercial composting processes exclusively. It was, therefore, suggested that home composting should also be promoted alongside commercial composting in Palmerston North. As part of a systematic future strategy, the present study encourages further examination of options for establishing a kerbside organic collection/food waste drop-off facility and enhancing home composting and commercial composting processes infrastructure and management practices.

The present study quantitatively assessed the current in-process diversion of organic waste from landfill via home composting. It was estimated that about 4005 tonnes of organic waste were at this point in time being diverted from landfill via home composting by the occupied dwellings in Palmerston North. Whilst this study does not establish a 'tonnes per annum' organic waste diversion rate for the City's total home composting, as a metric which can inform future PNCC 'Waste Assessment', the findings and research process have taken an important step towards a theoretical understanding of how this 'tonnes per annum' figure can be measured. Addressing these next data challenges represents a future research opportunity, whose outcome will be relevant to all international and local authorities seeking to understand and report on home composting practices. These research findings and researcher experience encourage

[aa] Independent expert advice was anticipated and sought from soil and compost scientists, but this was not immediately forthcoming, nor able to be incorporated in the tight time frame in which this research was conducted.

greater attention and further resources to be directed at further exploring and understanding the critical waste management practice and the scientific subject of home composting.

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Appendix A Survey questionnaire

Questionnaire # ______________	Suburb __________________		Start time: ___: __
Telephone number ______________________	Sample ID ________________	Date _______/_____/________	End time: ______: ____

Introduction: Hello, my name is Sabina, a Massey University student. As part of my Master thesis, I am carrying out research into home composting in Palmerston North. I am undertaking a phone survey which takes approximately 5 minutes. The participant needs to be over 18 years of age. Participation is entirely voluntary and completely anonymous and confidential and you can refuse to answer any questions and or withdraw at any stage. If you have any questions or concerns I will be happy to answer them. *"For this study, home composting is considered as the recycling of food and garden waste into compost in your home to be used in your own private garden. Food and garden waste stockpiled for collection by waste service providers for composting, as well as mulch mowing are not considered in this study. This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director, Research Ethics, telephone 06 356 9099 x 86015, email humanethics@massey.ac.nz".*

1. Would you or anybody in your household be willing to take part in my research project? () Yes ( ) No

If YES: 2a. Does your household do home composting? ( ) Yes ( ) No (*SKIP TO QUESTION 3b on the other side*) - if yes 3a. For how long? ( )

- If yes 4. Why do you do home composting? / What do you like about home composting?
( ) it saves landfill space ( ) compost can be used as soil amendment ( ) it reduces harmful effect on the environment ( ) it reduces organic waste ( ) use of organic waste ( ) it saves money on waste disposal cost ( ) free bins ( ) subsidised bins ( ) it saves money on fertilizers ( ) it saves money on seed raising mix ( ) it is cheaper than buying commercial compost ( ) peer pressure ( ) curiosity ( ) to teach children ( ) grow and eat healthier produce ( ) it is offered by the Council ( ) to help the Council's home composting program ( ) to save dustbin space Other:

5. Describe your home composting system? / What type of home compost bin do you use?
( ) single-bin system ( ) two bin system ( ) multi-bin system ( ) just a pile left to break down ( ) wooden box ( ) plastic bin / container ( ) wire fence ( ) concrete brick ( ) home made from scrap / recycled materials ( ) ground/soil incorporation ( ) worm farm / vermi-composter ( ) Bokashi system ( ) Commercially produced system - names: ( ) hungry bin ( ) earth maker ( ) bio stack ( ) tumbleweed ( ) cone composter - Other:

5a. What materials do you home compost?
( ) food leftovers ( ) leaves ( ) garden weeds ( ) grass clippings ( ) garden pruning ( ) tea bags / coffee grounds ( ) fruit and vegetable peelings ( ) eggshells ( ) manures ( ) saw dust / wood shavings ( ) sea weed - Other: [ ]

5b. Is there any material type you do not put in your home composting system? - name types: [ ]

5c. Do you take any of your food waste/garden waste to the commercial composting site or landfill? ( ) Yes ( ) No. if Yes name them [ ]

6. Management: **Which management practices do you normally undertake?** adding soil ( ) adding compost 'starters' / special bacterial formulations ( ) watering / wetting of compost pile when dry ( ) sourcing specific materials from off your section i.e. see weed bark or saw dust – Names

- Mixing: Do you mix the compost pile / bin / system ( ) No ( ) Yes - **How often do you mix the compost pile?** ( ) daily ( ) weekly ( )fortnightly ( ) monthly ( ) never

7. How long is the composting cycle i.e. till the material has finished composting & is ready to use? ( ) 1 month ( ) 3 mths ( ) 6 mths ( ) one year ( ) more

8. Where is the home composting system located? ( ) kitchen ( ) backyard / garden

9. Do you have any issues or problems with home composting? ( ) none ( ) insects ( ) rodents ( ) bad smell / odour ( ) cats / dogs ( ) time-consuming ( ) much effort required ( ) price of compost bins ( ) lack of information / knowhow ( ) lack of incentives ( ) requires a lot of space ( ) weed growth in compost ( ) slow process ( ) smelly / slimy / low quality compost ( ) bin / system is too small ( ) compost pile does not heat up ( ) overheated compost pile ( ) compost pile is too dry ( ) compost pile is too soggy ( ) others – describe [ ]

If NO: 2a. Would you like to offer a reason for not being able to participate?
(I don't do phone surveys
( ) I hate being disturbed.
( ) Not a good time
( ) I am busy
( ) I don't do home composting

(ASK ONLY IF THE RESPONDENT IS BUSY)
Can I call you back? ( ) Yes ( ) No
Would you prefer a face-to-face visit?
( ) Yes ( ) No
2c. *(If yes)* At what time is good for you?

(ASK ONLY IF THE RESPONDENT DOES NOT DO HOME COMPOSTING)
3b. ( ) Is there a specific reason why you don't do home composting?
(MOVE TO QUESTION 9 and 10)

10. Is there anything that would motivate you to start or to continue or do more home composting? ( ) nothing ( ) help from the PNCC ( ) free / subsidised bins or composting system ( ) provision of larger compost bins ( ) home composting workshops where you can learn ( ) other incentives or rewards ( ) other ideas

11. For my thesis, I need to collect compost samples for lab analyses, observe, evaluate and take photographs of the home composting system. Can I come to your house to do this? ( ) Yes () No
11b. (If yes) At what day/time will you be at home?

Appendix B Proposed HCET/physical assessment data collection tool

Proposed HCET/ physical assessment data collection tool							
Questionnaire #	**Telephone #**	**Date: / /**	**Photographic Observations**	**YES / NO**	**Start time *(mins)*:**		**Visit Duration *(mins)***
Suburb	**Sample ID**				**End time *(mins)*:**		

Parameters	**Observations / Discussion** *Where appropriate a yes vs no and / or metric [where poor =1 → good =5]*		**Evaluation** Yes	No	1	2	3	4	5	Av
EVALUATION OF COMPOST PROCESS QUALITY ASSURANCE										
Location / Siting	Appropriate proximity to house relates to the visual, odour & nuisance impacts									
	Usable, all weather access, good drainage - avoids water pooling									
	Access to water source adequate shade/shelter									
Design & Construction	Fitness for purpose cover system / containment (i.e. balancing aeration vs MC retention)									
	Adequate ventilation (included at base) to support aerobic conditions / O_2 porosity									
	Safety - any obvious hazards or ergonomic issues									
Feedstock / Inputs	Appropriate input types (no obvious exclusions via reference lists)									
	Indicators of inorganic contamination i.e. plastics, bones, glass, other									
	Indicators of oversized inputs vs shredding as required									
Blending / Amendment	Balanced / blended proportions of 'green & brown' materials (ref: C: N ratio aim @ >30:1)									
	Appropriate mix layering of inputs to support O_2 porosity of compost									
	Appropriate range of particle sizes to support O_2 porosity of compost									
Bulk Density	**One litre sample nett weight (g)**	**Bulk Density (kg/m³)**								
	NB: ref: NZS4454:2005 & community composting guidelines aiming for 200-300 kg.m³									
Process Management	Indicators of / ability for turning / mixing (i.e. by hand or other method)									
	Watering to optimise moisture content (50 – 60% ref hand squeeze test)									
	Covering to reduce evaporation / dry and or pest access to food scraps									
	Indicators of leakage excess leachate generated & uncontained									
Temperature	**Recorded ambient temp**	**Recorded compost temp**								
	NZS4454:2005 referenced against community composting guidelines (1= ambient or below → 5= 45 to 65°C)									
Moisture Content	Onsite MC observation	Follow up MC recorded in Lab								
	NZS4454:2005 referenced against community composting guidelines aiming for 50 – 60% ref hand squeeze test and criteria									
Biology	Observable presence of positive biological activity i.e. worms and other vertebrate decomposers									
Issue Management Odour / Smell	*Ammonia – NH_4 - (pungent odour)*	*NB b/c this group is a (-) ve parameter, ratings are reversed: poor = 1 = lots of bad smell & good = 5= no smell*								
	Hydrogen sulphide- H_2S- (rotten egg)									
	Putrid / Manure characteristic of Methane									
Issue Management Pests	Insects flies & or the precursor, maggots									
	Indicators of birds, rodent (rats & mice) or cats/dogs scavenging									
EVALUATION OF FINAL PRODUCT QUALITY ASSURANCE										
Colour	Colour on spectrum from light to dark brown – which indicates the formation of humus									
Maturity	Cool (near ambient) and stable temperature									
	Absence of evidence of any fresh inputs (i.e. introducing seeds)									
Texture	Friable/crumbly vs slimy/soggy i.e. breaks down to small particles in hand									
	Lumpy heterogeneous vs uniform homogenous range of particle sizes									
Notes:										

Identify Shape of Compost Bin	**Volume M³**
Shape # 1 (Cuboid/Cube) i.e. 2 or multi -bin option	
Bin one: (l=_____ w=_____ h=_____)	
Bin two: (l=_____ w=_____ h=_____)	
Bin three (l=_____ w=_____ h=_____)	
Bin four (l=_____ w=_____ h=_____)	
TOTAL	
Shape # 2 (Frustum)	
(h=_____ R=_____ r=_____)	
TOTAL	
Shape # 3 (Trapezoid prism)	
(h = ____ H____ b_1___ b_2___)	
TOTAL	
Shape # 4 (Cylinder)	
(r=_____ h=_____)	
TOTAL	
Shape # 4 (Sphere)	
(r=_____)	
TOTAL	
Shape # 5 (Cone)	
(r=_____ h=_____)	
TOTAL	
Shape # 6 (Pyramid)	
(l=________w=_____ h=_____)	
TOTAL	
FINAL HC EVALUATION	

Appendix C Guidelines for using the proposed HCET/physical assessment data collection tool

Parameters	Observations/Discussions		Evaluation				
			1-V. Poor	2-Poor	3-Average	4-Good	5-V. Good
Location/Siting	**Proximity**	Visually appealing, distance from households, neighbours, back door kitchen and garden	None present	Any one present	Any two present	Any three present	All present
	Usable	Usable/ all-weather access (especially during rainfall)/ no evidence of stagnant water and (potential) water pooling	None present	Any one present	Any two present	Any three present	All present
	Moisture content management	Graded section/easy access to water source/ not directly exposed to sunlight, rainfall or strong winds	None present	Any one present	Any two present	Any three present	All present
Design & Construction	**Fitness for purpose**	Sturdy/ no rotting of structure/ not too much rust/ sufficient size or volume (and section with respect to piles on the ground)/ contained	None present	Any one present	Any two present	Any three present	All present
	Ventilation	Evidence of e.g. raised on bricks, wire mesh, poles, sticks (some material are naturally porous example corrugated irons relative to plastics)	No evidence	Fairly-ventilated	Moderately ventilated	Ventilated	Sufficiently ventilated
	Safety	No obvious ergonomic issues such as tripping hazards, height related to lifting, width related to leaning over, sharp edges, presence of dirtiness	More than four present	Any four present	Any three present	Any one present	None present
Feedstock/inputs	**Appropriate inputs**	Presence of 'more compostable' than 'less compostable' materials	More than five 'less compostable'	Any four 'less compostable'	Any three 'less compostable'	Any two 'less compostable'	None present
	Contamination	No visible contamination	More than four present	Any four present	Any three present	Any one present	None present
	Shredding	Free from large materials which may require shredding	Very large	Large	Fairly large	Fairly small	None present
Blending/Amendment	**Blending**	Evidence of blended proportions of greens and browns	Excess greens	Excess browns vs greens	Fairly-balanced greens and browns	Moderately balanced greens and browns	Balanced greens and browns
	Layering	Evidence of layering (i.e. uniform and thin layers)	No layering	Fairly-layered	Thin but not uniform	Uniform and thin	Dry base, uniform and thin
Process Management	**Turning**	Evidence of turning for e.g. appropriate height of compost bin and large top opening for inserting garden/digging fork or shovel for turning/mixing	None present	Any one present	Any two present	Any three present	All present
	Moisture content	On site squeeze-test	More than two drops	Two drops	A drop of water	Moist and undeformed	Crumbles
		Lab test	10% or less	Below 25%	Between 30-35%	Between 40-50%	50-60%
	Covering	Cover or lid/ covered pile/ buried food waste/no likely access to pest	None present	Any one present	Any two present	Any three present	Buried food waste
	Leachate	Thick/thin/light brown/dark brown/odourless liquid	Colourless/pale yellow with offensive smell	Colourless/pale yellow with fruity smell	Colourless/pale yellow with no smell	Thick/thin/light brown/dark brown but smelly	Any present/no leachate
Temperature	**Process temp.**	Compost pile/finished compost	Below ambient	Ambient	ambient +1-5°C	ambient +6-10°C	ambient +>10°C
Biology	**Biological activity**	Presence of earthworms, mites and other decomposers	None present	Any one present	Any two present	Any three present	More than three present
Issue management	**Odour/smell**	Presence of earthy or no odour/smell	Very bad smell	Bad smell	Moderate smell	Slightly earthy smell	Earthy/no smell
	Pests	Insects (e.g. flies and maggots), rodents, cat/dog	All present	Any three present	Any two present	Any one present	None present
Colour	**Humification**	Light-dark brown	Very light brown	Light brown	Dark-brown	Light black	Dark-black
Maturity	**Product temperature**	Cool (near ambient) and stable temperature	ambient +>10°C	ambient +6-10°C	ambient +1-5°C	Below ambient	Ambient
	Unrecognised input	Absence of fresh feedstock	Undecomposed	Mostly partly decomposed	Less partly decomposed	Small pieces of leaves and edstock	Fully decomposed
Texture		Evidence of breakdown to small particles in hand	Very slimy and soggy	Slimy and soggy	Soggy	Damp but not slimy	Crumbly
		No evidence of e.g. lumpy, heterogeneous, sticky/powdery particles	None present	Any three present	Any two present	Any one present	Homogenous

Appendix D Quantification of organic waste diverted via home composting processes (telephone and door-to-door survey participants)

Sample ID	Bulk density(g/l)	Bulk density (kg/m3)	Volume measurements (m)						Volume[bb] (m^3)	Mass (kg)
			Shape	Length(l)	Height (h)	Width (w)	Radius of the lower base (R) (frustum)	Radius of the lower base (r) (frustum)		
10	580.34	580	Cylinder		0.8		0.44	0.26	0.79[cc]	456
20	672.5	673	Frustum		0.73		0.42	0.25	0.26	172
74	684.8	685	Frustum		0.73		0.34	0.30	0.23	159
	664	664	Rectangular prism	0.51	0.79	0.51			0.21	136
	514.63	515	Frustum		0.65		0.36	0.32	0.24	122
117	734.8	735	Frustum		0.73		0.34	0.27	0.21	157
	503.13	503	Cylinder		0.77			0.46	0.51	257
136	393.24	393	Frustum		0.68		0.64	0.58	0.80	313
159	433.91	434	Frustum	1.2	0.2				0.48[cc]	208
170	433.71	434	Frustum		0.87		0.69	0.47	0.93	403
172	548.71	549	Cylinder		0.82			0.31	0.74[dd]	407
180	438	438	Pyramid	2.91	1.21	1			1.17	514
220	578.6	579	Cube	1.14	0.4	0.68			0.31	179
270	435.02	435	Frustum		0.68		0.25	0.21	0.22[cc]	96
340	412.29	412	Cylinder		1.09			0.49	0.82	339
361	283.21	283	Cube	1.31	0.83	1.21			2.631[cc]	745
384	620.7	621	Cylinder		0.79			0.495	1.22[cc]	755
443	396.88	397	Cylinder		0.8		0.44	0.26	0.39	156
481	452.76	453	Pyramid	1.6	1	0.35			0.187	169
486	668.5	669	Cube	1.2	0.5	0.72			0.43	578
493	319.94	320	Cylinder		0.24			0.54	0.31	98
589	525.89	526	Pyramid	12.5	0.96	0.31			1.240	652
Total									**14**	**7072**
Average									**0.8**	**372**

[bb] The respective volume measurement for the various home composting system shapes are illustrated in Figure 11.

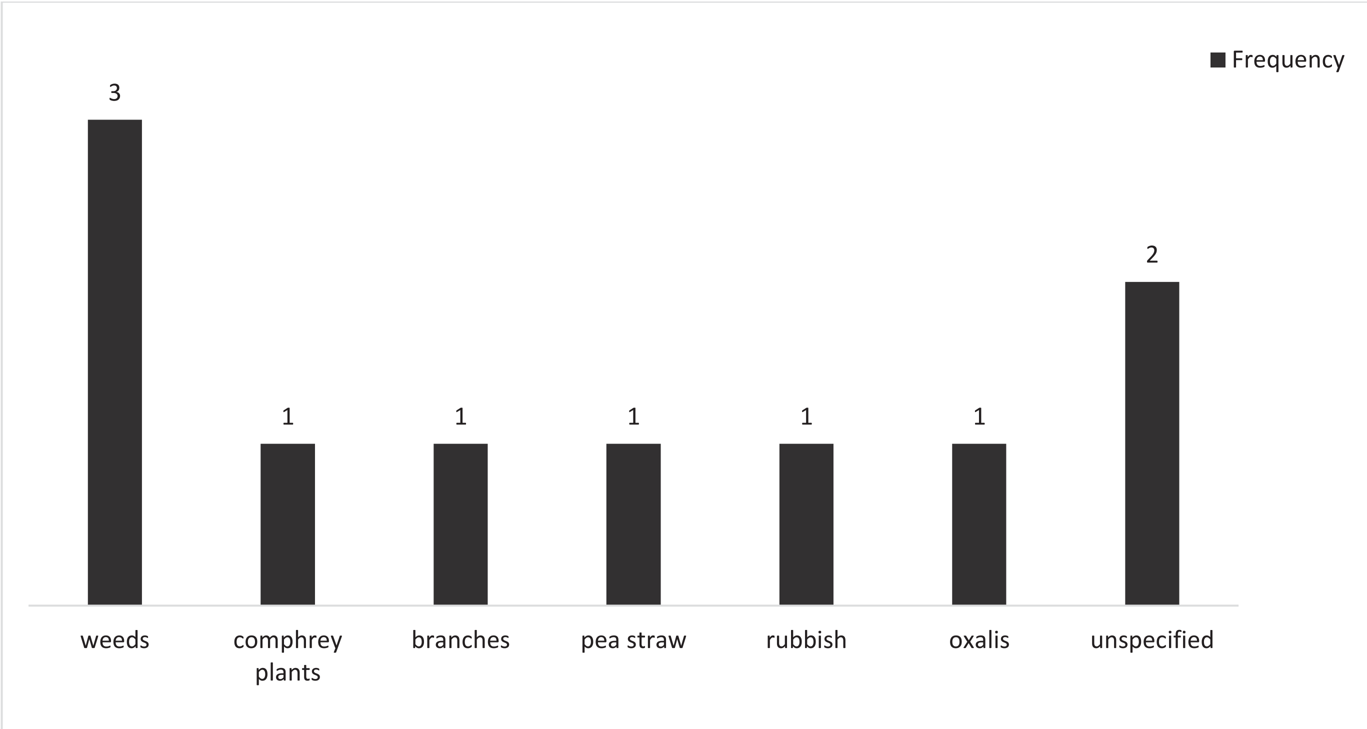
[cc] These are two-bin systems so the volumes obtained were multiplied by two to determine the total volume of the system.

[dd] These are three-bin systems so the volumes obtained were multiplied by three to determine the total volume of the system

Appendix E Quantification of organic waste diverted via home composting processes (voluntary participants)

Sample ID	Bulk density(g/m3)	Bulk density (kg/m3)	Volume measurements (m)						Volume (m^3)	Mass kg
			Shape	Length(l)	Height(h)	Width (w)	Radius of the lower base (R) (frustum	Radius of the lower base (r) (frustum)		
1	731	731	Cube	2.545	0.620	1.470			2.320	1696
2	795.4	795	Cuboid	1.03	1.03	1.03			1.093	869
	423.51	424	Cuboid	1.03	1.11	0.9			1.029	436
3	373.39	373	Frustum		0.73		0.67	0.53	0.83	310
	319.2	319	Cylinder		1.42			0.54	1.30	415
4	564.46	564	Cuboid	1.21	0.75	0.78			0.71	400
5	170.99	171	Cylinder		0.77			0.53	0.68	116
	265.95	266	Cylinder		0.77			0.53	0.68	181
	601.6	602	Cylinder		0.77			0.53	0.68	409
	751.9	752	Cylinder		0.75			0.51	0.61	461
6	447.34	447	Cube	1.420	0.760	0.580			0.626	280
	555.41	555	Frustum	1.2	0.2				0.240	133
7	579.91	579.91	Cube	1.36	0.45	0.97			0.594	344
Total									**11**	**6048**
Average									**1.6**	**864**

Appendix F Unwanted materials removed from the home compost pile



Appendix G pH values of fresh, semi-matured and matured feedstock (telephone and door-to-door survey participants)

Sample ID	pH	State of organic feedstock
10	9.6	Semi-matured
20	6.8	Matured
74	7.6	Matured
	9.6	Semi-matured
	7.6	Matured
117	9.8	Semi-matured
	7	Semi-matured
136	8.1	Semi-matured
159	7.8	Matured
170	8.8	Semi-matured
172	7.4	Matured
180	4.8	Fresh
220	8.8	Semi-matured
270	8.3	Semi-matured
340	8.4	Fresh
361	7.6	Fresh
384	8.6	Semi-matured
443	7.3	Fresh
481	7.7	Matured
486	8.4	Semi-matured
493	6.5	Fresh
589	7.8	Matured

Appendix H pH values of fresh, semi-matured and matured feedstock (voluntary participants)

Sample ID	pH	State of organic feedstock
1	7	Matured
2A	9.5	Fresh
2B	8.2	Matured
3A	7.3	Fresh
3B	8.3	Fresh
4	8.5	Semi-matured
5A	7.7	Matured
5B	9.3	Semi-matured
5C	8.3	Fresh
5D	8.4	Fresh
6A	6.2	Matured
6B	6.6	Matured
7	8	Matured

Appendix I Home composting evaluation scores (per sample)

Sample ID	Average scores							Total average per sample
	Location/siting	Design/Construction	Feedstock/input	Process management	Physicochemical properties	Issue management	Maturity	
10	4.7	5	4	4.3	2.5	4	3	3.9
20	4.7	4.7	4.3	4.6	4.3	5	5	4.6
74	3.7	4	4.7	4.4	3.3	4	3	3.9
117	5	4.7	4.3	4.3	3.5	4	3.3	4.2
136	4.3	4.7	4	4.6	3.0	4.5	4.0	4.2
180	4	5	3.7	3.6	2.3	5	4	4.0
159	4	4.7	4.3	3.9	2.5	5	3.8	4.0
172	5	5	5	4.9	3.3	5	4.8	4.7
170	4.3	4.7	4.7	3.0	3.0	4.5	3.5	4.0
220	4	3.7	5	2.9	2.8	3.5	3	3.5
270	5	4.3	4.3	4.3	3.5	5	3.8	4.3
340	5	4.7	3.7	3.4	2.5	4.5	2.5	3.8
361	4.3	2.7	4.3	2.9	3.3	4	2.8	3.5
384	5	5	4	4.7	3.0	4.5	4	4.3
450	4.7	3.7	3.7	3.3	-	4	1.0	3.4
443	4.7	4.7	4.7	4.9	2.5	4.5	4.5	4.3
486	4.7	1.7	5	3.7	3.8	4.5	3.8	3.9
493	4	4.7	4.3	3.4	2.8	4.5	3.8	3.9
481	4.3	4	3	3.7	3.2	5	4	3.9
589	4.7	3.7	3.7	3.7	4.0	5	4.3	4.1
FINAL HOME SCORE HOME COMPOSTING EVALUATION SCORE								**4.0**

Appendix J Home composting evaluation scores (per parameter)

Parameters	Observations / Discussion	Evaluation	
		Average score	Total score
EVALUATION OF COMPOST PROCESS QUALITY ASSURANCE			
Location / Siting	Proximity to house relates to the visual, odour & nuisance impacts	4.8	4.5
	Usable, all weather access, good drainage - avoids water pooling	4.3	
	Access to water source adequate shade/shelter	4.5	
Design & Construction	Fitness for purpose cover system / containment (i.e. balancing aeration vs MC retention)	4.5	4.3
	Adequate ventilation (included at base) to support aerobic conditions / O_2 porosity	4.3	
	Safety - any obvious hazards or ergonomic issues	4.0	
Feedstocks / Inputs	Appropriate input types no obvious exclusions via reference lists)	4.2	4.2
	Indicators of inorganic contamination i.e. plastics, bones, glass, other	4.6	
	Indicators of oversized inputs vs shredding as required	3.9	
Process Management	Balanced / blended proportions of 'green & brown' materials (ref: C: N ratio aim @ >30:1)	3.6	3.9
	Appropriate mix layering of inputs to support O_2 porosity of compost	3.0	
	Indicators of / ability for turning / mixing (i.e. by hand or other method)	4.1	
	Watering to optimise moisture content (50 – 60% ref hand squeeze test)	4.2	
	Covering to reduce evaporation / dry and or pest access to food scraps	4.1	
	Indicators of leakage excess leachate generated & uncontained	4.9	
	Biological activity	3.0	
Physicochemical properties	Bulk density	3.0	3.1
	Recorded process temperature	4.0	
	Follow up moisture content recorded in the laboratory	3.0	
	pH recorded in the laboratory	3.0	
Issue Management	Odour / Smell	4.1	4.5
	Insects flies, maggots, indicators of birds, rodent (rats & mice) or cats/dogs scavenging	4.9	
EVALUATION OF FINAL PRODUCT QUALITY ASSURANCE			
Colour	Colour on spectrum from light to dark brown – which indicates the formation of humus	3.7	3.7
Maturity	Absence of evidence of any fresh inputs (i.e. introducing seeds)	2.9	
Texture	Friable/crumbly vs slimy/soggy i.e. breaks down to small particles in hand	4.2	
	Lumpy heterogeneous vs uniform homogenous range of particle sizes	3.9	
FINAL HOME COMPOSTING EVALUATION SCORE			**4.0**

Appendix K Amended survey questionnaire for future home composting studies

Questionnaire # ______________	**Suburb** ___________________		**Start time:** ______: ______
Telephone number ________________________	**Sample ID** _________________	**Date** _______/_____/________	**End time:** ______: ______

Introduction: Hello, I am ……………. from ……….. As part of …………, I am carrying out research into home composting in ……….. I am undertaking a phone survey which takes approximately ………. The participant needs to be over 18 years of age. Participation is entirely voluntary and completely anonymous and confidential and you can refuse to answer any questions and or withdraw at any stage. If you have any questions or concerns I will be happy to answer them. *"For this study, home composting is considered as ……………… This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact …………………………………*

1a. Does your household do home composting? ( ) Yes ( ) No

2a. Would you or anybody in your household be willing to take part in this study? ( ) Yes ( ) No -***If No skip to 2a.***

3a. For how long have you been composting? ( )

4. Why do you do home composting? / What do you like about home composting?
( ) it saves landfill space ( ) compost can be used as soil amendment ( ) it reduces harmful effect on the environment ( ) it reduces organic waste ( ) use of organic waste ( ) it saves money on waste disposal cost ( ) free/subsidised bins ( ) it saves money on fertilizers ( ) it saves money on seed raising mix ( ) it is cheaper than buying commercial compost ( ) to teach children ( ) grow and eat healthier produce ( ) to save dustbin space **Other:[ ]**

5a. What type of compost bin do you use?
( ) open pile ( ) wooden box ( ) manufactured plastic bin ( ) wire fence ( ) concrete brick ( ) home made from scrap/recycled materials ( ) ground/soil incorporation ( ) roller bin - **Other:**

5b. Is your compost bin a single-bin or multi-bin system? *(If multi-bin system)*, how many systems are they?
( ) single-bin system ( ) two-bin system ( ) three-bin system ( ) four-bin system **Other: [ ]**

6a. What materials do you home compost?
( ) food leftovers ( ) leaves ( ) garden weeds ( ) grass clippings ( ) garden pruning ( ) tea bags / coffee grounds ( ) fruit and vegetable peelings ( ) eggshells ( ) manures ( ) saw dust / wood shavings ( ) sea weed ( ) newspaper ( ) branches ( ) straw **Other: [ ]**

6b. Is there any material type you do not put in your compost bin? ( ) beer and carbonated drinks ( ) cat and dog manure ( ) large and treated woods ( ) meat, fish and bones ( ) oils and fats ( ) diseased plants ( ) dairy products ( ) cooked and processed food ( ) citrus ( ) corn cobs ( ) onion ( ) pumpkin seed ( ) tree branches ( ) twigs ( ) weeds ( ) bark ( ) treated sawdust **Other: [ ]**

6c. Do you take any of your food waste/garden waste to the commercial composting site or landfill? ( ) Yes ( ) No.
***(if yes)* Name them** ( ) lawn clippings ( ) garden pruning ( ) tree branches ( ) garden waste **Other: [ ]**

7a. Which of the following management practices do you normally undertake? adding soil ( ) adding compost 'starters' / special bacterial formulations ( ) watering / wetting of compost pile when dry ( ) removal of unwanted materials from the pile if yes name them ( ) weeds ( ) comphrey plants ( ) branches ( ) pea straw ( ) rubbish ( ) oxalis **Other: [ ]**

7b. Do you mix/turn the compost pile ( ) No ( ) Yes - **How often do you mix the compost pile?** ( ) daily ( ) weekly ( ) fortnightly ( ) monthly ( ) 3 months ( ) 2 months ( ) 6 months ( ) barely ( ) never

7. How long is the composting cycle i.e. till the material has finished composting & is ready to use? ( ) 1 mth ( ) 3 mths ( ) 6 mths ( ) one year

8. Where is the home composting system located? ( ) kitchen ( ) backyard / garden

9. Do you have any issues or problems with home composting? ( ) none ( ) insects ( ) rodents ( ) bad smell / odour ( ) cats / dogs ( ) time-consuming ( ) much effort required ( ) price of compost bins ( ) lack of information / knowhow ( ) lack of incentives ( ) requires a lot of space ( ) weed growth in compost ( ) slow process ( ) smelly / slimy / low quality compost ( ) bin / system is too small ( ) compost pile does not heat up ( ) overheated compost pile ( ) compost pile is too dry ( ) compost pile is too soggy **Other** :[ ]

If NO: 2b. Would you like to offer a reason for not being able to participate?
( ) I don't do surveys
( ) Not a good time
( ) I am busy
( ) not interested
( ) hang-up
( ) poor English (if applicable)

(ASK ONLY IF THE RESPONDENT IS BUSY)
Can I call you back? ( ) Yes ( ) No
Would you prefer a face-to-face visit?
( ) Yes ( ) No
2c. *(If yes)* At what time is good for you?

(ASK ONLY IF THE RESPONDENT DOES NOT DO HOME COMPOSTING)
3b. ( ) Is there a specific reason why you don't do home composting?

4. Is there anything that would motivate you to start practising home composting?
( ) nothing ( ) help from the PNCC ( ) free / subsidised bins or composting system ( ) provision of larger compost bins ( ) home composting workshops where you can learn ( ) garden ( ) bigger section ( ) owned my house ( ) recycling scheme by Council (if applicable)
Others: [ ]

10. Is there anything that would motivate you to continue or do more home composting? ( ) nothing ( ) help from the PNCC ( ) free / subsidised bins or composting system ( ) provision of larger compost bins ( ) home composting workshops where you can learn ( ) more garden waste ( ) be at home ( ) garden ( ) bigger garden ( ) more bins ( ) much awareness ( ) small bins for small sections **Other:** [ ]

11. For the study, I need to collect compost samples for lab analyses, observe, evaluate and take photographs of the home composting system. Can I come to your house to do this? ( ) Yes ( ) No
11b. (If yes) At what day/time will you be at home?