

**Best Practice Guideline  
to Managing On-site  
Vermiculture Technologies**

**January 2002**

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## Preface to the *Best Practice Guideline to Managing On-Site Vermiculture Technologies* Information Sheets

The *Best Practice Guideline to Managing On-Site Vermiculture Technologies* series of Information Sheets have been produced to support the continuing development of the Recycled Organics industry in New South Wales and to provide best practice guidelines for the on-site treatment of compostable organic materials produced by the commercial and industrial (C&I) sector.

Treatment of compostable organics produced on-site by the C&I sector using vermiculture technology represents a potentially viable way of managing these materials. The production of vermicast also provides a product that may be used to maintain the landscaped environment.

The establishment and management of an on-site vermiculture unit can result in some uncertainties in terms of the performance capabilities of such units and the management practices required to sustain these capabilities. Failure can occur within vermiculture units due to a number of reasons that usually relate to an absence of information and management within the organisation.

Efficient management and monitoring of vermiculture units is necessary to maintain an effective processing system and to ensure adequate system performance without any adverse affects on the environment.

To ensure a vermiculture unit is efficient and effective, it must be installed at an adequate scale to meet the requirements of the organisation. The development of an on-site organics management system should also result in realistic expectations as to the performance capabilities of the system. A level of commitment from both management and staff is required to ensure operational success.

This guide to best practice management will support the appropriate and sustainable application of on-site vermiculture technology in the C&I sector. Information has been provided that will inform the vermiculture industry, the waste management industry and relevant C&I sector enterprises and institutions on the capabilities, management requirements and appropriate application of on-site vermiculture technology.

These Information Sheets have been developed to complement existing information resources and to provide an easy-to-read account of how to establish and manage an on-site, mid-scale vermiculture unit for the C&I sector. On-site, mid scale organics management systems are capable of processing between 20 and 250 kg of compostable organics per day. The guide gives practical information as to the development of such a system including feedstock preparation, monitoring and maintenance procedures and use of the vermicast end product.

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Recycled Organics Unit

The University of New South Wales.

Sydney, January 2002.

## 1. Information Sheets in “*Best Practice Guideline to Managing On-Site Vermiculture Technology*”

This package contains a collection of seven Information Sheets and four Appendices:

- Information Sheet No. 1: Introduction to establishing and managing an on-site vermiculture unit.
- Information Sheet No. 2: How much compostable material is produced?
- Information Sheet No. 3: Can vermiculture work for you?
- Information Sheet No. 4: Guide to feedstock preparation and determining what size vermiculture unit is required.
- Information Sheet No. 5: Guide to installing a vermiculture unit.
- Information Sheet No. 6: Management and maintenance of a vermiculture unit.
- Information Sheet No. 7: Guide to using the vermicast product.
- Appendix No. 1: Ancillary equipment requirements.
- Appendix No. 2: Vermicast product standard.
- Appendix No. 3: Signage.
- Appendix No. 4: Research Case Studies – Vermiculture processing of compostable organics.

## 2. Who should read the Information Sheets?

The package of Information Sheets has been developed to meet the needs of the developing vermiculture industry. It is suitable for stakeholders in the RO sector who wish to gain a better knowledge of the vermiculture industry, key points for establishing an on-site vermiculture unit, industry best practices, and product standards that significantly influence product quality.

More specifically, the package of Information Sheets have been developed for:

- commercial and industrial sector organisations;
- vermiculture industry consultants;
- commercial and industrial sector consultants;
- waste educators;
- waste managers;
- prospective RO processors; and
- local council waste management officers.

## 3. Terminology

Terms used throughout this package of Information Sheets have been officially adopted by the NSW Waste Boards in July 2000 in the form of the *RO Dictionary and Thesaurus: Standard terminology for the New South Wales recycled organics industry*, produced by the Recycled Organics Unit. This document is freely downloadable from <http://www.rolibrary.com>

## 4. How to cite this publication

This publication consists of a series of Information Sheets that are compiled into a set. When citing information from this publication, the set of Information Sheets must be cited (not individual Information Sheets), as shown below:

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- Mr. Karsten Eisenacher, Quality Assurance Manager and Process Control Coordinator, Vermitech Pty. Ltd.
- Mr. Mike Daniels, President, Australian Worm Growers Association Vermiculture Inc.
- Mr. David Murphy, Author (Earthworms in Australia: A blueprint for a better environment).

# Information Sheet No. 1

## Introduction to installing and managing an on-site vermiculture unit

Information Sheet No. 1  
January 2002

### Inside This Sheet

- 1** What is vermiculture?
- 2** What is an organics management system?
- 3** Components of a vermiculture unit  
Basic science of vermiculture  
Definitions
- 4** Types of vermiculture units
- 5** Materials that can be processed
- 6** Materials that cannot be processed
- 7** Management of vermiculture units  
Overview of best practice guidelines for on-site vermiculture technology
- 8** Notes  
Important references  
Acknowledgement

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### What is vermiculture?

*Vermiculture* involves the stabilisation of *compostable organics* under controlled conditions by particular worm species.

Compostable organic materials, such as residual *food organics* and *garden organics*, are loaded into the vermiculture unit where they are 'eaten' by the worm population.

Worms convert the fresh materials into *vermicast*, a brown soil-like material that is produced after organic materials have passed through the digestive system of a worm. Vermicast is high in nutrients and can be used as a valuable *soil conditioner*.

A limited range of enterprise types in the commercial and industrial (C&I) sector have the potential to utilise

vermiculture for on-site treatment of compostable organics.

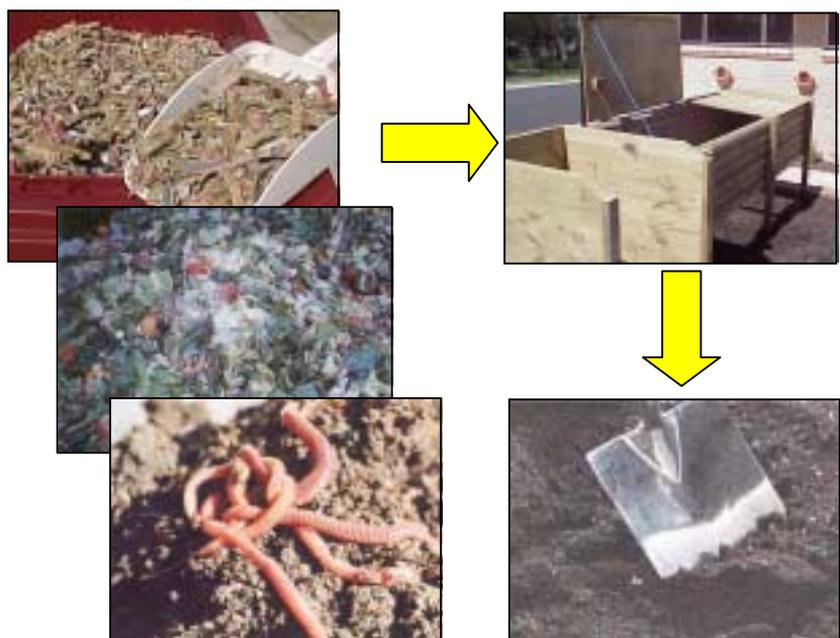
The implementation of vermiculture technology requires careful planning and management to ensure it will be able to continually process organic materials with minimal impact on the surrounding environment.

Worms convert compostable organic materials into a valuable end product – vermicast!



This series of information sheets details *best practice* requirements for implementing and managing such technology.

**Plate 1.** Components of an organics management system for processing compostable organic materials in a vermiculture unit.



## What is an organics management system?

An organics management system is the system that involves the processing of a compostable organic material into an end product.

An organics management system involves people, machinery, infrastructure, utilities and coordination. A variety of different technologies for organics processing exist. Two common types of organic processing technologies include vermiculture and *composting* to produce an end product of vermicast or *compost*.

An organics management system for the processing of compostable organic material in a vermiculture system is shown in Figure 1. This system is detailed throughout this series of Information Sheets and is applicable to *on-site*, *mid-scale* vermiculture processing by the C&I sector.

Establishing an organics management system for vermiculture processing is a complicated process and involves much more than simply applying compostable material to a vermiculture unit.

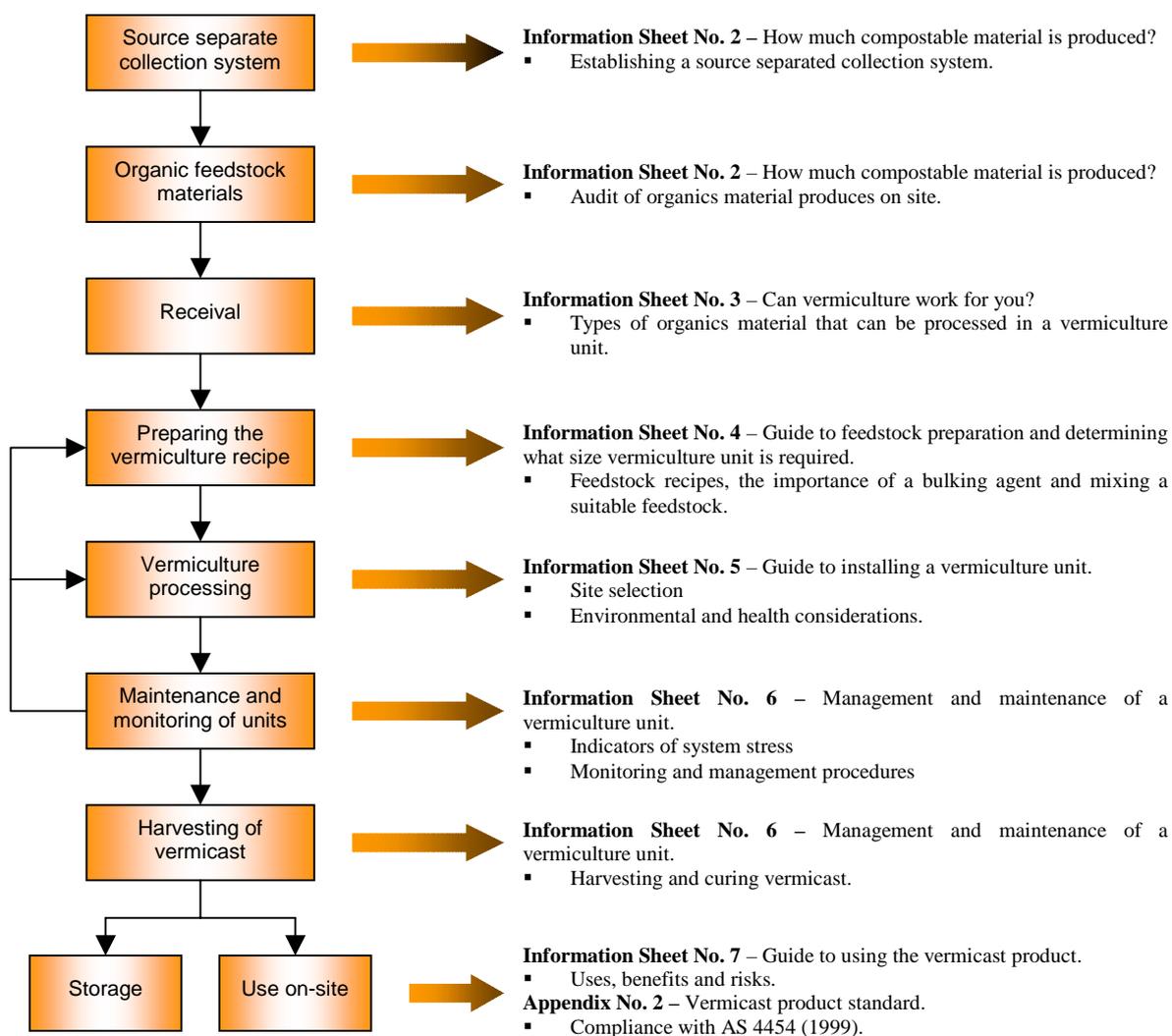
The receipt of the organic material, the development of a recipe for

mixing the material, establishing management and monitoring procedures for the vermiculture unit, and the harvesting of completed vermicast all require careful planning to ensure a successful and efficient system is in place.

This Best Practice Guideline will detail the required steps for implementing a successful organics management system for vermiculture processing.

The relevant Information Sheets for each step within this system are given in Figure 1.

**Figure 1.** An organics management system for processing compostable organic materials in an on-site, mid-scale vermiculture unit. A reference guide to relevant information sheets in this Best Practice Guideline is also shown.



## Components of a vermiculture unit

A vermiculture unit consists of four main components:

1. Container – houses the bedding and worm population so they can consume organic materials loaded into the unit. The container also excludes pests and protects worms from both the elements and predators.
2. Worm population – necessary to convert the compostable organic materials into vermicast that can be used as a soil conditioner.
3. Bedding – a deep layer of mature vermicast is recommended as a medium for worms to live in. A greater mass of bedding reduces the variation in bedding temperature and moisture.
4. Source of food and moisture for the worms – this is applied to the surface of the bedding.

The external and internal components of a vertical loading, continuous flow vermiculture unit are shown in Figure 2.

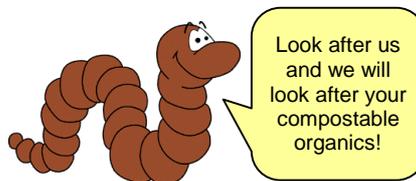
## Basic science of vermiculture

Processing of compostable organic materials via vermiculture is an *aerobic* (high oxygen) process performed by worms and microorganisms. The basic science of this process can be seen in Figure 3.

When organic materials are loaded into a vermiculture unit, bacteria, fungi and other microorganisms start to decompose or 'eat' them.

The worm population works with these microscopic organisms. Worms scavenge and eat the decomposing products (such as sugars, proteins and simple carbohydrates) released by the microorganisms and even eat the microorganisms as well!

Consequently, a well managed vermiculture unit involves the maintenance of conditions that are ideal for the survival and growth of microorganisms and worms.



## Definitions\*

### Vermiculture

System of stabilising organic materials under controlled conditions by specific worm species and microorganisms under mesophilic temperatures. Commercial vermiculture systems include: windrows or beds; stackable trays; batch-flow containers; and continuous flow containers.

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Food organics

The Food Organics material description is defined by its component materials, which include: fruit and vegetable material; meat and poultry; fats and oils, seafood (including shellfish, excluding oyster shells); recalcitrants (large bones >15mm diameter, oyster shells, coconut shells etc.); dairy (solid and liquid); bread, pastries and flours (including rice and corn flours); food soiled paper products (hand towels, butter wrap etc.); and biodegradeables (cutlery, bags, polymers). Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the *compostable organics* stream.

### Garden organics

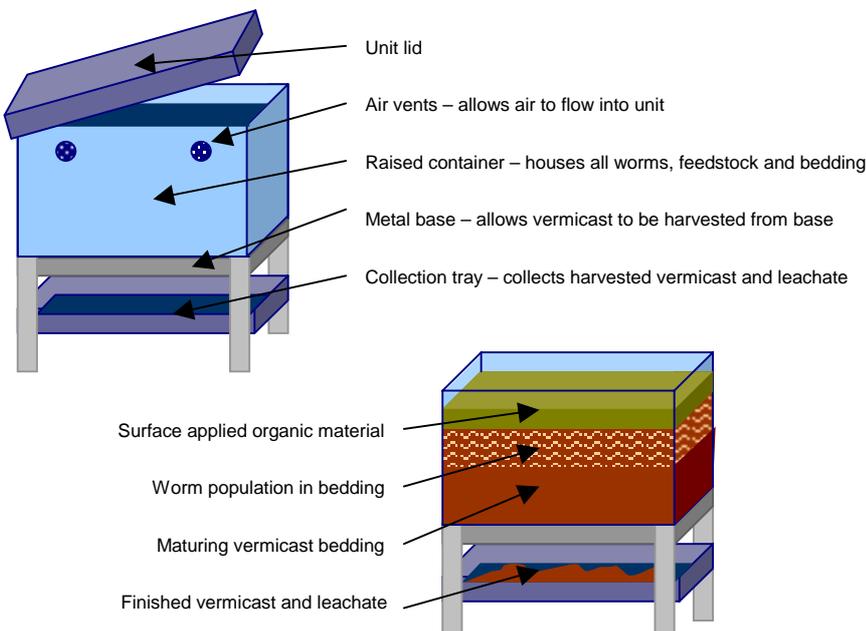
The Garden Organics material description is defined by its component materials including: putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs; stumps and rootballs. Such materials may be derived from domestic, Construction and Demolition and Commercial and Industrial sources. Garden Organics is one of the primary components of the *compostable organics* stream.

### Vermicast

Solid organic material resulting from the biological transformation of compostable organic materials in a controlled vermiculture process.

*Continued page 4*

**Figure 2.** Components of a vertical loading vermiculture unit and an internal view.



Ideal environmental conditions include:

- air – at least 10% oxygen (O<sub>2</sub>) present in the bedding where the worms are actively feeding (there is 21% O<sub>2</sub> in normal air);
- moisture – moisture content of the bedding material should be between 60 and 90%;
- warmth – ideal bedding temperatures are between 20 and 25°C but worms will survive between 5 and 35°C;
- food – such as fruit, vegetables, mixed food organics, paper, cardboard etc.;
- absence of pests – insect larvae compete with the worm population and pose a public health hazard; and
- protection from predators and environmental extremes.

- Tray or stacking units;
- Batching or box units; and
- Windrow systems.

Details of these types of vermiculture units are given below.

**Continuous flow units**

Continuous flow vermiculture units consist of a raised container with a mesh floor and a breaker bar that slides across the mesh floor to agitate and allow harvesting of the vermicast. Feed is applied to the top surface of the bedding and finished vermicast is harvested from the base, allowing the continuous processing of compostable organic materials.

Continuous flow units vary in terms of engineering complexity from low technology units with manual feeding and harvesting methods, to complex technology units that comprise a fully automated and hydraulically driven continuous reactor.

Continuous flow technology is the most efficient type of on-site, mid-scale vermiculture unit and the least labour intensive. Plate 2 details some commercially available continuous flow units.

**Types of vermiculture units**

A number of different types of vermiculture units are available for on-site processing of compostable organic material. These include:

- Continuous flow units;

**Soil conditioner**

Any composted or pasteurised organic material that is suitable for adding to soils. This term also includes 'soil amendment', 'soil additive', 'soil improver' and similar terms, but excludes polymers which do not biodegrade, such as plastics, rubber and coatings. Soil conditioners may be either 'composted soil conditioners' or 'pasteurised soil conditioners'. Soil conditioner has not more than 15% by mass of particles with a maximum size above 15 mm.

**Best practice**

For any area of waste management, this represents the current 'state-of-the-art' in achieving particular goals. Best Practice is dynamic and subject to continual review and improvement.

**Composting**

The process whereby organic materials are pasteurised and microbially transferred under aerobic and thermophilic conditions for a period of not less than six weeks. By definition, it is a process that must be carried out under controlled conditions yielding mature products that do not contain any weed seeds or pathogens.

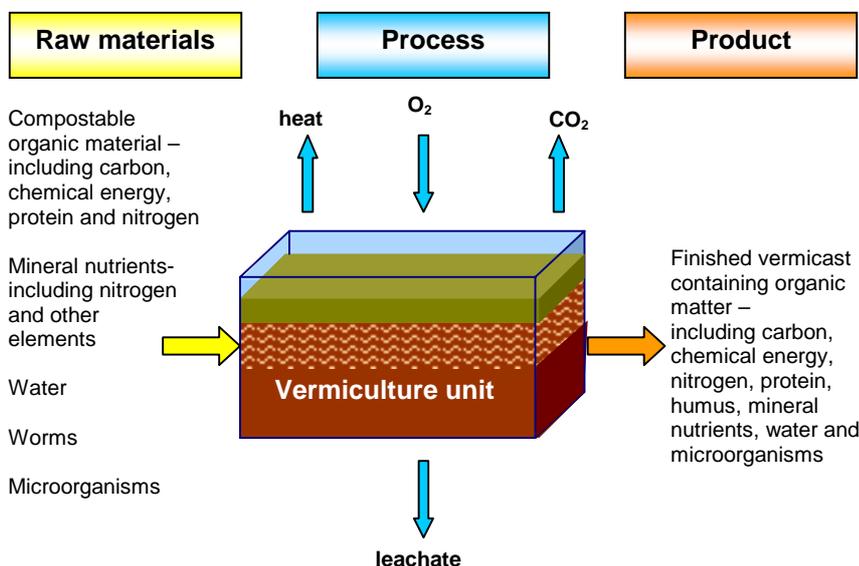
**Compost**

An organic product that has undergone controlled aerobic and thermophilic biological transformation to achieve pasteurisation and a specified level of maturity. Compost is suitable for the use as soil conditioner or mulch and can improve soil structure, water retention, aeration, erosion control, and other soil properties.

**On-site, mid-scale**

A category of on-site composting or vermiculture-based technology with the ability to process between 20 and 250 kg of compostable organics per day. Such systems are usually comprised of an in-vessel processing unit (composting or vermiculture-based) and size reduction equipment (eg. garden type petrol driven chippers or shredders). Procedures involved in the management of the processing system may involve a combination of manual labour and small mechanical equipment. Mid-scale systems are often used for the treatment of compostable organics produced by the commercial and industrial sector, hospitals and institutions etc.

**Figure 3.** Process diagram for a vermiculture unit (adapted from Recycled Organics Unit, 2001).



### Tray or stacking units

Tray or stacking units consist of a number of stacked trays with bedding and worms placed in the trays. Feed is applied to the top surface of the bedding and when the tray is full, the vermicast is left to mature before the entire batch (tray) is dug out manually.

Tray or stacking units can be relatively labour intensive at time of harvesting when each tray of mature vermicast needs to be removed from the unit.

Tray or stacking units are used for mid-scale vermiculture processing, however, these units are not as widely used as continuous flow units.

### Batching or box units

Batching or box units are a simple and relatively popular design for small-scale (domestic) vermiculture applications. This type of unit consists of a container that houses all bedding, worms and vermicast with feed applied to the top surface. The challenge is separating worms from vermicast to enable harvesting of the vermicast product.

Batching or box vermiculture units can be relatively labour intensive at time of harvesting and hence are not as popular for mid-scale applications.

Batching or box units are cheap, and

are widely used in household applications.

### Windrow Systems

Windrow systems are a traditional, low technology method for large-scale vermiculture activities. They consist of long beds placed directly on the ground with compostable organic material being applied to the surface and sometimes covered to reduce the incidence of pests.

Windrow systems are relatively inefficient as nutrients are lost through volatilisation and leaching and they require large areas of land. These systems also process organic materials relatively slowly taking between 6 and 18 months to complete processing (Edwards, 1995).

Windrow systems are most suitable to agricultural enterprises where large areas of land are available.

### Materials that can be processed

A range of compostable organic materials can be processed in vermiculture units, however some form of pre-processing may be required. Pre-processing usually involves:

- size reduction – to increase the surface area for microorganisms to attack;

*Continued from page 4*

#### **Aerobic**

In the presence of, or requiring oxygen.

#### **Bulking agent**

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably. See also composting amendment.

#### **Carbon to nitrogen (C:N) ratio**

The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

#### **Feedstock**

Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

#### **Anaerobic**

In the absence of oxygen, or not requiring oxygen.

\*Recycled Organics Unit, (2001b).

**Plate 2.** Commercially available continuous flow vermiculture units.

Vermi-Converter 2000 – Vital Earth Company



Worm Wigwam – EPM Inc.



Eliminator 1200 – Pad Engineering



- mixing – to achieve a suitable structure, moisture content and nutrient balance; and
- addition of a *bulking agent* – to improve structure, increase surface area and to absorb excess moisture.
- mixed food organics (mixed fruit and vegetables, breads, meat/poultry); and
- mixed garden organics (lawn clippings, non-woody plant materials such as stems, leaves and twigs of various plant species).

vermiculture unit as shredded paper or cardboard. These high carbon materials are called bulking agents and are common packaging wastes in the C&I sector.

The addition of a bulking agent, such as paper or cardboard (Plate 3), not only increases the C:N ratio but improves the structure and porosity of the material. A bulking agent will also absorb excess moisture and result in a less dense material. All these factors produce a material that is more readily processed by the worm population.

The amendment of compostable organic materials with a bulking agent to increase the C:N ratio may result in the material becoming too dry. Worms need a moist environment, as previously discussed, and so the material that they consume needs to be moist but not too wet.

The final mixture of organic material amended with a bulking agent and water (if necessary) is called *feedstock*. Feedstock is the result of blending the different components to produce a suitable source of food for the worm population.

These factors are important for acceptance of the feedstock by the worm population. A number of feedstock recipes and the process of mixing a suitable feedstock will be covered in Information Sheet No. 4.

### Materials that cannot be processed

Some compostable organic materials cannot be processed in a vermiculture unit.

Materials that are very high in nutrients, such as seafood and dairy products, are not recommended for vermiculture processing in any significant proportion. These materials can cause problems such as *anaerobic* (low oxygen) conditions that result in worm death.

Bulking agents like shredded paper or cardboard are needed to balance some types of food so I can process them!



The addition of a bulking agent, such as paper or cardboard, is very important when preparing compostable organic materials for processing in a vermiculture unit. Cardboard or paper are carbonaceous materials that absorb excess moisture, increase the porosity and structure of the material and increase the *carbon to nitrogen (C:N) ratio*.

The C:N ratio is the ratio of the weight of organic carbon to total nitrogen within the material. Some organic materials, such as meat and poultry, are rich in nitrogen. If these nitrogen-rich organic materials are processed in a vermiculture unit, carbon needs to be added to achieve a C:N ratio of 20 to 25 parts carbon to every one part nitrogen (C:N ratio of 20-25:1).

Carbon can be added to a

Earthworms more readily process a mixture of compostable organic materials rather than monostreams of specific waste types, for example, just bakery waste (Recycled Organics Unit, 2000).

Common compostable organic materials produced by the C&I sector that are readily processed by vermiculture units include:

- mixed fruit;
- mixed vegetables;

**Plate 3.** Shredded cardboard is a common source of bulking agent produced by the C&I sector.



Microorganisms break down these high nutrient materials very quickly resulting in rapid oxygen consumption. This can lead to health and safety issues such as odour production and the attraction of pests and vermin.

More information on materials that can and cannot be processed in vermiculture units can be found in Information Sheet No. 3.

## Management of vermiculture units

Vermiculture units can be used to process a limited range of compostable organic materials into a useful end product called vermicast.

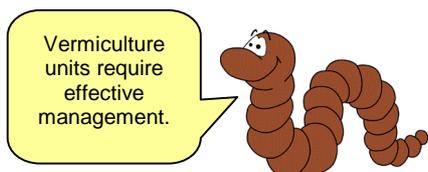
However, effective vermiculture processing requires significant management of the unit to ensure reliable performance and to prevent health and environmental issues from developing.

Effective best practice management of vermiculture units requires a dedicated approach to feedstock preparation, monitoring regimes and site hygiene.

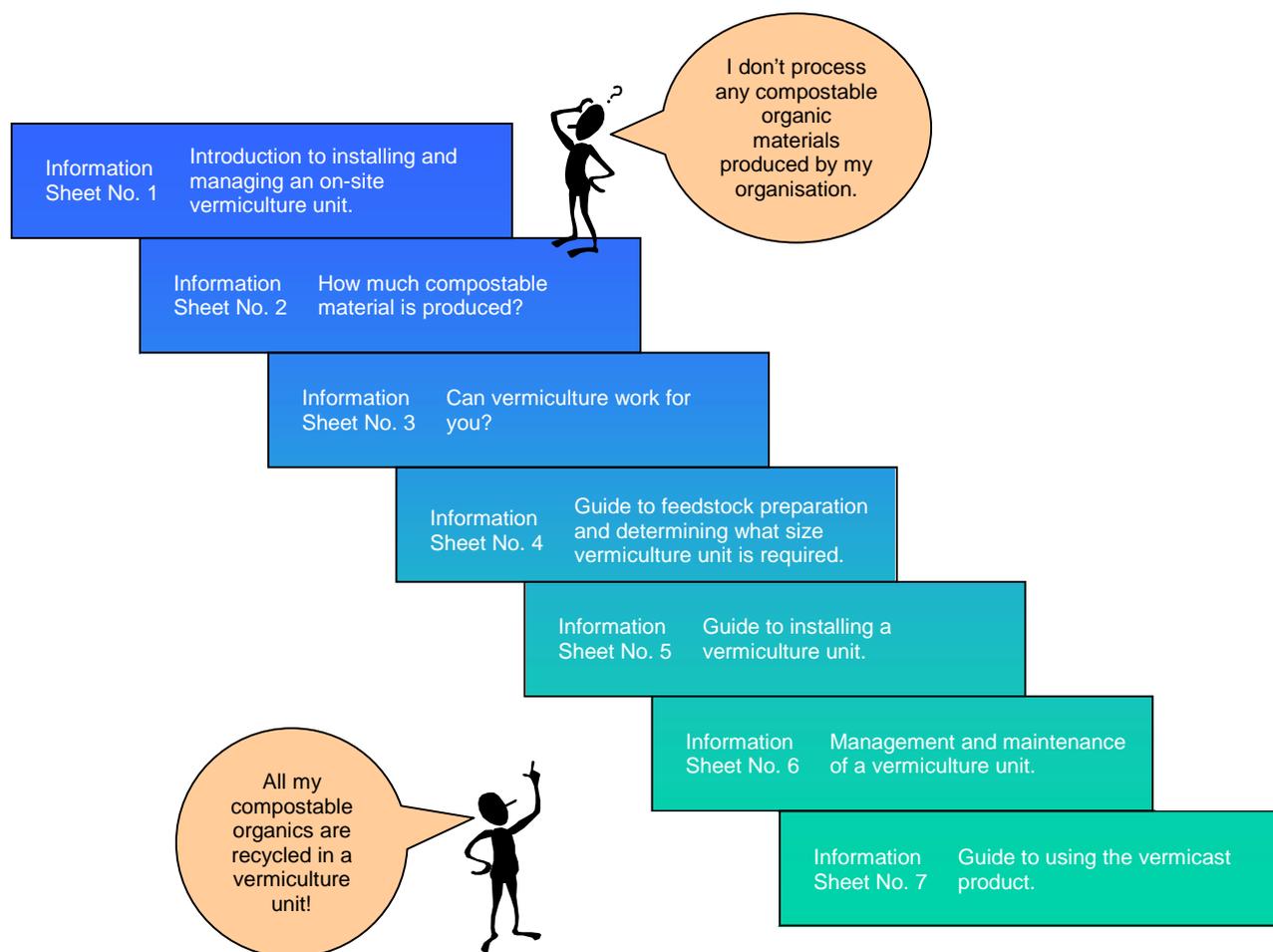
## Overview of best practice guidelines for on-site vermiculture technology

The *Best Practice Guideline to Managing On-Site Vermiculture Technology* series of information sheets provides an excellent introduction to the science of vermiculture and the best practice procedures for establishing and maintaining a successful vermiculture unit.

The process of achieving a successful vermiculture organics management system based on these best practice guidelines is illustrated in Figure 4.



**Figure 4.** Overview of the *Best Practice Guideline to Managing On-Site Vermiculture Technology* Information Sheets.





## Information Sheet No. 2

### How much compostable material is produced?

Information Sheet No. 2  
January 2002

#### Inside This Sheet

<b>1</b>	Simplified waste audit
	Implementation
<b>2</b>	What materials are you looking for?
	Definitions
<b>3</b>	The assessment process
	Food organics
<b>6</b>	Identifying your food organics materials
<b>8</b>	Garden organics
<b>10</b>	Wood and timber
<b>11</b>	Paper and cardboard
<b>12</b>	Estimating variation across the annual cycle
	Selecting an appropriate organics management system
<b>13</b>	Notes
	Important references
	Acknowledgement

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#### Simplified waste audit

Quantifying the *compostable organics* material in your organisation's waste stream is essential to determining the size and type of technology required to collect, handle and process this material.

Knowledge of the volume, composition and variation of the compostable organics stream across your annual "business" cycle will also help you identify an appropriate processing technology.

Understanding this variation throughout the year is important to determine peak periods and to design a system that is capable of managing peak volume.

Quantifying the volume and composition of materials is achieved by conducting an "audit". A solid *waste audit* involves the physical sorting of compostable organic materials from mixed waste. This is an unnecessary task that often involves unacceptable occupational

health and safety risks for staff (Plate 1).

This Information Sheet provides simplified methods that are more effective for quantifying the amount of organic material produced by your organisation.

Rather than conducting an unpleasant and unsafe "waste audit", simply collect compostable organic materials (eg. food) separately in dedicated bins. The quantity of this compostable material can then be determined. The challenge is to keep general waste out of the "organics only" collection bins (and vice versa), but this is simpler than sorting through mixed garbage.

Unnecessary risks are identified and removed, allowing for simpler and more accurate estimations than typical waste auditing practices.

#### Implementation

When implementing a *source separated* collection system, the needs of operations staff must be

**Plate 1.** Conducting a waste audit of non-source separated waste material. Even if safety clothing is used, this may still involve unnecessary risks if sharps and/or other contaminants are present.



addressed. If a new operational system is designed without adequate consultation, opportunities to create simpler and more efficient systems may be lost, contributing to problems that prejudice staff against the system.

Staff support is mandatory to maximise the diversion of organics from the *waste stream* and to minimise *contamination* levels in source separated material. Don't be discouraged by the terminology – it's simply encouraging colleagues to put their waste in the right bin, and making it convenient to do so.

Dissatisfaction with current practices and opportunities for reducing effort, can provide significant motivation for staff to support change. Aim to establish a system that better meets their expressed needs (eg. with respect to bin size, placement, ease of use etc.).

Generate awareness that discarding

of waste in the correct bin contributes to environmental improvement and that putting waste in the wrong bin creates unnecessary waste and safety risks for colleagues.

When presenting a new waste management system to staff, confirm that the new system is a result of their expressed needs.

### What materials are you looking for?

Prior to selecting an appropriate organics management system, it is important to identify the compostable materials generated by your organisation. Compostable organics may include (Plate 2):

- Food organics
- Garden organics
- Wood and timber
- Paper and cardboard

**Plate 2.** Materials you can use in your organics management system.

**Food organics** need *bulking agents* when used in organics management systems. They cannot be processed alone! Bulking agents include garden organics, wood and timber and paper and cardboard. Avoid using food organics high in oils and fats, as these may contribute to significant odour problems in your system.



**Wood and timber** can be used as bulking agents with food or garden organics. However, if these materials have been chemically treated, they should not be used in your organics management system. It is therefore important for you to know the composition (history) of your wood and timber and any associated health issues.



**Garden organics** can be processed on their own or used as bulking agents with food organics. These materials have a relatively high *carbon to nitrogen ratio*, complementing the low carbon to nitrogen ratio of food organics.



**Paper and cardboard** can be used as a bulking agent with food organics and/or garden organics. Due to the high carbon content and very low nitrogen content of paper and cardboard, these *feedstock* materials cannot be processed alone.



## Definitions\*

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Waste Audit

Determination of the quantities and qualities of individual components present in a waste stream.

### Source separation

Physical sorting of the waste stream into its components at the point of generation.

### Bulking agents

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms "bulking agent" and "amendment" are often used interchangeably. See also composting amendment.

### Carbon to nitrogen ratio

The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

*Continued page 5*

## The assessment process

### Food organics

The identification of food organics generated by your business will be simpler, safer and more effective if the food organics are collected separately for a period of 2 weeks. This also provides an excellent opportunity for a short-term trial of a separate collection system.

Food organics include the following subcategories. These categories are useful in identifying suitable handling and processing technologies:

Material	Detail
Fruit and vegetable material	
Bread, pastries and flours	Including rice and corn flours
Meat and poultry	
Fats and oils	
Seafood	Including shellfish, excluding oyster shells
Food soiled paper products	Hand towels, butter wrap etc.
Biodegradeables	Cutlery, bags, polymers
Dairy	Solid and liquid
Recalcitrants	Large bones, oyster shell, coconut shells etc.

Use the following steps to identify the quantity and nature of your food organics:

1. Identify primary locations/sources of generation of the food;
2. Consult with staff to identify current practice – what they like/dislike and existing inefficiencies;
3. Design separate organics collection system in consultation with staff employed at operation level to ensure that the system design meets their needs

A source separated organics collection system must meet the needs of operational staff within your

organisation. If the new system is designed without adequate consultation, problems may arise that may discourage staff from disposing of materials correctly into “food only” bins.

With staff support, the diversion of organics from the waste stream will be maximised (maximising environmental benefits and cost savings), and contamination rates of the organics stream minimised (minimising unnecessary effort and safety risks).

Aim to establish a system that meets the expressed needs of staff (eg. with respect to bin size, placement, ease of use etc.)

Confirm with operational staff that the new system will meet their needs.

4. Install source separate collection bins with appropriate signage etc

Install the new source separate collection bins. Make sure that all bins are placed at the same time to avoid confusion, organics ‘leakage’ to the waste stream or contamination of organics collected. Where possible, ensure that “organics only” bins are:

- a standard size and distinct colour with consistent clear signage;
- readily recognisable from garbage bins;
- obviously marked/labelled;
- appropriate size, location and number;

- placed next to each garbage/waste bin; and
- located so that the same amount of effort is required to place material in the “food only” bin or the garbage bin (if one requires a lid to be removed, or is a little further away the other may receive both waste streams).

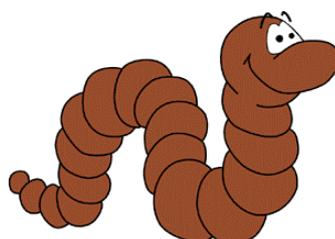
Promote the commencement of the trial period. Have someone from kitchen management or elsewhere communicate to all staff the purpose, timeframe and process of quantifying the amount of compostable materials produced.

Let staff know they will play a valuable role in ensuring the success of the project. Also engage them in the process to identify improvements in the system and to make it more consistent and efficient for use.

5. Collect organics generated over a two-week period

The waste audit results will inform selection of a processing technology that is capable of meeting your organisations needs.

In order to obtain reliable and accurate estimates of the volume and composition of your organisation’s organics stream, it is important to sample organics over a period of at least two weeks. In addition, it may be necessary to spend one week preparing for the audit – ironing out any bugs in the process. You should record audit information on Form 1 (attached to this Information Sheet).

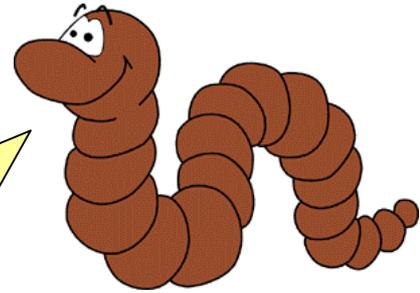


A source-separated food organics collection system should be developed to meet the expressed needs of operational staff. Staff input gained in previous consultation should be directly incorporated.

The steps involved are summarised below:

- Collect the filled separated “food organics only” bins on a daily basis);
- Remove waste contaminants (plastics, drink containers etc.) – document type and source of contamination;
- Tip contents of bins containing only small amounts of material together to minimise the number of bins being weighed;
- Weigh the filled bins on a platform scale;
- Record the weight on the data recording sheet supplied, attached to this Information Sheet;
- Use the bottom of a bucket to compress the food organics firmly into each bin so that the contents are reasonably well packed;
- Estimate total food organics volume from the size of the bin and the amount of material in it (compressing material avoids counting low density materials (eg. cabbage/lettuce leaves) as a full bin);
- Tip bin contents into shallow tubs for visual (percentage) estimates of organics composition;
- Combine your contaminants into one bin and weigh them;
- Empty tubs into a garbage skip or bin for collection;
- Wash out “food organics only” bins and return to kitchen staff;
- At the end of each week, calculate the total weight of the food organics material and the average volume of each type of material identified;

Contamination of the organics stream, or leakage of organics into the waste stream should be rectified immediately! Communicate the importance of achieving system operational success, and let staff know that their contribution really matters.



- Estimate seasonal variation from business records, staff numbers etc. to establish peak volumes of material that would be expected during busy periods.

Data on seasonal fluctuations in catering, generation of garden organics etc. can be obtained from business records and consultation with operational staff.

#### 6. Tools and materials required

The materials required to determine the amount and composition of the food organics are listed below:

- Platform scales
- Data recording sheets (attached)
- Tubs for estimating composition
- Food waste collection bins
- Stickers for identifying bins
- Tongs for removing contaminants
- Gloves (heavy duty kitchen gloves)
- Scrubbing brush and access to water for cleaning out bins
- Educational posters for staff room
- Presentation materials for staff meeting

Supplier information and prices for this equipment is contained in Appendix No. 1.

#### 7. Contamination

Contaminants in food organics comprise anything not compostable, including:

- individual portion wrappers (plastic or foil);
- plastic bags, cling wrap films and plastic cutlery;
- glass;
- stainless steel cutlery, foil and other metals;
- ceramics, and
- drink containers.

Contamination increases the workload and labour costs of an organics management system. In addition, contaminants make work very unpleasant (removal of contaminants) and create safety hazards for staff (glass and metals, see Plate 3).

#### 8. Monitor solid waste stream to identify any organics ‘leakage’;

Improve organics diversion success through education. Remember to address any problems in system implementation immediately. All staff working at operational level should understand clearly how the separation system works, and should have had the opportunity to contribute to system design to ensure it is convenient and efficient for their use.

There should be no general waste contamination of the collected food

**Plate 3.** Contaminants such as glass may be encountered during waste audits – especially if a source separation system has not been developed.



*Continued from page 2*

**Waste Stream**

Flow of materials from a point of generation to ultimate disposal.

**Contamination**

Contaminants within this context include physical inorganic materials (metals, glass etc.), non-biodegradable organic materials (plastics), chemical compounds and/or biological agents that can have a detrimental impact on the quality of any recycled organic products manufactured from source separated compostable organic materials.

**Feedstock**

Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

\* Recycled Organics Unit (2001a).

organics and no leakage of food organics into the general waste. If this does occur, rectify the problem by communicating directly with those responsible and encouraging them to help achieve successful outcomes.

9. Improve organics diversion rate and maintain through consultation and education.

**10. Bin hygiene**

Bins must be cleaned and maintained to control odours. Water and a long handled scrubbing brush can be used to achieve this. In some instances, a small amount of detergent may also be required.

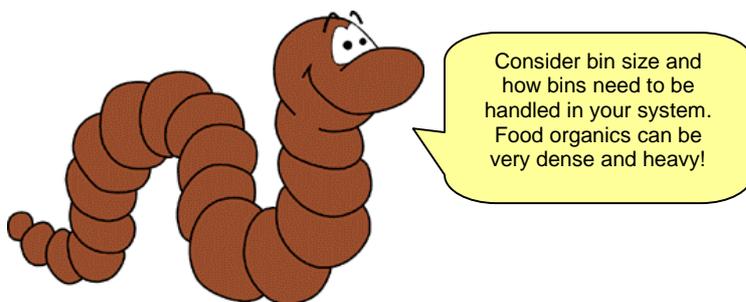
**11. Bin size**

Consider bin size and how bins need to be handled in your system. Food organics can be very dense and heavy, ranging in weight from 0.4 kg to over 0.8 kg per litre. At the upper end of this scale, a 120 litre bin could weigh over 90 kg, which is both unsafe and well in excess of the maximum capacity of the bin.

Given the nature of food organics, 80 litre wheelie bins are the most appropriate size available for food organics collection. Larger bin sizes can be too heavy (when full) for collecting dense food material.

**12. What happens now?**

After the two-week sampling period, you should have a clear understanding of the volume and composition of food organics generated within your organisation. You should also have estimates of variation across the annual business cycle. This information (in combination with other factors) can be used to identify a system that best suits your requirements.



# Identifying your food organics materials

**1** **Collect** the separate food organics bins on a daily basis



**6** **Empty** bin contents into shallow tubs for visual (%) estimation of food organics composition.



**2** **Remove** waste contaminants (glass, plastics, drink containers etc.), document type and source of contamination.



**7** **Combine** your contaminants into one bin and weigh them.



**3** **Minimise** the number of bins you use (combine contents of bins that only have small amounts of material in them).



**8** **Empty** tubs into skip/bin for collection.



**4** **Compress** the organics into each bin so that the contents are reasonably well packed. You can use the bottom of a bucket to do this.



**9** **Wash** out bins and return to kitchen staff. Bins must be cleaned and maintained to control odours.



**5** **Weigh** the filled bins on a scale. Record the total volume and weight on data recording sheets.



**10** **Calculate** the total weight of the food organics material and the average volume of each type of material identified.



**11** **Estimate** seasonal variation from business records.

**Form 1: Auditing your food organics.**

Day	Weight	Volume (estimate)	Fruit and vegetables	Bread, pastry and flours	Meat and poultry	Dairy products	Seafood	Food soiled paper	Recalcitrants	Biodegradables	Contaminants	Special event/holiday? (Please provide details)	Initial
Week 1	Kg	L	% v/v*	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v		
Mon.													
Tue.													
Wed.													
Thu.													
Fri.													
Weekly total and average	Total	Total	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.		
Week 2	Kg	L	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v	% v/v		
Mon.													
Tue.													
Wed.													
Thu.													
Fri.													
Weekly total and average	Total	Total	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.		

**Instructions:**

1. Collect the filled source separated food organics bins (note: food organics should be collected daily)
2. Remove waste contaminants (plastics, drink containers etc.), document type and source of contamination
3. Minimise the number of bins you use (combine contents of bins that only have small amounts of material in them).
4. Compress the organics into each bin so that contents are reasonably well packed
5. Weigh the filled bins on a scale
6. Record the weight on the above data recording sheet (remember to subtract the bin weight from the total weight)
7. Estimate food organics volume from the approximate size of the bin and the amount of material in it
8. Tip bin contents into shallow tubs for visual estimation of organics composition (\* record % of total volume – v/v)
9. Combine your contaminants into one bin and weigh them
10. Empty tubs into “garbage” bin/skip for disposal
11. Wash out bins and return to kitchen staff
12. At the end of each week, calculate the total weight of the food organics material and the average volume of each type of material identified
13. Use weekly average to estimate seasonal variation from business records

## Garden organics

Garden organics material can form a substantial proportion of the solid waste stream, particularly during summer and after storm events.

In some instances quantifying the garden organics produced by your organisation may be difficult. Nevertheless, you should try to characterise this component of your waste stream.

Garden organics materials include the following subcategories, which are useful in identifying suitable handling and processing technology:

Material	Detail
Putrescible garden organics	grass clippings
Non-woody garden organics;	leaves, sapwood, prunings (<10 mm Ø)
Woody garden organics;	branches, twigs (>10 mm Ø)
Trees and limbs;	
Stumps and rootballs.	

Use the following steps to quantify and identify the nature of your garden organics (Plate 4):

### 1. Consult with relevant staff

Consultation with relevant staff members is essential to determine the amount of garden organics material produced. Identify materials present and the quantities of materials generated. If possible, ask gardening staff to fill out Form 2 for a two week period to characterise the garden organics generated.

If gardening staff cannot give you accurate estimations of garden organics generated, it will still be useful to have garden staff provide a guesstimate of the amount of each material produced.

### 2. The audit process

**Plate 4.** Quantifying the amount and type of garden organics produced by your organisation may be difficult, but it is still important if you want to use this material in your new organics management system.



Over a two week period, encourage gardening staff to record the volume and composition of the garden organics generated. In addition, identify current practices with your garden organics – are they stock piled, mulched, burnt, dumped in a skip etc.?

Use the following steps to determine the amount and type of garden organics produced by your organisation:

- Have gardening staff count the number of grass catchers, trailers, trucks, and/or skips filled with garden organics each day.
- Determine the volume of each type of storage medium.
- To determine the overall volume of materials generated on a daily basis, multiply the number of times a container is filled by its volume.
- Estimate the total volume of material generated on a weekly basis by adding the daily totals together.
- Try to characterise the proportion of different garden organics generated on a daily/weekly basis.

- Make notes of any storm events etc. that may have influenced the amount of material generated/collected during the audit period.

Note: If your garden organics have been size reduced/shredded prior to auditing, the volume of material will be significantly reduced.

### 3. Exclude materials from the audit

If materials such as lawn clippings are usually left uncollected on lawn areas, then do not count this material in the audit. Leaving this material on the ground is the optimal choice – not requiring further effort or management. The goal of the organics management system is to improve poor practice, not to change best practice where it already occurs.

### 4. Check the audit results

After the two week period, it will be useful to feed data back to gardening staff and confirm the audit results. Determine if the results are typical or atypical of what is usually produced.

Identify the effects of season or the impact of other events such as storms on the amount and type of material produced.

**Form 2. Auditing your garden organics**

Day	Volume (total)	Grass catcher	Trailer	Truck	Skip/other	<b>Identify your garden organics:</b> LC: lawn clippings NW: non-woody garden organics (<10 mm Ø) WG: woody garden organics (>10 mm Ø) TL: trees and limbs SR: stumps and rootballs	Special event/time of year? (Please provide details)	Initial
Mon.								
Tue.								
Wed.								
Thu.								
Fri.								
Weekly total and average	Total	Total (L)	Total (L)	Total (L)	Total (L)			
Week 2	L	No.	No.	No.	No.			
Mon.								
Tue.								
Wed.								
Thu.								
Fri.								
Weekly total and average	Total	Total (L)	Total (L)	Total (L)	Total (L)			

**Instructions:**

- Count the number of grass catchers, trailers, trucks, and/or skips filled with garden organics each day.
- Determine the volume of each type of storage medium.
- To determine the volume (litres) of materials generated on a daily basis, multiply the number of times a container is filled by its volume.
- Estimate the total volume of material generated on a weekly basis by adding the daily totals together.
- If possible try to characterise the proportion of different garden organics generated on a daily/weekly basis. Use the abbreviations given in this form to identify the different garden organics types.
- Make notes of any storm events etc. that may have influenced the amount of material generated during the audit period.

## Wood and timber

Wood and timber materials can be a substantial proportion of the solid waste stream for some types of enterprises. These materials have a very high *carbon to nitrogen ratio*, complementing the low carbon to nitrogen ratio of food organics.

Wood and timber organics include the following subcategories, which are useful in identifying suitable handling and processing technologies:

Material
off-cuts
crates
pallets and packaging
saw dust
timber shavings

For use in your organics management system, you should consider only saw dust and/or timber shavings, and

only if the material is from wood that is not painted or treated. The use of other wood and timber materials may create more problems than benefits.

**Avoid chemically treated or composite wood products**

Avoid using chemically treated wood and composite wood materials, as they contain dangerous chemical compounds (eg. formaldehyde, creosote, etc.) that may pose potential health risks to your staff.

**Use wood materials that are already in a form to be processed**

For OH&S reasons and also for ease of management, it is best to use wood and timber materials that are already in a form to be processed (saw dust and shavings).

Size reduction of materials adds considerable time to the processing of the wood and timber, requires expensive equipment and also

exposes staff to unnecessary risks.

### The audit process

As with garden organics and food organics, collect residual wood and timber materials over a two week period.

- Remove any contaminants
- Place the residuals in easy to weigh containers and weigh on a daily or weekly basis (depending on quantity produced)
- Identify type and source of contamination (if any)
- Dispose of material, as is usual practice
- Clean containers (if necessary)
- At the end of the two-week period calculate the quantity and composition of material generated using Form 3.

**Form 3.** Auditing your wood and timber residuals

Day	Weight	Volume (estimate)	Off-cuts	Crates	Pallets and packaging	Saw dust	Timber shavings	Contaminants	Special event/time of year? (Please provide details)	Initial
Week 1	Kg	L	%	%	%	%	%	%		
Mon.										
Tue.										
Wed.										
Thu.										
Fri.										
Weekly total and average	Total	Total	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.		
Week 2	Kg	L	%	%	%	%	%	%		
Mon.										
Tue.										
Wed.										
Thu.										
Fri.										
Weekly total and average	Total	Total	Ave.	Ave.	Ave.	Ave.	Ave.	Ave.		

## Paper and cardboard

Paper and cardboard materials can be a substantial portion of the solid waste stream for many enterprises. Whilst not wanting to impact on effective paper recycling, some of this material may be useful to the organics management system. Paper and cardboard has a very high carbon to nitrogen ratio – complementing the very low carbon to nitrogen ratio of food organics.

If you have not established a paper recycling system, the guidelines are provided in “Office Paper, Recycle it” NSW EPA (1990).

Use pre-shredded paper/cardboard

For ease of management and to facilitate the organics management

system, only use non-waxed paper and cardboard. The size reduction of paper and cardboard can be difficult and time consuming without expensive equipment. So be sure to identify shredded paper and cardboard. It will be much easier to use in your organics processing system.

### The audit process

As with other materials, monitor the amount of paper produced by your organisation over a two-week period. Quantify volumes generated on a daily/weekly basis, identifying contaminant levels and the effects of special events etc. on volumes generated. To quantify materials produced, your organisation should:

- Collect paper in easy to weigh containers or as per existing system;
- Weigh paper on a daily/weekly basis using platform scales as identified previously;
- Determine the volume of paper generated from the size of the containers.
- Identify type and source of contamination (if any);
- “Dispose” of or recycle paper through regular practice;
- At the end of the 2 week period, calculate the amount of material generated weekly.

**Form 4.** Auditing your paper and cardboard

Day	Weight	Volume (estimate)	Paper	Shredded paper	Cardboard	Waxed cardboard	Contaminants	Special event/time of year? (Please provide details)	Initial
Week 1	Kg	L	% v/v	% v/v	% v/v	% v/v	% v/v		
Mon.									
Tue.									
Wed.									
Thu.									
Fri.									
Weekly total and average	Total	Total	Ave.	Ave.	Ave.	Ave.	Ave.		
Week 2	Kg	L	% v/v	% v/v	% v/v	% v/v	% v/v		
Mon.									
Tue.									
Wed.									
Thu.									
Fri.									
Weekly total and average	Total	Total	Ave.	Ave.	Ave.	Ave.	Ave.		

If you don't have a paper recycling system, provide a copy of the previous page and Form 4 to someone else who is interested in developing paper recycling in your organisation.

### Estimating variation across the annual cycle

Different seasons and events influence the volume of "waste" materials produced over a given period. Examples of these influences are identified below:

Material	Events
Food	<ul style="list-style-type: none"> <li>▪ Public holidays</li> <li>▪ Christmas party</li> <li>▪ Daily weather</li> </ul>
Garden	<ul style="list-style-type: none"> <li>▪ Seasonal variation</li> <li>▪ Storm events</li> <li>▪ Landscape redevelopment</li> </ul>

Your organics management system needs to be designed to cope with the

maximum expected volumes. If the "audit" is conducted during a quiet period – use business records (eg. purchasing, reservations, bookings etc.) and consult with operational staff to estimate maximum expected volumes.

Document maximum expected volumes in the following format:

"Food organics: as measured  $\pm$  30% (eg.) during busy Christmas period"

You can now summarise the volumes of compostable organic materials generated by your organisation in Form 5.

### Selecting an appropriate organics management system

Conducting an audit will allow the identification of the types and quantities of compostable organic materials produced by an

organisation. The selection of an appropriate organics management system can be made according to this identification of specific compostable materials produced.

Vermiculture units are suitable for processing the following compostable organic materials:

Material	Events
Food organics	<ul style="list-style-type: none"> <li>▪ Fruit and vegetable material</li> <li>▪ Bread, pastries and flours;</li> <li>▪ Meat and poultry;</li> <li>▪ Food soiled paper products (hand towels, butter wrap etc.)</li> </ul>
Garden organics	<ul style="list-style-type: none"> <li>▪ putrescible garden organics (grass clippings);</li> <li>▪ non-woody garden organics; (leaves, sapwood, prunings &lt;10 mm)</li> </ul>
Paper and cardboard	<ul style="list-style-type: none"> <li>▪ size-reduced, non-waxed paper and cardboard</li> </ul>

**Form 5.** Weekly volume of material generated by your organisation

Material	Weekly average volume (from audit) (L)	Estimated maximum volume during 'busy' periods (L)	Explanation
Food organics			
Garden organics			
Paper and cardboard			
Wood and timber			



# Information Sheet No. 3

## Can vermiculture work for you?

Information Sheet No. 3  
January 2002

### Inside This Sheet

- 1** Vermiculture processing
- Food organics suitable for vermiculture processing
- 2** Choosing a suitable processing technology
- Definitions
- 3** Notes
- Important references
- Acknowledgements

### Vermiculture processing

The use of vermiculture for processing *compostable organics* material is often promoted as a suitable means of recycling materials to produce valuable horticultural products.

However, even well managed vermiculture units can fail if they are fed with unsuitable materials.

Vermiculture technology cannot process all categories of compostable organics with the same efficiency. Only a limited range of organic materials can be effectively managed via on-site vermiculture technology.

The audit of 'waste' material produced on site (Information Sheet No. 2), is an essential step in identifying the type of compostable materials that you produce. This will enable you to decide whether or not vermiculture technology is suitable for your organisation.

### Food organics suitable for vermiculture processing

The Recycled Organics Unit has performed a number of trials that examined the ability of vermiculture technology to process a range of common compostable organic materials (see Appendix No. 4).

These trials established that vermiculture is most effective for processing fruit and vegetables however a certain amount of feedstock preparation is required, as shown in Plate 1 (Recycled Organics Unit, 2000).

See Appendix No. 4 for research conducted by the Recycled Organics Unit regarding suitable materials for vermiculture processing.



**Plate 1.** Mixed fruit and vegetables suitable for vermiculture processing (left). Preparation of the materials, including size reduction (right), is necessary prior to treatment in a vermiculture unit.



The trials performed by the Recycled Organics Unit also found that *food organics* can be processed using vermiculture, however, materials need to be prepared into a suitable feedstock.

The definition for food organics contains the following sub-categories:

Material	Detail
Fruit and vegetables	
Bread, pastries and flours	Including rice and corn flours
Meat and poultry	
Fats and oils	
Seafood	Including shellfish, excluding oyster shells
Food soiled paper products	Hand towels, butter wrap etc.
Biodegradeables	Cutlery, bags, polymers
Dairy	Solid and liquid
Recalcitrants	Large bones, oyster shell, coconut shells etc.

Of these categories, the trials performed by the Recycled Organics Unit indicated that seafood, dairy, and monostreams of bread, pastries and flours and meat are not suited to vermiculture processing in any significant quantity.

Also, previous qualitative experience has indicated that as higher proportions of bread, meat and dairy are combined with fruit and vegetables in a mixed food organics feedstock, the capacity of vermiculture technology to process this material, is significantly decreased (Kater, 1998; Recycled Organics Unit, 2000).

As a result of these studies, the Recycled Organics Unit recommends that on-site vermiculture technology is suitable for the following categories of food organics material:

- only fruit and vegetables; or
- predominantly fruit and vegetables with a relatively small proportion of bread and meat/poultry.

Although it may be possible for vermiculture to process a wider range of food materials, the risk of problems occurring and the management skill and effort required to sustain the process means that vermiculture processing is not appropriate for C&I sector on-site applications.

### Choosing a suitable processing technology

Performing an audit of all compostable organic materials produced on-site will allow an identification of the types and quantities of compostable materials produced by your organisation.

If large quantities of fruits and vegetables were identified in the audit, vermiculture technology may be a suitable option for processing this compostable material. However, if materials that are difficult to process using vermiculture make up a significant proportion of your total material, a different form of processing technology, for example on-site *composting* or a source separated collection system for centralised processing, will be more suitable.

More information on other forms of processing technology can be found in “*Implementing an Organics Management System: A planning and implementation workbook for the commercial and industrial sector*” (Recycled Organics Unit, 2001a) or from <http://www.recycledorganics.com>.

## Definitions\*

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Food organics

The Food Organics material description is defined by its component materials, which include: fruit and vegetable material; meat and poultry; fats and oils, seafood (including shellfish, excluding oyster shells); recalcitrants (large bones >15mm diameter, oyster shells, coconut shells etc.); dairy (solid and liquid); bread, pastries and flours (including rice and corn flours); food soiled paper products (hand towels, butter wrap etc.); and biodegradeables (cutlery, bags, polymers). Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the *compostable organics* stream.

### Composting

The process whereby organic materials are pasteurised and microbially transferred under aerobic and thermophilic conditions for a period of not less than six weeks. By definition, it is a process that must be carried out under controlled conditions yielding mature products that do not contain any weed seeds or pathogens.

\*Recycled Organics Unit, (2001b)



# Information Sheet No. 4

## Guide to feedstock preparation and determining what size vermiculture unit is required

Information Sheet No. 4 January 2002	
Inside This Sheet	
1	Selection of a vermiculture unit
2	Feedstock composition
	Preparing material for processing
	The importance of a bulking agent
5	Mixing a suitable feedstock
6	Maximum processing capacity
7	What size vermiculture unit do I require?
8	Stocking the unit with worms
9	Space availability
	Definitions
10	Example
11	Caution
	Notes
	Important references
	Acknowledgements
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ISBN 1-876850-04-3	

### Selection of a vermiculture unit

Selection of the type and size of vermiculture unit required will vary from site to site depending on a number of factors. These factors include:

- type of materials to be processed;
- cost;
- purpose of the vermiculture unit;
- availability of complementary materials;
- vermiculture processing capacity for the organic material; and
- availability of space and other site specific constraints.

In order to determine what size vermiculture unit is required a 'waste' audit needs to be conducted to determine the quantity and type of

materials you produce. This auditing process has been detailed in Information Sheet No. 2.

Establishing a *source separated* collection system is essential for the collection of *compostable organic* material for processing in a vermiculture unit. This process is also detailed in Information Sheet No. 2.

Refer to Information Sheet No. 2 for the process of auditing your waste and establishing a source separated collection system



Following this, you need to evaluate whether vermiculture technology is suited to processing the materials that are produced by your organisation. This process is detailed in Information No. 3.

**Plate 1.** Feedstock for successful vermiculture processing requires a combination of size reduced organic materials and a carbonaceous bulking agent.



## Feedstock composition

The volume of compostable material a vermiculture unit can process (see *processing capacity*) will vary depending on the type of material being processed, the size of the unit, the amount of worms housed in the unit, and management of the unit.

Vermiculture units more readily treat a mixture of organic materials than 'monostreams' of a single material.

## Preparing material for processing

Organic materials to be processed by a vermiculture unit should be size reduced to enable effective processing by the worm population (Plates 2 and 3).

The addition of a *bulking agent* is required to form a feedstock that will support problem free processing.

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**Plate 2.** Fruit and vegetables prior to size reduction using a bucket and spade method.



**Plate 3.** Fruit and vegetables after size reduction using a bucket and spade method. Note the very watery texture. Shredded cardboard can be added to soak up the excess water.



Plate 4 shows a final feedstock of size reduced fruit and vegetables blended with a cardboard bulking agent.

## The importance of a bulking agent

A bulking agent is a carbonaceous material, such as paper or cardboard, that is added to a feedstock to increase the *carbon to nitrogen (C:N) ratio* and to help achieve a suitable moisture level, thereby improving the structure and porosity of the feedstock.

An ideal C:N ratio of a feedstock for vermiculture processing is 20 to 25 parts carbon to 1 part nitrogen (20-25:1). Maintaining this C:N ratio is especially important when processing organic materials that are high in nitrogen such as meats and poultry.

If the C:N ratio is not ideal, these high nutrient materials will decompose rapidly and problems such as odour development and pest attraction may occur.

The addition of a bulking agent also increases the structure and porosity

of a feedstock. These factors result in a more suitable environment for the worms and hence processing will be more effective.

Cardboard and office paper are common residual materials of the C&I sector and these materials can provide an excellent on-site source of bulking agent if they can be size reduced.

Bulking agents need to be size reduced and thoroughly mixed with the organic materials to create a suitable feedstock (Plate 4).

In some instances achieving the desired C:N ratio **and** moisture content may require the addition of water. Feedstocks containing materials such as breads, for example, tend to be quite dry yet are high in nitrogen. A moisture content of approximately 80% is ideal for a vermiculture feedstock mixture.

A number of generic recipes (by weight and by volume) for feedstock mixtures comprising organic materials commonly produced by C&I sector organisations are shown in Tables 1 and 2.

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**Plate 4.** Blended feedstock of mixed fruit and vegetable and cardboard bulking agent ready to be processed by a vermiculture unit.



**Table 1. Feedstock recipe guide (by weight) for compostable organics material and cardboard bulking agent.**

<b>Feedstock type<sup>1</sup></b>	<b>Maximum sustainable processing capacity (kg/m<sup>2</sup>/wk)</b>	<b>Components<sup>3</sup></b>	<b>Composition by weight (%)</b>	<b>Composition by weight (kg)</b>	<b>Ratio of organics to bulking agent</b>
Fruit and/or vegetables + cardboard	16.5	Fruit	41.0	6.8	4.7:1
		Vegetables	41.0	6.8	
		Cardboard	18.0	2.9	
		Total:	100.0	16.5	
Mixed food organics + cardboard	10.0	Fruit	22.0	2.2	2.6:1
		Vegetables	20.0	2.0	
		Bread	3.0	0.3	
		Meat/poultry	9.0	0.9	
		Cardboard	21.0	2.1	
		Water	25.0	2.5	
Total:	100.0	10.0			
Garden organics	5.8	Lawn clippings and non-woody plant materials	70.0	4.0	No bulking agent required
		Water	30.0	1.8	
		Total	100.0	5.8	
Miscellaneous food organics + cardboard (eg. Café food scraps)	13.3	Pre-consumer fruits and vegetables	51.0	6.8	4.3:1
		Post-consumer plate scrapings (mixed food organics)	30.0	4.0	
		Cardboard	19.0	2.5	
		Total:	100.0	13.3	

<sup>1</sup> Note that this data is a result of extensive applied trials that have shown such feedstock mixtures can support sustained vermiculture processing without resulting in negative environmental impacts or system failure (Recycled Organics Unit, 2000).

<sup>2</sup> Processing capacity is the maximum amount (kg) of compostable organics that can be added to a vermiculture unit per week without causing system failure. System failure is evident when the processing technology produces problematic environmental emissions and/or declines in processing efficiency and/or produces a product of unacceptable quality (Recycled Organics Unit, 2000b). Overfeeding of a vermiculture unit will exceed the maximum processing capacity resulting in problems and management requirements.

<sup>3</sup> Shredded paper is a common C&I sector waste material that can be used as a bulking agent when combined with compostable organics material. However, no data is available at present on appropriate mixing ratios to enable processing in vermiculture units. Experimentation with blending ratios is recommended in order to use shredded paper as a bulking agent.

**Table 2. Feedstock recipe guide (by volume) for compostable organics material and cardboard bulking agent**

Feedstock type <sup>1</sup>	Maximum sustainable processing capacity <sup>2</sup> (L/m <sup>2</sup> /wk)	Components <sup>3</sup>	Composition by volume <sup>4</sup> (%)	Composition by volume <sup>4</sup> (L)	Ratio of organics to bulking agent
Fruit and/or vegetables + cardboard	24.0	Fruit	34.0	8.0	2.2:1
		Vegetables	35.0	8.5	
		Cardboard	31.0	7.5	
		Total:	100.0	24.0	
Mixed food organics + cardboard	18.0	Fruit	14.0	2.5	0.8:1
		Vegetables	14.0	2.5	
		Bread	5.0	1.0	
		Meat/poultry	5.0	0.9	
		Cardboard	48.0	8.6	
		Water	14.0	2.5	
Total:	100.0	18.0			
Garden organics	30.0	Lawn clippings and non-woody plant materials	94.0	28.3	No bulking agent required
		Water	6.0	1.7	
		Total	100.0	30.0	
Miscellaneous food organics + cardboard (eg. Café food scraps)	21.6	Pre-consumer fruits and vegetables	38.0	8.3	1.2:1
		Post-consumer plate scrapings (mixed food organics)	16.0	3.4	
		Cardboard	46.0	9.9	
		Total:	100.0	21.6	

<sup>1</sup> Note that this data is a result of extensive applied trials that have shown such feedstock mixtures can support sustained vermiculture processing without resulting in negative environmental impacts or system failure (Recycled Organics Unit, 2000).

<sup>2</sup> Processing capacity is the maximum amount (kg) of compostable organics that can be added to a vermiculture unit per week without causing system failure. System failure is evident when the processing technology produces problematic environmental emissions and/or declines in processing efficiency and/or produces a product of unacceptable quality. (Recycled Organics Unit, 2000b). Overfeeding of a vermiculture unit will exceed the maximum processing capacity resulting in problems and management requirements.

<sup>3</sup> Shredded paper is a common C&I sector waste material that can be used as a bulking agent when combined with compostable organics material. However, no data is available at present on appropriate mixing ratios to enable processing in vermiculture units. Experimentation with blending ratios is recommended in order to use shredded paper as a bulking agent.

<sup>4</sup> Note that all volumes are for size reduced feedstock components.

## Mixing a suitable feedstock

Preparing a suitable feedstock for processing in a vermiculture unit is a crucial step in ensuring a healthy environment for the worm population.

Many failures of vermiculture units can be attributed to the addition of unsuitable feedstocks or excessive quantities of feedstock. Problems that can result from an unsuitable feedstock include:

- feedstock too moist – resulting in *anaerobic* (low oxygen) conditions;
- feedstock too dry – not suitable for worm movement and habitation;
- feedstock containing components that cannot be readily processed by the vermiculture unit – such as seafood or dairy material;
- feedstock loading rate too high – too much feedstock applied to the unit resulting in feedstock build up, anaerobic (low oxygen) conditions and worm death;
- feedstock particles too large – size reduction is necessary for

effective processing (eg. particles >50 mm should be size reduced).

Some generic vermiculture feedstock recipes have been given in Tables 1 and 2. The steps for preparing a suitable feedstock are given below and will follow the recipe for a mixed fruit and vegetable feedstock (by volume).

1. Feedstock should be prepared daily. Storage of feedstock and unprocessed food organics components should be avoided as this can result in odour production and pest attraction.
2. Wear gloves and an apron whilst handling materials and preparing feedstock.
3. Collect source separated mixed fruits and vegetables from collection point (eg. kitchen).
4. Place the raw size reduced food organics (Plate 2) in a tub or tray suitable for mixing.
5. Size reduce by chopping with a spade (Plate 3).
6. Estimate the volume of raw organics material – using buckets of known volume is

helpful for this task, or mark the inside of tub for different volumes.

7. Determine the quantity of bulking agent required (see Table 2) to obtain a suitable C:N ratio, moisture content and structure (Plate 5).
8. Combine the raw organics material and bulking agent thoroughly. A fork or shovel is useful for this task (Plate 6).
9. Check the moisture content is suitable by performing the ‘fist test’ (also known as ‘squeeze test’).

Take a handful of feedstock and squeeze firmly (Plate 7). Some moisture should be released between the fingers however the feedstock should not be saturated.

If the feedstock is too moist, it may be beneficial to allow the bulking agent in the feedstock to absorb moisture for 10 minutes and then checking the moisture content again. The bulking agent may absorb more of the moisture over time. If the feedstock is still too moist, more bulking agent

**Plate 5.** Blending of a cardboard bulking agent with raw fruit and vegetable feedstock to soak up excess water and to raise the C:N ratio to an optimum level.



**Plate 6.** Use a fork or shovel to blending the feedstock components.



**Plate 7.** ‘Fist test’ used to determine the correct moisture content for the feedstock.



**Plate 8.** Final feedstock of mixed fruit and vegetables blended with a cardboard bulking agent.



should be added. This will increase the C:N ratio, which is not ideal, but may be the balance of variables possible.

If the feedstock is too dry (which may be the case for feedstocks made from dry materials such as bread), water should be added and the moisture content checked using the 'fist test'.

10. The final feedstock should have a suitable moisture content, a good structure and a C:N ratio of between 20-25:1 (Plate 8).

Feedstocks should be applied immediately to a vermiculture unit, and then the tools used and site should be cleaned, ensuring no food material is left exposed to the environment as this can result in odour generation and pest attraction.

### Maximum processing capacity

The processing capacity of vermiculture technology refers to the maximum amount of organic material that can be added to a vermiculture unit per unit time (eg. week) without causing system failure.

Vermiculture units have a limit to the amount of organic materials that can be processed over time.

If the maximum processing capacity is exceeded, problems can arise such as anaerobic (low oxygen) conditions, worm death, odour production, pest attraction and ultimate system failure.

The maximum processing capacity of a vermiculture unit is dependent on the type of materials being fed to it (feedstock composition) as worms process different organic materials at different rates.

As discussed in Information Sheet No. 3, the installation of a

vermiculture unit will only be successful if the appropriate compostable material is processed in the unit at an appropriate loading rate.

Trials performed by the Recycled Organics Unit found that fruit and vegetables are the most appropriate organic materials for vermiculture processing

Seafood, dairy, and monostreams of bread and meat are not suited to on-site vermiculture processing in any significant quantity.

Also, previous qualitative experience has indicated that as higher proportions of bread, meat and dairy are combined with fruit and vegetables in a mixed food organics feedstock, the capacity of vermiculture technology to process this material, is significantly decreased (Kater, 1998; Recycled Organics Unit, 2000).

As a result of these studies, the Recycled Organics Unit recommends that on-site vermiculture technology is suitable for the following categories of food organics material (Plate 9):

- only fruit and vegetables; or
- predominantly fruit and vegetables with a relatively

small proportion of bread and meat/poultry.

Although it may be possible for a vermiculture unit to process a wider range of food materials, the risk of problems occurring and the management skill and effort required to sustain the process means that vermiculture processing is not appropriate for C&I sector on-site applications.

The maximum processing capacity of a vermiculture unit in relation to two feedstocks with varying compositions is shown in Figure 1, based on research performed by the Recycled Organics Unit (see Appendix No. 4).

Note that a mixed food organics and cardboard feedstock, containing meat and bread material, requires a higher proportion of bulking agent (due to the higher nitrogen content in meat and bread) and can be processed by a vermiculture unit at a lower application rate than the fruit and vegetable and cardboard feedstock.

The maximum processing capacity is expressed as the volume of feedstock applied per square metre of bedding surface per week (given appropriate siting, worm population and management).

**Plate 9.** Food organics suitable for processing in vermiculture units include only fruit and vegetables or predominantly fruit and vegetables with relatively small proportions of bread and meat/poultry.



## What size vermiculture unit do I require?

The size of the vermiculture unit required for on-site processing of compostable organic materials will be calculated from the results of an audit of waste produced on-site as previously discussed. The size calculated is actually the number of square metres (m<sup>2</sup>) of surface feeding area that is required (Figure 2).

The size/number of vermiculture units selected must be large enough to effectively process the volumes of organic materials produced on-site. If your vermiculture unit is too small,

the process is likely to fail.

The processing capacity of a number of example feedstocks is shown in Table 3. This table will aid in calculating the surface area (m<sup>2</sup>) that is required to process the volumes of organic materials produced on-site.

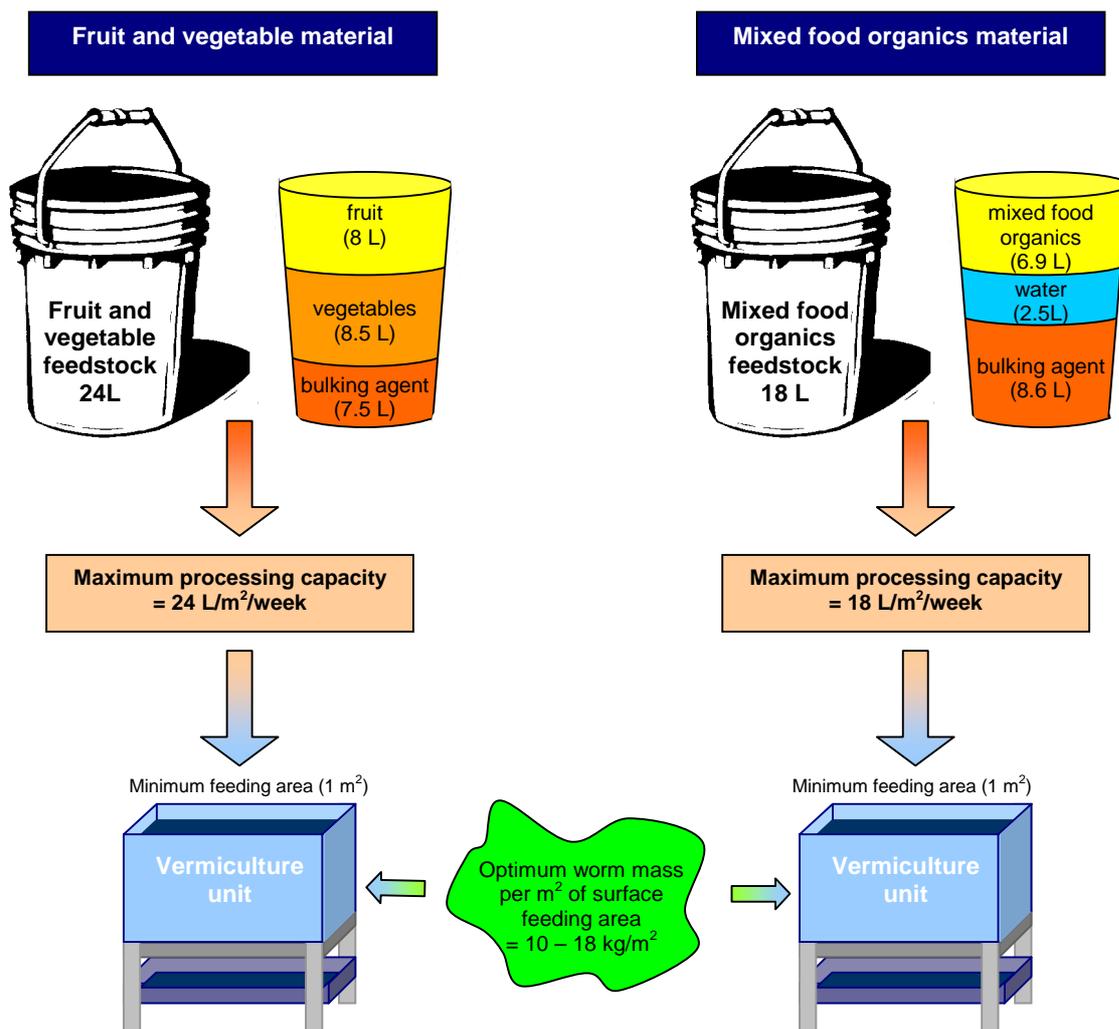
This can be done by following these steps:

1. The type and volume of food organic material is found by the audit (Information Sheet No. 2).
2. **Volume of feedstock** – calculate the volume of feedstock (raw size reduced food material +

**Figure 2.** The size of a vermiculture unit required to adequately process the amount of organic material produced onsite is dependent on the size of the surface feeding area. The surface feeding area for an example vermiculture unit is shown below. This unit has a surface feeding area of 0.53 m<sup>2</sup>.



**Figure 1.** Maximum processing capacity of a mid-scale on-site vermiculture unit for a mixed fruit and vegetable + bulking agent feedstock and a mixed food organics + bulking agent feedstock.



**Table 3. Processing capacities and estimated surface feeding area required for suggested feedstocks**

Feedstock	Composition	Maximum processing capacity of blended feedstock (L/m <sup>2</sup> /wk)*	Volume of feedstock from your site after blending with bulking agent where appropriate (L/wk)	Calculated surface feeding area of vermiculture unit required (m <sup>2</sup> )
Mixed fruit and/or vegetables	<ul style="list-style-type: none"> <li>▪ Mixed fruit</li> <li>▪ Mixed vegetables</li> <li>▪ Bulking agent</li> </ul>	24	<i>a</i>	$= \frac{a}{24} m^2 = x^{\#} m^2$
Mixed food organics	<ul style="list-style-type: none"> <li>▪ Mixed fruit</li> <li>▪ Mixed vegetables</li> <li>▪ Meat/poultry</li> <li>▪ Bread</li> <li>▪ Bulking agent</li> </ul>	18	<i>b</i>	$= \frac{b}{18} m^2 = x^{\#} m^2$
Garden organics	<ul style="list-style-type: none"> <li>▪ Lawn clippings</li> <li>▪ Garden organics</li> </ul>	30	<i>c</i>	$= \frac{c}{30} m^2 = x^{\#} m^2$
Miscellaneous organics (eg. Café food scraps)	<ul style="list-style-type: none"> <li>▪ Pre-consumer mixed fruits and vegetables</li> </ul>	24	<i>a</i>	$= \frac{a}{24} m^2 + \frac{b}{18} m^2$
	<ul style="list-style-type: none"> <li>▪ Post consumer plate scrapings (mixed food organics)</li> </ul>	18	<i>b</i>	$= x^{\#} m^2$
	<ul style="list-style-type: none"> <li>▪ Bulking agent</li> </ul>			

\* Based on maximum loading rates calculated by the Recycled Organics Unit (2000).

# Where *x* is the calculated surface feeding area required based on the amount of feedstock to be processed on-site.

bulking agent) to be processed each week (and the amount of bulking agent necessary to make the process work). This can be calculated using Table 1 or 2.

3. Feeding area required – calculate the surface feeding area required (m<sup>2</sup>) according to the equation in Table 3 and the feedstock type (see Figure 2).
4. Use this calculated surface feeding area requirement to select one or more vermiculture unit/s that will provide the required surface feeding area.

### Stocking the unit with worms

The types of worms used in vermiculture units are not worms that are commonly found in gardens.

Worms used in vermiculture units tend to process larger amounts of organic material, reproduce in confined environments (such as vermiculture units), and cope well with disturbances (such as feeding and maintenance procedures) when compared with other common species (Appelhof, 1997).

*Eisenia fetida* (Tiger worm) is the worm most commonly used in vermiculture units in warm climates (Plate 10). These worms process relatively large amounts of organic

materials and naturally occur in manure, compost and decaying leaves. These worms also reproduce quickly, have a relatively wide tolerance to temperatures and moisture (for worms), and are readily handled (Edwards, 1988).

Other names for *Eisenia fetida* include the ‘Tiger worm’, ‘Redworm’ and ‘Red wiggler’.

When establishing a vermiculture unit, the correct type of worm needs to be incorporated at a sufficient quantity to process the organic materials produced on-site.

Depending on the feedstock types, a worm application rate of between 10 and 18 kg per metre of bedding

surface (10 – 18 kg/m<sup>2</sup>) is recommended as a sufficient rate to quickly establish maximum processing capacity (Recycled Organics Unit, 2000).

When establishing a vermiculture unit, it is important to provide a suitable environment for the worm population. The unit must be filled with bedding material to provide a safe and desirable habitat for the worm population.

The most suitable bedding material is mature vermicast that is composed of organic materials already processed by a worm population. Approximately 30 cm of mature vermicast will provide an excellent habitat for the worms. This amount of bedding will result in a more established environment ultimately increasing the processing capacity of the unit.

Introducing the worm stock to a vermiculture unit should be performed in the morning. This will ensure the worm population does not exit the unit, as daylight will deter the worms from escaping. Alternatively, a bright light can be used to encourage the worm stock to burrow into the new environment.

Sprinkle the worm stock carefully over the surface of the vermiculture unit. The worms will quickly burrow into the bedding material. Ensure the bedding material is moist but not too

wet. The ‘fist test’ should be used to ensure the moisture content of the bedding material is suitable moisture for the worm stock. This procedure is described in detail in Information Sheet No. 6.

A period of acclimatisation is necessary for the worm stock when introduced to this new environment. Refrain from applying feedstock for a week after introducing the worms to allow them to settle. Gradually introduce the feedstock over two to four weeks until the maximum processing capacity is reached.

To purchase worms and bedding material (vermicast) for a vermiculture unit, look under “worm farms” in the Yellow Pages or advertisements in gardening magazines.

### Space availability

The type of vermiculture unit selected for on-site processing of compostable organics material needs to suit the availability of space for the site. For example, a stacking tray unit may offer the same feeding area but take up less floor space than a continuous flow unit.

When determining how much space is required for vermiculture processing, it is important to consider that other equipment is required for a vermiculture process to operate successfully.

This equipment includes:

- size reduction equipment (eg. mixing tub, bucket and spade for soft food organics, shredder for cardboard);
- material handling and feedstock preparation equipment (eg. buckets, mixing tubs, garden fork);

## Definitions\*

### Source separation

Physical sorting of the waste stream into its components at the point of generation.

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Processing capacity

The maximum amount (mass or volume) of feedstock that can be added to a processing technology (e.g. composting technology) per unit time (e.g. per week) without causing system failure. System failure is evident when the processing technology produces problematic environmental emissions and/or declines in processing efficiency and/or produces product of unacceptable quality.

### Bulking agent

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably. See also composting amendment.

### Carbon to nitrogen (C:N) ratio

The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

### Anaerobic

In the absence of oxygen, or not requiring oxygen.

\* Recycled Organics Unit (2001)

- monitoring and maintenance equipment (eg. thermometer, pest deterrent devices);

**Plate 10.** Tiger worms (*Eisenia foetida*) are a common worm species used in vermiculture units.



- dry storage areas for bulking agent and area for blending feedstocks; and
- washing up area (eg. sink, hose) and bin wash area.

### Example

A summary of the steps required for determining the scale of vermiculture processing technology and the size of the vermiculture unit required for your operation is shown in Figure 3.

Refer to past Information Sheets for important details on auditing, establishing a source separated collection system and whether vermiculture can work for you.



Figure 3. Summary of steps for determining what size vermiculture unit you require

<h1>1</h1>	<p>Conduct an audit of the compostable organics material produced on-site.</p> <p>See Information Sheet No. 2.</p>	
<h1>2</h1>	<p>Determine the quantity of compostable organics material that can be processed using vermiculture technology.</p> <p>See Information Sheet No. 3.</p>	
<h1>3</h1>	<p>Calculate the feedstock recipe based upon the quantity of compostable organics material produced on-site and the amount of bulking agent required to make a suitable feedstock.</p> <p>See Table 1 or 2 in this Information Sheet.</p>	
<h1>4</h1>	<p>Determine the maximum processing capacity (kg/m<sup>2</sup> of surface feeding area) of the feedstock. This is dependent on the components of the feedstock as some materials are more difficult to process (eg. meat/poultry).</p> <p>See Table 3 in this Information Sheet.</p>	
<h1>5</h1>	<p>Calculate the size of vermiculture unit required to provide this surface feeding area.</p> <p>See Table 3 in this Information Sheet.</p>	
<h1>6</h1>	<p>When selecting a vermiculture unit, remember to also consider the space required for ancillary equipment.</p> <p>See Appendix No. 1.</p>	



# Information Sheet No. 5

## Guide to installing a vermiculture unit

Information Sheet No. 5  
January 2002

### Inside This Sheet

<b>1</b>	Where to locate a vermiculture unit
<b>2</b>	Site selection
	Vermiculture management activities
<b>3</b>	Environmental and health considerations
	Definitions
<b>5</b>	Other considerations
<b>6</b>	Notes
	Important references
	Acknowledgement

### Where to locate a vermiculture unit

When installing vermiculture technology to process organic material, careful consideration should be given to the siting (or location) of the vermiculture units and the ancillary equipment.

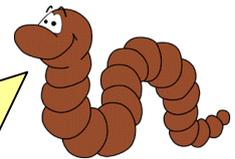
Determining the most suitable location of an *on-site, mid-scale* vermiculture unit is dependent on a number of factors. These include:

- accessibility;
- maintaining climatic conditions (shading and controlling temperature and moisture);
- security measures;
- proximity to neighbours;
- areas for storage of materials and *feedstock* preparation;
- noise and odour considerations;
- *leachate*;

- pest exclusion; and
- availability of services such as water and power if required.

Site selection for an on-site vermiculture installation is important both for efficiency of handling materials, and because worm activity is dependent upon environmental conditions including temperature and moisture.

Appropriate siting of a vermiculture unit will help to avoid potential problems.



Effective proper placement and management (of a unit of suitable size) will ensure effective operation without any adverse impacts on people or the environment (Plate 1).

**Plate 1.** Example of an on-site, mid-scale vermiculture unit installation in a nursing home.



When locating a vermiculture installation, consideration of the required area should include the actual vermiculture unit, area for feedstock preparation and storage, and also area for equipment such as size-reduction equipment, monitoring and maintenance equipment.

This process of calculating the size of vermiculture technology required to process a given volume of material has been covered in Information Sheet No. 4.

### Site selection

The selection of a suitable site for the location of a vermiculture unit is important in order to maintain both operational efficiency and vermiculture *processing capacity*. The location should be easily accessible from related operational activities, as feedstock material will need to be transported to the vermiculture installation.

The vermiculture units should be placed at a distance from neighbours and public areas but not in an area

that is subject to vandalism.

Security measures should be in place to prevent any interaction with the treatment process by unauthorised personnel.

The placement of the vermiculture installation should be adjacent to or on route to the existing waste management and recycling area (Figure 1). This will increase the efficiency of the source separated collection system (see Information Sheet No. 2).

### Vermiculture management activities

#### Storage of material

Ideally, food materials should be processed immediately to avoid any odour production. Compostable work practices may require short-term storage of *compostable organics* material prior to processing in the vermiculture unit. Short-term storage of spoiled food is common place in many commercial kitchens. Such spoiled food is often stored overnight

in cool storage for disposal the next day. Storage areas should be kept clean and tidy and any spillage cleaned up immediately to prevent pest attraction and odour production.

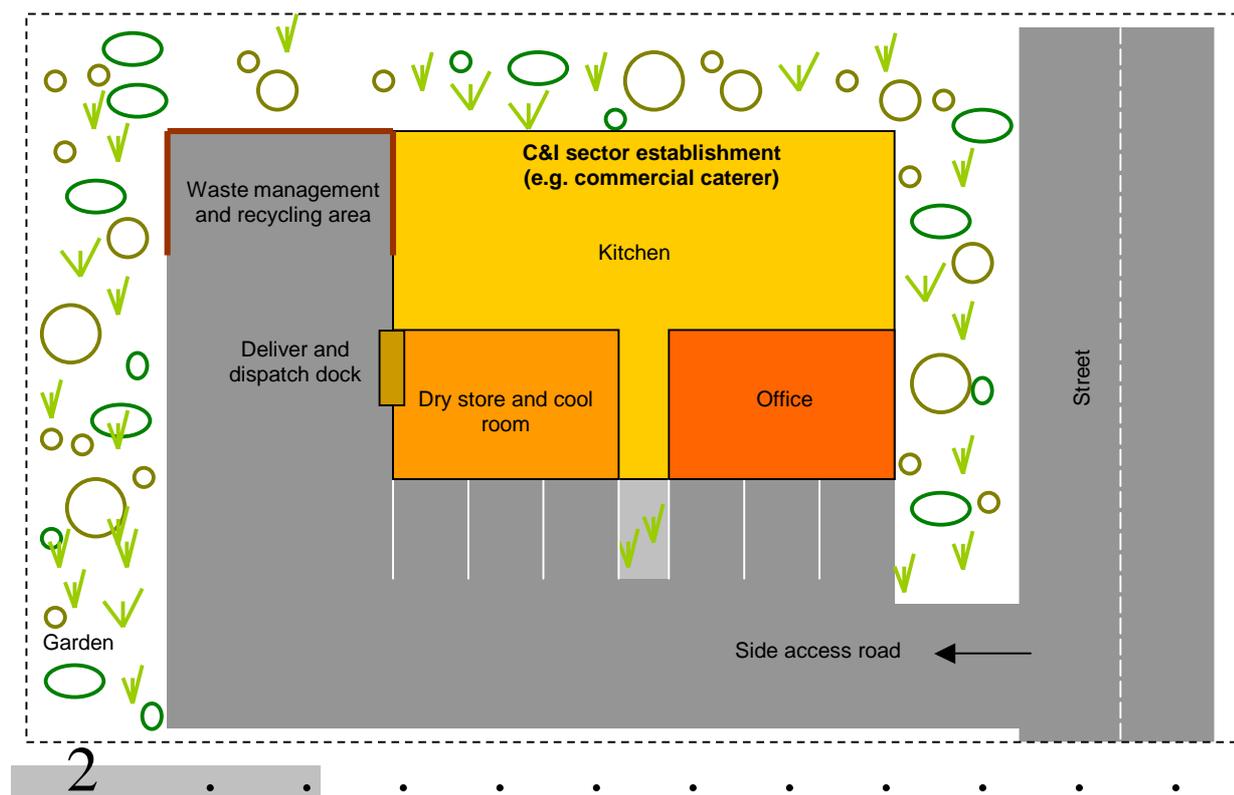
Material should be stored in sealed containers (eg. in 80 L mobile garbage bins).

### Feedstock preparation

A feedstock preparation area should be located adjacent to the vermiculture installation. This area should ideally include a small storage area to house equipment required for size-reduction, measuring and blending of the feedstock mixture, as well as clean-up equipment including brushes and hoses (Plate 2). Equipment such as garden forks and wheelbarrows or similar should be accessible to enable use of the vermicast product.

Details on the types of equipment required for feedstock preparation and supplier information is contained in Appendix No. 1.

**Figure 1.** Example of an on-site mid-scale vermiculture installation operated at a commercial catering establishment. This establishment generates primarily mixed food organics including a small amount of food-soiled paper. The material storage, feedstock preparation areas and vermiculture units are located adjacent to the waste disposal bins, the kitchen and the delivery dock.



**Plate 2.** Equipment used for feedstock preparation and clean up including hose, garden forks, watering can, mixing tub, brushes and brooms.



### Storing vermicast for use

When the vermicast product is removed from the vermiculture unit, it should be stored on site for use on the gardens of your organisation.

Specialist storage bins are available which aid in maturing the vermicast whilst in storage (Plate 3). Mobile garbage bins (MGB's) are also a suitable storage unit. 120 L MGB's are a good size for this purpose as they are still moveable once reasonably full.

See Information Sheet No. 7 for a guide to using the vermicast product.

**Plate 3.** Vermicast maturing bin.



## Environmental and health considerations

Effective siting of the vermiculture units will minimise any adverse effects on people or the environment.

Environmental and health issues that need to be considered when siting vermiculture units include:

- microclimate;
- noise production;
- odour production;
- site hygiene;
- sustainable loading rates; and
- sustainable feedstock recipe.

These issues are very important for an effective vermiculture processing operation and with careful consideration, problems such as complaints from neighbours, pest attraction and health issues will be minimised.

### Microclimate

Vermiculture units should be situated in an area where there is a degree of protection from extremes of weather (eg. temperature).

Worms are very susceptible to changes in climatic conditions. The acceptable temperature range for the Tiger worm (*Eisenia fetida*), a common species used in vermiculture systems, is 15 to 25 °C (Edwards, and Bohlen, 1996; Edwards, 1998) with an optimal temperature of 20°C (Murphy, 1993).

This optimal temperature range refers to the bedding temperature and not the ambient air temperature. Control should be exercised over the environment of the worms to maintain temperatures within the ideal range to maximise the efficiency of the vermiculture process.

## Definitions\*

### On-site, Mid-scale

A category of on-site composting or vermiculture-based technology with the ability to process between 20 and 250 kg of compostable organics per day. Such systems are usually comprised of an in-vessel processing unit (composting or vermiculture-based) and size-reduction equipment (eg. garden type petrol driven chippers or shredders). Procedures involved in the management of the processing system may involve a combination of manual labour and small mechanical equipment. Mid-scale systems are often used for the treatment of compostable organics produced by the commercial and industrial sector, hospitals and institutions etc.

### Feedstock

Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

### Leachate

Liquid released by, or water that has percolated through, waste or recovered materials, and that contains dissolved and/or suspended substances and/or solids and/or gases.

### Processing capacity

The maximum amount (mass or volume) of feedstock that can be added to a processing technology (e.g. composting technology) per unit time (e.g. per week) without causing system failure. System failure is evident when the processing technology produces problematic environmental emissions and/or declines in processing efficiency and/or produces product of unacceptable quality.

### Compostable organics

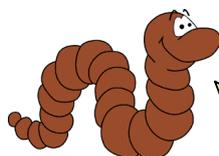
Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

*Continued page 4*

The temperature of the bedding material within a vermiculture unit can be influenced by the ambient air temperature and from direct sunlight. The lower the mass of bedding, and/or the higher the surface area to volume ratio of the bedding, the more it will be effected by daily fluctuations in air temperature and moisture.

When siting a vermiculture unit, ideally the units should be placed in an area not exposed to full summer sun. A location that is shaded in summer, yet sunny in winter is ideal.

Alternatively, an enclosed area may be suitable, but again only if the area is shaded and well ventilated so as to be relatively cool during hot summer periods. It may be possible to locate the vermiculture installation in an enclosed area where the temperature is already controlled via air conditioning.



We need a controlled environment to effectively process organic material!

If the units are located indoors in a temperature controlled environment, an ideal temperature range would be approximately 20-25°C, consistent with the desirable temperature range for people. A reverse cycle air-

conditioner (such as Plate 4) would provide good temperature control in a relatively constant environment such as the coastal New South Wales region.

Situating a vermiculture unit indoors is a luxury and is often not possible. Most vermiculture units are located outdoors and if this is the case, the minimum degree of climate control should be shade, especially in summer.

A shaded area such as a veranda is suitable for a vermiculture unit. However, if this is not possible, shade cloth covering the unit would also suit.

During summer months, damp hessian or old carpet should cover the surface of the bedding mass to prevent the units from drying out (Windust, 1997). In extreme temperatures, evaporative cooling can be used to lower the temperature of the entire vermiculture unit. This involves draping a wet cloth over the unit and moving air over the unit by the use of a fan or a breeze (Appelhof, 1997).

Additional layers of hessian, carpet underlay or similar can also be placed over the bedding surface during colder months to help insulate the bedding and to retain heat generated by the decomposition process.

### Bulking agent

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably. See also composting amendment.

\* Recycled Organics Unit (2001)

### Noise production

The production of noise from size-reduction equipment, such as a shredder or chipper, may pose problems if this equipment is located in close proximity to offices, neighbours or public areas.

Such equipment should be operated in accordance with proper occupational health and safety procedures, including the wearing of ear and eye protection.

### Odour production

The generation of offensive odours may occur if a vermiculture unit is not managed effectively.

If a vermiculture unit produces odours, management procedures should be implemented to identify and rectify the problem. These management procedures are covered in Information Sheet No. 6.

The production of odours can also result in the attraction of addition pests and vermin relative to current waste disposal practices. This may pose health risks and should be rectified immediately.

Plate 4. Example of a reverse-cycle air-conditioner used for climate control.



## Site hygiene

Ensuring the vermiculture installation is clean and hygienic is important to minimise odour production and to avoid potential occupational health and safety issues.

Any spillage of compostable material, vermicast or leachate should be cleaned up immediately. No food materials should be left exposed as this will attract pests and create odour problems.

Ensure staff wear gloves at all times when handling materials and that they wash their hands after any contact with the vermiculture operation. This will avoid cross contamination with any germs that may be present on spoiled food material.

## Sustainable loading rates

The application of feedstock to a vermiculture unit at sustainable rates will minimise the accumulation of unprocessed feedstock within the units. Feedstock accumulation will result in temperature increases and will make the unit undesirable to the worm population. If this situation is not rectified, system failure will occur.

Loading rates depend on the type of organic material within the feedstock mixture. See Information Sheet No. 4 for some feedstock recipes and suitable loading rates.

## Suitable feedstock recipe

The application of compostable organics to a vermiculture unit will only be successful if the material is in a suitable form for vermiculture processing. This involves only processing suitable organics, size reducing the material, amendment with a *bulking agent* and ensuring a suitable moisture content and structure. Information Sheet No. 4 has a comprehensive guide to feedstock preparation that will help you to produce a suitable feedstock for successful vermiculture processing.

## Other considerations

Further considerations that should be addressed when installing a vermiculture unit include:

- leachate production;
- pest attraction;
- related services; and
- security.

## Leachate production

The generation of leachate from a vermiculture unit is undesirable and can be rectified by effective management procedures. These are covered in Information Sheet No. 6.

If a vermiculture unit produces leachate, this liquid must be collected to avoid potential problems such as odour. The leachate should be collected and either re-treated in the

vermiculture unit (small volumes only) or removed. See Information Sheet No. 7 for a guide to using leachate (vermiculture liquid).

## Pest attraction

When installing a vermiculture unit, opportunities for pest attraction should be minimised.

Where units are enclosed in small areas, this may include the installation of pest deterrent devices.

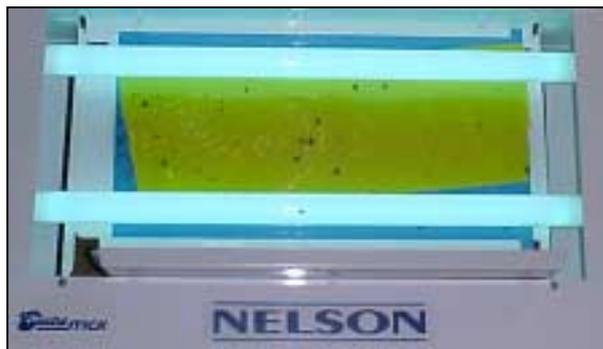
Crawling insects can be deterred by standing the units in moats (buckets of water and detergent, Plate 5 or in salt water). Alternatively, the legs of the vermiculture unit can be coated in axle grease or sticky pest traps (see Appendix No. 1 for equipment suppliers).

Flying insect pests can be deterred using various baits or traps, for example fluorescent (black-light) zappers or devices such as in Plate 6.

**Plate 5.** Legs of free-standing vermiculture units can be placed in buckets of water and detergent to prevent crawling pests such as ants from entering the units.



**Plate 5.** Flying insect attraction devices. See Appendix No. 1 for supplier details





# Information Sheet No. 6

## Management and maintenance of a vermiculture unit

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Information Sheet No. 6  
January 2002

### Inside This Sheet

<b>1</b>	Best practice management and maintenance Process control
<b>2</b>	Material receipt and size reduction
<b>3</b>	Feedstock preparation and application
<b>4</b>	Monitoring and management of vermiculture units Monitoring and testing safety tips Definitions
<b>5</b>	Indicators of system stress Worm activity; feedstock accumulation; oxygen; temperature; moisture content; sampling
<b>15</b>	Maintenance of vermiculture units Tossing; odour prevention; leachate collection; pest deterrence; harvesting vermicast; light.
<b>18</b>	Timetable of management and maintenance procedures
<b>19</b>	Notes Important references Acknowledgement

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### Best practice management & maintenance

Effective processing of *compostable organics* material in vermiculture technology requires proper management and maintenance.

This information sheet details *best practice* management procedures for *on-site, mid-scale* vermiculture technology and associated maintenance procedures that may also be required.

When establishing a vermiculture unit, the following issues need to be considered:

- collection – separate collection system for compostable organic materials;
- *feedstock* preparation – size reduction of material, preparation of feedstock mix and application to vermiculture technology;
- monitoring and management – observations of worm activity, feedstock accumulation, oxygen,

temperature, moisture content, and sampling *vermicast*; and

- maintenance – tossing beds, odour, leachate production, deterring pests, and harvesting vermicast.

Ensuring these issues are dealt with throughout the operation of the organics management system will result in a well-managed process. This process can therefore continue to operate effectively without producing negative environmental impacts.

### Process control

*Process control* involves the management and monitoring of the vermiculture process. This management and monitoring ensures that the process operates effectively to produce quality vermicast.

The process control plan for on-site vermiculture processing (Figure 1) documents the steps involved in establishing and maintaining a successful vermiculture unit.

**Plate 1.** Monitoring temperature and oxygen within a vermiculture unit. Management and maintenance will enable a vermiculture unit to operate effectively.



Procedures for each of these steps have been documented in this series of information sheets.

### Material receipt and size reduction

Proper receipt of compostable organic material will avoid health issues associated with odour production and pest attraction.

If short-term storage of materials is to occur, feedstocks should be sealed at all times and refrigerated or frozen where possible.

Materials should be size reduced to enable efficient processing by the vermiculture unit. Size reduction can be performed using a bucket and spade as shown in Plates 2 and 3.

This method will adequately size reduce the organic material and, with the addition of a *bulking agent*, will produce a feedstock that can be readily treated in a vermiculture unit. Alternatively, mechanical shredders can be used, however, at a greater cost.

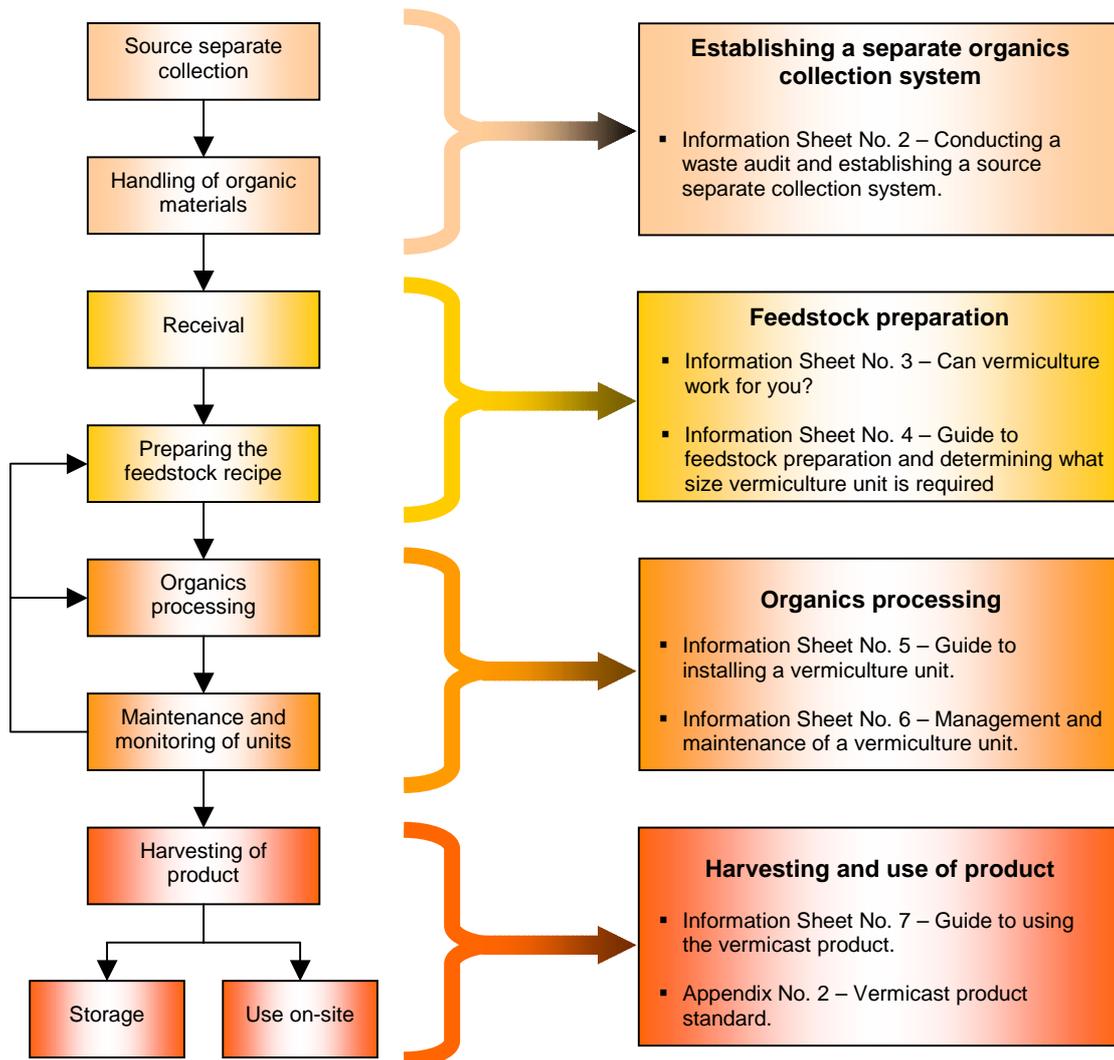
Size reduction increases the surface area that can be attacked by the microorganisms and worms, and will result in a feedstock that will be processed quickly and thoroughly. Size reduction of feedstock is essential for effective processing in a vermiculture unit.

Further details can be found in Information Sheet No. 3.

**Plates 2 and 3.** An example of fruit and vegetable organic material before (top) and after (below) size reduction using a bucket and spade.



**Figure 1.** Process control plan for on-site, mid-scale vermiculture processing. A reference guide to relevant information sheets in this Best Practice Guideline is also shown.



## Feedstock preparation & application

The preparation of a suitable feedstock is crucial in maintaining a successful vermiculture unit.

Many problems can result if the feedstock is inappropriate to the vermiculture unit. These can include:

- feedstock too moist – resulting in *anaerobic* (low oxygen) conditions, worms need oxygen to survive;
- feedstock too dry – not suitable for worm habitation;
- feedstock recipes that contain components that are difficult to process by vermiculture technology – such as seafood, dairy products and hard materials (eg. bones);
- feedstock loading rate too high – too much feedstock applied to the unit resulting in feedstock accumulation, anaerobic (low oxygen) conditions and subsequent worm death;
- feedstock too acidic/alkaline/high in salts; or
- feedstock particles too large – size reduction is necessary for effective processing.

The preparation of an appropriate feedstock involves careful consideration of the raw feedstock components. Vermiculture units process a mixture of compostable organics more readily than monostreams of single organic materials, for example, just bakery waste (Recycled Organics Unit, 2000).

A number of feedstock recipes have been given in Information Sheet No. 4 and these recipes are an excellent guide to preparing a suitable feedstock. Plates 4, 5, 6 and 7 show the steps in preparing a mixed fruit and vegetable feedstock.

The actual proportions of raw ingredients in a feedstock are not as crucial as the overall feedstock texture based on structure and moisture content. The addition of a bulking agent will influence the feedstock texture.

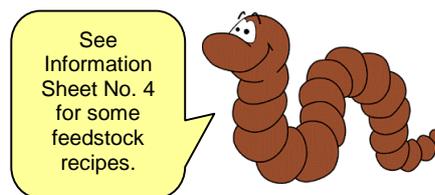
The addition of a bulking agent, such as paper or cardboard, is necessary to provide an adequate environment for worm habitation. Bulking agents increase the particle size of the feedstock which increases porosity and the *carbon to nitrogen (C:N) ratio*. These factors are essential for a feedstock suitable for processing by a vermiculture unit

The addition of moisture may also be necessary if the feedstock contains raw ingredients that are quite dry, for example breads.

The 'fist test' can be used when preparing a feedstock to estimate the moisture content of the material.

The method for performing the fist test is given later in this Information Sheet under 'Moisture Content'.

This method is used for determining the optimum bedding moisture content. However, since the worms will inhabit the feedstock whilst they process it, the feedstock moisture content should also be at this optimum moisture content.



**Plates 4, 5, 6 and 7.** Preparation of mixed fruit and vegetable feedstock. Raw size-reduced fruit (far left) combined with cardboard bulking agent (left). Mixed thoroughly (right). Final feedstock of size reduced mixed fruit and vegetables with cardboard bulking agent (far right). Note the good structure present in the final feedstock mix. See Information Sheet No. 4 for more information.



## Monitoring & management of vermiculture units

Effective monitoring and management of vermiculture units is essential for the process to operate effectively and efficiently.

The monitoring and management procedures described in this Information Sheet are quick and easy to perform 'field tests'.

The procedures described below are effective ways of ensuring a vermiculture process is operating effectively. It should be noted, however, that a wider range of testing procedures might be relevant for specific installations.

Monitoring procedures will be described for:

- worm activity;
- feedstock accumulation;
- oxygen;
- temperature;
- moisture content; and
- sampling vermicast.

Suppliers and approximate prices of associated equipment required for these tests are detailed in Appendix 1.

Details of further tests, performed in a laboratory, that maybe necessary to ensure the final vermicast product is safe for use will also be described. These include taking a sample to be analysed for:

- pathogens; and
- heavy metal concentrations.

Note that these tests may only be relevant if the operator intends to sell the vermicast product commercially.

A number of more complex tests can be performed during vermiculture processing, for example salt content

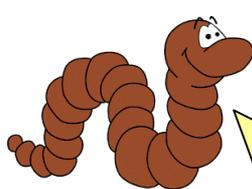
(measured by the electrical conductivity test), pH, and total carbon and nitrogen content. These tests, however, require laboratory analysis and are not normally necessary for on-site, mid-scale processing.

A form for recording weekly management and maintenance procedures and for monitoring system performance has been included in this Information Sheet (Form 1).

## Monitoring & testing safety tips

The monitoring and management procedures discussed here are not hazardous however a few safety precautions need to be observed.

- Gloves – should be worn when handling feedstocks and vermicast.
- Apron – protects clothing whilst handling material and preparing feedstocks.
- Safety glasses – should be worn during size reduction procedures.
- Ventilation – activities such as size reduction and feedstock preparation should be conducted in a well-ventilated area.
- Equipment – should be used safely, and tasks should be supported by standard operating procedures that define safe and effective operating practice.
- Hygiene – if handling materials or feedstock, hands should always be washed with soap and warm water afterwards.



Always wash your hands with soap and warm water after handling feedstock or vermicast.

## Definitions\*

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Best Practice

For any area of waste management this represents the current 'state-of-the-art' in achieving particular goals. Best practice is dynamic and subject to continual review and improvement.

### On-site, Mid-scale

A category of on-site composting or vermiculture-based technology with the ability to process between 20 and 250 kg of compostable organics per day. Such systems are usually comprised of an in-vessel processing unit (composting or vermiculture-based) and size-reduction equipment (eg. garden type petrol driven chippers or shredders). Procedures involved in the management of the processing system may involve a combination of manual labour and small mechanical equipment. Mid-scale systems are often used for the treatment of compostable organics produced by the commercial and industrial sector, hospitals and institutions etc.

### Feedstock

Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

### Vermicast

Solid organic material resulting from the biological transformation of compostable organic materials in a controlled vermiculture process.

*Continued page 5*

## Indicators of system stress

Effective monitoring and management of a vermiculture unit will result in a reliable and efficient organics management system. Particular occurrences within the system may indicate system success or failure and these should be regularly investigated as indicators of system health.

The hierarchy of system performance indicators (shown in Figure 2) is as follows:

1. Worm activity – is the first indication that a system is stressed. Worms will attempt to escape the vermiculture unit if conditions are unsuitable for habitation.
2. Feedstock accumulation – feedstock will accumulate if the worms are no longer processing it but are attempting to escape. The feedstock will accumulate and cause the conditions to be even more unsuitable for worm habitation.
3. Oxygen – if feedstock accumulates, oxygen levels will decrease and cause anaerobic conditions. This will add to the uninhabitable conditions of the unit.
4. Temperature – finally temperature will rise within the unit as the feedstock accumulates and decomposes.

### Process Control

Process Control refers to the management system employed to regulate the production of a 'product' consistently to defined specifications. A Process Control System uses procedures to control a given process whenever their absence would prejudice product quality, jeopardise worker safety or harm the environment and public health.

### Bulking agent

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms "bulking agent" and "amendment" are often used interchangeably. See also composting amendment.

### Anaerobic

In the absence of oxygen, or not requiring oxygen.

### Carbon to nitrogen (C:N) ratio

The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

### Aerobic

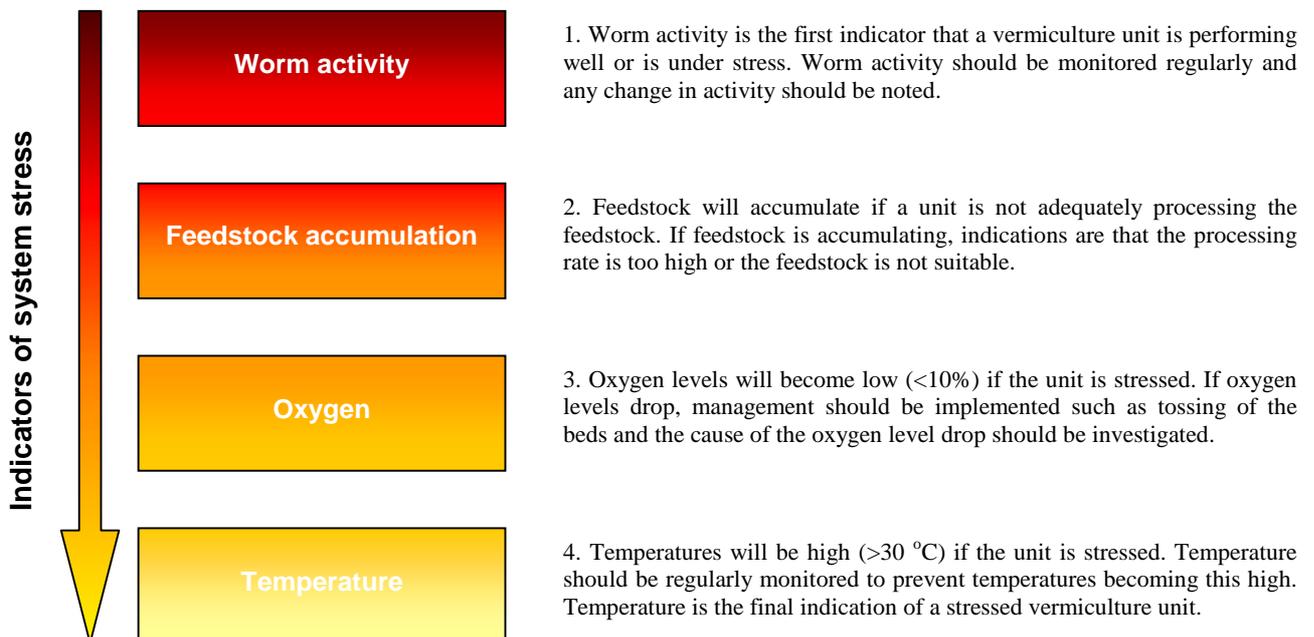
In the presence of, or requiring oxygen.

### Curing

Final stage of vermiculture processing in which stabilisation of the vermicast continues but the rate of decomposition has slowed.

\*Recycled Organics Unit (2000b).

**Figure 2.** Hierarchy of indicators of system stress. Regular monitoring of indicators of stress will ensure problems are identified promptly, allowing operators to correct these problems to maintain overall performance.



## =Worm activity

Worm activity is an effective qualitative method for assessing system performance.

Worms will behave according to the degree of stress that they are under. If the vermiculture unit is not suitable for habitation by worms, they will attempt to escape. For this reason, observations of worm activity are usually the first indication that a vermiculture unit is under stress.

Worm activity should be monitored regularly using a classification system. An example of such a system is shown in Table 1. This system uses various categories of worm activity to define the performance of a vermiculture unit.

Some examples of worm activity exhibiting system stress are shown in Plates 8, 9 and 10. These units are under significant stress and maintenance procedures should be performed well before a vermiculture unit reaches these levels.

If worm activity is monitored regularly, system stress and ultimate system failure can be prevented. The method for observing worm activity is given below.

## Materials

- Classification system of worm activity (such as Table 1).
- Gloves

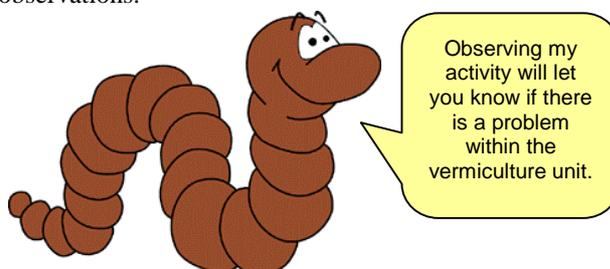
## Methods

1. Worm activity should be monitored within a vermiculture unit at least once per week.
2. Observe worm activity prior to feeding.
3. Scrape back a section of feedstock to expose the bedding surface (see Figure 3 for a description of the zones of worm habitation).
4. Observe the regions where worms are congregating, for example, if the majority of worms are throughout the feedstock then the system is performing well, but if the worms are on the edges of the feedstock or feeding from below the feedstock, the system is under some stress.
5. Record observations.

## Management

Management of stressed vermiculture units will vary depending on the category of worm activity. The regions that the worms do not inhabit tend to indicate where the problems are occurring. These may include:

- Worms are not in feedstock but feeding from below or edges of feedstock – this indicates the feedstock is unsuitable which may be due to particle size, moisture, temperature, or feedstock content. The feedstock recipe should be revised.
- Worms are actively trying to escape the unit – the system has failed and all aspects should be reconsidered (ie. feedstock, bedding depth, climate control, monitoring and maintenance procedures).



**Plates 8, 9, and 10.** Worm activity indicating severe system stress. Worms are trying to escape vermiculture unit through base (left), worms are on top of the hessian covering and not in the feedstock layer (centre), worms are trying to escape unit through unit rim (right).



**Table 1.** Observations of worm activity and indicators of vermiculture unit performance.

Category	System Performance	Diagnostic Indicator
A	No system stress – optimal/good performance	<ul style="list-style-type: none"> <li>Worm population mostly located in feeding layer. No detrimental temperature increase (&lt;30 °C).</li> </ul>
B	Some system stress – moderate system performance	<ul style="list-style-type: none"> <li>Worm population largely in feeding layer. Some below feeding layer and some trying to escape unit indicated by worms massing around unit rim. Some detrimental temperature increase in feeding layer (&gt;30 °C).</li> </ul>
C1	Moderate/high system stress – sub-optimal performance	<ul style="list-style-type: none"> <li>Population largely around sides of unit and trying to escape through unit lid or accumulating on surface of hessian. Significant detrimental temperature increase in feeding layer (30 – 35 °C).</li> </ul>
C2	Moderate/high system stress – sub-optimal performance	<ul style="list-style-type: none"> <li>Little worm population in feeding layer. Most worms feeding from underneath feeding layer. No substantial detrimental temperature increase (&lt;30 °C).</li> </ul>
D	System failure	<ul style="list-style-type: none"> <li>No worms in feedstock. Worm population extensively swarming in corners of unit or around unit lid and escaping unit.</li> </ul>

**Form 1.** Weekly management and maintenance form for an on-site vermiculture unit. Management and maintenance procedures should be performed at least once per week to ensure the unit is operating efficiently.

Weekly Management and Maintenance Form						
Monitoring						
Date	Worm activity (see criteria above)	Feedstock accumulation (cm)	% Oxygen concentration		Temperature (°C)	
			Centre of feedstock	Below bedding surface	Centre of feedstock	Below bedding surface
Maintenance						
Date	Add water (L)	Tossed beds	Removed leachate (L)			
General comments						
Date	Comment or description of weekly performance					Staff initial

## Feedstock accumulation

The accumulation of feedstock within a vermiculture unit should be monitored to ensure the loading rate for the unit is adequate.

If feedstock accumulates within a unit, too much feedstock is being applied and the worms do not have time to process it before the next feeding occurs.

Feedstock accumulation can result in problems such as anaerobic (low oxygen) conditions, odour production, worm stress and ultimate system failure.

The method for determining feedstock accumulation is given below.

### Materials

- Ruler
- Gloves

### Method

1. Feedstock accumulation within a vermiculture unit should be monitored at least once per week.
2. Scrape back a section of the feedstock layer to reveal the bedding surface as shown in Plate 11 (see Figure 3 for a

description of the zones of worm habitation).

3. Measure the amount of feedstock that has accumulated on top of the bedding material (Plate 12).
4. Record this measurement.

### Management

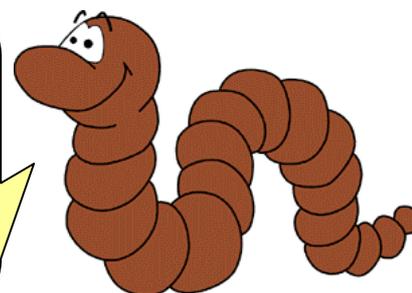
An accumulation of unprocessed feedstock of greater than 20 cm can be detrimental to the vermiculture unit.

Feedstock accumulation indicates that the vermiculture unit is under stress. This stress may be due to:

- Loading rate too high – too much feedstock is being applied and the worms do not have time to process it. Decrease the loading rate to allow thorough processing.

- Feedstock unsuitable – the feedstock recipe may be undesirable to the worms and the recipe should be revised.

If feedstock is accumulating, the recipe may not be suitable. See Information Sheet No. 4 for some information on preparing a suitable feedstock and some recipe ideas.



**Plates 11 and 12.** Measuring the accumulation of feedstock within a vermiculture unit. Pull back an area of the feedstock layer to reveal the interface with the bedding material (left). Using a ruler, measure the thickness of the feedstock layer above the bedding material (right).



## Oxygen

Oxygen is essential for vermiculture processing. Worms and *aerobic* microorganisms require oxygen to live.

Oxygen in a vermiculture unit has an effect on the rate of decomposition and on the production of odour. Consequently, maintaining an aerobic (high oxygen) vermiculture environment is the key to maximising the rate of organic decomposition and minimising odours.

The concentration of oxygen in air is approximately 21%. To minimise odour generation and to maximise the rate of vermiculture processing, the concentration of oxygen within a vermiculture unit should be kept above 10% (Recycled Organics Unit, 2000).

The method for monitoring the oxygen concentration of a vermiculture unit is given below.

Note that an oxygen meter can be expensive – approximately \$2,400. Although a vermiculture unit can be managed without one, it can be useful for quickly diagnosing system problems. The meter shown in Plate 13 is a combined temperature and oxygen meter. Thus, a separate temperature meter (eg. in Plate 15, see next section), is not necessary.

### Materials

- Hand-held oxygen meter with a probe at least 50 cm long (Plate 13).
- Gloves

### Method

1. Oxygen concentrations within a vermiculture unit should be measured at least once per week.
2. Turn the meter on and check battery status. Depending on the

type of meter, a warm-up period of up to 5 minutes may be required.

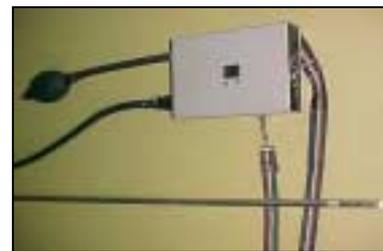
3. If needed, calibrate the instrument by aspirating the cell (squeezing and releasing the rubber bulb to draw fresh air into the unit). Check the display to ensure it is reading 21% (most meters round the result to the nearest whole number). Adjust calibration screw if required.
4. Oxygen readings should be taken in the zones of worm habitation – the centre of the feedstock layer and below the bedding surface to a depth of 5 cm (see Figure 3). Insert the probe into these regions and aspirate the bulb until the reading becomes steady (Plate 14).
5. Record readings. The average of a number of readings for each zone can be taken for a more representative reading.

### Management

If the oxygen probe indicates the concentration of oxygen within the system is insufficient (ie. <10%), management procedures should be implemented. These may include:

- Tossing – this aerates the system by lifting (with a garden fork) and loosening the material without burying feedstock. See the section on ‘Tossing’ in this

**Plate 13.** Example of a combined Temperature/Oxygen meter (Demista, USA).



### Information Sheet.

- Loading rate – if the feedstock is building up, the lower regions may become anaerobic (low in oxygen) due to compaction. The loading rate may need to be decreased to allow the worms time to process the feedstock.
- Feedstock recipe – if the feedstock is too moist or has a structure with particles that are too small, oxygen will be unable to penetrate this layer and it will be unsuitable for processing by the worms. The feedstock recipe should be revised.
- Bedding thickness – the overall thickness of the vermiculture unit bedding should not exceed 45 cm as compaction can result. Harvesting of the vermicast may be required to decrease the bedding thickness. See the section on ‘Harvesting Vermicast’ in this Information Sheet.

**Plate 14.** Insert oxygen probe into the desired zone and aspirate the bulb until the reading becomes steady.



## Temperature

Worms are living organisms that require particular conditions for survival. Temperature is one of these conditions and is a factor that influences the ability of worms to process compostable organics.

Appropriate temperature ranges need to be maintained within a vermiculture unit and temperature should be monitored as an indicator of system health.

There are two distinct zones within a vermiculture unit that can exhibit temperatures that will influence the ability of worms to process organic materials. These zones are: the feedstock layer and the bedding material. Figure 3 shows the location of these zones within a vertical loading vermiculture unit.

These zones can exhibit different temperatures due to the variation in the amount of decomposing organic material present in each layer.

Heat is produced in vermiculture units by microorganisms when they consume food (organic materials). Heat builds-up in the unit due to the feedstock acting as an insulator to the surrounding environment.

The feedstock layer is generally higher in temperature than the bedding material of the unit due to the higher content of decomposing organic material in this zone. Measuring the temperature for both of these zones is important to understand the processes occurring within the unit.

Temperature can be influenced by the amount of feedstock that has accumulated within the unit. Temperatures can also vary due to other factors such as limited moisture or air (Recycled Organics Units, 2001b).

The optimum temperature for the bedding material in a vermiculture

unit is dependent on the type of worms inhabiting the units (see Information Sheet No. 4 for details on worms suitable for vermiculture processing).

*Eisenia fetida* or Tiger worm is a common worm species used in vermiculture units. The ideal temperature range for the Tiger worm is 20 to 25°C.

A standard method for monitoring temperature is given below.

### Materials

- Hand-held temperature meter with a probe at least 50 cm long (Plate 13 – a combined temperature/oxygen probe or Plate 15). The device can be analogue or digital.
- Gloves

### Method

Temperature readings should be taken in the zones of worm habitation: the centre of the feedstock layer; and below the bedding surface to a depth of 5 cm (Figure 3).

1. Temperatures within a vermiculture unit should be measured at least once per week.
2. Insert the temperature probe into the centre of the feedstock layer

and record the temperature (Plate 16). Repeat at a number of locations across the surface. The average of these readings can be taken for a more representative assessment.

3. For the bedding temperature, scrape back a section of the feedstock to reveal the interface between the feedstock layer and the bedding surface (Plate 17). Insert the probe to a depth of 5 cm (Plate 18). A piece of tape can be placed around the temperature probe to mark this 5 cm depth. Again, an average of a number of readings can be taken.
4. Record readings.

### Management

If temperatures within a vermiculture unit are found to be unsuitable, management procedures should be implemented to rectify this problem, particularly if temperatures have been exhibiting an upward trend over time. This upward trend indicates emerging problems that must be addressed before the vermiculture process deteriorates. Management procedures may include:

- Climate control – placing the units in a more controlled environment to prevent climatic

Plate 15. Example of a temperature probe (REOTEMP, USA).



conditions from influencing the processing (eg. frosts). If temperatures are too low (ie. <15°C), placing some layers of hessian or cardboard over the feedstock layer can insulate the unit and retain heat. See Information Sheet No. 5 for details of climate control.

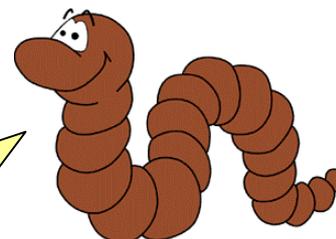
- Loading rate – decreasing the amount of feedstock being applied to the unit at each feeding. If too much feedstock is applied to a unit, temperatures will rise, so decreasing the loading rate will allow the worms to process the feedstock more thoroughly before the next

feeding.

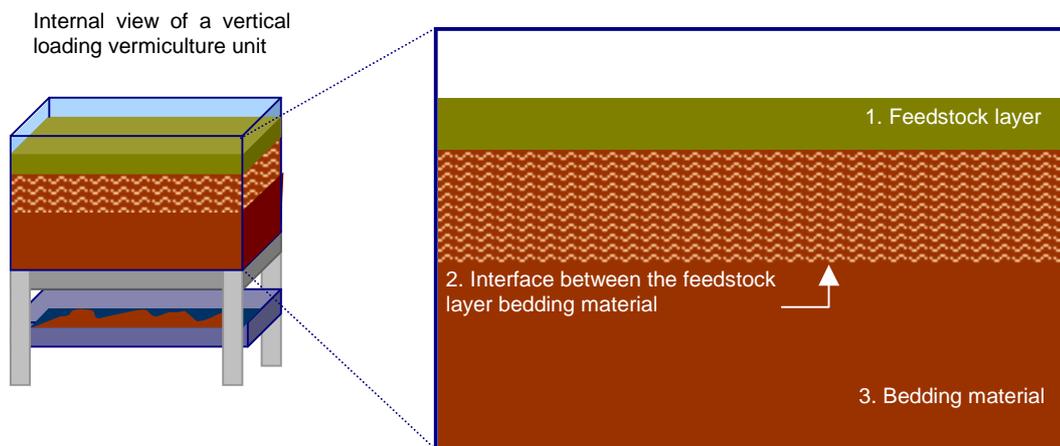
- Feedstock recipe – if the feedstock is not being processed by the worm population and the temperatures are increasing, the feedstock recipe may not be suitable (eg. too moist/dry, components not suitable, more bulking agent required). The feedstock recipe should be reviewed in this case.

- Bedding material too deep – if the bedding material has accumulated to a depth of greater than 45 cm, temperatures within the unit can rise. This is due to the insulating effect of the bedding and the feedstock layer. Harvesting vermicast will reduce this bedding depth and lower the temperature of the bedding material over time.

See Figure 3 for a description of the important monitoring zones within a vermiculture unit.



**Figure 3.** Zones of worm activity within a vermiculture unit that can exhibit distinct changes in oxygen concentration and temperature. These zones are: the feedstock layer, and below the bedding surface. An oxygen/temperature probe should be inserted into these zones to monitor the conditions for worm habitation.



**Plate 16.** Insert probe into the centre of the feedstock layer (Zone 1 on Figure 3 above).



**Plate 17.** Scrape back the interface between the feedstock layer and bedding material (Zone 2 on Figure 3 above).



**Plate 18.** Insert probe 5 cm below the bedding surface (Zone 3 on Figure 3 above).



## Moisture content

Moisture content is the proportion of a material's total weight that is water. It is often expressed as a percentage. The non-water portion of a material is referred to as dry matter (Recycled Organics Unit, 2001c).

Moisture content is an important variable when monitoring vermiculture units. The bedding of a vermiculture unit must be sufficiently moist to allow worm habitation. However, if the moisture content is too high, anaerobic (low oxygen) conditions can develop.

The optimum moisture content for vermiculture processing using mixed worm stock in a temperate environment is approximately 80% (Recycled Organics Unit, 1999).

A simple method for estimating the moisture content of vermicast is given below. This method is based on the 'fist test' (Federal Compost Quality Assurance Organisation, 1994).

The 'fist test' provides a rough estimate of moisture content but cannot be used to estimate the volume of water required to increase the moisture content of a material.

The 'fist test' simply gives an indication as to whether a material may be 'too dry' or 'too wet' for vermiculture processing.

### Materials

- ~ 1 L of fresh test sample
- Gloves

### Method

1. Press a sub-sample into the flat of hand (Plate 19).
2. Close hand around the sample and press firmly (Plate 20).
3. Open fist and evaluate structure of sample.

**Plates 19 and 20.** Pictures showing how to conduct the Fist Test for approximating moisture content. Press a sub-sample into the flat of hand (left). Close hand around the sample and press firmly (right).



**Plates 21 and 22.** Sample with suitable moisture content for vermiculture processing glistens slightly - some water released between the fingers (left). Sample too dry for vermiculture processing (right). Sample crumbles without further action when the fist is opened.



**Plates 23 and 24.** Sample too wet for vermiculture processing (left and right). The sample deforms significantly after the fist is opened, does not fall apart when pressure is applied or if a large amount of water is released, the sample is too wet for vermiculture processing (right).



If the sample is sufficiently wet for vermiculture processing, it should glisten slightly, that is, some water should be released between the fingers (Plate 21).

If the sample crumbles without further action when the fist is opened, the sample is too dry (Plate 22).

If the sample deforms significantly after the fist is opened, does not fall apart when pressure is applied or if a large amount of water is released, the sample is too wet for vermiculture processing (Plates 23 and 24).

### Management

Moisture can be added to a vermiculture unit using a watering can (Plate 25). Moisture should only be added in the morning as a very moist environment overnight may cause worms to leave the unit.

Problems that can be encountered if the bed moisture content is not suitable include:

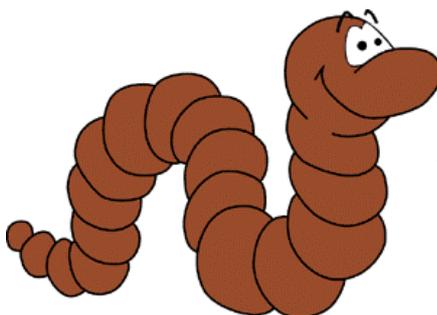
- Slumping – the bedding material is too moist and falls through the vermiculture unit into the collection tray.

- Anaerobic (low oxygen) conditions – the bedding is too moist and becomes compacted resulting in low oxygen conditions and worm death.

- Leachate production – excess leachate can result in pest attraction and problems of disposal.

These problems of excessive moisture within a vermiculture unit may result from a feedstock mixture that is too wet. If such problems occur, the recipe should be revised to decrease the moisture content of the feedstock. Increasing the proportion of bulking agent or not adding water to a feedstock recipe can help to decrease the moisture content.

The ‘fist test’ can also be used to estimate the optimum moisture content for a feedstock recipe.



Only add moisture to the vermiculture unit in the morning or we might leave!

**Plate 25.** Addition of water to a vermiculture unit. See Appendix No. 1 for information on equipment suppliers.



## Sampling

Samples of the final vermicast product should be analysed if the product is to be sold in a commercial context, or in instances where the feedstock is likely to contain high concentrations of microbial pathogens. This however is not practical for most C&I sector organisations.

If microbial analysis is to be performed, samples should be taken and analysed in a commercial laboratory. Laboratories accredited by the National Association of Testing Authorities (NATA) are recommended as they are assessed for testing proficiency on a regular basis (Recycled Organics Unit, 2001d).

The method for sampling of a vermiculture unit is given below.

### Materials

- Tough polythene bag (Plate 26)
- Waterproof marker
- ~ 1 L of fresh test sample
- Gloves
- Cool pack with ice brick

### Method

1. Take a sample of vermicast (approximately 1 L) that represents the overall vermicast product. This can be done by sampling from a number of representative locations and combining the materials into one sample.
2. Seal the sample in a polythene bag and clearly label (eg. type of sample, date of sampling and client name) with a waterproof marker.
3. Tape or tie the bag securely and place in a cool pack (eg. esky)

with an ice brick. Samples must be kept at approximately 4°C.

4. Send to the laboratory by courier on the same day of sampling.

### Human Microbial Pathogens

Analysis for pathogens such as *E. coli* and *Salmonella spp.* is important particularly for vermicast produced from feedstocks containing decomposing meat, as contamination by these human pathogens is likely (Recycled Organics Unit, 2000).

Testing for human microbial pathogens should be performed by a NATA accredited laboratory according to methods reported in the NSW EPA Biosolids Guidelines (1997).

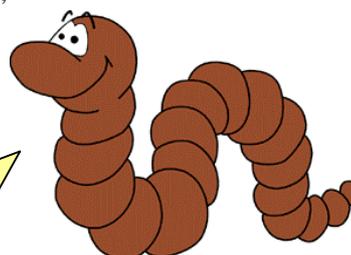
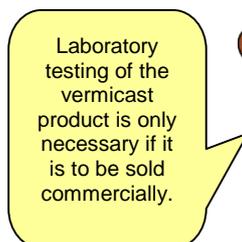
If human microbial pathogens such as *E. coli* and *Salmonella spp.* were detected in the final vermicast product above a certain level,

restrictions on the use of the product would be applied.

### Further information

For more information on producing a quality vermicast product, obtain a copy of “Producing Quality Compost: Operation and management guide to support the consistent production of quality compost and products containing recycled organics” produced by the Recycled Organics Unit or visit <http://www.recycledorganics.com>.

Alternatively, Appendix No. 2 in this Best Practise Guideline contains a brief informative on the vermicast product standard.



**Plate 26.** Materials required to sample vermicast for commercial laboratory analysis.



## Maintenance of vermiculture units

Maintenance procedures should be performed regularly on vermiculture units to prevent problems from developing.

Maintenance procedures include:

- tossing;
- odour prevention;
- leachate collection;
- pest deterrence;
- harvesting vermicast; and
- light.

## Tossing

'Tossing' of bedding material is an effective way of aerating or increasing the oxygen within a vermiculture unit.

Tossing involves the lifting and loosening of material without inverting any of the feedstock. A garden fork is ideal for manual tossing as it minimises worm casualties. See Appendix No. 1 for equipment suppliers.

Tossing should not excessively disturb the vermiculture unit. The process of tossing is given below.

### Materials

- Garden fork.

## Method

1. Slide the fork into the bedding material to the depth of approximately half the prong length (Plate 27).
2. Gently pivot the fork down so that the prongs lift the bedding material gently (Plate 28).
3. Lift the fork until the bedding material opens slightly allowing air to penetrate the unit and any compaction is loosened (Plate 29).
4. Slide the fork out without inverting material or removing material from the unit (Plate 30).
5. Repeat across surface of vermiculture unit.

**Plate 27.** Slide the fork in gently to a depth of approximately half the length of the prongs.



**Plate 28.** Gently lift the bedding material to aerate.



**Plate 29.** Loosen the bedding material without inverting or burying feedstock.



**Plate 30.** Gently slide the fork out without removing material.



## Odour prevention

To prevent health and environmental issues such as odour development, areas used for feedstock preparation, storage and processing should be kept clean and tidy at all times.

Odours produced by a vermiculture unit indicate that the unit is unhealthy. In a healthy unit, worms can remove odour from putrescible organics within 24 to 48 hours (Edwards, 1998).

Odours tend to occur if the unit is progressing to anaerobic (low oxygen) conditions. Anaerobic microorganisms that thrive in this environment cause these offensive odours.

If a vermiculture unit produces odour, maintenance is necessary to increase aeration and to determine the cause of the anaerobic conditions.

The feedstock recipe should be revised as well as the loading rate to ensure that excessive amounts of feedstock are not accumulating. Periodic tossing will help in reducing the production of odours by aerating the unit. However, odour production is an indication of an unhealthy unit

and the cause of this should be investigated and prevented rather than just treating the symptoms.

## Leachate collection

Vermiculture units can produce leachate as microorganisms release water during the natural decomposition of organic materials.

Excessive moisture within the unit will percolate to the bottom layers where drainage must be allowed to occur. Drainage and collection of this leachate is important to prevent saturation of the vermiculture unit and attraction of pests (Plates 31 and 32).

Excessive moisture levels will lead to high leachate production and may cause problems with waterlogging if the leachate is not able to freely drain. Collection devices need to be regularly monitored to ensure accumulation of liquid does not occur within the unit.

The addition of moisture may need to be reduced if excess leachate is being produced or if the unit becomes too moist for worm habitation. The feedstock recipe may also be the cause of leachate production and

should be revised, for example, by adding more bulking agent.

## Pest deterrence

Pests can be attracted to vermiculture processing areas and can include vermin, ants and insects.

Problems can occur if such pests (eg. insects) are able to enter the unit and breed as eggs and larvae can make the unit undesirable to the worm population.

The potential for pests to interfere with a vermiculture unit should be minimised by installing pest deterrent devices.

Methods for deterring pests include:

- Ensuring all areas are kept clean especially after feedstock preparation. All feedstocks should be sealed when in storage.
- Free-standing vermiculture units should have the legs of the units placed in buckets of water and detergent or coated in axle grease or sticky pest traps (see Appendix No 1). This acts as a barrier for crawling insects such

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**Plates 31 and 32.** Leachate collection tray (left). Any leachate produced should be removed from the vermiculture unit (right) and either disposed of or stored in a sealed container. The liquid can be used as a liquid fertiliser for plants. See "How to Use Recycled Organics Products" published by the Recycled Organics Unit (2001d) for more information.



**Plate 33.** Legs of vermiculture units placed in buckets of water and detergent to prevent crawling insects, such as ants, from entering the system.



as ants (Plate 33).

- Installing flying-insect catching devices such as fluorescent (black) lights and sticky fly-paper (Plates 34, 35 and 36).
- Enclosing the vermiculture units within a room with an extractor fan and minimising odour production.

It should be noted however that vermiculture is an ecosystem in itself and that cohabitation of various organisms will exist. Only those organisms that are a direct pest and that interfere with the vermiculture process such as ants, flies and particularly vermin need to be controlled.

### Harvesting vermicast

The benefits of treating residual organics in a vermiculture unit is that a useable end product, vermicast, is produced.

Harvesting of this product occurs when the organic materials from the feedstock have been processed and the worms have moved out of this region.

When harvesting vermicast, it is often beneficial to allow the material to rest or cure before use. Whilst it is possible to use vermicast immediately after harvesting, *curing* is a way of completing the decomposition process and results in a more finished product (Grossman and Weitzel, 1997).

Curing involves the stabilisation of the organic materials as the rate of decomposition slows and the remaining organic material is consumed (Recycled Organics Unit, 2000b).

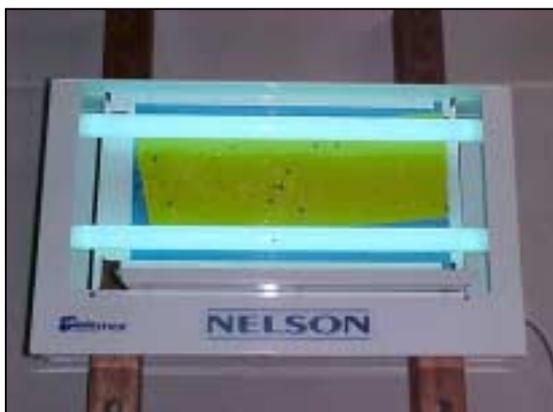
Curing can be accomplished by storing the vermicast in a way that allows oxygen to penetrate the material. This can be done in modified 240 L mobile garbage bins. A bin that has a perforated raised floor and air holes on the sides is an ideal unit to use (Plate 37).

Curing should occur for approximately 4 weeks. Information Sheet No. 7 provides details on using the vermicast product.

**Plate 37.** Modified mobile garbage bin used for curing of vermicast. See Appendix No. 1 for supplier information.



**Plates 34, 35 and 36.** Attraction device for flying insects. *Nelson Electro Stick* (left), *Efekto Fly Trap* (centre) and *Yard Guard* (right).



## Light

Light can be used to ensure the worm population remain within the vermiculture unit. Worms can migrate out of the units under particular conditions of cool air temperatures and 100% humidity (Wilson, 1999).

To prevent migration of a worm population a light shining on to the

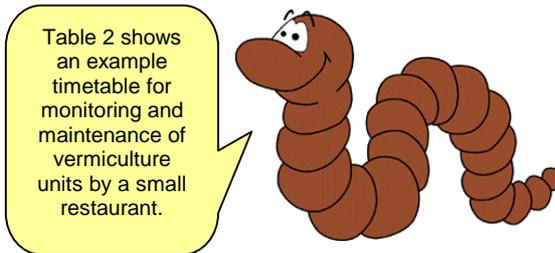
vermiculture unit can be used. Worms will only migrate at night and therefore a continual light source will prevent this situation from occurring.

## Timetable of management and maintenance procedures

An example of an effective monitoring and maintenance regime is shown in Table 2.

This timetable shows the monitoring and maintenance regime for a small restaurant using a top loading continuous flow vermiculture unit to process mixed food organics.

The timetable details how often these procedures should be undertaken and gives the approximate time required for the procedures.



**Table 2.** Timetable of monitoring and maintenance for a small restaurant processing mixed food organics. The vermiculture units used in this scenario are top loading continuous flow systems with 3 m<sup>2</sup> of processing surface area. The feedstock consists of pre-consumer fruits and vegetables and post-consumer plate scrapings (mixed food organics). The restaurant is open 6 days per week and feeding occurs after closing each day so the compostable organics need not be stored prior to feeding.

Activity	Time required (hours)						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
<b>Feedstock</b>							
Feedstock preparation	closed	0.5	0.5	0.5	0.5	0.5	0.5
Feeding of vermiculture units		0.5	0.5	0.5	0.5	0.5	0.5
<b>Monitoring</b>							
Oxygen	closed	0.25					
Temperature		0.25					
Moisture content					As required		
Worm activity		0.25					
Feedstock accumulation		0.25					
<b>Maintenance</b>							
Tossing	closed	0.5					
Leachate collection					As required		
Pest deterrence					0.5		
Harvesting vermicast					As required		
<b>Clean-up</b>							
Washing up, site hygiene etc.		0.5	0.5	0.5	0.5	0.5	0.5
<b>Total time (hours)</b>	<b>0</b>	<b>3.0</b>	<b>1.5</b>	<b>2</b>	<b>1.5</b>	<b>1.5</b>	<b>1.5</b>

Notes:

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# Information Sheet No. 7

## Guide to using the vermicast product

Information Sheet No. 7  
January 2002

### Inside This Sheet

**1** Vermicast product

Uses

**2** Potting mix

Soil conditioner

Vermiculture liquid

Definitions

**3** Benefits

Risks

**4** More information

Notes

Important references

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### Vermicast product

Vermiculture processing of *compostable organics* material has a number of benefits. Primarily, valuable resources that would otherwise be disposed of in landfill are processed into a beneficial end product – *vermicast* (Plate 1).

Vermicast is the 'soil-like' material produced from compostable organic materials processed through vermiculture technology.

The vermicast product is usually classed as a *soil conditioner*.

### Uses

Vermicast produced on-site is a valuable organic product that can be used to maintain the landscaped environment of an organisation.

In this way, the treatment of compostable organics in a vermiculture unit not only reduces waste to landfill (and reduces waste disposal costs) but also produces a valuable soil conditioner for use on-site.

Vermicast is the end product of the vermiculture process and can be used as a soil conditioner.



Vermicast can be used in a variety of applications. These include:

- a component in potting mix;
- as a soil conditioner; and
- to produce vermiculture liquid.

Details for the uses of these various products are given below.

Vermicast should be left to mature (or cure) prior to use. Note that the information provided refers to the use of mature vermicast. Information on harvesting and curing vermicast is given in Information Sheet No. 6.

**Plate 1.** Mature vermicast produced from food organics.



## Potting mix

A potting mix is a growing medium suitable for the establishment and development of plants in containers (Plate 2).

A potting mix is produced by blending a range of materials together to achieve the desired balance of drainage, moisture retention, aeration and nutrients.

Vermicast can be used as a minor component in potting mixes. The addition rate to potting mixes should not exceed 30% (by volume), as this will reduce the level of air-filled porosity in the mix.

The addition of vermicast to potting mixes can help to retain water and can supply plant nutrients and improve plant growth (Atiyeh *et al.*, 1999).

A suggested potting mix blend (by volume) is given below:

- 25 % vermicast – for nutrients;
- 75% coarse sand – for drainage.

## Soil conditioner

Vermicast can be used as a soil conditioner by mixing the product into soils to improve soil condition

and plant growth.

Soil conditioners, such as vermicast, are usually incorporated into bare soil containing no plants. Seeds, seedlings, or established plants are usually planted after the soil conditioner has been applied (Recycled Organics Unit, 2001a).

In small areas, such as domestic gardens, soil conditioners can be dug into soil with a garden fork or spade.

The rate of vermicast application depends on maturity.

For fresh (immature) vermicast that has not been cured, the rate of application to soil depends upon the length of time to planting. If seeds, seedlings or established plants are to be planted within a couple of days from the incorporation of the vermicast, rates should not exceed 20 L/m<sup>2</sup> (layer not exceeding 20 mm depth).

If planting is to proceed at least two weeks after application, the application rate can be up to 50 L/m<sup>2</sup> (layer not exceeding 50 mm depth) though this will depend on application. At greater application rates, oxygen availability to plants will be reduced and may impair plant growth or result in plant death.

For mature vermicast, the rate of application can be up to 150 L/m<sup>2</sup> (150 mm in depth). At greater rates, oxygen availability to plants will reduce and may impair plant growth. Planting can proceed directly after incorporation of mature vermicast.

## Vermiculture liquid

Vermiculture liquid is a water based liquid extracted from vermicast that can contain varying levels of plant nutrients.

This liquid is suitable for adding to soil surfaces and/or onto plants as a foliar spray.

## Definitions\*

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Vermicast

Solid organic material resulting from the biological transformation of compostable organic materials in a controlled vermiculture process.

### Soil conditioner

Any composted or pasteurised organic material that is suitable for addition to soils. This term also includes 'soil amendment', 'soil additive', 'soil improver' and similar terms, but excludes polymers which do not biodegrade, such as plastics, rubber and coatings. Soil conditioners may be either 'composted soil conditioners' or 'pasteurised soil conditioners'. Soil conditioner has not more than 15% by mass of particles with a maximum size above 15 mm.

### Leachate

Liquid released by, or water that has percolated through, waste or recovered materials, and that contains dissolved and/or suspended substances and/or solids and/or gases.

### Pasteurisation

The process whereby organic materials are treated to kill plant and animal pathogens and weed propagules.

### Pathogens

Microorganisms capable of producing disease or infection in plants or animals. Pathogens can be killed by heat produced during thermophilic composting.

\*Recycled Organics Unit (2001c)

**Plate 2.** Example of a general potting mix.



Vermiculture liquids can be produced in two ways:

- worm-bed *leachate*; and
- aqueous vermicast extracts.

Worm-bed leachate is the leachate produced from the base of a vermiculture unit. The leachate is collected and can be applied to plants or soil as a fertiliser, however, it should be noted that pathogens could be present in this vermiculture liquid.

The production of worm-bed leachate is not recommended by the Recycled Organics Unit as it tends to be a result of unsuitable moisture contents within the feedstock or bedding material. If excessive volumes of worm-bed leachate are produced, management procedures should be implemented to rectify the problem (Information Sheet No. 6).

Aqueous vermicast extracts are matured vermicast products that have been soaked/steeped in water and have had their solids strained off to produce a liquid product.

A suggested method for making aqueous vermicast extracts is given below (Murphy, 1993):

1. Mix pure vermicast with water at

a ratio of 1:20 (by weight).

2. Shake/stir thoroughly and allow to soak for twenty four hours.
3. Allow the solids to settle and drain off liquid.
4. Depending upon application method, it may be desirable to strain the liquid prior to use.

Application rates are difficult to specify due to variability in vermiculture liquid product quality and due to the absence of product standards. However, in most cases, these products need to be diluted with water before they are applied to soils and/or plants.

Vermiculture liquids usually contain a solution of organic and inorganic nutrients and a large number of organisms including bacteria and fungi.

Vermiculture liquids are also known as vermi-liquids, vermiculture liquid extracts, liquid vermicasts, liquefied vermicast, vermicast liquid teas and a number of other commercial brand names.

### Benefits

Vermicast has beneficial properties when incorporated into soil. These include:

- Reduced soil erosion, particularly in areas with exposed soils;
- Increased water retention in the upper soil profile, thereby reducing the frequency of watering to maintain plant growth;
- Release of nutrients for plant growth, thus reducing the need for chemical fertilisers (Vasanthi and Kumaraswamy, 1999);
- Improved plant growth (Atiyeh *et al.*, 2000); and

- Suppression of soil borne plant diseases (Kannangara *et al.* 2000), thereby reducing fungicide and/or bactericide requirements.

It has also been suggested that vermicast have disease suppression qualities. The extent to which these products provide such benefits, however, vary with different methods of production and feedstock mixtures used (Kannangara *et al.*, 2000).

### Risks

A number of problems can occur with the use of vermicast. This is because vermicast, unlike other soil conditioners such as composts, do not undergo *pasteurisation*.

Effective pasteurisation results from the aerobic (high oxygen) and thermophilic (high temperatures of >55 °C) processing of organic materials. This process destroys weeds, seeds and plant/animal *pathogens* that may have been present in the original organic materials.

However, the risks associated with materials that have not undergone pasteurisation can be avoided if the product complies with the Australian Standard AS 4454 (Draft) (2001).

### More information

More details on using vermicast and other recycled organics products can be found in “*How to Use Recycled Organics Products – A guide on the proper use of recycled organics products*” (Recycled Organics Unit, 2001a).

For more information on the benefits and avoiding risks associated with inappropriate use of vermicast, see the “*Buyers Guide for Recycled Organics Products*” (Recycled Organics Unit, 2001c).

Plate 3. Collecting worm-bed leachate.





# Appendix No. 1

## Ancillary equipment requirements

Appendix No. 1  
January 2002

### Inside This Appendix

<b>1</b>	Equipment requirements
	Process control plan
<b>2</b>	Definitions
<b>3</b>	Equipment required for establishing a separate organics collection system
<b>4</b>	Equipment required for feedstock preparation
<b>5</b>	Equipment required for organics processing
<b>7</b>	Equipment required for harvesting and use of product
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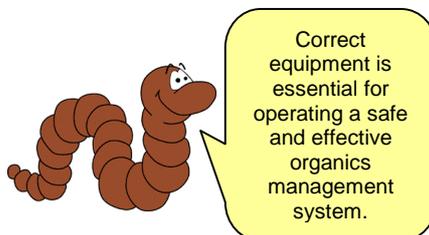
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### Equipment requirements

Reliable management of compostable materials requires effective monitoring and management procedures.

This Appendix identifies a range of equipment that may be useful for your organics management system. Such equipment may be required for establishing and implementing a system, for preparing feedstock, monitoring system performance, maintaining a healthy system, and for safe and efficient handling of materials.

The use of each item of equipment is listed as well as potential suppliers. Contact details for the suppliers are also given.



### Process control plan

The equipment required is listed according to the generic *process control* stages in an organic management system (Figure 1).

These steps can be grouped into a number of categories:

1. Establishing a separate organics collection system – handling and collection of compostable organic material produced on-site.
2. Feedstock preparation – receipt of compostable materials, size-reduction, mixing of materials into feedstocks, and storage of *bulking agents*.
3. Organics processing – loading/applying feedstock into processing unit, management and monitoring procedures of the unit.

**Plate 1.** Example of some maintenance equipment required for a successful on-site vermiculture system.



4. Harvesting and use of product – harvesting compost/vermicast product, *curing*, storage of product, and on-site use of product.

Process control involves the stringent monitoring of an organics management system to ensure a quality product is produced.



## Definitions\*

### Process control

Process Control refers to the management system employed to regulate the production of a 'product' consistently to defined specifications. A Process Control System uses procedures to control a given process whenever their absence would prejudice product quality, jeopardise worker safety or harm the environment and public health.

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Bulking agent

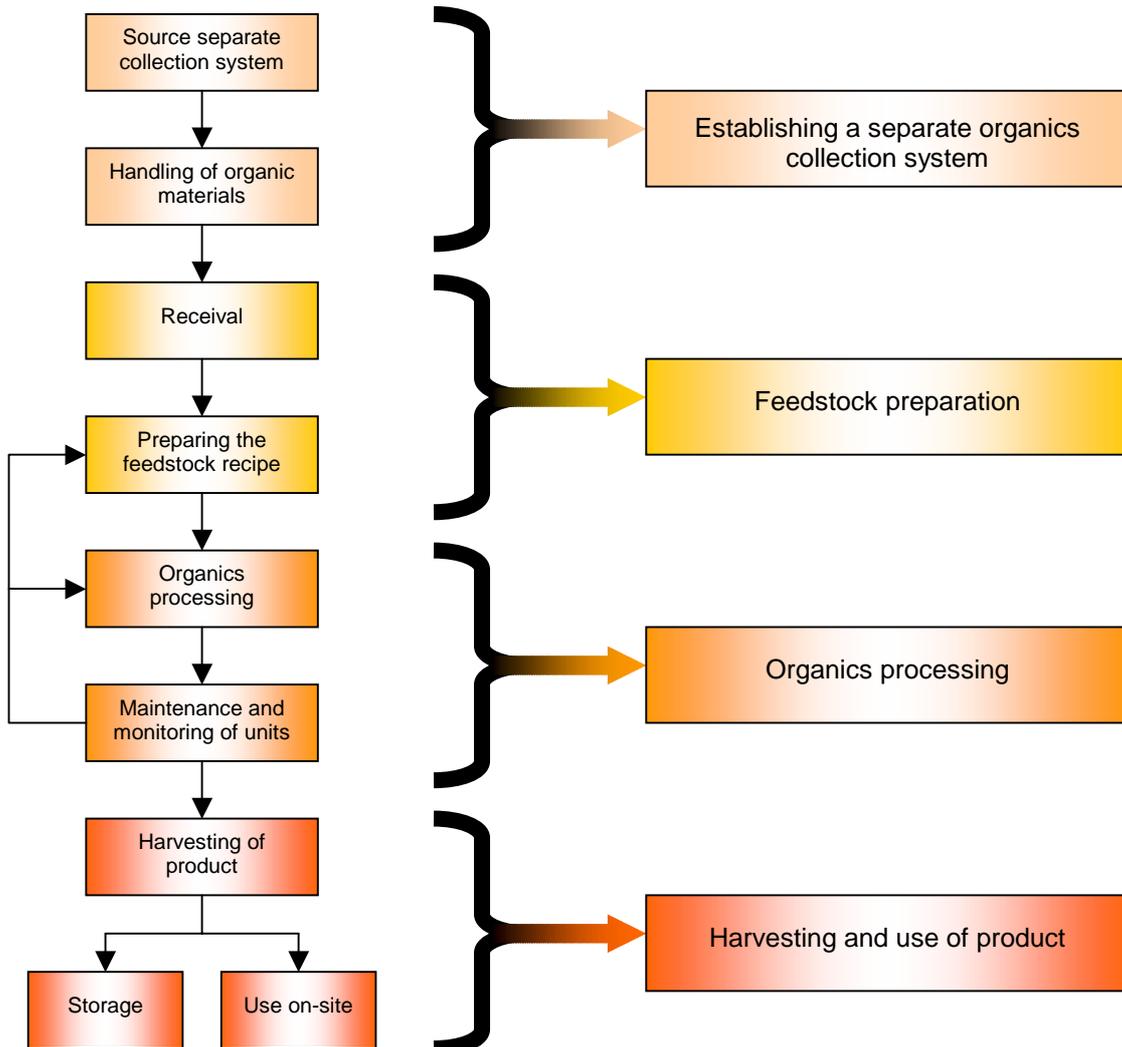
An ingredient in a feedstock mixture that is included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles. The terms 'bulking agent' and 'amendment' are often used interchangeably.

### Curing

Final stage of organics processing in which stabilisation of the product continues but the rate of decomposition has slowed.

\*Recycled Organics Unit (2001)

Figure 1. Generic process control stages for an operational organics management system. Equipment required for the four categories is detailed in this Appendix.



# Equipment required for establishing a separate organics collection system

This category includes establishing a source separate organics collection system, auditing to quantify the amount of compostable organic material produced on-site, and handling and collection of compostable organic materials.

See the section on 'Supplier details' in this Appendix for locations and contact details of appropriate suppliers. Appendix No. 3 contains example signs and stickers that may be useful for labelling this equipment.

## Buckets

**Use:** Collection of materials. Buckets with lids are useful for transporting compostable materials and feedstock mixtures.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$12.00 (25 L white bucket)  
\$4.00 (10 L blue bucket)



## Gloves

**Use:** Handling compostable materials feedstock mixtures and product.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$15.00



## Apron

**Use:** Protecting clothes during feedstock preparation and application of feedstock to the processing units.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$10.00



## Scoops

**Use:** Handling raw materials and mixing feedstocks.

**Supplier:** Reflex and other plastics suppliers or Hardware stores

**Price:** \$15.00 for two



## Collection bins

**Use:** Mobile garbage bins (80 L) are suitable for collecting and transporting source separated organic materials.

**Supplier:** Reflex, Sulo and other plastics suppliers

**Price:** \$80.00 (80 L)



## Platform scale

**Use:** Weighing organic materials collected during an audit and when mixing feedstocks on a weight basis.

**Supplier:** Wedderburn and other electronics suppliers

**Price:** \$990.00



# Equipment required for feedstock preparation

This category includes size reduction of organic materials and mixing of materials to make a suitable feedstock for composting/vermiculture processing.

See the section on ‘Supplier details’ in this Appendix for locations and contact details of appropriate suppliers.

## Buckets, gloves, apron, scoops

See previous section

### Mixing/size reduction tub and spade

**Use:** Large tub (320 L, model no. M322) and spade are suitable for size reduction of most categories of food organics and for mixing materials to form feedstock.

**Supplier:** Reflex and other plastics suppliers or Hardware stores

**Price:** \$211.20 (320 L) tub  
\$25.00 spade



### Size reduction equipment

**Use:** Rotary-shear shredder used for size-reduction of high volume raw feedstock components and bulking agents. For many C&I sector applications, a large tub and spade may be most suitable (see above).

**Supplier:** Brentwood Shredders and Recycling Systems or other machinery suppliers

**Price:** Depends on size of shredder



### Storage bins

**Use:** Mobile garbage bins (240 L) are suitable for storing size-reduced cardboard or paper bulking agents.

**Supplier:** Reflex, Sulo and other plastics suppliers

**Price:** \$88.00 (240 L)



### Plastic shovel

**Use:** Food grade, “deep bucket” spade for mixing raw components and bulking agent to achieve a suitable feedstock for vermiculture processing. Mouth width of shovel fits into 25 L buckets.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$25.00



### Hose and trolley

**Use:** Site clean-up after preparation of feedstock including rinsing down work area, buckets and tubs.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$30.00 hose  
\$50.00 trolley



### Brooms and dustpan

**Use:** Site clean-up after preparation of feedstock.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$10.00 broom  
\$5.00 dustpan



# Equipment required for organics processing

This category includes monitoring and maintenance of the processing units to ensure the system is operating efficiently and effectively.

See the section on 'Supplier details' in this Appendix for locations and contact details of appropriate suppliers.

## Gloves, apron, broom and dustpan

See previous section

## Buckets

**Use:** Applying feedstock mix to the organics processing system

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Cost:** Approximately \$4.00 depending on size



## Ladies garden fork

**Use:** Used for 'tossing' of vermiculture units and/or manually turning small compost heaps. A Ladies garden fork has shorter prongs that are better suited to this activity.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$40.00



## Watering can

**Use:** Used for adding water to a processing system.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$10.00



## Thermometer

**Use:** Used for monitoring maximum/minimum, day/night ambient temperatures.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$10.00



## Temperature and oxygen meter

**Use:** Hand-held temperature/oxygen meter with a probe at least 50 cm long to measure temperature and oxygen concentrations within vermiculture units or compost piles.

**Supplier:** Recycled Organics Unit

**Price:** ~ \$2,400.00



## Ruler

**Use:** 50 cm metal ruler used for measuring feedstock accumulation in vermiculture units.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$10.00



# Equipment required for organics processing

Continued from previous list

## Pest control devices

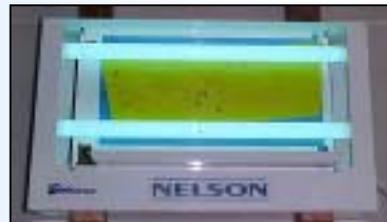
**Use:** Detering or killing pests that may interfere with or be associated with composting/vermiculture units.

These devices can feature fluorescent (black-light) bulbs, sticky paper, liquid attractants, or electrocution devices.

*Nelson Electro Stick*

**Supplier:** Nelson Lamps (Aust) Pty. Ltd. or other supplier for similar product

**Price:** \$245.00



*Yard Guard*

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$138.00



*Efekto Fly Trap*

**Supplier:** Green Harvest Organic Gardening Supplies

**Price:** \$33.00



*Yellow Tape Trap*

**Supplier:** Green Harvest Organic Gardening Supplies or other supplier for similar product

**Price:** \$44.00



## Bin lift

**Use:** Loading feedstock from mobile garbage bins (MGBs) into vermiculture units. Bin lifts can be used to empty 80 to 240 L MGBs. Note that this equipment may only be relevant to large-scale processing operations.

**Supplier:** Reflex or other supplier for similar product

**Price:** \$4,268.00



# Equipment required for harvesting and use of product

This category includes harvesting compost/vermicast from the unit, storage of the product for curing and use of the product on-site for landscaping purposes.

See the section on 'Supplier details' in this Appendix for locations and contact details of appropriate suppliers.

## Gloves

See previous section

## Shovel/spade

**Use:** Removing compost/vermicast from the processing system.

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** \$25.00



## Vermicast curing bin

**Use:** Modified mobile garbage bin used for storing harvested vermicast over time to allow curing or maturing. This bin has a perforated, raised floor and air holes.

**Supplier:** Shaefer Systems International Pty. Ltd. or other supplier for similar product

**Price:** \$181.50 (120 L)

\$220.00 (240 L)



## Landscaping/gardening tools

**Use:** Applying the compost/vermicast product for on-site landscaping as mulch and/or soil conditioner (depending on product).

**Supplier:** Hardware stores (eg. Hardwarehouse, Blackwoods or similar)

**Price:** variable



## Supplier details

The supplier information given in this Appendix is for suggested suppliers only. The equipment required and listed above can be acquired from a number of sources not limited to those listed below. This information is a guide only.

<b>Blackwoods</b>	Stores across NSW	<a href="http://www.blackwoods.com.au">http://www.blackwoods.com.au</a>
<b>Brentwood Shredders and Recycling Systems</b>	238 Berkeley Rd Unanderra, NSW, 2526	Ph: (02) 4271 7511 Fax: (02) 4272 9339 <a href="mailto:brent@brentwood.com.au">brent@brentwood.com.au</a> <a href="http://www.brentwood.com.au">http://www.brentwood.com.au</a>
<b>Green Harvest Organic Gardening Supplies</b>	52 Crystal Waters Maleny, Qld, 4552	Ph: (07) 5494 4676 Fax: (07) 5494 4674 Freecall: 1800 68 10 14 <a href="mailto:inquiries@greenharvest.com.au">inquiries@greenharvest.com.au</a> <a href="http://www.greenharvest.com.au">http://www.greenharvest.com.au</a>
<b>Hardwarehouse</b>	Stores across NSW	<a href="http://www.hardwarehouse.com.au">http://www.hardwarehouse.com.au</a>
<b>Nelson Lamps (Aust) Pty. Ltd.</b>	Unit 2, 5 Stanton Road Seven Hills, NSW, 2147	Ph: (02) 9624 2200 Fax: (02) 9624 7213 <a href="http://www.nelsonlamps.com.au">http://www.nelsonlamps.com.au</a>
<b>Recycled Organics Unit</b>	Building B11b The University of New South Wales, UNSW, 2052	<a href="http://www.recycledorganics.com">http://www.recycledorganics.com</a>
<b>Reflex Handling and Storage Equipment</b>	Cnr Kareena Road and The Boulevard Caringbah, NSW 2229	Ph: (02) 9525 9644 Fax: (02) 9525 3891 <a href="http://www.reflexequip.com.au">http://www.reflexequip.com.au</a>
<b>Shaefer Systems International Pty. Ltd.</b>	17/30 Heathcote Road Morebank, NSW 2170	Ph: (02) 9824 3844 Fax: (02) 9824 3855 <a href="mailto:Schaeferssi@schaeferssi.com.au">Schaeferssi@schaeferssi.com.au</a>
<b>Sulo MGB Australia</b>	123 Wisemans Ferry Road Morebank, NSW 2250	Ph: (02) 4348 8188 Fax: (02) 4348 8123 <a href="http://www.sulo.com.au">http://www.sulo.com.au</a>
<b>Wedderburn</b>	90 Parramatta Road Summer Hill, NSW 2130	Ph: (02) 9797 0111 Fax: (02) 9799 2013 <a href="http://www.wedderburn.com.au">http://www.wedderburn.com.au</a>



## Appendix No. 2

### Vermicast product standard

Appendix No. 2  
January 2002

#### Inside This Appendix

**1** Vermicast product standard

**=** Australian Standard AS 4454 (1999)

**2** Why is an industry standard needed?

Benefits of compliance with an Australian Standard

How to comply with the vermicast standard

Definitions

**3** What products are covered in AS 4454 (Draft) (2001)?

Summary

**5** Notes

Important references

Acknowledgements

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#### Vermicast product standard

The processing of *compostable organics* material in vermiculture technology minimises waste to landfill and produces *vermicast* as a beneficial end product.

Vermicast is a valuable *soil conditioner* and is useful for landscaping and improving gardens. It is recommended by this Best Practice Guideline to use the vermicast product on-site.

However, if vermicast was to be sold commercially, it is useful to be aware of the relevant vermicast product standards. Managing the vermiculture process will support the production of vermicast that complies with the standard, and therefore valued by the market. Compliance with this standard will also minimise risks of a poor quality product being sold to buyers.

An industry standard for vermicast exists and at time of printing, this vermicast industry standard has been included in the 2001 draft update of

the Australian Standard AS 4454 for *composts*, soil conditioners and *mulches*.

Until this standard is released, however, as vermicast can be considered to be a soil conditioner, manufacturers should aim for compliance against the current standard, AS 4454 (1999).

It should be noted that most C&I sector establishments will use vermiculture as an on-site waste management tool for recycling organics on-site and not as a tool to produce vermicast commercially. As such, compliance with AS 4454 (1999) is only recommended if the vermicast is to be sold commercially.

#### Australian Standard AS 4454 (1999)

The Australian Standard AS 4454 (1999) contains guidelines to provide manufacturers, local government bodies, consumers and growers with:

- Minimum requirements for the physical, chemical and

**Plate 1.** A soil conditioner certified under AS 4454 (1999) for composts, soil conditioners and mulches. This product is suitable for incorporating into soil to improve soil conditions and plant growth.



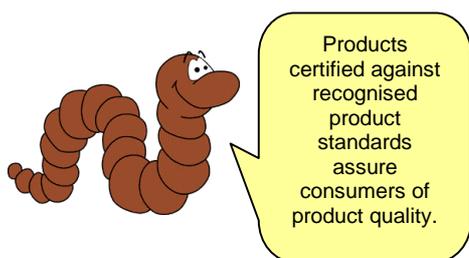
biological properties of composts, soil conditioners and mulches; and

- Labelling and marketing requirements, in order to facilitate beneficial processing and use of organic materials with minimal adverse impact on the environment and public health.

The standard also sets out *best practice* guidelines to enable producers to consistently produce quality composts, soil conditioners and mulches (Recycled Organics Unit, 2001a).

### Why is an industry standard needed?

The production of vermicast from vermiculture processing of *food organics* and *garden organics* requires best practice guidelines to ensure the vermicast product is not contaminated with animal *pathogens* (including human), plant pathogens and plant propagules (weeds). An industry standard provides generic best practice guidelines that apply to all vermiculture units and provide the basis for market confidence in vermicast quality.



**Figure 1.** Certified product logo demonstrating compliance to a recognised product standard.



Some products made from recycled organics that are commercially available do not live up to consumer's expectations. These products can be variable in quality and damaging to plants when applied as a compost, soil conditioner or mulch.

### Benefits of compliance with an Australian Standard

When purchasing a recycled organic product, consumers can be assured the product is of a high quality if it is certified against the Australian standard. Also, manufacturers can ensure consumers are receiving a quality product by testing the product according to this standard prior to sale.

Australian standard certification allows the manufacturer to label the product with the recognised Australian standard 'five ticks' logo (Figure 1). To achieve this certification, the manufacturer must comply with criteria defined by the relevant standard.

Products certified against an Australian standard are easily recognisable in the market place and provide assurance of quality. Consequently, consumers can buy a certified product with confidence.

### How to comply with the vermicast standard

Quality vermicast is best achieved by effectively controlling the manufacture of the vermicast product. Implementing a management system based on *quality management system* principles, and best practice vermiculture management principles, will provide an optimum outcome.

A quality management system is the implementation of operational procedures that support the manufacture and supply of a consistently high quality product. Best practice principles are used to

## Definitions\*

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Vermicast

Solid organic material resulting from the biological transformation of compostable organic materials in a controlled vermiculture process.

### Soil conditioner

Any composted or pasteurised organic material that is suitable for adding to soils. This term also includes 'soil amendment', 'soil additive', 'soil improver' and similar terms, but excludes polymers which do not biodegrade, such as plastics, rubber and coatings. Soil conditioners may be either 'composted soil conditioners' or 'pasteurised soil conditioners'. Soil conditioner has not more than 15% by mass of particles with a maximum size above 15 mm.

### Compost

An organic product that has undergone controlled aerobic and thermophilic biological transformation to achieve pasteurisation and a specified level of maturity. Compost is suitable for the use as soil conditioner or mulch and can improve soil structure, water retention, aeration, erosion control, and other soil properties.

### Mulch

Any pasteurised organic product (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Mulch has at least 70% by mass of its particles with a maximum size of greater than 15 mm.

### Best practice

For any area of waste management, this represents the current 'state-of-the-art' in achieving particular goals. Best Practice is dynamic and subject to continual review and improvement.

*Continued page 3*

develop a set of efficient and consistent operational procedures that will maintain product quality and minimise the impact of vermiculture technology on the environment. This best practice guideline, and the vermicast industry product standard, will assist in producing a quality vermicast product.

In order to comply with the vermicast industry standard, the vermicast product must exhibit a number of physical and chemical requirements. These requirements are given in Table 1.

If claiming certification against the standard, compliance must be demonstrated periodically by testing by an independent laboratory.

### What products are covered in AS 4454 (Draft) (2001)?

At the time of printing, the standard provides quality guidelines for three major categories of product: *pasteurised products*, composted products and vermicast.

Products defined in this standard are manufactured by the controlled microbial transformation of organic materials.

Vermiculture derived products can be subject to pre-processing or post-processing *pasteurisation*. Pre-processing pasteurisation involves pasteurising the feedstock material before vermiculture processing. This eradicates pathogens and weed seeds. Post-processing pasteurisation involves pasteurising the finished vermicast product, however, this also results in the destruction of the beneficial microorganisms present in the vermicast.

Studies have shown that human and plant pathogens are reduced through processing under *mesophilic* conditions in vermiculture units (Brown and Mitchell, 1981; Amaravadi *et al.*, 1990; Pederson and Henrikson, 1993).

*Continued from page 2*

#### **Food organics**

The Food Organics material description is defined by its component materials, which include: fruit and vegetable material; meat and poultry; fats and oils, seafood (including shellfish, excluding oyster shells); recalcitrants (large bones >15mm diameter, oyster shells, coconut shells etc.); dairy (solid and liquid); bread, pastries and flours (including rice and corn flours); food soiled paper products (hand towels, butter wrap etc.); and biodegradeables (cutlery, bags, polymers). Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the *compostable organics* stream.

#### **Garden organics**

The Garden Organics material description is defined by its component materials including: putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs; stumps and rootballs. Such materials may be derived from domestic, Construction and Demolition and Commercial and Industrial sources. Garden Organics is one of the primary components of the *compostable organics* stream.

#### **Pathogen**

Microorganisms capable of producing disease or infection in plants or animals. Pathogens can be killed by heat produced during thermophilic composting.

#### **Quality management system**

Management system to direct and control an organisation with regard to quality.

#### **Pasteurised product**

A process whereby organic materials are treated to kill plant and animal pathogens and plant propagules. Pasteurisation can be achieved by the controlled biological transformation of organic materials under aerobic and thermophilic conditions such that the whole mass of constantly moist material is subjected to at least 3 consecutive days to a minimum temperature of 55°C (or by equivalent process).

#### **Pasteurisation**

The process whereby organic materials are treated to kill plant and animal pathogens and weed propagules.

#### **Mesophilic**

A temperature range of 20 – 45 °C.

\*Recycled Organics Unit (2000b)

AS 4454 (Draft) (2001) requires that if pre- or post-processing pasteurisation is not performed, analytical testing must be performed to confirm the absence of plant propagules and problematic human pathogens (including *E. coli* and *Salmonella*).

In a well-managed system, vermicast produced from materials containing human pathogens (such as meat etc.) can undergo an adequate level of sanitation, however, testing is recommended and pre- or post-processing pasteurisation will significantly decrease the risk of transmitting pathogens.

**Table 1.** Physical and chemical requirements for vermicast (Standards Australia AS 4454, 2001 Revised draft).

<b>Characteristic and unit of measurement</b>	<b>Requirement</b>
<b>pH</b> pH units	5.0 – 7.5 If pH > 7.5 determine total CaCO <sub>3</sub>
<b>Electrical conductivity</b> dS/m	No limit
<b>Phosphorous, soluble</b>  mg/L in extract	≤ 5 For products which claim to be for phosphorus-sensitive plants No requirement otherwise
<b>Phosphorous, total</b>  % dry mass	≤ 0.1 For products which claim to be for phosphorous-sensitive plants No requirements otherwise
<b>Ammonium-N</b> mg/L in extract	No requirement
<b>Ammonium-N plus nitrogen-N</b> mg/L in extract	>100 If a contribution to plant nutrition is claimed
<b>Nitrogen, total</b> % dry matter	≥ 0.8 If a contribution to plant nutrition is claimed
<b>Organic matter content</b> % dry matter	≥ 25
<b>Boron<sup>1</sup></b> mg/kg dry mass	< 200 Products with a total B of < 100 can have unrestricted use
<b>Sodium</b> % dry mass	< 1 or at least 7.5 moles calcium plus magnesium for each mole of sodium in the dry matter
<b>Wettability</b>  minutes	< 7 For the < 16 ± 1 mm fraction. If <5% of the product is <16 mm, the wettability test does not apply.
<b>Toxicity index</b> %	≥ 20 for all products except those labelled as manure, for which EC criteria are more appropriate
<b>PARTICLE SIZE GRADING</b>	
<b>Maximum size</b> millimetre	≤ 16
<b>Tolerance</b> % mass	Not more than 20% by mass in the shortest dimension to be retained by the sieve
<b>Total CaCO<sub>3</sub> equivalent</b> % dry matter	To be determined and stated if pH > 7.5
<b>Chemical contaminants (includes heavy metals)</b>	To comply with current national guidelines for unrestricted use
<b>Organic contaminants</b>	To comply with current national guidelines for unrestricted use
<b>Moisture content</b>  %	Minimum 25 Maximum = % organic matter (OM) + 6 if OM > 40% Maximum = % organic matter + 10 if OM < 40%
<b>CONTAMINANTS</b>	
<b>Glass, metal and rigid plastics &gt; 2 mm</b>	≤ 0.5
<b>Plastics – light, flexible or film &gt; 5 mm</b>	≤ 0.05
<b>Stones and lumps of clay ≥ 5 mm</b>  % dry matter (w/w)	≤ 5 Suppliers and their customers are advised to agree upon an acceptable maximum level of visual contamination by light weight plastic (5% by volume has been suggested but there may be reason to differ)
<b>Self heating</b> °C	No requirement
<b>Vermicast sieve test</b>	90% passing through the 1.8 mm sieve apertures
<b>Plant proppules</b>	Nil

<sup>1</sup> Note: testing for B will generally only be necessary for products that are based on seaweed, seagrass or unseparated municipal solid wastes that have a component of cardboard packaging

## Summary

Compliance with the vermiculture product standard Australian Standard AS 4454 (1999) for composts, soil conditioners and mulches, will increase the perceived quality and commercial value of a product.

The treatment of compostable organic materials via vermiculture processing on-site produces an end product of vermicast. This product can be sold commercially however

compliance with the relevant product standard involves pre- or post-processing pasteurisation and/or product testing. These requirements will increase the cost of the vermiculture process, however, such costs may be returned through the sale of a quality vermicast product.

Vermicast is best used on-site to improve the landscaped environment of the organisation. This use of the vermicast product therefore avoids

the need for equivalent landscape products that would otherwise be purchased at commercial rates.

Vermicast is a valuable end product that can improve the commercial viability of on-site vermiculture treatment of compostable organic materials. However, most C&I sector establishments will find greater benefit by focusing on managing the system to reduce the amount of waste sent to landfill.

### Notes:

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### Important references

- Amaravadi, L. Bisesi, M. and Bozarth, R.F. (1990). Vermial virucidal activity: implications for management of pathogenic biological wastes on land. *Biological Wastes*, 34(4): 349-358.
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## Appendix No. 3 Signage

Appendix No. 3  
January 2002

### Inside This Appendix

**1** Standard signage

**2** Example

**3** How to use signage effectively

**4** Generic signs

Definitions

**14** Notes

Important references

Acknowledgements

### Standard signage

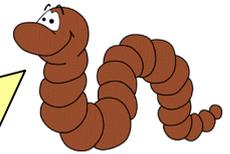
This Appendix contains example signage for use in Commercial and Industrial (C&I) sector organisations where *source separate, compostable organics* collection systems have been installed.

The signage can be used in areas where compostable organic material is to be collected – for example, food preparation and consumption areas (Plate 1).

Signage clearly informs people of what materials should be placed in each type of bin, and what should not.

All collection containers should be labelled with the same markings (and ideally all be the one colour) so they are readily distinguished from bins that are used for other purposes.

Information signage should be specific to the types of materials produced by your organisation.



Materials that are not compostable (eg. metal, plastic, glass) are considered as *contaminants* and can cause a range of inefficiencies and problems later on.

A standard range of bin labels have been developed that comprise consistent colours and symbols to represent waste, recyclables and compostable organic materials (Plate 2).

These colours and symbols are often seen on mobile garbage bins used in public places.

**Plate 1.** Compostable organics bin and site specific sign in a commercial kitchen



**Plate 2.** Standard colour collection bin and label



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Easy identification and clearly distinguishable containers are key elements in a successful recycling system.

Examples of standard bin labels are contained at the end of this Appendix and details of suppliers are also provided.

It may be more useful, however, to develop signage that is relevant to the specific types of materials produced from your organisation (see Plate 1).

### Example

As mentioned, information signage tends to be more effective if it is directly relevant to your organisation.

Generic information sign examples are shown below, however, particular attention should be given to distinguish compostable (eg. paper)

from non-compostable (eg. plastic) single portion items like sugar or jam.

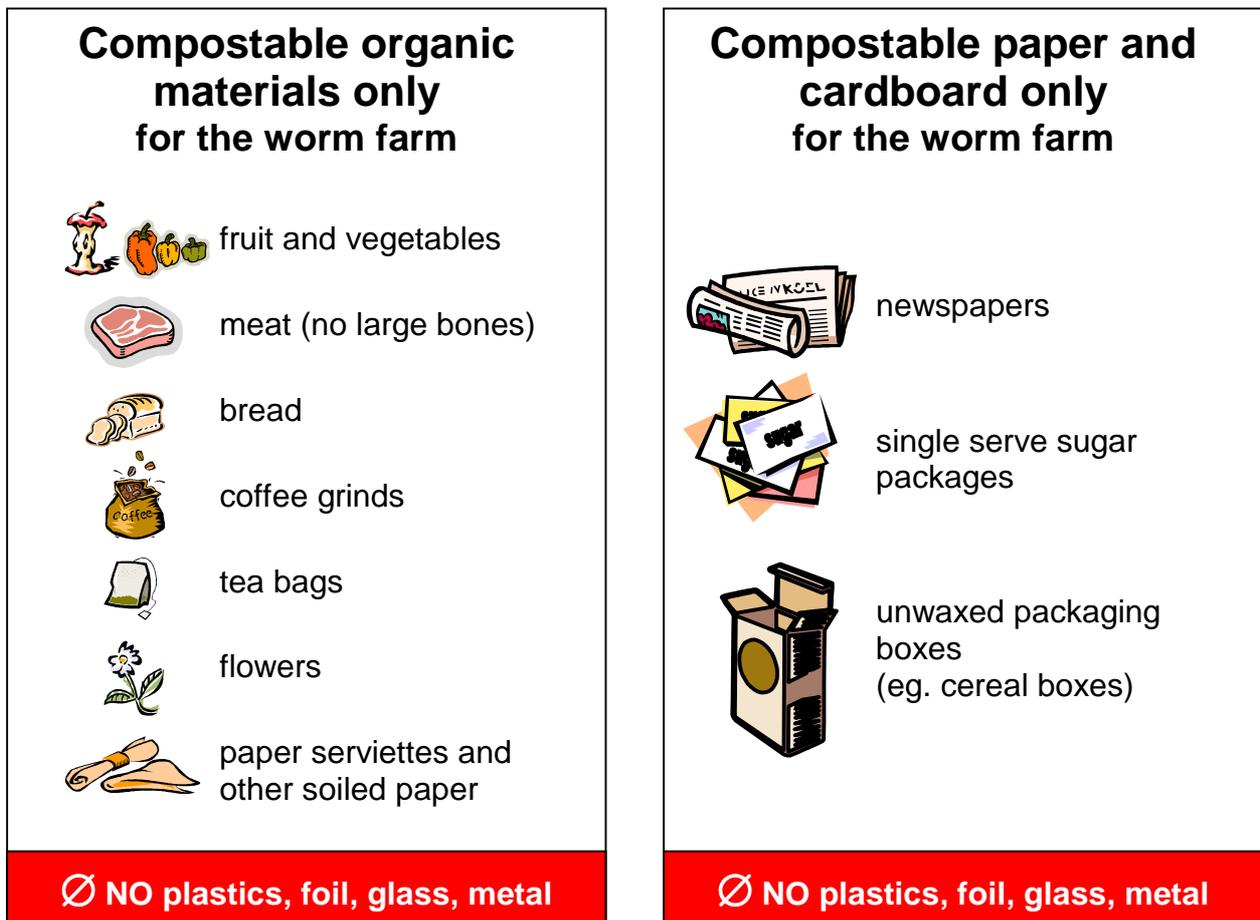
A small hotel that provides meals of breakfast, lunch and dinner has implemented a source separate collection system for compostable organic materials. The material could be processed on-site via *composting* or *vermiculture*, or could be collected for composting at a centralised facility. In this example, the material is being processed on-site in a vermiculture unit.

Food is prepared on-site and plate scrapings are cleared by kitchen staff. “Compostable organic material only” bins are placed in the kitchen area and are emptied regularly. A previous audit identified the following range of organic materials produced on-site:

- pre-consumer fruit, vegetables, bread and meat from food preparation activities;
- post-consumer plate scrapings of fruit, vegetables, meat, bread and soiled paper serviettes;
- paper packaging materials from single serve items such as condiments, sugar and tea bags;
- coffee grinds;
- newspapers and packaging boxes such as cereal boxes; and
- flowers from table displays.

General rubbish signs for this hotel should directly compliment “organics only” information signs by targeting the key materials so that staff can clearly identify which items go into which bin.

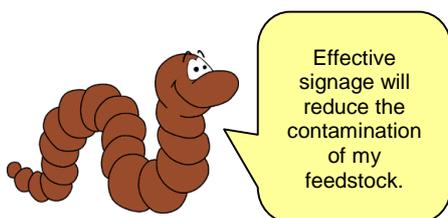
**Figure 1.** Example signage for a small hotel based on an audit of organics produced on-site. Identifying key organic fractions for vermiculture processing will educate staff and minimise contamination levels.



Example signs are shown in Figures 1 and 2 for compostable organic materials and general garbage respectively.

## How to use signage effectively

Effective signage for separate collection of compostable organic materials and *bulking agents* will reduce contamination, avoiding risks associated with post collection sorting.



For example, contamination of organic material with broken glass will pose a safety risk to staff handling the material and preparing the *feedstock*, and harvesting and using the *compost/vermicast* product.

The potential for contamination, and the difficulties associated with sorting through contaminated organic material, leads to the necessity of having clear and effective signage.

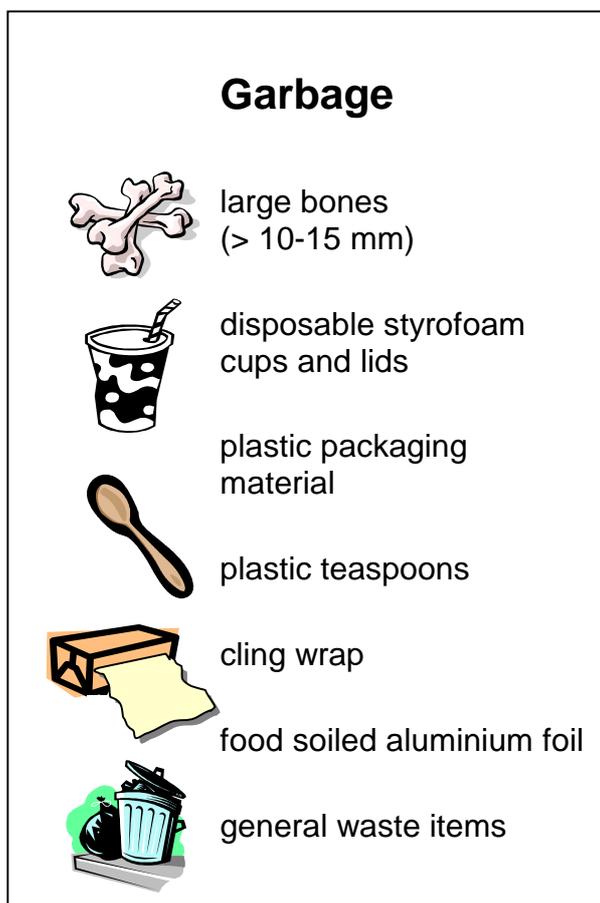
Some suggestions on using signage effectively are given below:

- Consistent bin colour – using a consistent colour and bin shape will increase the effectiveness of collection bins.
- Consistent bin labels – bin labels must also be consistent. Use standard designs as staff will recognise the bin colours and

label combination to differentiate between “organics only” bins, paper bins, general recyclables and also garbage bins. Details for suppliers of durable stickers are given at the end of this section.

- Combining words, colour and pictures – a combination of words, colour and pictures should be used to differentiate between different types of bins.
- Accessibility – place the bins in areas that are easily accessible and are efficient to use. Make garbage bins and “organics only” bins equally accessible so as not to increase the amount of work staff need to do in order to place materials in the correct bin.
- Inform clearly – use information signs to clearly communicate which items go in which bins.
- Location – try to locate the “organics only” bins adjacent to a general garbage bin, otherwise mixed materials are likely to go into both.
- Ensure the different bins are equally user friendly/efficient – if the garbage bin has a lid that needs to be removed and the adjacent organics bin does not, you can guarantee that more general rubbish (contamination) will be disposed of in the organics bin.

**Figure 2.** Example signage for a small hotel based on an audit of organics produced on-site. Identifying key general waste items for landfill disposal will educate staff and minimise contamination levels for collection of residual organics.



## Generic signs

A number of generic bin labels that can be photocopied are included at the end of this Appendix.

It is recommended, however, that site specific information signs be produced such as those given in the example above. If this is not possible, these generic signs may help.

The signs provided are applicable to:

- compostable organics
- *food organics*;
- cardboard;
- paper and cardboard; and

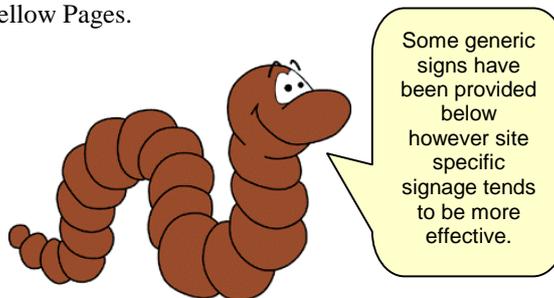
- garbage.

Generic signs for bins are available from “Associate Labels” in Sydney.

Ph: (02) 9905 6522

PO Box 238, Brookvale,  
Sydney, 2100

For other suppliers look under “labels” in the Yellow Pages.



## Definitions\*

### Source separation

Physical sorting of the waste stream into its components at the point of generation.

### Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

### Composting

The process whereby organic materials are pasteurised and microbially transferred under aerobic and thermophilic conditions for a period of not less than six weeks. By definition, it is a process that must be carried out under controlled conditions yielding mature products that do not contain any weed seeds or pathogens.

### Vermiculture

System of stabilising organic materials under controlled conditions by specific worm species and microorganisms under mesophilic temperatures. Commercial vermiculture systems include: windrows or beds; stackable trays; batch-flow containers, and continuous flow containers.

### Contamination (composting)

Contaminants within this context include physical inorganic materials (metals, glass etc.), non-biodegradable organic materials (plastics), chemical compounds and/or biological agents that can have a detrimental impact on the quality of any recycled organic products manufactured from source separated compostable organic materials.

### Bulking agent

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably. See also composting amendment.

### Feedstock

Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

### Compost

An organic product that has undergone controlled aerobic and thermophilic biological transformation to achieve pasteurisation and a specified level of maturity. Compost is suitable for the use as soil conditioner or mulch and can improve soil structure, water retention, aeration, erosion control, and other soil properties.

### Vermicast

Solid organic material resulting from the biological transformation of compostable organic materials in a controlled vermiculture process.

### Food organics

The Food Organics material description is defined by its component materials, which include: fruit and vegetable material; meat and poultry; fats and oils, seafood (including shellfish, excluding oyster shells); recalcitrants (large bones >15mm diameter, oyster shells, coconut shells etc.); dairy (solid and liquid); bread, pastries and flours (including rice and corn flours); food soiled paper products (hand towels, butter wrap etc.); and biodegradables (cutlery, bags, polymers). Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the *compostable organics* stream.

\*Recycled Organics Unit (2001)

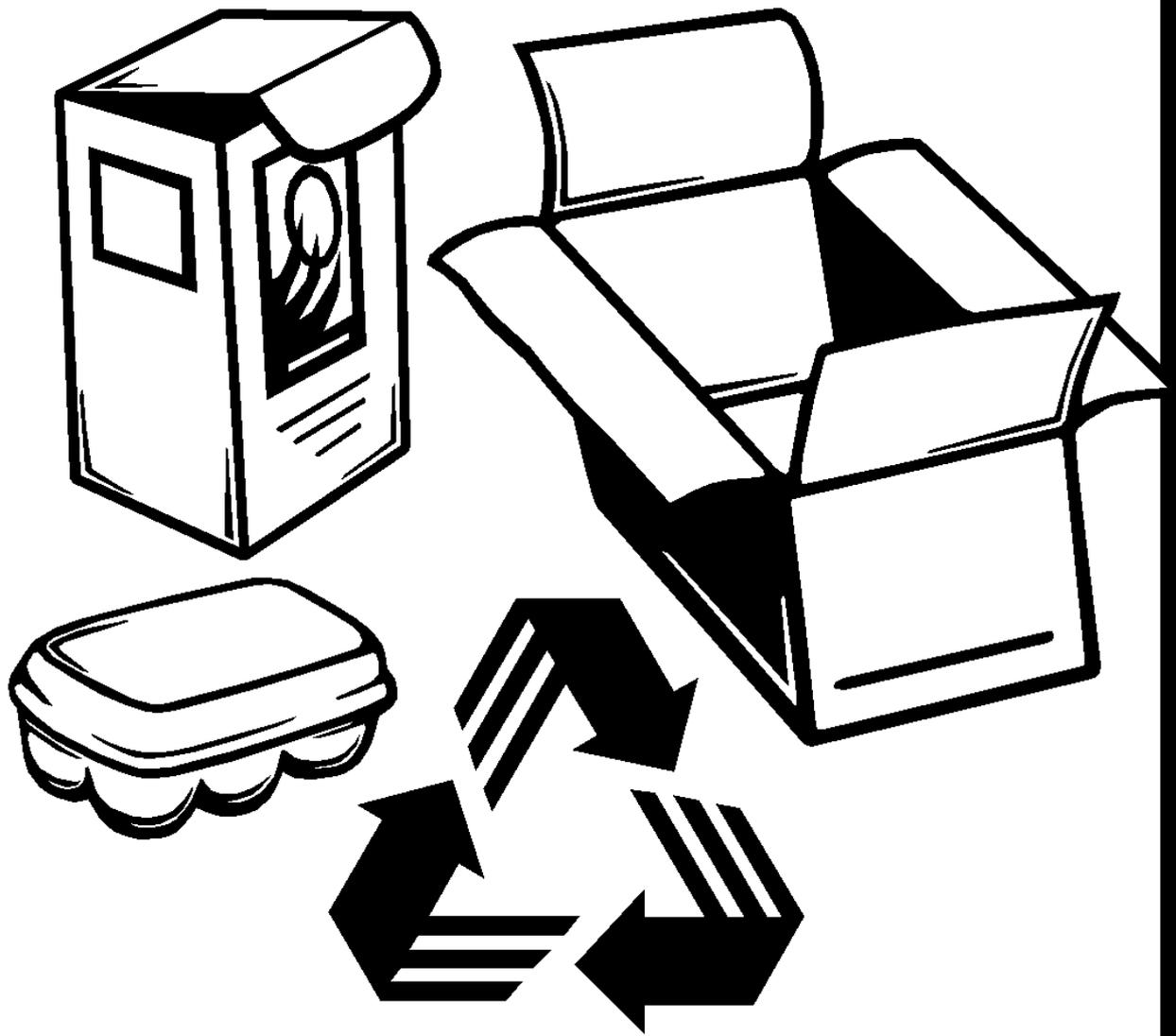
**RECYCLING BIN**



**COMPOSTABLE  
MATERIAL  
ONLY**



**Food  
organics**



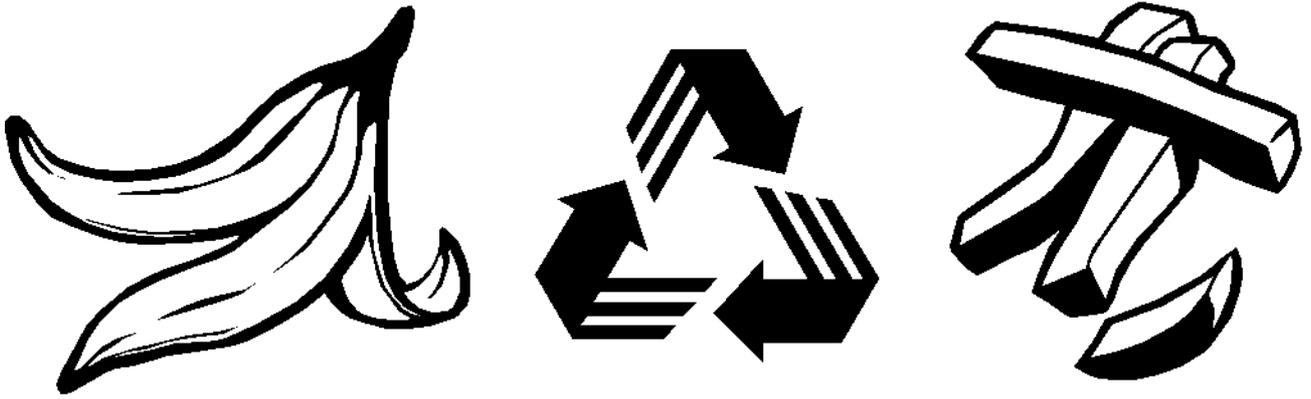
**Cardboard**



**Paper &  
cardboard**

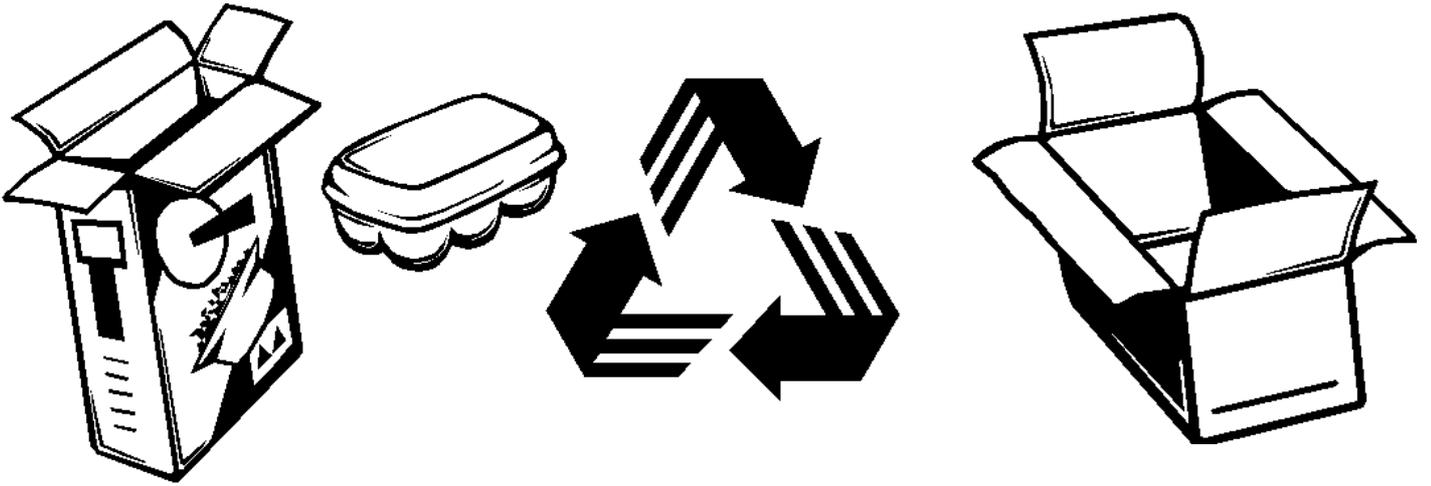


**Garbage**



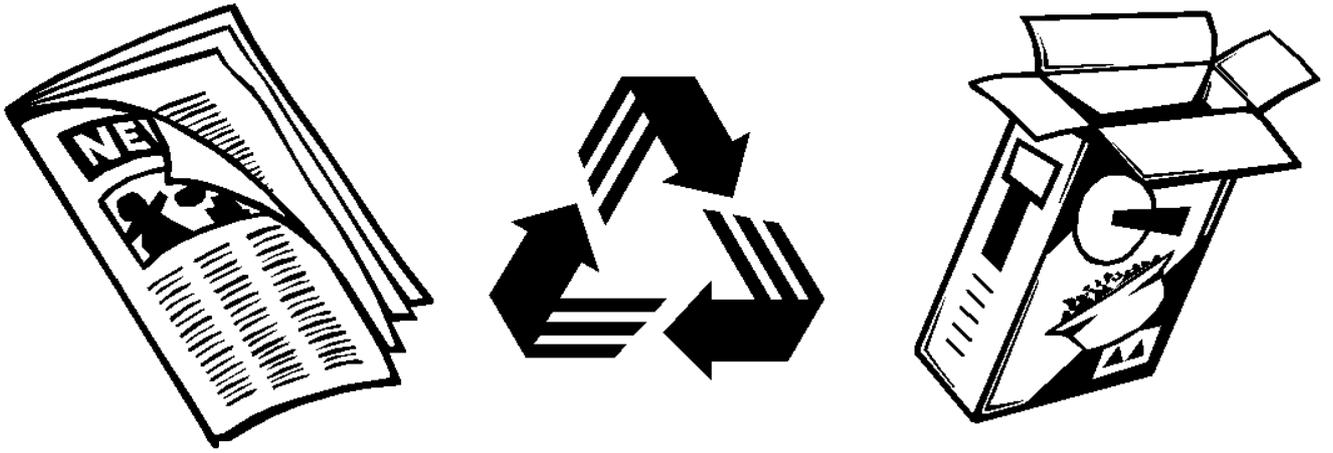
# **Food organics**

Place all food  
organics in this bin  
for processing in  
the worm farm



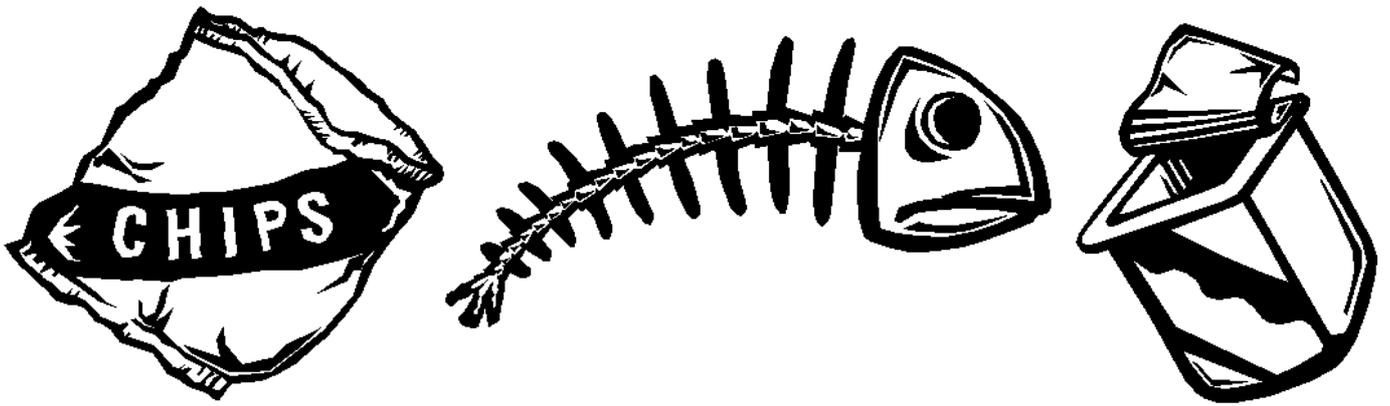
# Cardboard

Place all  
cardboard in this  
bin for processing  
in the worm farm



# **Paper and Cardboard**

Place all paper and  
cardboard in this bin  
for processing in the  
worm farm



# Garbage

Place all garbage in  
this bin that cannot  
be processed in the  
worm farm



## Appendix No. 4

### Research Case Studies – Vermiculture processing of compostable organics

Appendix No. 4  
January 2002

#### Inside This Appendix

**1** Vermiculture processing of compostable organics

**2** Research case study 1 – Feedstock acceptance trial

**5** Research case study 2 – Bench-scale vermiculture trial

**9** Definitions

Important References

Acknowledgements

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#### Vermiculture processing of compostable organics

The Recycled Organics Unit has conducted a series of research projects on the processing of organic materials using vermiculture technology.

The purpose of the research was to determine what categories of organic materials are capable of being processed via *in-vessel* vermiculture technology, and to quantify the sustainable *processing capacity* of vermiculture technology for these materials (Recycled Organics Unit, 2000).

This research program involved a literature review that provided information for the subsequent analytical trials. The vermiculture units used in the trials were designed to closely simulate conditions experienced in vertical loading, continuous-flow *in-vessel* vermiculture units.

A number of reports have documented the feasibility of using vermiculture technology for the treatment of *compostable organics* material. However, extremely limited quantitative information has been available on the processing of *food organics*.

The research performed by the Recycled Organics Unit primarily focussed on the vermiculture processing of food organics, and to a lesser extent, on complementary materials including cardboard, lawn clippings and non-woody garden organics.

Food organics is defined by its component materials as detailed in the following table:

Material	Detail
Fruit and vegetable material	
Bread, pastries and flours	Including rice and corn flours
Meat and poultry	
Fats and oils	
Seafood	Including shellfish, excluding oyster shells
Food soiled paper products	Hand towels, butter wrap etc.
Biodegradeables	Cutlery, bags, polymers
Dairy	Solid and liquid
Recalcitrants	Large bones, oyster shell, coconut shells etc.

These types of materials tend to dominate the metropolitan solid waste stream. Food organics in particular tend to dominate the commercial and industrial sector waste stream, and the diversion of this material to processing for beneficial land applications offers a range of environmental benefits.

The case studies of trials performed by the Recycled Organics Unit detailed in this Appendix include:

1. Feedstock acceptance trial
2. Bench-scale vermiculture trial

These Research Case Studies provide valuable information on the types and quantities of material that can be processed by vermiculture technology.



*“Fruit, vegetables and lawn clippings, when mixed with a cardboard bulking agent, can be successfully treated in vermiculture units”*

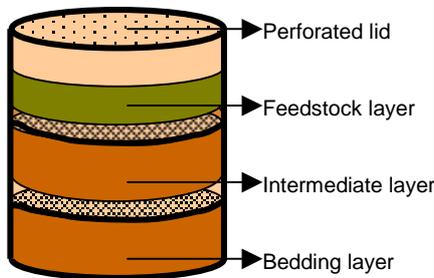
**Feedstocks**

Fruit, vegetables, lawn clippings, garden organics, mixed food organics, pastry, bread, meat/poultry, seafood and dairy products.

**Vermiculture unit size**

3 L plastic vessels with lid. 12 mm mesh (square holes) separated unit into bedding layer, intermediate feeding layer and surface applied feedstock layer.

Internal view:



**Worm stock**

Approximately 40 mature Tiger worms (*Eisenia* spp.) per unit.

**Time period**

15 days.

**Successful feedstocks**

Mixed fruit + cardboard, mixed vegetables + cardboard, lawn clippings + cardboard, garden organics.



**Research Case Study 1**

**Feedstock acceptance trial**

**Introduction**

The potential for in-vessel vermiculture units to process organic materials produced by the C&I sector (eg. food organics) has received little attention in comparison to treatment of *agricultural organics* and *biosolids*.

A number of studies have documented the processing of mixed streams of organic materials comprising vegetables, fruit, manure and *garden organics* however no credible quantitative data has been available on the treatment of food organics using vermiculture technology.

Examples of compostable organic materials produced by the C&I sector include bread/pastry from bakeries; vegetables/fruit from supermarkets; garden organics from landscaping and gardening businesses; and meat/poultry, seafood and dairy products from specialised retail outlets or food processing operations.

The processing of organic materials from the C&I sector represents a significant challenge to vermiculture technologies as unamended, these materials tend to have an inappropriate moisture and nutrient content for vermiculture processing.

Excess nutrients, water and a lack of air filled porosity can result in rapid microbial growth and the

development of *anaerobic* conditions. This can lead to problems such as odour production, worm death and even total system failure.

The addition of a carbonaceous *bulking agent* that is readily available to most C&I sector businesses – such as cardboard – to these organic materials results in a more suitable *feedstock* for vermiculture processing. This cardboard amendment improves the porosity, absorbs excess moisture and moderates the nutrient content of the organic materials so that they are more effectively processed using vermiculture technology.

**Objective**

The objective of this trial was to evaluate the ability of vermiculture to process a range of monostream organic materials that are typically produced by C&I sector enterprises over a fifteen day period.

The addition of a shredded cardboard bulking agent to problematic materials containing excess nutrients and moisture was also evaluated.

**Materials and methods**

A total of thirteen monostreams of organic materials were evaluated for acceptability by a worm population. Nine of these materials were also blended with a cardboard bulking agent giving a total of twenty two

**Plate 1.** Small-scale vermiculture vessels used in the feedstock acceptance trial (left) and garden organics treatment (right).



**Table 1.** Feedstocks used in feedstock acceptance trial and the major components of each.

Feedstock	Component
Mixed fruit*	Watermelon, honeydew, rockmelon, orange, pineapple, plum, peach, banana and apple.
Mixed vegetables*	Pumpkin, parsnip, shallot, bean sprout, tomato, onion, capsicum, lettuce, cabbage, carrot, corn, celery and avocado.
Mixed food organics*	Mixed vegetables, mixed fruit, bread, pastry and meat/poultry.
Meat/poultry*	Blood, bone, mice, fat, beef, lamb and chicken.
Seafood*	Assorted whole fish and carcasses.
Pastry*	Croissants, danishes, baklava and biscuits.
Bread*	Multi-grain bread, whole-grain bread and white rolls.
Lawn clippings*	Lawn clippings.
Mulched garden organics	Various non-woody plant species.
Dairy products*	Yoghurt, shredded cheese, butter and cream.
Paper	Shredded office paper.
Cardboard	Plain corrugated cardboard.

\* These feedstocks were also blended with a shredded cardboard bulking agent (to achieve a C:N ratio of ~20:1) to form an additional nine feedstocks.

feedstocks (Table 1).

A control feedstock consisting of vermicast was also used for comparative purposes. Shredded paper and cardboard were evaluated for their suitability as bulking agents. All feedstocks shown in Table 1 were size-reduced using a 6.5 hp garden-type shredder to a particle size of 20 mm with the exception of dairy

products and lawn clippings.

Three litres of mature and stable vermicast were loaded into clean 3 L plastic vessels used to simulate the vermiculture process (Plate 1). A layer of bedding on the bottom of the vessel was employed to simulate the bedding layer present in all in-vessel vermiculture units. The bedding layer provided a habitat for the worm population when conditions in the

feedstock were unsuitable for habitation.

Approximately 40 mature Tiger worms (*Eisenia* spp.) were subsequently inoculated into each vessel. Wire mesh, with holes large enough to support worm movement, divided each unit into three distinct layers. This partitioning was performed to aid in determining the spatial distribution of worm stock after the fifteen day period.

The location of the worms was assessed four times over the fifteen day period.

Each feedstock treatment was replicated three times and vessels were randomly ordered and positioned on benches under constant lighting and temperature conditions (20 °C).

## Results

The feedstocks that were found to be readily processed using vermiculture are shown in Table 2. These successful treatments include: mixed fruit + cardboard; mixed vegetables + cardboard; lawn clippings + cardboard; and garden organics.

The organic material to cardboard mixing ratio is also shown in Table 2. Note that due to the high nitrogen content of seafood, meat/poultry and dairy, a significant quantity of

**Table 2.** Monostream organics that can and cannot be readily processed in vermiculture units, as determined by the feedstock acceptance trial.

Feedstock	Treatable in vermiculture unit		Organics to cardboard mixing ratio (w/w)
	Without cardboard	With cardboard	
Fruit	no	yes	21:1
Vegetables	marginal	yes	21:1
Lawn clippings	no	yes	21:1
Garden organics <sup>1</sup>	-	yes	-
Mixed food organics <sup>2</sup>	no	no	22:1
Pastry	no	no	3:1
Bread	no	no	3:1
Meat/poultry	no	no	0.9:1
Seafood	no	no	1:1
Dairy organics	no	no	2:1

<sup>1</sup>Garden organic feedstock was not blended with a bulking agent. <sup>2</sup>Mixed food organics comprised a mixture of meat, poultry, pastry, bread, vegetables and fruit. <sup>3</sup> The ability of vermiculture units to treat feedstocks was determined by assessing the spatial distribution of the worm stock in the bedding, feeding layer and in the surface applied feedstock over a period of 15 days.

cardboard was required for blending with these raw feedstocks.

The cardboard bulking agent is important as excessive nitrogen levels in feedstock can result in considerable ammonia production during microbial decomposition. Ammonia is highly toxic to worms and hence a bulking agent is required to dilute the nitrogen component to form a feedstock suitable for habitation by the worm population.

The spatial distribution of the worm population was determined and used as an indication of the suitability of the feedstock for treatment in a vermiculture unit (Figure 1).

If a significant proportion of worms were found to migrate out of the bedding layer and into the intermediate feeding zone or the feedstock layer over the fifteen day period, the feedstock was considered

to be acceptable. In addition to this spatial distribution of worms, if significant worm mortality did not occur, the feedstock was considered to be acceptable.

Feedstocks that were found to be unsuitable for worm consumption included food organics + cardboard; meat/poultry; meat/poultry + cardboard; seafood; seafood + cardboard; dairy; dairy + cardboard; pastry; pastry + cardboard; bread; and bread + cardboard.

These conclusions were drawn by observing that significant worm mortality occurred in these unacceptable feedstocks that did not occur in the acceptable feedstocks or in the vermicast control. Also, that considerable proportion of the worm population in these treatments remained in the bedding layer.

**Conclusions**

This study found that fruit, vegetables and lawn clippings, when mixed with a cardboard bulking agent, could be successfully applied as feedstocks in vermiculture units.

Garden organics without a bulking agent amendment are also suitable for processing in vermiculture units.

**Source**

Recycled Organics Unit (2000)

**Contact details**

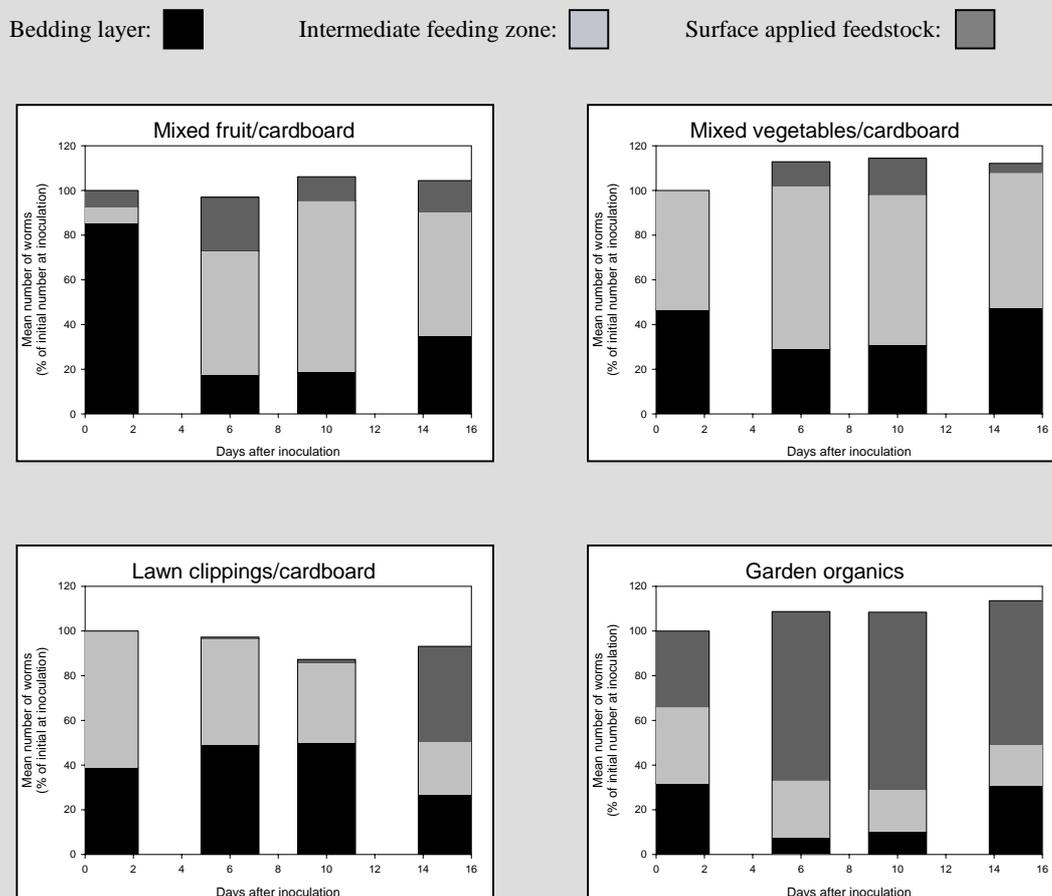
Recycled Organics Unit  
Building B11b,  
The University of New South Wales,  
UNSW Sydney 2052

Internet:

<http://www.recycledorganics.com>

(report available on-line)

**Figure 1.** Spatial distribution of worm stock in the small-scale vermiculture units that were found to be suitable for worm consumption over a period of 15 days.



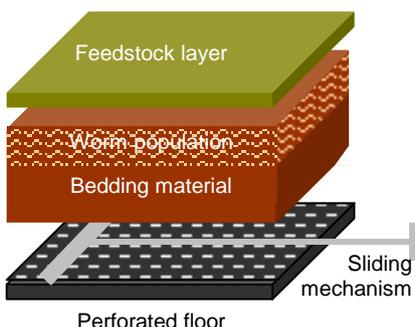
“Monitoring of worm activity, feedstock accumulation, oxygen concentration and unit temperature is needed to ensure the continuous successful operation of a vermiculture unit”

**Feedstocks**

Fruit + cardboard, vegetables + cardboard, mixed food organics + cardboard, pastry/bread + cardboard, lawn clippings/garden organics, meat/poultry + cardboard.

**Vermiculture unit size**

84 L plastic rectangular containers (0.35 × 0.53 × 0.45 m). Surface feeding area of 0.19 m<sup>2</sup> and maximum depth of 0.45 m. Perforated floor with sliding grate to allow harvesting of vermicast. Internal view:



**Worm stock**

1.9 kg of Tiger worms (*Eisenia* spp.) per unit.

**Time period**

10 weeks.

**Successful treatments**

Fruit + cardboard, vegetables + cardboard, food organics + cardboard, pastry/ bread + cardboard, lawn clippings/garden organics.



## Research Case Study 2

### Bench-scale vermiculture trial

**Introduction**

The bench-scale vermiculture trial assessed the feasibility of treating a range of monostream organics produced by the C&I sector in bench-scale, vertical loading vermiculture units.

This trial was designed to simulate conditions likely to be experienced in mid-scale vermiculture processing by C&I sector organisations.

The feedstock acceptance trial (Research case study 1) examined the organic materials that are suitable for processing in vermiculture units and this trial continued by determining the maximum loading rate for these suitable feedstocks.

The maximum loading rate was determined by monitoring a number of environmental variables that impact on system performance, such as bed temperature, pH, electrical conductivity and oxygen concentration.

The feedstocks examined in this trial included those that were considered successful in the feedstock acceptance trial. Mixed food organics, pastry, bread and meat/poultry, although considered difficult to process in the feedstock acceptance trial, were also evaluated

by the bench-scale trial.

**Objective**

The objective of this trial was to determine the rate at which the organic feedstocks, determined as suitable feedstocks (Case study 1), can be added to vermiculture units for processing.

This rate is termed the maximum loading rate and is expressed as the amount of material that can be applied per square metre of bedding surface per week (kg/m<sup>2</sup>/wk).

The quality of the final vermicast product was also assessed.

**Materials and methods**

A total of six feedstocks were investigated in this trial (shown in Table 3). The trial occurred over a period of ten weeks.

Feedstocks were size reduced to a particle size of less than 20 mm and blended, with the exception of the lawn clippings/garden organics feedstock, with shredded cardboard to achieve a *C:N ratio* of approximately 20:1.

Moisture was also added to some feedstocks to achieve a suitable moisture content (80-90% w/w) as determined by the ‘fist test’.

Vertical-loading, continuous-flow

**Plate 2.** Bench-scale vermiculture units used in the trial (left) showing the perforated bottom and sliding mechanism (right).



vermiculture units (Plate 2) were used in this trial that were considerably larger than the small-scale units used in the feedstock acceptance trial (Research case study 1). The bench-scale units consisted of a loading volume of 84 L. The units were rectangular with a surface feeding area of 0.19 m<sup>2</sup> and a maximum depth of 0.45 m.

The vermiculture units also featured a perforated floor with a sliding grate mechanism to assist in the harvesting of the vermicast product.

Feedstocks were applied three times per week (Monday, Wednesday and Friday) at three loading rates: light, moderate and high.

For feedstocks that were found to be readily treatable in the feedstock acceptance trial (Research case study 1), materials not containing meat, dairy or yeast-based products, these loading rates were 10, 17.5 and 25 L/m<sup>2</sup> (per application) for light, moderate and heavy rates respectively.

Feedstocks that were found to be difficult to treat, meat/poultry, pastry/bread and food organics, were

applied at 5, 10 and 15 Lm<sup>2</sup> (per application) for light, moderate and heavy rates respectively.

Each feedstock treatment was replicated three times, randomised and incubated under standard laboratory conditions.

A comprehensive monitoring regime was employed to assess the performance of the vermiculture units under the various feedstock rates.

The following parameters were monitored: ambient room temperature; bed temperature; bed oxygen concentration; worm activity; accumulation of feedstock; bed pH and electrical conductivity.

At the completion of the trial, the final vermicast product was assessed for quality and the worm biomass was removed and weighed (Plate 3).

### Results

The maximum processing capacities (kgm<sup>2</sup>/wk) for the successful feedstocks, shown in Table 4, were found to be at the lower end of the range of loading rates applied.

The successful treatments included fruit + cardboard, vegetables + cardboard, mixed food organics + cardboard, and bread/pastry + cardboard at the light application rate for each. The lawn clippings/garden organics treatments survived at all application rates.

Although the mixed food organics feedstock was found to be unsuccessful as a feedstock in the feedstock acceptance trial (Research case study 1), this feedstock could be processed in this trial at a much lower rate. Mixed food organics is an important feedstock for treatment by vermiculture units as it represents a residual organic stream that would be common to C&I sector organisations.

Unsuccessful treatments included the meat/poultry + cardboard treatment at all application rates and the moderate and heavy rates for fruit + cardboard, vegetables + cardboard, mixed food organics + cardboard and bread/pastry + cardboard.

Treatment failure was indicated by observing and monitoring a number of parameters. The hierarchy for this determination of treatment failure was: worm activity; quantity of

**Table 3.** Feedstocks used in the bench-scale vermiculture trial, including the major components of each and the addition of a bulking agent and moisture.

Feedstock	Component	Bulking agent added	Moisture added	Organics to cardboard mixing ratio (w/w)
Mixed fruit	Apple, watermelon, rockmelon, orange, grape, pear, nashi, persimmon, nectarine, plum, pineapple, peach, paw paw, banana, mandarine.	yes	no	21:1
Mixed vegetables	Cabbage, lettuce, tomato, carrot, corn, pumpkin, capsicum, shallot, bean sprout, celery, onion, endive, bok choy.	yes	no	21:1
Mixed food organics	Mixed vegetables, mixed fruit, bread/pastry and meat/poultry.	yes	no	22:1
Bread/pastry	Croissants, muffin, danish, baklava, sweet buns, white/multigrain/wholemeal/rye/sourdough loaves and rolls.	yes	yes	3.4:1
Meat/poultry	Blood, bone, mice, fat, beef, lamb and chicken.	yes	yes	0.9:1
Lawn clippings and mulched garden organics	Non-woody plant materials (leaves, stems and twigs of various plant species), lawn clippings.	no	yes	-

**Table 4.** Loading rates for feedstocks used in the bench-scale vermiculture trial and the survival of each feedstock based on performance indicators.

Feedstock	Loading rate			Surviving treatment
	Class	Per application (L/m <sup>2</sup> )	Per week (kg/m <sup>2</sup> /wk)	
Fruit + cardboard	Light	10	24.79	yes
	Moderate	17.5	43.37	no
	Heavy	25	61.97	no
Vegetables + cardboard	Light	10	24.07	yes
	Moderate	17.5	42.11	no
	Heavy	25	60.16	no
Mixed food organics + cardboard	Light	5	9.95	yes
	Moderate	10	19.89	no
	Heavy	15	29.84	no
Bread/pastry + cardboard	Light	5	4.74	yes
	Moderate	10	9.47	no
	Heavy	15	14.21	no
Meat/poultry + cardboard	Light	5	4.09	no
	Moderate	10	8.18	no
	Heavy	15	12.27	no
Lawn clippings and mulched garden organics	Light	10	5.75	yes
	Moderate	17.5	10.06	yes
	Heavy	25	14.37	yes

unprocessed feedstock and chemical/environmental monitoring data.

Observations of worm activity were found to be very important for determining when a vermiculture unit was approaching failure.

The nutrient content of the final vermicast product from the various treatments was high indicating that the vermicast product could be used

to improve soil conditions and increase plant growth.

Microbiological tests, however, indicated that all vermicast contained high levels of the faecal organism *E. coli*, even in units that were loaded with feedstocks not containing this organism (eg. garden organics/lawn clippings). This presence may have occurred as the initial vermicast bedding was produced using pig

manure as the primary food source.

The high presence of *E. coli* within the final vermicast product would result in the product failing the Australian Standard for composts, soils conditioners and mulches (AS 4454, 1999). Restrictions would consequently apply on the use of this end product.

The worm biomass for each treatment was determined at the

**Plate 3.** Separation of worms and vermicast using a trommel screen to determine the worm biomass at the completion of the trial. The worms and vermicast are fed into the trommel screen (left) which rotates (centre) and separates the worms from the vermicast (right).



completion of the trial and indicated whether an increase or decrease in the worm population had occurred. All treatments exhibited an increase in worm biomass with the exception of the lawn clippings/garden organics treatment (all loading rates) and the meat/poultry + cardboard treatment (light loading rate).

Processing capacity was determined for each treatment that represented the maximum gross mass of a feedstock (kg) that can be applied per unit area (m<sup>2</sup>) per unit time to a vermiculture unit under managed environmental conditions.

Processing capacity usually varies with environmental conditions, loading rates (including feedstock variables) and carrying capacity (including worm species employed).

The maximum processing capacity for the C&I sector organics that were found to be treatable in vermiculture units from this trial are summarised in Table 5. Note that these successful loading rates are much lower than expected.

The maximum processing capacities for the feedstocks are supported by extensive chemical and environmental data in the form of bed temperatures, oxygen concentrations, pH and electrical conductivity measurements.

The processing capacity is also

highly dependent on the size and activity of the worm population. The worm biomass required at inoculation for a successful unit is also shown in Table 5.

### Conclusions

The bench-scale vermiculture trial examined the feasibility of treating six monostream organic materials at various loading rates with Tiger worms (*Eisenia* spp.) in bench-scale vermiculture units under controlled laboratory conditions. The maximum processing capacities (kg/m<sup>2</sup>/wk) were determined by monitoring worm biomass and key environmental variables.

Five of the six feedstocks were successfully treated in vermiculture units. Each of these were the light loading rates for fruit + cardboard, vegetables + cardboard, mixed food organics + cardboard, pastry/bread + cardboard and lawn clippings/garden organics.

Processing capacities and worm biomass carrying capacities were determined for each of these treatments. Maximum processing capacities ranged from 4.7 kg/m<sup>2</sup>/wk for pastry/bread + cardboard mixes to 24.8 kg/m<sup>2</sup>/wk for fruit + cardboard mixes.

Oxygen, temperature, pH, and electrical conductivity levels present in the bedding material were all

monitored, in conjunction with worm activity and the depth of unprocessed feedstock, to determine the on-going performance of vermiculture units fed with specific quantities of feedstock.

A monitoring hierarchy was developed that proved valuable for assessing system performance. This hierarchy was: observing worm activity; feedstock accumulation; oxygen concentration and unit temperature.

The microbiological quality of the vermicast produced by the successful treatments was not high, possibly because the vermicast was not allowed the opportunity to undergo further stabilisation after harvesting.

### Source

Recycled Organics Unit (2000)

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**Table 5.** Maximum recorded processing capacities for the five successful feedstocks in the bench-scale vermiculture trial, detailing the processing capacity of blended feedstock material, the proportion of raw feedstock material and the quantity of worm biomass required to inoculate a vermiculture unit to treat these feedstocks.

Successful feedstock	Worm biomass required at inoculation to maximise processing capacity (kg/m <sup>2</sup> )	Maximum processing capacity including cardboard (kg blended material /m <sup>2</sup> /wk)	Maximum processing capacity (kg raw feedstock material /m <sup>2</sup> /wk)
Fruit + cardboard	18.5	24.79	23.66
Vegetables + cardboard	12.3	24.07	22.98
Mixed food organics + cardboard	16.3	9.95	9.52
Pastry/bread + cardboard	13.0	4.74	2.24
Lawn clippings/garden organics	6.2	5.75	5.75

# Definitions\*

## Processing capacity

The maximum amount (mass or volume) of feedstock that can be added to a processing technology (e.g. composting technology) per unit time (e.g. per week) without causing system failure. System failure is evident when the processing technology produces problematic environmental emissions and/or declines in processing efficiency and/or produces product of unacceptable quality.

## In-vessel

A containerised unit in which vermiculture, compost or anaerobic digestion-based processes are performed. Containers vary in size, configuration, degree of automation and level of process control. In-vessel systems are often used for treatment of putrescible organics in populated areas as they have minimal or no significant impact on the environment (eg. through the generation of odour, leachate or attraction of pests or vermin).

## Compostable organics

Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.

## Food organics

The Food Organics material description is defined by its component materials, which include: fruit and vegetable material; meat and poultry; fats and oils, seafood (including shellfish, excluding oyster shells); recalcitrants (large bones >15mm diameter, oyster shells, coconut shells etc.); dairy (solid and liquid); bread, pastries and flours (including rice and corn flours); food soiled paper products (hand towels, butter wrap etc.); and biodegradeables (cutlery, bags, polymers). Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the *compostable organics* stream.

## Agricultural organics

Any residual organic materials produced as by-products of agricultural and forestry operations, including: weeds (woody and non-woody); animals (processing residuals, stock mortalities, pests), crop residuals (woody and non-woody), and manures.

## Biosolids

Organic solids or semi-solids produced by municipal sewage treatment processes. Solids become biosolids when they come out of an anaerobic digester or other treatment process and can be beneficially used. Until such solids are suitable for beneficial use they are defined as waste-water solids. The solids content in biosolids should be equal to or greater than 0.5% weight by volume (w/v). Biosolids are commonly co-composted with garden organics and/or residual wood and timber to produce a range of recycled organics products.

## Garden organics

The Garden Organics material description is defined by its component materials including: putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs; stumps and rootballs. Such materials may be derived from domestic, Construction and Demolition and Commercial and Industrial sources. Garden Organics is one of the primary components of the *compostable organics* stream.

## Anaerobic

In the absence of oxygen, or not requiring oxygen.

## Bulking agent

An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably. See also composting amendment.

## Feedstock

Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

## Carbon to nitrogen (C:N) ratio

The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

\*Recycled Organics Unit (2001)

## Important references

- Recycled Organics Unit (2000) Processing of Commercial and Industrial Organics in Vermiculture Systems. Report for Southern Sydney Waste Board, October 2000.
- Recycled Organics Unit (2001) Recycled Organics Industry Dictionary & Thesaurus: standard terminology for the NSW recycled organics industry. 2<sup>nd</sup> Edition. Internet publication: <http://www.rolibrary.com>
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