This initiative is supported by **PacWastePlus**-a 72 month project funded by the European Union (**EU**) and implemented by the Secretariat of the Pacific Regional Environment Programme (**SPREP**) **to sustainably and cost effectively improve regional management of waste and pollution.**

Guidelines and Standards for Composting and Compost Quality for Pacific Island Countries and Timor-Leste

December 2022

This Composting Standard provides an overview of management activities for consideration when planning and designing organics recycling facilities in the Pacific and Timor-Leste.

SPREP Library Cataloguing-in-publication data

Guidelines and standards for composting and compost quality for Pacific Island Countries and Timor-Leste – Apia, Samoa : SPREP, 2022.
39 p. 29 cm.

ISBN: 978-982-04-1201-9 (print)
978-982-04-1202-6 (ecopy)

1. Recycling (Waste, etc.) – Technical reports – Oceania.
2. Waste management – Handbooks, manuals - Oceania.
I. Pacific Regional Environment Programme (SPREP). II. Title.
363.7280961

Disclaimer: This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of SPREP and do not necessarily reflect the views of the European Union. This document has been compiled in good faith, exercising all due care and attention. SPREP does not accept responsibility for inaccurate or incomplete information.

Acknowledgment: The PacWastePlus programme acknowledges Mr Johannes Biala, CROWN and Mr Angus Johnston, BioCarbon Soil for their contributions towards the development of this *Guidelines and Standards for Composting and Compost Quality* publication. This guidance is based on an Environment Protection Authority document titled Designing, constructing and operating composting facilities (*EPA Victoria 2017*).

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Our vision: A resilient Pacific environment sustaining our livelihoods and natural heritage in harmony with our cultures.

PacWastePlus Programme

The Pacific – European Union (EU) Waste Management Programme, PacWastePlus, is a 72-month programme funded by the EU and implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP) to improve regional management of waste and pollution sustainably and cost-effectively.

About PacWastePlus

The impact of waste and pollution is taking its toll on the health of communities, degrading natural ecosystems, threatening food security, impeding resilience to climate change, and adversely impacting social and economic development of countries in the region.

The PacWastePlus programme is generating improved economic, social, health, and environmental benefits by enhancing existing activities and building capacity and sustainability into waste management practices for all participating countries.

Countries participating in the PacWastePlus programme are: *Cook Islands, Democratic Republic of Timor-Leste, Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, Republic of Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu*.

Key Objectives

Outcomes & Key Result Areas

The overall objective of PacWastePlus is "*to generate improved economic, social, health and environmental benefits arising from stronger regional economic integration and the sustainable management of natural resources and the environment*".

The specific objective is "*to ensure the safe and sustainable management of waste with due regard for the conservation of biodiversity, health and wellbeing of Pacific Island communities and climate change mitigation and adaptation requirements*".

Key Result Areas

- **Improved** data collection, information sharing, and education awareness
- **Policy & Regulation** - Policies and regulatory frameworks developed and implemented.
- **Best Practices** - Enhanced private sector engagement and infrastructure development implemented
- **Human Capacity** - Enhanced human capacity

Learn more about the PacWastePlus programme by visiting

www.pacwasteplus.org

Our Regional Organics Project

Organic material is biodegradable matter such as kitchen scraps (*food*); garden cuttings, grass and branches; and paper. Combined data from 13 waste audits in the Pacific found that approximately 40% of waste disposal to our landfills and dumps is organics.

When processed correctly (*in an "aerobic" or oxygen-filled environment*), organic materials can produce valuable nutrient rich products, such as compost, suitable for soil enhancement and food cultivation. However, when intermingled with other waste and disposed in a landfill or dump (*an "anaerobic" environment*), organic material can release toxic leachate and generate methane gas.

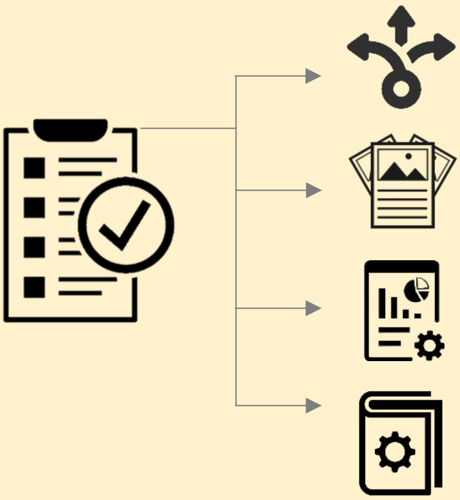
The purpose of this regional project is for Pacific stakeholders, now and into the future, to have practical and resources and decision-support needed to design and implement their own effective organics management solutions, appropriate for their own context and communities. Fiji, FSM, RMI, and the Solomon Islands have chosen organics as a priority or secondary priority of their PacWastePlus country project.

The Organics regional project will review existing Organic facilities from the region, undertake technical research, and adopt findings and resources from Country Projects to develop:

- a "Minimum Standard" technical framework for countries to have as a resource when designing and operating their own organics processing facility
- a "decision guidance resource/tool" – to guide informed decision making around processing system design/technologies, size and equipment requirements, operational processes, etc to suit any context and scale
- on-line training package to guide the application of "decision guidance resource/tool"
- resources to communicate with and empower communities to convert their organic "waste" to a valuable "resource" using appropriate solutions available (*i.e., backyard, on-farm, community-level, or national-level organics processing*).

This **Composting Standard** is part of a range of resources to assist Pacific Island Countries and Timor-Leste to divert organic materials from landfill into a beneficial use.

Use this **Composting Standard** in **combination with the other resources** to guide all aspect of organics management, from choosing the appropriate management solution for your compost, operating your facility, and complying with recognised standards.



RELATED RESOURCES

Decision support tools to support the selection of suitable organics management solution for the Pacific and Timor-Leste

A **series of Factsheets** introducing eight types of organics management solutions appropriate for the Pacific and Timor-Leste context

Framework Operations Plans and editable **Design Drawings** for eight organics management solutions

A **Composting Handbook** providing practical information for composting common organic materials found in the Pacific and Timor-Leste

Learn more about our regional organics management programme by visiting

https://pacwasteplus.org/regional-project/organics-management/

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Glossary

Term	Description
Aerobic process	An aerobic process is a composting process with oxygen or air, as opposed to an anaerobic process that does not require it.
Anaerobic process	An anaerobic process is a composting process in which organic matter is degraded by micro-organisms in the absence of oxygen.
Bacteria	Bacteria are the smallest living organisms and the most numerous in compost; they make up 80 to 90% of the billions of microorganisms typically found in a gram of compost. Bacteria are responsible for most of the decomposition and heat generation in compost. They are the most nutritionally diverse group of compost organisms, using a broad range of enzymes to chemically break down a variety of organic materials.
Bioaerosol	Bacteria or fungi in drops of mist in the air.
Carbon	Carbon is an energy-element and is one of the basic building blocks of life. Plants are nearly half carbon. In composting, carbon provides an energy food that sustains the microbes. Some organic materials, like fallen palm fronds and flax/tree litter, dead clippings from yard/community beautification projects, and paper / cardboard, have a lot of carbon.
Carbon to Nitrogen (C:N) ratio	The proportion or ratio of the amount of carbon to the amount of nitrogen contained in organic materials. This ratio can be calculated for a mix of different materials to be composted. Carbon is the main ingredient in organic material. It is used for energy and building bodies by all living things. Nitrogen is an important ingredient in organic material. Used for building amino acids in living things that are used as building blocks in bodies.
Compost	Organic material that has been broken down during composting and now looks and smells like dark, fertile garden soil.
Composting	Composting is a natural biochemical process in which naturally occurring microorganisms transform raw organic materials into compost products. Although these processes are natural and will happen on their own, compost facility operators are recommended to understand and control the process to produce the desired compost product. provides ideal environmental conditions for bacteria, fungi, and other decomposing organisms such as worms and nematodes.
Composting facility	Facility that accepts compostable material, and processes this into a recycled organic product (compost) through either aerobic or anaerobic processes.
Compostable material	Material that was once part of a living thing. Includes: clippings from yard/community beautification projects, fallen palm fronds and flax/tree litter, peelings and scraps from food preparation, by-product from food production facilities, manure, and paper / cardboard. Does not include petrochemicals. Has the same definition as organic material.
Fungi	A group of spore-producing organisms feeding on organic matter. Fungi include moulds, yeast, and mushrooms. Fungi are heterotrophs (cannot make their own food) and have important roles in nutrient cycling in an ecosystem.
Food organics	Residues from food, which can be from food preparation, such as fruit and vegetable peelings and trimmings, or leftover, unconsumed food. Spoiled food that is no longer fit for consumption. Note: References to composting food organics in this FOP also apply generally to other inputs that are moist and high in nitrogen, such as animal manures.

Term	Description
Front End Loader (FEL)	Tractor with hydraulic bucket on the front that mechanically lifts and moves large quantities of material. General term that also covers bobcats and telehandlers.
Garden organics	Vegetation residues from gardens, parks, or landscape management. Can include grass clippings, leaves, weeds, crop residues, twigs, branches, vines, palm fronds,
Leachate	Liquid that seeps out of a compost pile.
Microbes	Tiny living organisms including bacteria and fungi which process organic materials into compost.
Nitrogen	Nitrogen is a protein-element essential for growth and reproduction in both plants and animals. In composting, microbes use nitrogen to grow and reproduce. Some organic materials, like fresh clippings from yard/community beautification projects, peelings and scraps from food preparation, and manure, have a lot of nitrogen.
Organics / Organic Material	Organics or Organic Material are materials that were once part of a living thing. Includes: clippings from yard/community beautification projects, fallen palm fronds and flax/tree litter, peelings and scraps from food preparation, by-product from food production facilities, manure, and paper / cardboard. Does not include petrochemicals. Has the same definition as compostable material.
Odour	Bad smells. In compost facilities they come from not enough oxygen, or too much nitrogen.
Palm Organics	Trunks and leaves (fronds) from palm trees and similar species. Contains tough fibres that can be hard to work with.
Parasite	A living thing that steals from another living thing to stay alive
Pathogen	A microorganism (bacteria, fungi, virus) that can cause disease or death in plants, animals, or humans.
Physical contaminants	Non-organic materials that cannot be composted, including all types of plastic, glass, metal, rubber, and stones.
Shredder	Machine designed to break up woody organic material into smaller pieces. While chippers produce a slightly different output a reference to a shredder in this FOP is also a reference to a chipper.
Turning	Mixing and fluffing up of composted material. Turning often involves moving of the material, (e.g., from one composting bin to another, or from the centre of a composting pile to the outside).
Virus	An ultramicroscopic, metabolically inert, infectious agent that replicates only within the cells of living hosts, mainly bacteria, plants, and animals. Many viruses cause diseases as part of their reproduction process.
Windrow	A long pile (row) of organic material undergoing the composting process

1 Summary for Composting Facilities

Organic recycling activities such as composting is generally perceived as positive in its impact; it reduces waste disposed to landfill, minimises the generation of methane and leachate, and produces a valuable nutrient-rich material which can increase soil quality and crop yield.

However, when not undertaken appropriately, composting may pose a risk to the environment, human health, and the amenity of residents. The larger a facility is, the higher the potential risk and severity.

To minimise risks, generic guidelines and standards for composting and compost quality are presented in this Composting Standard to guide the planning, design, and operation of a compost facility. This guidance is provided in addition to any existing applicable regulations, rules, or guidelines for organics recycling, or for managing factors such as release of odour, worker health and safety, etc. present in any Pacific Island Country. Country regulations, rules, or guidelines must be complied with in the first instance. This Composting Standard document is recommended to be used in addition to, or in the absence of, any country regulations.

Recommended standards for planning, designing, and operating a compost facility is summarised in **Table 1.**

Table 1: Summary of Recommended Standards for Operating a Compost Facility

Recommended Guidelines and Standards	Recommended Actions	For more information
Organics recycling facilities should not:		
Cause environmental damage, particularly to surface and groundwater	• Construct roof or cover to protect compost from rain events • Instal impervious or sealed surface for areas of the site where feedstock is received, mixed and processed, and product is stored • Installing a product mixing area where excessively moist feedstock is mixed with drier feedstock • Construct bunding and interception drains, storage tanks, ponds to collect run off from process and storage areas	**Section 5.2**
Cause offensive odour for neighbours	• Fit and maintain appropriate odour control equipment • Develop and implement an odour management plan • Create a balanced feedstock recipe • Train staff to prepare and process material according to best practice • Locate facility at least 200 m from sensitive areas such as residential houses and schools.	**Section 5.3**
Generated compost products should not spread pathogens and weeds, and is fit for purpose	• Ensure all compost material has been effectively pasteurised (see **Section 7.1.1**) • Ensue the compost does not become re-contaminated	**Section 5.5**
Pose a risk for spreading pathogens or weeds	• Ensure all compost material has been effectively pasteurised (see **Section 7.1.1**) • Conduct appropriate quality assurance • Ensue the compost does not become re-contaminated	**Section 5.5**

Recommended Guidelines and Standards	Recommended Actions	For more information
Accept organic materials that are contaminated or are unsuitable for processing at your facility	• Deliver clear community education and engagement messages • Establish a clear process and equipment to simplify process for collection / delivery of material to the compost facility • Develop and enforce controls for collection contractors • Check incoming organic materials for contaminants materials before unloading. • Reject loads of material where the level of contamination is unacceptable	**Section 6**
The composting process should ensure:		
Temperatures are recorded and reach levels above 55 °C for prolonged periods to ensure pasteurisation	• Closely monitor composting process (time and temperature as specified in **Table 3**) and keep records to demonstrate finished compost has been pasteurised and therefore free of weeds and pathogens	**Section 7.1**
Moisture content of the composting material is in the desired range	• Check the moisture content of composted material by visually inspecting the pile or handling the material and completing a hand squeeze test (**Figure 5**)	**Section 7.2**
Staff are not at risk of injury or ill-health	• staff to utilise appropriate PPE including gloves, mask, and dust resistant eye protection • staff to wash hands after handling organic materials or compost and wash work clothing regularly • staff trained in operating equipment and comply with machinery safety controls • segregation operation of vehicles / equipment and pedestrians though appropriate site layout, traffic control measures, and barriers and guarding • fit vehicles and equipment with warning lights and reversing alarms	**Section 8**

A template Composting Monitoring form can be found here to use as a guide to track and monitor your composting process.

2 INTRODUCTION

Composting is a biological process for processing organic materials and converting it into beneficial products for soil quality and crop yield. Composting is well understood have beneficial impacts for waste management and land management applications, including increased soil properties and plant growth.

Notwithstanding the value of composting, organics recycling activities, when not undertaken appropriately, may pose a risk to the environment, human health, and the amenity of residents. If the composting process is undertaken improperly, recycled organic products may negatively impact plant growth, spread weeds or pathogens, or even kill plants. In some rare circumstances, recycled organics can also be the cause of environmental pollution, either through the introduction of pollutants, or through loss of nutrients, which can be above ground (*erosion, overland flow*) or below ground (*leaching*).

In many countries, regulations, guidelines, and product quality standards (*standards*) have been established for commercial scale (*usually greater than 1 tonne/day*) organics recycling activities, including the sale/use of recycled organic products, to minimise risks to the environment, human health, and amenity.

A 'minimum standard' creates and preserves confidence in composting as acceptable options for processing organic materials and the use of generated recycled organic products.

This document presents minimum standards for accepting and processing organic inputs and the use of generated compost and digestate, specific for the Pacific and Timor-Leste context. The requirements and standards presented are designed to manage the common impacts to environment, human health, and amenity that may be experienced.

The minimum standards include:

- Requirements for acceptance and handling of inputs
- Requirements for process monitoring and control, including pasteurisation
- Practical field testing prior to product release
- Measures for mitigation of impacts on environment and human health
- Management of risks to worker health and safety

3 Who can use this Standard

This Composting Standard is recommended for compost facility operators in Pacific Island Countries and Territories and Timor-Leste. Compost facility operators in other Small Island Developing States with similar vegetation and climate may also benefit from using these standards.

This Composting Standard is recommended for operations processing more than 1 tonne/day of organics material. At this scale, potential detrimental impacts are large enough that the full range of design and operational risk mitigation measures recommended in this document can be applied. For smaller facilities the scale of potential detrimental impacts is such that not all measures will be practical or necessary.

This Pacific Composting and Compost Standard can be used in combination with the Pacific Organic & Ethical Trade Community (POETCom) Pacific Organic Standard, which provides guidance for organic production and processing in Pacific islands countries and territories.

The POETCom standard can be obtained here:
https://www.organicpasifika.com/poetcom/membership/pacific-organic-standard/

4 How to use this Standard

This Composting Standard provides an overview of management activities for consideration when planning and designing organics recycling facilities in the Pacific and Timor-Leste.

This Composting Standard can be used for guidance for planning, designing, and operating an organic composting facility, in combination with local rules and regulations in each country where they exist.

This Composting Standard is part of a range of resources to assist Pacific Island Countries and Timor-Leste to divert organic materials from landfill into a beneficial use. Use this Composting Standard in combination with the other resources to guide all aspect of organics management, from choosing the appropriate management solution for your compost, operating your facility, and complying with recognised standards.

5 Regulatory Requirements

Organics compost facilities, when not operated efficiently, may pose a risk to the environment, human health, and the amenity of residents through surface water run-off, or the generation of odour, dust, and noise.

The following chapters summarise these impacts and describe how to consider the risk, and provides a minimum standard operational risk mitigation measures that may be employed to manage these impacts.

5.1 Facility Location

The appropriate locating of a proposed facility will be determined at the planning stage to ensure the facility will not be negatively affected by, or have a negative effect on, surrounding land uses.

Furthermore, appropriate locating may provide benefits for local communities, through generation of jobs, and low-cost transport of feedstock.

When determining the location of a recycled organics processing facility, consideration of management issues is recommended including:

- expected feedstocks (*type of material, and quantities*)
- technology to be utilised (*size, noise, vibration, etc.)*
- meteorological and topographic elements (*that will impact on water sensitive urban design features to be included in the facility design and operation*)
- proximity to sensitive land use
- proximity to local communities, and impacts on amenity (*as well as benefits for jobs, and low-cost transport of feedstock and product to markets*).

5.1.1 RECOMMENDED DESIGN AND OPERATIONAL MEASURES

When determining the location of a recycled organics processing facility, the following factors are recommended:

- facility is not located on land subject to flooding and inundation
- facility is sited at least 100 metres from surface water (*e.g., rivers, lagoon, ocean*). In atoll and small nations, this separation from surface water may not be possible. In these scenarios, careful management of runoff as described in **Section 4.2** is recommended.
- facility is sited at least 200 metres sensitive areas such as residential houses and schools

5.2 SURFACE WATER, GROUNDWATER, AND LAND CONTAMINATION

Without appropriate control, composting has the potential to contaminate groundwater, surface water, and land through rainwater infiltration and leachate / runoff.

5.2.1 RECOMMENDED DESIGN AND OPERATIONAL MEASURES

Leachate from the composting facility to surface waters, groundwater or land impacts on the environment and human health. Water at a composting facility is recommended be carefully managed through:

- Constructing a roof or cover to protect compost from rain events, minimising or avoiding excess runoff or production of leachate
- Installing an impervious or sealed surface for areas of the site where feedstock is received, mixed and processed, and product is stored
- Installing a product mixing area, where excessively moist feedstock is mixed with drier feedstock to achieve the desired moisture content Constructing bunding and interception drains, storage tanks, ponds to collect run off from process and storage areas

These controls are particularly recommended for areas of the facility used for feedstock receival and storage, feedstock pre-processing and mixing, processing (*pasteurisation and maturation*), post-screening and product storage.

5.2.1.1 Sealed Surfaces

All process areas are recommended to be sealed using suitable, stable, low-permeability construction material, strong enough to support the weight of the composting material as well as movement of trucks and mobile equipment. Concrete is considered as best practice; however, bitumen and clay can also be appropriate.

Where process areas are sealed using clay, the impermeable clay layer is recommended to:

- have a hydraulic conductivity of less than 1×10^{-9} m/s using both fresh water and 50,000 ppm NaCl solution.
- be covered with a suitable material to physically protect the clay from desiccation and subsequent cracking and from physical damage from composting activities, vehicle movements and removal (*scraping*) of compost mass during or after processing.

The surface of the process areas is recommended to be graded to carry surface run-off to collection drains. The grade is recommended to be between 2% and 4% to provide sufficient fall and to avoid erosion from excessive flow rates. These areas are recommended to drain to the leachate water collection system at the facility.

5.2.1.2 Liquid Mixing Area

Liquid mixing areas are used to prevent contamination of surrounding soil and groundwater from liquid feedstocks or excessively moist feedstocks. They can also be a source of odour. The liquid mixing areas is recommended to:

- be completely impervious (*for example, made of concrete with high-density polyethylene (HDPE) liner)*
- have drainage infrastructure (**Section 5.2.1**)
- be fully bunded to prevent spillages polluting nearby land or surface water.

5.2.1.3 Bunding and Interception Drains

Leachate is water containing high load of contaminants due to contact with the organic material. The compost facility design should account for leachate management through management and control of run-off from any 'process' areas. It is good practise to separate surface water run-off from 'clean' stormwater catchment areas and leachate from the process areas.

This separation can be achieved by:

- considering run-off during the design of the facility and installing appropriate drainage infrastructure (**Section 5.2.1**)
- strategically locating cut-off drains, and bunds (barriers) to enable all leachate to be collected and directed to storage points (*e.g., align process pads along contour lines so that water collected from clean areas automatically drains into a different storage area to that from process areas*).

5.2.1.4 Leachate Storage

Leachate is recommended to be captured, pre-treated (*for example, using a silt trap*) and directed to a storage structure, such as a tank or pond that prevents pollution of the underlying land and groundwater. Leachate can be reused during the early stages of the composting process but is recommended not be added to the composting material after it has been pasteurised, as it may contaminate the material.

When designing a leachate flow and storage system, a water balance calculation is recommended to be undertaken to determine how much leachate will be generated in a rainfall event. The storage structure is recommended to:

- be sufficient in capacity to accommodate run-off from the total outdoor process area resulting from a one-in-20-year storm event
- have sufficient built-in redundant capacity to accommodate leachate during periods of persistent rainfall, and when process needs are low
- be lined to provide a hydraulic conductivity of less than 1×10^{-9} m/s using both fresh water and 50,000 ppm NaCl solution
- maintain a minimum freeboard depth to protect against overtopping
- be maintained in an aerobic state in order to minimise the generation of odour from the nutrient-rich water.

5.2.1.5 Clean Stormwater Capture and Storage

It is recommended that clean stormwater is captured and stored for reuse onsite wherever possible (*for example, for moisture adjustment of curing compost mass, firefighting, equipment wash-down, etc*.).

The catchment for clean stormwater may include roofs, parking areas, and other areas where potentially contaminating materials are absent. To manage clean stormwater, the following design features are recommended:

- surface of the ‘clean’ areas is recommended to be gravel or sealed to limit entrainment of sediment by the stormwater
- storage infrastructure (*i.e., tank, pond*) for the clean stormwater is recommended to have sufficient capacity to accommodate run-off.

5.3 Odour

A consequence of the breakdown of organic materials is the production of a wide range of odorous (*smelly*) chemical compounds. Odour is one of the most common causes of community impacts relating to composting operations. Odour can be generated from various sources at the facility, including:

Continuous odour sources:

- Raw organics – delivered feedstocks can be odorous if they have begun to decay
- Product – when stockpiled, the products can become odorous if it is not well managed
- Process – breakdown of organic material generates volatile organic compounds. If the recipe and the process is well managed the volatile organic compounds are less offensive and less prevalent.
- Leachate - leachate storage can become odorous if it is allowed to stagnate.

Intermittent odour sources:

- Machinery - machinery and vehicles may produce odour if material get stuck to surfaces or wheels
- Turning/aeration - odour can be generated in the mixing and preparation phase as it breaks up any zones of anaerobic decay in raw feedstocks. The aeration of the organics being processed, either through aeration systems or turning, can be the peak odour generation point at the facility.
- Screening and movement of feedstock and product.

5.3.1 Recommended Design and Operational Measures

The design and operation of a facility will affect odour emissions. The following are recommended measures compost facilities can use to minimise odour emissions:

- fit and maintain appropriate odour control equipment such as biofiltration system or odour barrier (**Section 5.3.1.1**)
- develop and implement an odour management plan to proactively reduce the potential for odour generation and have a reactive plan for managing odour if detected at the facility. An odour management plan may include the following:
  - an inventory of all sources of odour
  - odour sources and controls under normal conditions
  - odour monitoring and recording regime
  - odour management during upset conditions
  - daily equipment and surface area wash-down
  - routine maintenance of odour control equipment (*where installed*)
- create a balanced feedstock recipe that enables parameters to be met for oxygen, temperature, carbon/nitrogen ratio, and pH levels
- train staff to prepare and process material according to best practice (*as specified in the factsheet and Operation Plan associated with your composting technology*)
- site facility at least 200 metres from sensitive areas such as residential houses and schools.

5.3.1.1 Odour control infrastructure

The requirement for odour control infrastructure is dependent on the feedstocks and technology being used by the facility.

A review of best practice odour control equipment and a rationale for selecting specific equipment for a site is recommended to be conducted. Considerations for odour control infrastructure include:

- for enclosed facilities, odour control equipment such as biofiltration can be installed to filter the odorous components of the facility’s emissions
- a barrier may be constructed around an open facility between operations and sensitive areas
- to reduce odour generation from the leachate collection pond, prevent pond from stagnating (becoming anaerobic) by using UV (*sunlight*) filtration or installing an aeration system.

5.4 Dust and Airborne Particles

Dust and airborne particulates (*bioaerosol that may contain bacteria, fungi and fungal spores, pathogens, and other micro-organisms*) may be generated during the composting process, including during:

- movement of materials by front-end loaders and delivery trucks
- during storage, grinding, mixing, and screening of feedstocks and products
- during the turning of composting materials, although this is less likely due to the normally high moisture content of compost. Note: If dust is generated it might indicate insufficient moisture in the composting mass, which may require adjustment
- from wind on the stockpiles

5.4.1 Recommended Design and Operational Measures

During facility operations, dust suppression activities may include:

- covering dusty materials with tarpaulin or applying a light water spray
- processing the raw and finished materials inside a facility or constructing barrier downwind to capture dust during dusty activities
- suction-sweeping machines to maintain dust-free sealed surfaces
- applying a light water spray before or during turning.

Using excessive amounts of water for dust suppression should be avoided, as water introduced to the process will need to be managed as leachate.

5.5 Pathogens and Weeds

Vermin, birds, water, and wind can act as vectors that transport waste, weeds, and/or pathogens away from a compost facility, posing a potential risk to the environment, biosecurity, amenity, and human health. Compost facilities may also act as habitats for populations of pests to proliferate, if not properly managed.

Pathogens of concern are:

- viruses (*e.g., hepatitis, enteric viruses*)
- bacteria (*e.g., faecal coliforms, Salmonella spp., Legionella, epidermal and respiratory pathogens*)
- protozoa *(e.g., Cryptosporidium, Giardia*)
- helminths (*e.g., parasitic worms, tapeworms, roundworms, and flukes*)

Weeds, weed seeds, and plant propagules are a concern as the spread of noxious weeds has a negative impact on the environment as well as on human health. Weeds may spread to new areas though the use and application of unfinished or unpasteurised compost (*i.e., material does not reach 55°C for at least 3 days*).

This is due to the seeds and plant propagules not being “cooked” or “killed” during the process and so can continue to grow.

5.5.1 Recommended Design and Operational Measures

Pasteurisation of composting material eliminates the human, animal, and plant pathogens and plant propagules. Some spores and weed seeds may survive the pasteurisation process if the temperature/time relationship is not suitable or if the pasteurisation is not uniform.

To reduce the risk of pathogen transmission, it is recommended to ensure:

- every part of the material is effectively pasteurised though managing temperature and turning (see **Section 7.1.1**)
- appropriate quality assurance is conducted and required product standards are met
- the product does not become re-contaminated, through:
  - separation of the feedstock and product handling equipment, vehicles, and areas
  - washing of machinery between use for handling untreated feedstock and pasteurised product
  - not applying leachate to composted material after it has gone through the heat treatment stages for pathogen control
- Testing of compost for pathogens occurs at the start of production of each new product type and every time there is a significant change in feedstock or processing procedures
- Compost derived from animal excreta or offal, sewage sludge, or other wastes with a high pathogen risk is regularly tested for pathogen content.

5.6 Noise

Noise nuisance from composting operations may arise from the use of both mobile and fixed machinery within the facility and from movements of transport vehicles servicing the facility.

5.6.1 Recommended Design and Operational Measures

Compost facilities may use the following measures to reduce noise levels:

- select and maintain appropriate equipment for the facility
- fit and maintain appropriate mufflers on mobile equipment
- enclose noisy equipment inside a facility, or construct a barrier or noise attenuation screen between sensitive areas
- develop and implement noise control strategies in the environmental management plan, including limiting the hours that a facility is operating (*i.e., avoiding certain operations before 7 am and after 6 pm on weekdays, before 7 am and after 1 pm on Saturdays and throughout Sundays and public holidays*).

5.7 Litter

Litter, from contamination of feedstock, vehicles entering or leaving the facility, or from other sources, can be wind-blown into the surrounding areas and can impact on the local amenity.

5.7.1 RECOMMENDED DESIGN AND OPERATIONAL MEASURES

Windblown litter is recommended to be managed by:

- Ensuring any rejected material or residual waste (*plastic wraps, tape, packets etc*) is collected and stored appropriately in bins (*with lids when outside*) and removed and recycled / disposed of appropriately
- Installing fences and moveable litter screens around the site perimeter, ensuring these are relocated to account for prevailing wind direction.
- Undertaking daily site clean-up to collect any waste items from around the facility which may become a windblown litter component.

All litter is recommended to be cleaned up immediately.

5.8 FIRE

Fire at composting operations can arise from several sources, including:

- spontaneous combustion occurring because of the compost piles/windrows overheating. Overheating can occur because of piles being made too high and getting too dry, and restricted airflow through the pile.
- a spark igniting the piles/windrows from cigarettes, lightning strikes, equipment, or scrub-fire
- fragments and shards of glass acting like a magnifying lens.

Fire can pose a risk to the local air quality and human health, the facility and surrounding residential and industrial uses.

5.8.1 RECOMMENDED DESIGN AND OPERATIONAL MEASURES

Sufficient firefighting water supply relevant to the size of the facility, and appropriate fire control equipment such as hoses/sprinklers, and fire extinguishers must be installed and maintained at the facility. The local fire authority is recommended to be consulted regarding facility layout, installation of suitable fire prevention and control measures, and to agree on a plan of action to be followed in the event of a fire.

A fire contingency plan is recommended to be prepared, at a minimum including:

- Identification of high-risk areas where a fire might occur
- Identification of conditions that may lead to a fire (**Section 5.8**)
- location of firefighting water source and fire control equipment
- Emergency contact numbers and process for alerting the local fire authority and other appropriate regulatory and safety authorities.

6 Requirements for Acceptance and Handling of Inputs

Contaminants such as general waste, chemical sprays, and noxious weeds mixed throughout feedstock can potentially contribute to elevated chemical contaminants and reduce the quality of the finished compost. Source separation of material (*i.e., at removing contaminants where the organics are generated*) is the most effective way to remove the unwanted items.

When receiving material at a compost facility, it is recommended to undertake the following activities:

- check incoming materials for non-compostable materials, i.e., contaminants and noxious weeds
- if the level of physical contaminants is above a set limit, e.g., 2%, then the load is recommended to be rejected and not unloaded for processing
- record accepted and rejected incoming materials, as a minimum data collected is recommended to comprise: (i) date and time of delivery, (ii) person or organisation that delivers, (iii) type and quantity (weight or volume) of material delivered, and (iv) whether load was accepted or rejected.

Standards for encouraging source separation and reducing contaminants in organic materials can vary depending on where the material is received from.

6.1 Organics from Households

Household generated organic material can supply compost facility input materials such as garden organics, food organics, and paper / cardboard for processing.

To encourage households to supply organic material without general waste contaminants, the following actions are recommended:

- Deliver clear community education and engagement messages, highlighting what are suitable organic materials and what are contaminants and noxious weeds not suitable for composting
- Establish a clear process so communities know how to deliver organic material to the compost facility or make them available for collection
- Provide separate bins to households or placed around communities providing for collection of organic materials
- Develop and enforce controls for collection contractors specifying maximum tolerable contaminant levels, e.g., 2% beyond which loads can be rejected, and price penalties for supply of contaminated materials
- Incoming organic materials is recommended to be checked for contaminants materials upon arrival before unloading. Loads where the level of contamination is unacceptable are recommended to be rejected and sent to landfill.

6.2 Organics from Businesses and Industry

Businesses generating organics include growers and growers' markets, importers and wholesalers, retail stores, restaurants, and accommodation and hospitality providers.

Manufactures and food and fibre processing industries (*i.e., copra, fish-processing, coffee processing, breweries, noni processing*) may also produce organic materials available for composting (the waste or "by-product" from their manufacturing).

The following actions are recommended to encourage businesses and industry to supply organic material without general waste contaminants:

- Deliver clear community education and engagement messages, highlighting what are suitable organic materials and what are contaminants and noxious weeds not suitable for composting
- Establish a clear process so businesses and industry know how to deliver organic material to the compost facility or make them available for collection
- Provide separate bins to businesses providing for collection of organic materials
- Develop and enforce controls for collection contractors specifying maximum tolerable contaminant levels, e.g., 2% beyond which loads can be rejected, and price penalties for supply of contaminated materials
- Incoming organic materials is recommended to be checked for contaminants materials upon arrival before unloading. Loads where the level of contamination is unacceptable are recommended to be rejected and sent to landfill
- By-product from manufacturing is commonly subject to physical or heat treatment processes (*e.g., squeezing, de-husking, grinding, boiling, steaming*) which are acceptable inputs to a composting process. If manufacturing by-product is subjected to chemical treatment or extraction processes, a chemical analysis may be required to ensure the material is not contaminated.

6.3 Handling Inputs

Once checked and received, material handling can vary depending on material type and characteristics.

6.3.1 Garden Organics

Incoming garden organics should be tipped and spread out in a dedicated receival area. Once spread, it can easily be inspected for any segregation and removal of physical contaminants and/or weeds. Once physical contaminants are removed, the garden organics should be moved into an open stockpile awaiting the next stage in the process.

6.3.2 Food Organics

Incoming food organics should be tipped and spread out in a dedicated receival area. Once spread, it can easily be inspected for any segregation and removal of physical contaminants.

Food organics usually have high moisture content and easily become odorous due to their putrescible nature. Therefore, food organics should not be stockpiled for extended periods of time. It is recommended for food organics to quickly be mixed with bulking material (*usually shredded garden organics*) and incorporated into the composting process no later than 48 hours after receival.

Newly established piles that contain food organics are recommended to be monitored for up to two weeks to ensure no or only minimal leachate is generated. If leachate generation is excessive amounts (*leachate runs off concrete / compacted area*), additional dry material is recommended to be incorporated into the mix.

6.3.3 Sludges and Liquid Materials

Liquid and semi-liquid materials, including sludges, sewerage, and biosolids should be received at a compost facility only if the facility has an impervious receival bund and/or mixing area that is lined with concrete (**Section 5.2.1.2**) and is licenced to receive this material. It is recommended adequate dry bulking material able to absorb the liquid is used to reduce excess moisture that will drain from compost piles once established (weight of piled up material forces moisture out).

As with food organics, newly established compost piles that contain sludges and liquid materials are recommended to be monitored for up to two weeks to ensure minimal leachate is generated. If leachate generation is excessive (leachate runs off concrete / compacted area), additional dry material is recommended to be incorporated into the mix. A moisture, contaminant and nutrient analysis is recommended to be obtained for all liquid and semi-liquid materials before they are accepted into a composting facility.

6.3.4 Paper and Cardboard

Incoming paper and cardboard should be stored in a dry location until it is shredded and mixed with other organic material into the composting process. Effort should be placed into removing plastic labels and tape from cardboard boxes prior to shredding. Glossy magazines are not recommended to be shredded and composted. Shredded paper and cardboard are recommended to be stored where it cannot become airborne.

6.3.5 Noxious Weeds

Noxious weeds should be received at a compost facility only if the facility can certify they will be processed with temperatures over 55°C for at least 3 days. Noxious weeds are not suitable for composting if the required heat cannot be sustained for the required timeframe. It is recommended to ensure the weeds are not covered in weed killer such as paraquat. Before accepting weeds at your facility, confirm with the owner that the material is not covered in this spray.

7 Requirements for Process Monitoring and Control in Composting

For the composting process to work efficiently and effectively, feedstock is recommended to be mixed with ratios of various materials to ensure appropriate nutrients, bacteria, moisture, and airflow are present to sustain the composting process. **Table 2** shows optimal and acceptable range of indicators for composting feedstock**.**

Table 2: Desirable characteristics for composting feedstock [Source: Rynk et al 2022]

Characteristic	Unit	Optimum	Acceptable Range
Moisture content	% (w/w)	50 - 60	40 – 65
Carbon to nitrogen (C:N) ratio		25 – 40 : 1	20 – 60 : 1
pH		6.5 – 8.0	5.5 – 9.0
Particle size	Cm	< 5	Variable
Bulk density	kg/m^3	400 - 600	< 700

To maintain appropriate composting conditions and produce a quality product, monitoring of the composting process is important (*e.g., temperature monitoring can determine when a pile should be* turned to sustain optimum microbial activity). Monitoring is also a requirement for many composters who operate within a regulatory framework.

Monitoring of composting can be undertaken using the senses of a facility manager (*smell, and touch while undertaking the "hand-squeeze" test (**7.2.1**) for determining moisture content*). Temperature is the key measured indicator for the state of the composting process, as such it is important to have a good thermometer. Additional processing information can be gained by measuring oxygen or carbon dioxide concentrations inside the composted material, its bulk density, and pH.

7.1 Temperature

The heat generated during the composting process is due to the release of surplus energy during the microbial decomposition of organic matter. The temperatures reached during composting are primarily determined by microbial activity, which in turn is governed by the availability of food for the microbes - principally carbon and nitrogen, the moisture content and aeration of the composting material. Although composting temperatures vary to some degree, they usually follow the pattern shown in **Figure** 1, which is used to distinguish different phases of the composting process, namely:

- The initial phase in which temperatures rise (*initial mesophilic phase)*
- The primary hot or thermophilic phase (> 45 °C)
- The curing and maturation phase during which the temperature slowly falls again.

Figure 1 demonstrates that temperature can indicate at what stage the composting process is at and when the product is near stable or mature. However, temperatures can also rise and fall during composting because of other factors (*e.g., not enough moisture or air, or too much air flow in static aerated piles*).

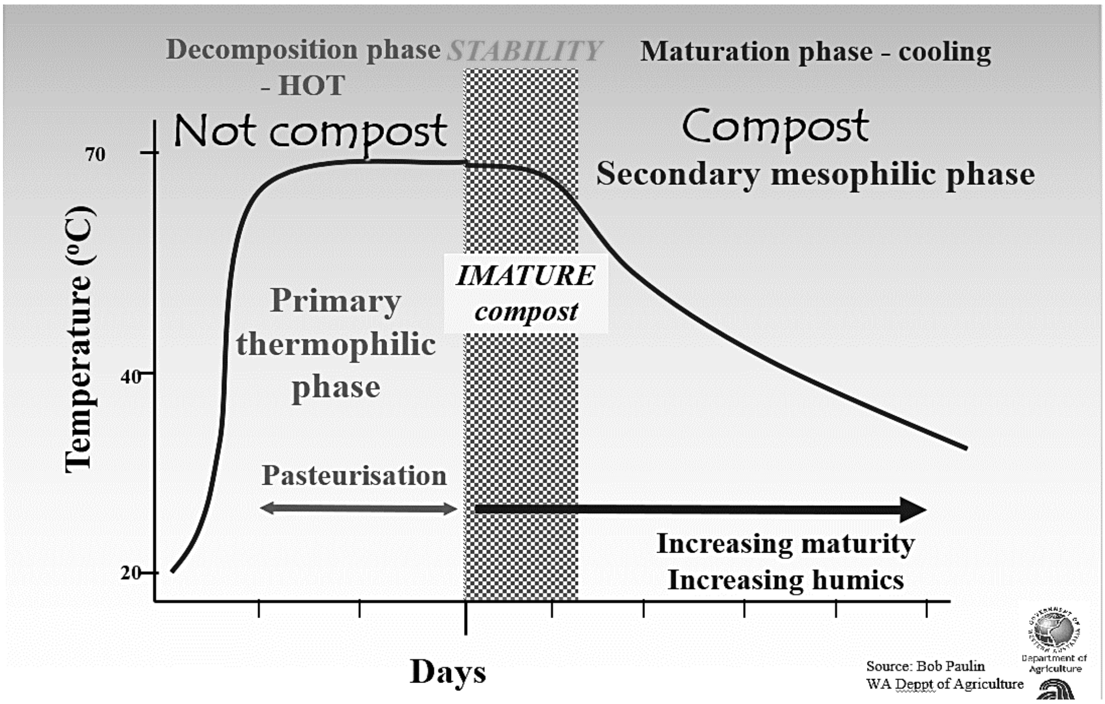


Figure 1: Temperature development and stages in aerobic composting [*Source: Paulin 2010*[1]]

The size of the pile/windrow determines the maximum temperature, and heat preservation. Heat builds up in composting material when the insulating properties of the mass results in the rate of heat gain being greater than the rate of heat loss. Small volumes of organic materials (<1-2 m^3) may not heat up because the heat generated by the microbial population is lost quickly to the atmosphere.

Temperature has a self-limiting effect on microbial activity and thus the rate of degradation of organic materials. The highest rates of decomposition of organic materials usually occur at temperatures between 45 ºC and 55 ºC.

Only a small number of microorganisms remain active and survive temperatures above 65 ºC to 70 ºC, causing a rapid reduction in the rate of composting.

Table 3 highlights the general range of temperature during the composting process. Monitoring temperature and understanding these temperatures will assist in the management of the composting process.

Table 3: Composting temperature guidelines [*Source: adapted from Rynk et al 2022*]

Transition from mesophilic to thermophilic microbes	40 – 45 ºC
Good range for thermophilic composting	55 – 65 ºC
Minimum temperature for pasteurisation	55 ºC
Level at which microbial populations decline and composting process slows	> 70 ºC

[1] Taken from presentation provided by Bob Paulin, Western Australian Dept of Agriculture, ca. 2010

7.1.1 CONTROLLING PATHOGENS AND WEEDS (PASTEURISATION)

High temperatures in a composting process will kill pathogens and weeds.

Most compostable materials, except for paper / cardboard, potentially contain weed seeds / viable plant parts, or human, animal, or plant pathogens. Human pathogens put public and worker health and safety at risk, while plant pathogens and weeds can cause damage to the environment. Pathogen and weed elimination must be a prime objective of every composting operation.

Operators are recommended to closely monitor their composting process (*temperature as specified in* **Table 4**) and keep good records to demonstrate that good care was taken to ensure that finished compost has been pasteurised for a minimum number of days (**Table 5**) and therefore are free of weeds and show negligible pathogen counts.

Most pathogens and weed propagules are more susceptible to high temperatures than the microorganisms that are active during the thermophilic stage of composting. The effect of heat is dependent on the length of exposure and moisture content of the surrounding compost as well as on the hardiness of the pathogen or weed seeds. **Table 4** outlines the time / temperature / turning requirements for pasteurisation during composting.

A **template Composting Monitoring form** can be found here to use as a guide to monitor the composting process.

Note: Small compost piles (<1-2 m^3) usually do not generate enough heat (> 55 ºC) over a prolonged period and therefore are not likely to generate pasteurised compost that is free of pathogens and weed seeds / viable plant parts.

Table 4: Time / temperature / turning ratio required for pasteurisation during composting
* [*Source: EPA Victoria 2017*]

Processing	Material	Time / temperature ratio
Open composting (windrow, bay, static pile)	Low-risk materials	Appropriate turning of the compost so that the whole mass is subjected to a minimum of three turns with the internal temperature reaching a minimum of 55 ºC for three consecutive days before each turn.
	High-risk materials	The core of the compost mass shall be maintained at 55 ºC or higher for 15 days or longer, during which the pile shall be turned a minimum of five times.
Enclosed composting	All materials	The whole mass shall be maintained at 55 ºC or higher for a minimum of three consecutive days. (To meet this, the material will need to be in the enclosed vessel for longer to ensure it gets to and maintains temperature.)

** as prescribed by EPA Victoria (Australia)*

The effectiveness of the composting process in reducing pathogens and eliminating weeds / viable plant matter is assessed by determining the level of pathogenic indicator organisms and weeds in the finished compost product.

A range of potential end product requirements that demonstrate satisfactory pasteurisation of compost products is shown in **Table 5.**

Table 5: Various potential end product requirements that demonstrate pasteurisation [*Source: EPA Victoria 2017*]

Pathogenic organism / weeds	Requirement
Enteric viruses	< 1 PFU per 10 grams (dry weight)
Helminth ova (Ascaris sp. and Taenia sp.)	< 1 per 4 grams (dry weight)
E. coli	< 100 MPN per gram (dry weight)
Faecal coliforms	< 1,000 MPN per gram (dry weight)
Salmonella spp.	Absent in 50 grams (dry weight)
Weed seeds and viable plant material	Nil germination after 21 days incubation

PFU = plaque-forming units, MPN = most probable number

7.1.2 Guidelines for Temperature Monitoring

Frequent (*at least daily*) temperature monitoring and an analysis of the readings is recommended during the commencement of operations at a new compost facility, when significant changes are made at an existing facility, or when a new feedstock is received.

Temperatures should be monitored throughout the composting process to:

- provide information on the progress and stage of the composting process
- provide support for operational decisions (*especially when and how often to turn or when to add water*)
- ensure that pathogens and weed propagules are absent from the end-product.

Once operations have stabilised and operators are familiar with the behaviour of feedstock and compost mixes, a reduced monitoring program can be designed for routine temperature monitoring (***Section 7.1.2.1***), deigned to ensure observed temperatures are representative throughout the composting material and for the whole duration of the composting process.

7.1.2.1 Frequency of Temperature Monitoring

The frequency of temperature monitoring depends on the duration of composting. **Table 6** provides guidance on appropriate temperature monitoring depending on the length of composting process.

Table 6: Temperature Monitoring Frequency

Composting Process	Temperature monitoring	Comments
Less than 6-weeks	Every two days	Producing pasteurised compost in short timeframe may require more frequent monitoring to ensure that the composting material is subjected to temperatures sufficient to kill pathogens and weed propagules
More than 6-weeks	Twice weekly for the first four weeks Weekly thereafter	Pasteurisation occurs predominantly within the first 2 to 4 weeks of composting. The longer composting period at elevated temperatures presents an additional safeguard for the elimination of pathogens and weeds, and less frequent temperature monitoring is required

Temperature monitoring should occur at a similar time of day, and not within 24 hours of a turning event. The use of fast response temperature probes reduces the time required to record measurements and increases accuracy of temperature readings.

Figure 2: Temperature probes of varying length (30 – 150 cm) are available with dial readout (**left**) or digital display (**right**)

Temperature monitoring is recommended to the following minimum guidelines:

- take temperatures in at least 6 central points, no more than 10m apart, on either side of the compost pile
- insert temperature probe at half pile height at penetration depths of 40, 70 and 100cm.

For guidance, **Figure 3** provides an indication of likely temperature variations within a typical composting pile larger than $2m^3$.

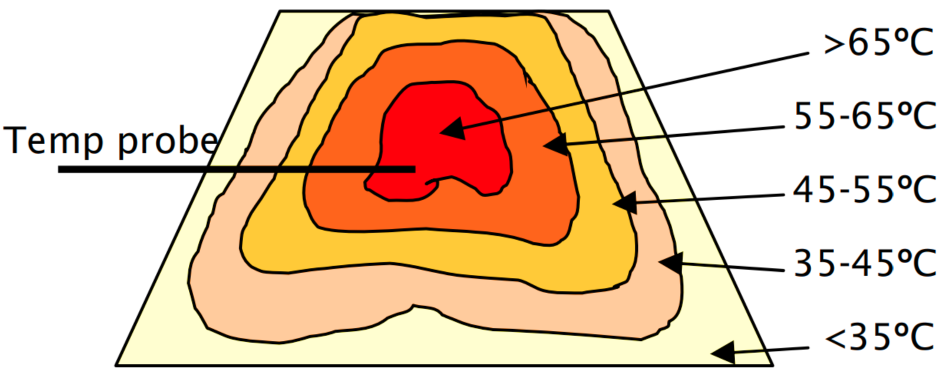


Figure 3: Schematic temperature variation within a typical composting pile [*Source: Wilkinson and Biala 2007*]

A 'typical' temperature profile should emerge for a given feedstock after several batches have been composted successfully and monitored by detailed temperature profiling.

Once a typical temperature profile is established, temperature monitoring can become a routine procedure that involves fewer readings than in the initial phase, aimed at identifying deviations from the typical temperature profile.

Routine temperature monitoring procedures are recommended to be developed according to the following general guidelines:

- Take enough readings to ensure that typical conditions are being measured on both sides of the compost pile. Do not rely only on one or two readings
- Determine peak temperatures deep in the compost pile at approximately 100 cm
- Determine the proportion of the compost pile above 55ºC or a similar target temperature, by taking readings at intermediate depths, of approximately 40 and 70 cm. This will indicate whether a compost pile is overheating (*expanding hot zone*) or cooling down too fast (contracting hot zone) compared to the expected temperature profile
- Record data on a temperature monitoring sheet

7.2 MOISTURE

Moisture is essential to all living organisms, including microorganisms in compost piles. The optimum moisture content for starting the composting process is generally between 50% and 60%. Moisture content above 50% are necessary for effective pathogen and weed control during the initial (*thermophilic*) composting stage.

Significant amounts of moisture are lost during composting, which is why monitoring of moisture content is recommended. Towards the end of the process, moisture content in compost often falls below 40%, so the compost can be easily handled, screened and stored. However, care is recommended to ensure that the compost does not dry out too much as microbial activity virtually stops below about 30% moisture.

Water can be added most effectively and evenly during turning with a mechanical turner connected to the water supply. Where this is not possible, or where loaders are used for turning, water can be added manually by hoses or sprinklers.

Overwatering and excess moisture should be avoided, as this reduces oxygen flow leading to odour generation, and leachate generation.

7.2.1 MEASURING MOISTURE CONTENT

The easiest way of checking the moisture content of composting material is to visually inspect the pile and handle the material. Dust is a sure sign of a pile that is too dry, and areas where there is freely draining liquid, are odorous, or have attracted flies, is most likely too wet.

A general rule for the correct moisture content of composted material is that it should feel damp, like a wrung-out sponge.

The hand squeeze test (**Figure 4**) provides a simple method for estimating moisture content in composted material. Rynk et al (2022) provide the following procedures and interpretation (**Table 7**) for the hand squeeze test:

- Reach into the pile or a composite sample and collect a handful of material
- Squeeze the material hard and check for drips
- Release grip and allow the material to stay in your hand, smear some between your finger and thumb
- Inspect the material and your hand and review findings against interpretation in **Table 7**

Table 7: Estimating moisture content through the hand squeeze test [*Source: Rynk et al 2022*]

Observation / description	Estimated moisture
Water flows freely out of your hand	> 65%
A few drops of water are visible between your fingers	60% - 65%
You don't see any water between your fingers. When opening your hand, a sheen of moisture is clearly visible.	55% - 60%
No sheen of water is visible, and a ball of material remains in your hand. If you tap the ball gently, it remains intact.	50% - 55%
A ball of material forms but breaks apart during tapping	45% - 50%
After squeezing, the material does not remain in a ball when opening your hand	40% - 50%
No ball forms and a dry talcum-like feel remains on your hand after discarding the material	< 40%

Figure 4: Example of the hand squeeze test, where the material holds together after releasing the squeeze, indicating an approximate moisture content of 50% - 55%. [*Source: Rynk et al 2022*]

A more accurate way of determining moisture content is to weigh a sample of composting material before and after drying. The weighing and drying procedures are simple, but equipment (*scales and oven*) is required, and it takes time until results are available. The drying process can be done via air drying in a protected warm room or by using a kitchen oven (*with setting at or below 100 ºC, do not use this oven for food preparation*), a microwave oven, or a laboratory drying oven.

The basic procedure of determining moisture content by weight is as follows:

- Weigh the container that will hold the material sample
- Weigh the 'wet' weight of the compost sample and deduct the weight of the container
- Dry the sample until no moisture is left
- Weigh the 'dry' weight of the sample and deduct the weight of the container
- Determine the weight of the water in the sample by deducting 'dry' weight from 'wet' weight
- Determine the moisture content, expressed as decimal fraction, by dividing the weight of the water by the wet weight of the sample

7.2.2 Adjusting Moisture Content

After assessing the moisture content of the compost, it may be necessary to increase or reduce the water content of the compost pile.

The moisture content of the composting process during pasteurisation should generally be between 50% and 60%. If it is outside this range, the following remediation measures are recommended:

- If lower than 50% (*too dry*), add water to the pile using hoses or sprinklers or add additional moist feedstock such as manure
- If higher than 60% (*too wet*), turn the pile and add additional drier feedstock with larger particle sizes such as shredded high fibrous woody material.

7.3 Oxygen

The microorganisms responsible for aerobic composting cannot survive and grow in the absence of oxygen.

When microorganisms feed on the carbon component of organic materials for their energy, oxygen is used up and carbon dioxide is produced. The oxygen concentration in air is about 21%, but considerably lower in composting materials. The oxygen level can decrease rapidly in a composting process and is governed by microbial activity and the efficiency of the aeration system. Ideally, oxygen concentrations of about 10-14% is required for optimum composting conditions. Aerobic microorganisms cannot function effectively at concentrations below about 5% in compost.

In non-aerated composting systems, aeration is assisted by physical turning with a loader or a turner. The main reason for turning a compost pile is to move the outside portions into the middle, and to loosen the material so that air can move more freely into the pile. The agitation of composting particles that occur during turning stimulates higher rates of decomposition by exposing new surfaces to microbial activity. In compost piles, oxygen is replenished by convection and diffusion. Natural convection is the movement of outside air into a compost heap as a result of the concentration deficit created by the steady flow of hot air upwards through the pile and out the top (**Figure** 5). Diffusion then transports oxygen into the smaller pores of compost and into the water layer surrounding compost particles.

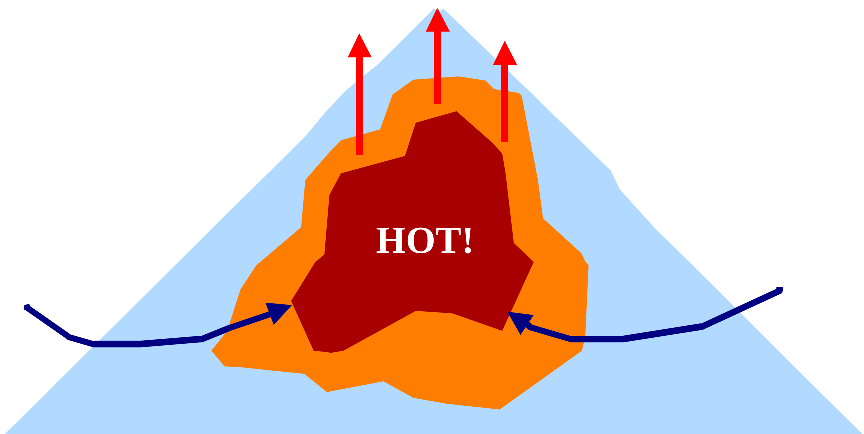


Figure 5: Convection in a compost pile [*Source: Wilkinson et al 2001*]

Turning only adds a small amount of oxygen directly, but it loosens and fluffs the material so that air can move more freely into the compost pile by convection. It is possible to provide for sufficient aeration for up to seven days without turning, provided that careful attention is paid to optimising the particle size and mixing of organic material. Convection can be increased by constructing passively aerated piles over channels or inserting pipes that extend from the outside through to the core of the compost pile.

Air can also be supplied mechanically with forced aeration**,** which delivers air by suction and/or blowing. Composting with forced aeration is mainly a feature of static aerated piles or in-vessel composting systems. When air is blown from the bottom of the pile, it cools the base and delivers warm air to the cooler outer layers. Reverse aeration (*suction*) can prevent excessive odour emissions from uncovered compost piles. Forced aeration systems tend to dry out composting materials, requiring moisture to be added to maintain the necessary moisture content required for efficient composting to occur.

As microbial activity demand diminishes towards the end of the composting process, so does the need for aeration and turning.

7.3.1 MEASURING OXYGEN OR CARBON DIOXIDE

Most composting operations do not monitor oxygen levels as:

- sound compost management decisions can be made using temperature and moisture data
- obtaining accurate oxygen data is difficult and expensive than measuring temperature
- interpreting oxygen results can be difficult.

Measuring oxygen may be helpful for certain operations and in troubleshooting issues during the composting process. There are two options for measuring oxygen (O_2) concentrations in compost piles: (i) directly by measuring O_2, and (ii) indirectly by measuring carbon dioxide (CO_2).

During composting, O_2 and CO_2 have a direct and inverse relationship. The consumption of one O_2 molecule produces one CO_2 molecule. So as O_2 disappears, CO_2 appears. As the O_2 concentration degreases from around 21% (*in ambient air*) to near 0%, the CO_2 concentration increases in step from near 0% toward 21%. Thus, by subtracting the measured CO_2 concentration from 21%, one gets a good estimate of O_2 concentrations in the pile.

CO_2 concentrations in compost are measured with a basic combustion gas analyser (**Figure 6)**. This device consists of a long pipe that is perforated at one end, a hand pump, water trap and a cylinder that contains a selected fluid that absorbs CO_2 and subsequently expands after mixing.

The air sample is pumped from the pile into the fluid through the pipe and moisture trap by means of the hand pump. The operating manual provides specific instructions about how many times the hand pump should be squeezed, and how to mix the gas before the CO_2 measurement is read on the scale of the fluid chamber. The indicator fluid is good for about 300 measurements, depending on how much CO_2 it has absorbed.

Figure 6: Equipment for measuring oxygen (**left**) and carbon dioxide (**right**)

A variety of direct O_2 sensing probes are available. Most O_2 sensors are electrical cells that generate a voltage that is related to the O_2 concentration (*e.g., the Clark Oxygen Electrode*). The gas sample is either drawn out of the pile, similar to the process seen with the CO_2 sensor, and across the sensor where the O_2 molecules penetrate a selective membrane barrier of the cell, or O_2 concentrations are measured in-situ inside the pile, as is the case with the oxygen probe shown in
Figure 6. Oxygen sensors also record temperature data.

The electric signals from the cell are converted into digitally displayed O_2 concentrations.

7.3.2 ADJUSTING OXYGEN

After assessing the oxygen content of the compost, it may be necessary to increase or reduce the oxygen concentration inside the compost pile.

The oxygen concentrations should be about 10-14% is required for optimum composting conditions. If it is outside this range, the following remediation measures are recommended:

- If lower than 10%, add oxygen by turning the pile and add additional items with large particle sizes such as shredded woody materials, or increase oxygen by inserting pipes or a mechanical forced aeration system
- If higher than 14%, your pile may be too dry and "open". In this case add water to the pile using hoses or sprinklers or add additional moist feedstock

7.4 MONITORING PH

It is rare that pH is monitored routinely during composting. Organic materials can vary widely in pH without greatly affecting their compostability. It might be of value to assess pH at the beginning of the composting process if high proportion of easily degradable components (*food organics, fish by-product*) are composted, as their degradation results in the formation of organic acids, that can lower the pH to the point where microbial activity is inhibited.

Later in the process, the pH rises as organic acids are oxidised and ammonia forms and volatilises, with the pH usually settling between values of 7 and 8 during the maturation phase. Odours from ammonia production are often a problem when the pH exceeds 9.

7.4.1 ADJUSTING PH

If the pH of the compost pile is outside recommended range of 5 and 7.5, the following remediation measures are recommended:

- If the pH is lower than 5 (*acidic*), turn your compost to improve air circulation and additional drier feedstock with larger particle sizes such as shredded high fibrous woody material. Adding crushed coral sand or wood ash may also improve the alkalinity and aid in neutralising a compost pile.
- If higher than 7.5 (*alkaline*), the best way to increase the acidity of a compost pile is to add high acid materials, such as coffee grounds or by-product from coffee processing to the compost.

7.5 ODOUR

Odour is a key process control parameter in the composting process. The presence of odours and their character indicate how well the process is being managed.

The character of an odour can be a key process-control indicator. Odours with a putrid, rotting, or hydrogen sulphide (*rotten egg smell),* are indicative of anaerobic processing conditions.

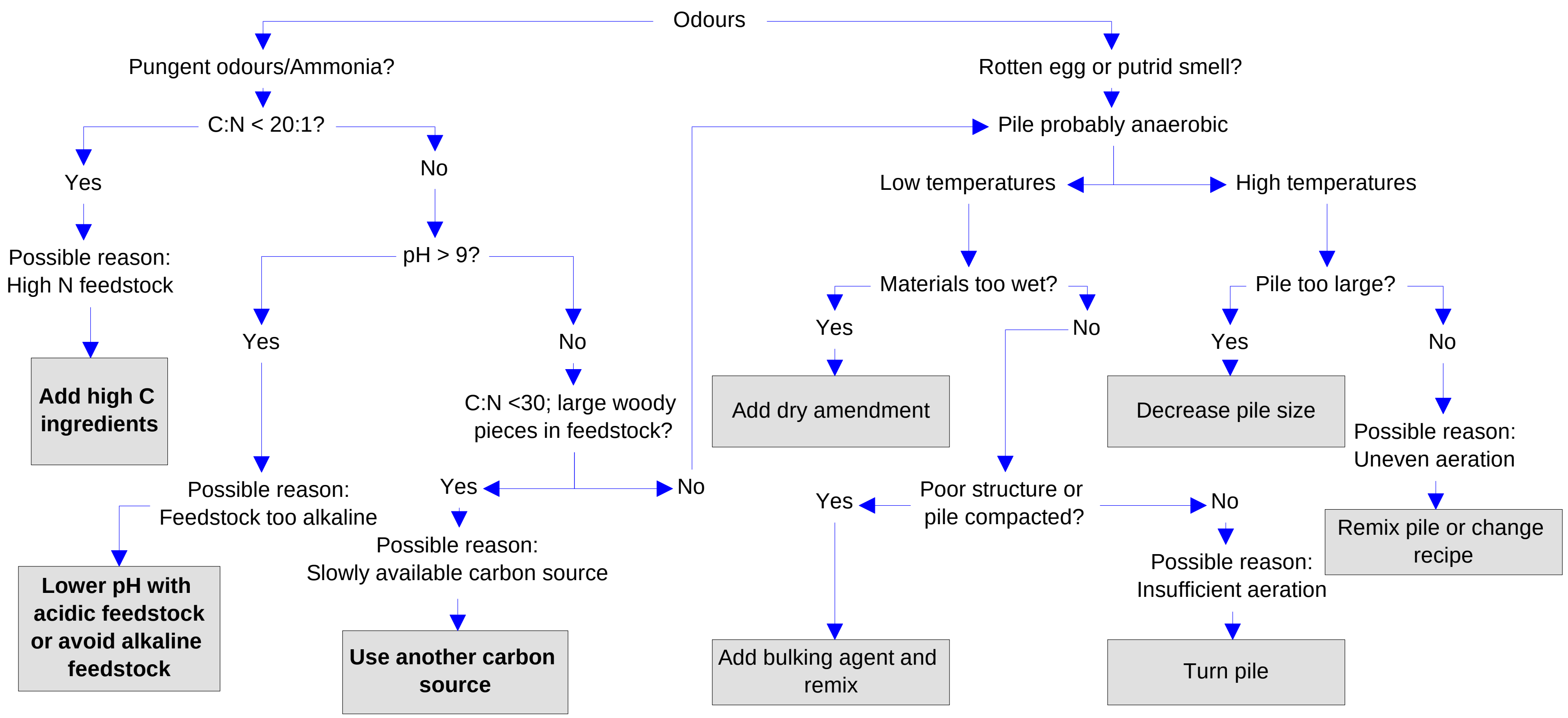
There is no better odour monitoring tool available to composters than their own sense of smell.

7.5.1 ADJUSTING OXYGEN

If the compost pile is producing excessive odour, the following remediation measures are recommended:

- Turn the pile and add additional drier feedstock with larger particle sizes such as shredded high fibrous woody material.
- Follow the flow chart described in **Figure 7** to diagnose the source of odour.

Figure 7: Flow-chart for diagnosing the source of odours during composting [*Source: Wilkinson et al 2001*]



8 HEALTH AND SAFETY

8.1 GENERAL

Raw and processed organic materials contain living microorganisms including moulds, bacteria, fungi, and protozoa. These microorganisms can cause adverse reactions, particularly in people with a weakened immune system. Similarly, dust particles or bioaerosols released from handling materials may cause skin irritations, eye infection, or respiratory illness.

The following precautions are recommended when handling organic materials:

- wear gloves
- wash hands after handling organic materials or compost
- wear a mask and dust resistant eye protection in dusty conditions
- wash work clothing regularly
- complying with machinery safety controls (**Section 8.2**).

8.2 MACHINERY

Organics processing machinery may be fixed or mobile, both present different health and safety risks.

Fixed plant and equipment present potential safety risks to during operation and maintenance activities. Risks include but are not limited to: trapped limbs; clothes being snagged; and material being forcibly ejected.

Risks can be minimised through appropriate design, including guarding and shielding equipment, good maintenance and safe operating procedures.

Mobile plant and equipment are heavy, and drivers often have limited visibility. The working environment of this equipment can be slippery and confined, which requires careful manoeuvring. Operation of mobile equipment presents a risk to any personnel and pedestrians in the area.

The segregation of vehicles and pedestrians in working areas are to be carefully considered. Methods for managing this risk could include site layout, traffic control measures, and barriers and guarding. Vehicles are recommended to be fitted with warning lights and reversing alarms.

9 Assessing Product Quality

Compost is a multi-purpose product that delivers a wide range of soil and plant nutrition benefits. Compost is primarily used as surface mulch to reduce moisture loss, weed growth and erosion; or as a soil additive to improve soil quality and nutrient supply. Fine mature compost can be used as component in growing media. Assessing the quality of the product can be undertaken to verify to buyers the compost can perform certain functions. There are numerous measurable parameters (*e.g., pH, soluble salts (electrical conductivit*y), maturity, stability, organic matter content, nutrient content (total and available), carbon to nitrogen ration, particle size distribution, cation exchange capacity and viable weed seeds and plant parts) that relate to compost capacity.

Table 8 provides the acceptable range of indicators for pasteurised mulch and composted soil conditioner as specified in the Australian Standard for Composts, Soil Conditioners and Mulches AS4454 - 2003 (*Standards Australia 2003*).

Table 8: Physical and chemical requirements for pasteurised mulch and composted soil conditioners [*Source: Standards Australia 2003*]

Characteristic	Composted soil conditioner	Pasteurised mulch
pH	5.0 – 7.5	5.0 – 7.5
Electrical conductivity (dS/m)	No limit	No limit
Phosphorous total (% dry mass)	No requirement, but ≤ 0.1 for phosphorous sensitive plants	No requirement, but ≤ 0.1 for phosphorous sensitive plants
Phosphorous soluble (mg/L in extract)	No requirement, but ≤0.5 for phosphorous sensitive plants	No requirement, but ≤0.5 for phosphorous sensitive plants
Nitrogen total (% dry mass)	≥ 0.6 if contribution to plant nutrition is claimed	≥ 0.6 if contribution to plant nutrition is claimed
Ammonium-N (mg/L in extract)	< 200	No requirement
Nitrate-N (mg/L in extract)	≥ 10 if contribution to plant nutrition is claimed	No requirement
Ammonium-N + Nitrate-N (mg/L in extract)	> 200 if contribution to plant nutrition is claimed	No requirement
Organic matter (% dry mass)	≥ 25	≥ 25
Boron (mg/kg dry mass)	< 200	< 200
Sodium (% dry mass)	< 1	No requirement
Wettability (minutes)	< 7 for the < 16mm fraction	< 7 for the < 16mm fraction if >10% is smaller 16mm
Radish bioassay (toxicity) (mm root length)	≥ 60	No requirement
Particle size grading (% mass retained in 16mm sieve)	< 20	≥ 70
Moisture content (%)	> 25	No requirement
Physical contaminants (% dry mass)		
Glass, metal rigid plastic > 2mm	≤ 0.5	≤ 0.5
Light, flexible, film plastic > 5mm	≤ 0.05	≤ 0.05
Stones and lumps of clay ≥ 5mm	≤ 5	≤ 5
Weed seeds, viable plant parts	Nil after 21 days	Nil after 21 days

9.1 Product Release

Compliance with minimum product quality requirements facilitates composting with minimal adverse impact on the environment and public health, particularly regarding the spread of weeds and plant pathogens. This aspect is of particular importance when compost products are sold or distributed to locations other than where they were made.

Compost products that are ready for use and distribution should be pasteurised and free of weed seeds and pathogens. Compliance with this objective can be demonstrated with temperature records that show temperatures above 55°C over a prolonged period that includes repeated turning (*use the template Composting Monitoring form to monitor and verify the composting process*).

Table 9 describes product quality indicators and criteria recommended to be assessed and met before compost products are released for use or sale and summarises the testing methodologies that can be completed on-site using visual observations or with simple equipment / test kits. It has been adapted from the *Handbook for small-scale composting facility management* (*SCOW 2014*) and other sources.

Laboratories may be available at universities and other tertiary institutes to undertake further detailed analysis of compost characteristics and quality. For undertaking laboratory testing, or to conduct further product testing on nutrient load or other indicators, refer to standards and guidance available in the Australian Standard for Composts, Soil Conditioners and Mulches AS4454 – 2003.

Table 9: Assessing Product Quality

Product Quality Criteria	How to Assess*	Examples
Moisture content: approximately 35% to 45%	Undertake a hand squeeze test to estimate moisture content: • Reach into the pile or a composite sample and collect a handful of material • Squeeze the material hard and check for drips • Release grip and allow the material to stay in your hand, smear some between your finger and thumb • Inspect the material and your hand and review findings against interpretation in **Table 7** • Refer to **Section 7.2** for more details	Example of conducting a hand squeeze test  
Physical contaminants: not exceeding limits shown in Table 8	Undertake an assessment of physical contaminants (e.g., plastic, glass, or stones): • Screen the dried product through a sieve with 2mm mesh and discard the fine fraction < 2mm • Remove by hand or with tweezers from the > 2mm fraction all visible pieces of glass, hard plastic and metal and determine their weight • Screen the > 2 mm fraction through a sieve with 5 mm mesh and discard the fine fraction < 5 mm • Remove by hand from the 5 mm fraction all visible pieces of light plastic or plastic film and determine their weight	Example of conducting a physical contaminants assessment 

Product Quality Criteria	How to Assess*	Examples
	• Remove by hand from the 5 mm fraction all visible stones and clods of clay and determine their weight • Determine the percentage of the different types of physical contaminants based on the dry weight of the compost sample.	
pH: **range between 5 and 7.5**	Test the pH using a pH meter or soil pH test kit. Follow the instructions on the kit, generally including: • Make a watery extract by adding clean water to the compost sample at a ratio of 1:5 (*sample: water*) • Shake the container for 30 minutes manually at 5-minute intervals • Determine the pH with a pH meter or simple soil pH test kit.	Example of soil pH test kit 
Electrical conductivity: less than 2.2 dS/m if used in growing media and less than 1.5 dS/m if used in seedling mix; no limit if used as soil amendment	Undertake an assessment of Electrical Conductivity using a meter and probe with two metal electrodes. Note: Electrical Conductivity meters can vary by instrument so follow the manufacturer's instructions. Assessment generally includes: • Turn on the meter and calibrate the probe • Collect filtered slurry in a container, at a volume so the probe tip can be submerged in the sample • Submerge the probe into the sample and obtain Electrical Conductivity reading	Example of Electrical Conductivity meter 
Solivita testing as test of compost maturity. Measuring CO_2 and NH_3 test results to provide a Maturity Index	Undertake a maturity assessment using a Solvita Compost Test Kit. Follow the instructions on the kit. ***Note**: Solvita tests measure both the evolution of carbon-dioxide (CO_2) and ammonia (NH_3), the two most common gases released during composting. High release of either or both gases indicate an unstable and possibly odorous condition associated with actively degrading compost. The CO_2 and NH_3 test results are combined to provide a Maturity Index.*	Example Solvita compost maturity test kit 

* **Note:** When taking an assessment of product quality, it is important that the sample taken is representative of the entire compost pile and an appropriate sampling methodology is used:

- Turn material to be sampled to increase its uniformity
- The number of points to be sampled will depend mainly on the composting system and its size. If the pile is well mixed, 5-10 sampling points is sufficient.
- The samples should not be taken from the surface of the pile. Depending on the size of the composting pile, the samples RE recommended to be collected at 30cm, 50cm or 75cm depth.
- The total quantity of material that must be taken will depend on the size of the compose pile and its uniformity. In general:
  - take 1-2 litres of compost from each sampling point and cumulate in a large bucket
  - Spread and mix the content the compost samples on a clean surface or a plastic sheet
  - Combine the material into a pile or pyramid and separate it in four parts of approximately the same size
  - Take randomly one of those parts and stir and mix it again
  - Place the material in a clean bucket or a plastic bag for sampling
  - Analyse the sample as soon as possible or store in a fridge

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ISBN 978-982-04-1201-9

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