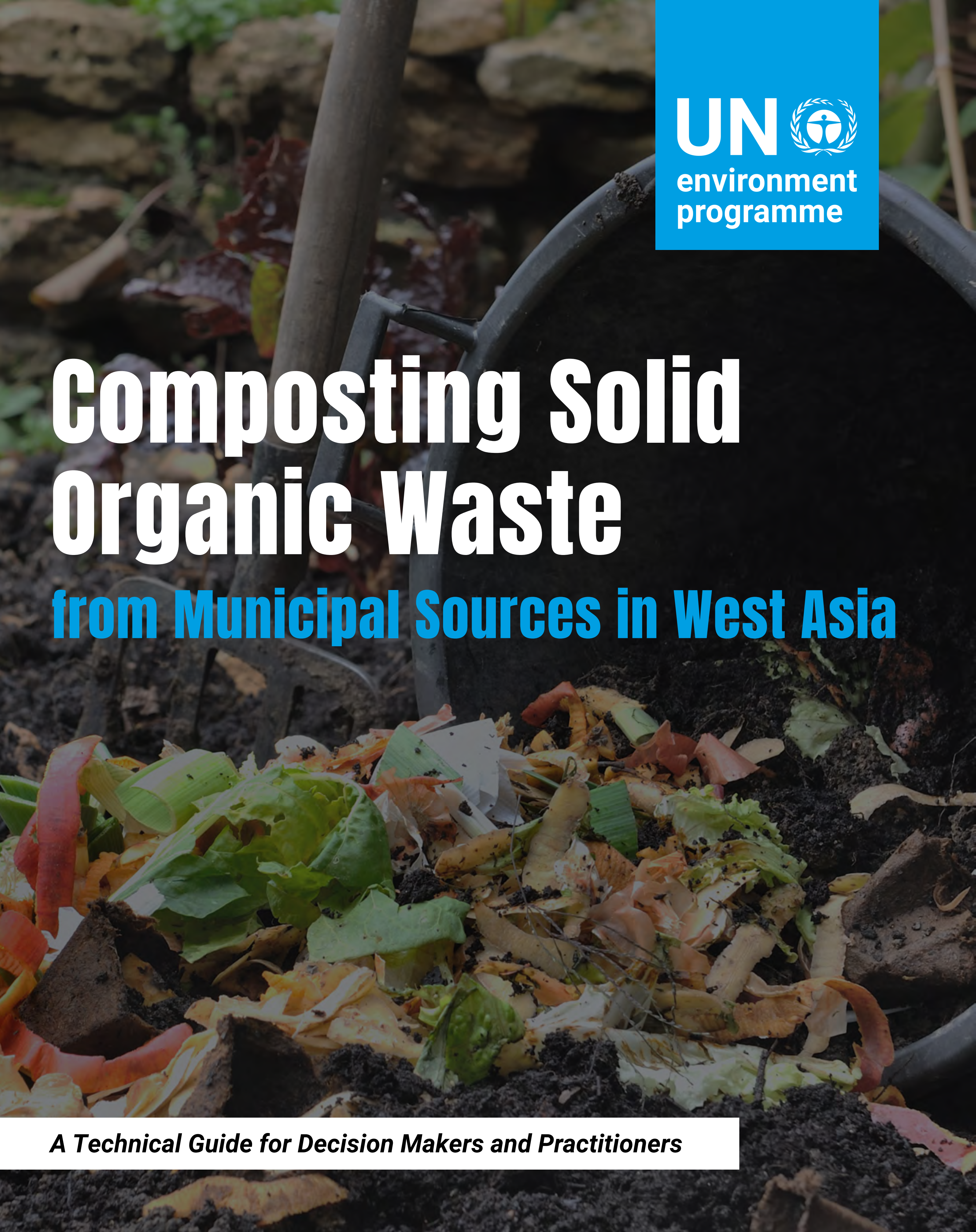


UN environment programme

Composting Solid Organic Waste

from Municipal Sources in West Asia

A Technical Guide for Decision Makers and Practitioners


© Freepik

© 2024 United Nations Environment Programme

ISBN: 978-92-807-4210-7

Job No: ROWA/2692/NA

Reproduction
This publication may be reproduced in whole or in part and in any form for educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. The United Nations Environment Programme would appreciate receiving a copy of any publication that uses this publication as a source. No use of this publication may be made for resale or any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme. Applications for such permission, with a statement of the purpose and extent of the reproduction, should be addressed to unep-communication-director@un.org.

Disclaimers
The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory or city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of a commercial company or product in this document does not imply endorsement by the United Nations Environment Programme or the authors. The use of information from this document for publicity or advertising is not permitted. Trademark names and symbols are used in an editorial fashion with no intention on infringement of trademark or copyright laws.

The contents and views expressed in this publication do not necessarily reflect the views of the United Nations Environment Programme. We regret any errors or omissions that may have been unwittingly made.

© Maps, photos and illustrations as specified.

Suggested Citation
United Nations Environment Programme (2024): Composting Solid Organic Waste from Municipal Sources in West Asia – A Technical Guide for Decision Makers and Practitioners. Nairobi.

United Nations Environment Programme (UNEP)
PO Box 30552, Nairobi, Kenya
Tel: +254 20 7621234
www.unep.org

Co-produced with:

IGES Institute for Global Environmental Strategies

ISWA International Solid Waste Association

Acknowledgements

Preparation of this report was led by the United Nations Environment Programme (UNEP) Regional Office for West Asia (ROWA), in collaboration with IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) and the International Solid Waste Association (ISWA). UNEP would like to thank the authors, reviewers and collaborators who have contributed to the report. UNEP Regional Office for West Asia serves twelve countries of the region namely: Kingdom of Bahrain, Republic of Iraq, The Hashemite Kingdom of Jordan, State of Kuwait, Republic of Lebanon, Sultanate of Oman, State of Palestine, State of Qatar, Kingdom of Saudia Arabia, Syrian Arab Republic, United Arab Emirates, and Republic of Yemen.

Main Authors

Gamaralalage, P.J.D., Gilbert, J., Mazumdar, N.B.,

Overall Supervision

This Report was developed under the general oversight of Sami Dimassi, UNEP Representative and Regional Director for West Asia.

Reviewers

Haddad, A.M., Hleihel, Y., Mylvakanam, I.,Ramola, A.

Production and Launch Support

El-Turk, H.

Editorial, Design and Translation Support

Copy Editing: Gilbert,J.

Design and Layout: Chawla, K.

Foreword

Waste management poses a significant challenge to sustainable development. Practices on waste management in West Asia have predominantly involved high levels of disposal, primarily in landfills and dumpsites. Over 50 per cent of the municipal solid waste destined for land disposal in West Asia is comprised of organic waste, with food waste making up around 85 per cent of this fraction.

All this causes adverse environmental impacts and health hazards, along with the depletion of valuable natural resources such as water and land. In response to these challenges, countries in the region have instituted waste governance, outlining essential strategic goals and guiding principles at different stages of implementation.

In support of countries' efforts, UNEP Regional Office for West Asia has developed the present guide to promote the recycling of organic waste through locally tailored composting techniques. It serves as a valuable resource for decision-makers and waste managers, to turn this waste into economic opportunities and transition away from landfill disposal by encouraging the composting of organic waste.

This guide covers context, composting process, feedstocks, facility management, planning, operations, marketing, awareness raising, personnel requirements, and worked examples. It offers technical information to plan, design, and operate composting facilities. Tailored for developing West Asian countries with limited access to high-cost capital infrastructure, it focuses on medium to large-scale composting operations while being applicable to smaller scale setups. It is expected to assist waste management authorities and stakeholders in effectively managing organic waste including food waste in an environmentally sound manner.

We extend our special thanks to our partners at the Institute for Global Environmental Strategies (IGES) and the International Solid Waste Association (ISWA) for their role in developing this guide.

Sami Dimassi
UNEP Representative and Regional Director for West Asia

Table of Contents

List of Figures

List of Tables

List of Abbreviations

3R	Reduce, Reuse, Recycle
AD	Anaerobic Digestion
CapEx	Capital Expenditure
FAS	Free Air Spaces
km	Kilometre
MENA	Middle East and North Africa
MIS	Management Information System
MSW	Municipal Solid Waste
OpEx	Operational Expenditure
PPE	Personal Protective Equipment
QC	Quality Control
QMS	Quality Management System
RDF	Refuse Derived Fuel
SOP	Standard Operating Procedure
t	Tonne
tpa	Tonnes Per Annum
tpd	Tonnes Per Day

Terms and Definitions

aerobic	In the presence of oxygen.
anaerobic	In the absence of oxygen.
anaerobic digestion (biomethanisation)	The controlled microbial decomposition of organic waste in the absence of air.
biochar	Organic material that has been subjected to a pyrolysis process.
black soldier fly	A species of fly (Hermetia illucens) used to degrade organic waste to create an animal protein out of their larvae.
compost	solid particulate material that is the result of composting, that has been sanitized and stabilized and that confers beneficial effects when added to soil, used as a component of a growing medium, or is used in another way in conjunction with plants.
compost pad/ platform	A hard impermeable surface, preferably concrete, on which composting is carried out.
composting	The process of controlled biological decomposition of biodegradable materials under managed conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat that convert the inputs to compost.
forced aeration	Introducing pumped fresh air into the composting mass through perforated pipes or a plenum lying underneath the composting mass.
hazard	Something that has the potential to cause injury, illness, damage to property, or other adverse effects. They can be physical, chemical, biological, ergonomic, or psychosocial in nature.
humification	The formation of humus (dark brown organic matter that is a major component of compost).
inoculant	A mixture of micro-organisms used to promote composting.
in-vessel	A type of composting system that is enclosed in a vessel or container. It usually offers greater levels of process control than open-air windrow systems.

leachate	A dark coloured liquid that has escaped from composting materials. It contains high levels of soluble biodegradable substances, so has potential to pollute and release malodours.
maturation (curing)	The final stage of composting where the temperature drops and mesophilic micro-organisms predominate.
mesophile (mesophilic)	Microbes that thrive in the temperature range of 20-45 °C.
organic waste	Biodegradable materials that originate from living organisms, primarily plants and animals and can be decomposed by natural processes.
passive aeration	Aeration of composting materials relying on diffusion of gases without the use of pumps of fans.
per annum	Every year
pyrolysis	The heating of an organic material to a high temperature in the absence of oxygen.
refuse-derived fuel	A combustible fuel produced from dry components of waste, such as, paper, fabric, dry organic material having more lignin or ligno-cellulosic material, which are not easily compostable.
risk	the likelihood or probability of a hazard causing harm or damage and its severity.
sanitisation (sanitising)	Phase of composting where high temperatures are reached to destroy harmful pathogens and weed seeds.
source segregation (source separation)	Storing waste separately from other types of waste at the point at which it is produced.
static pile	A composting pile that is not turned for aeration. It may be aerated passively ('passive aeration') or actively ('active aeration').
thermophile (thermophilic)	Microbes that thrive in temperatures above 45 °C.
turning	Mixing of composting material to introduce fresh air, release stale gases and re-form free air spaces (pores).
vermicomposting	Processing and biodegradation of wastes principally by appropriate worm species resulting in 'vermicompost' ('vermicasts').
windrow	A long row of composting materials, usually trapezoidal in shape.

Executive Summary

Approximately one billion tonnes of municipal organic waste are generated globally every year, although only a small fraction of this is currently recycled, with the remaining factions being either burnt or dumped in landfill sites. Composting is one of a number of different ways in which organic wastes can be converted into valuable products such as compost. Composting helps to alleviate pressures on land management, encourage sustainable farming practices and reduce fugitive emissions of methane gas from dumpsites and landfills.

Although composting harnesses natural micro-organisms to decompose organic materials under controlled conditions, the planning and management of a composting facility is complex. It requires a unique blend of knowledge and understanding spanning a number of disciplines, including amongst others, engineering, biology, chemistry, physics, marketing and occupational safety and health. It is particularly challenging when municipal sources of organic waste, such as food and green/garden wastes, are composted. Understanding how to prevent problems, and troubleshooting when they do occur, takes skill and technical know-how.

The purpose of this guide is to provide decision makers and waste managers with sufficient technical information to plan, design and operate a composting facility. It is aimed at developing Asian countries where access to high-cost capital infrastructure may not be possible. It focuses on medium- to large-scale composting operations, although the principles described apply equally to smaller scale operations. It is split into different chapters as follows:

Waste Mapping
Chapter 2 provides background information on the history of composting, why it is used to treat municipal organic wastes and some of the different composting technologies that have been developed globally. Examples of composting facilities in a selected number of Asian countries have been summarised.

The Composting Process
Chapter 3 explains the main composting parameters and the key composting stages that form essential background information for all composting practitioners.

Composting Feedstocks
Chapter 4 discusses why organic waste needs to be managed effectively in order to prevent problematic emissions and the importance of effective source segregation to minimise contamination.

Planning a Composting Facility
Chapter 5 sets out important information that should be considered when planning a composting facility, irrespective of its size. The failings of many facilities have their root cause in inadequate sizing, poor design and inappropriate sourcing of feedstocks. Fundamentals, such as site location and compliance with regulatory requirements, need to be understood by all stakeholders during the planning and commissioning stages. The information in this chapter should lead to effective planning of a new composting facility.

Operating a Composting Facility

Chapter 6 provides step-by-step instructions on how to develop an effective site management system, including compost monitoring, contaminant management, worker health and safety, and training. Good site management can also prevent problems occurring, such as generating odours and starting fires; problems that may cause a facility to cease operations and potentially close permanently. This chapter therefore sets out essential information that should be incorporated into a site's standard operating procedures.

Compost Products and Markets

Chapter 7 provides background information on the properties of compost, its benefits when applied to soil and the different types of products that can be manufactured. However, compost products do not sell themselves; hence a comprehensive marketing strategy should be developed as part of the planning process before the site becomes operational. As compost is a relatively new product to many people, product awareness and practical demonstrations may be necessary to build consumer demand. Without an effective sales strategy, the organic waste-to-compost-to-soil circle cannot be connected.

Awareness Raising

Chapter 8 provides some suggestions about how a composting company can target its three main stakeholders: technical professionals; farmers, agricultural advisers, landscapers and marketing professionals; and citizens. Communicating with each target group before operations begin should help build trust and understanding, as well as create market demand for compost.

Worked Examples

Information about four differently sized composting facilities, including site infrastructure, equipment and operational steps, are set out in Appendix 1. This is intended to illustrate how some of the principles described in the previous chapters have been put into practise.

Personal Requirements

Finally, Appendix 2 lists specimen job descriptions and desirable attributes of the different employees or volunteers needed at a successful composting operation.

This guide therefore sets out some of the key success factors needed for effective composting, namely:

- Adequate knowledge and understanding of the composting process and operational parameters by those planning and operating a facility,
- Sourcing appropriate feedstocks having minimal contamination,
- Effective planning of the site and operational parameters,
- Robust management of the site, including a quality management system and detailed standard operating procedures,
- Effective marketing of quality compost products, and
- Ongoing communications with all stakeholders.

Chapter 1

Introduction

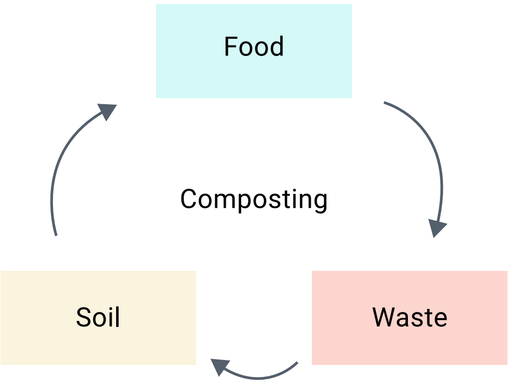
Composting is an essential practice for sustainable living and environmental stewardship. It serves as a natural recycling process, transforming organic waste into a valuable soil improver that can then be used to enrich gardens and agricultural fields. It has been practised for millennia by farmers as a means of recycling essential plant nutrients and returning organic matter to soil in which food is grown.

Over the past century, however, growing global urbanisation has seen an increasing proportion of the world's population move from rural to urban areas, leading to the growth and expansion of towns and cities. It has thus distanced production from consumption of food; breaking what was once a circular flow of nutrients and organic matter into and out of soil.

In many parts of Asia, waste food and other organic materials are disposed of in landfills and dumpsites, where their uncontrolled decomposition results in fugitive emissions of methane gas. The environmental consequences of this are significant, with waste estimated to account for 20 per cent of global anthropogenic methane emissions (United Nations Environment Programme and Climate and Clean Air Coalition 2021). As methane is a potent greenhouse gas, preventing these emissions can therefore have a profound effect on reducing the rate of global warming.

In parallel, agricultural soils are also experiencing unprecedented pressures, caused by intensive agricultural practices and the heightened effects of climate change. Soil erosion, through loss of organic matter, undermines the productivity and resilience of agricultural systems, and is a serious threat to food security.

Re-establishing the connectivity between food, waste and soil through composting therefore has potential to begin to tackle these problems simultaneously.



"Composting Solid Organic Waste from Municipal Sources" aims to provide technical know-how and guidance for municipalities, mayors, local and national policy makers, non-governmental organisations and waste managers. The guide provides background information on composting basics, including the main process parameters, feedstock identification, collection and management. It sets out detailed information on the many factors that need to be taken into account when planning and operating a composting facility, including the marketing of compost and promotion of the operations.

The guide is aimed at developing Asian countries where access to high-cost capital infrastructure may not be possible. It provides worked examples of four different composting scenarios located across Asia, setting out basic site plans, the operational steps involved and equipment in use.

The focus of the guide is on medium- to large-scale composting operations, although the principles involved, and the examples described, are equally applicable to small scale community and on-farm initiatives.

Chapter 2

Composting Context

2.1. Historical Background

Composting is one of the simplest and most effective ways of recycling organic waste. It has been practised by farmers for millennia, with the earliest written records dating back to ancient Mesopotamia over four thousand years ago. On-farm composting of animal manures and crop residues continues to form an integral part of sustainable agricultural practices.

The first scientifically based method for composting municipally derived organic waste was carried out by the British agronomist, Albert Howard, in the 1920s. He prepared 1.5-metre-high windrows (long piles of composting materials) consisting of layers of different types of organic waste, then monitored their temperature over a three-month period. This method successfully made nutrient rich compost and has taken the name of the city in India where it was developed: the 'Indore Process'.

Further research in the first half of the twentieth century into different composting methods and technologies also resulted in new processes being developed; including, amongst others, the Bangalore process (India), the VAM process (the Netherlands), the Beccari method (Italy) and the Dano system (Denmark).

During the 1950s to 1980, many more processes were developed, so that by the late 1960s, there were an estimated two-and-a-half thousand composting facilities globally. During this period, the primary aim was the extraction and composting of the organic fraction of mixed municipal solid waste (MSW) streams. This reflected the low value placed on 'waste'; with it being viewed as a problem that needed to be disposed of, rather than a resource that could be reused or recycled. Consequently, these composting facilities tended to manufacture poor quality compost containing fragments of glass and plastics, and high levels of heavy metals and organic pollutants.

This mindset started to change in the 1980s as municipalities began collecting organic wastes separately, often alongside dry recyclables. During this time countries, such as Germany and the Netherlands, led the way by providing householders with wheeled bins and other receptacles solely for organic wastes such as garden (yard) trimmings and food waste. The sector has developed rapidly, so that today there are a large number of in-vessel composting systems in operation employing sophisticated computer operated hardware, alongside simpler windrow composting processes.

A more detailed summary of the history of composting can be found in Annals of Composting (Bidlingmaier and Diaz 2022).

2.2. Composting and Solid Waste Management

Presently, composting stands as a widely adopted and established technique for the recycling of organic waste. It plays an important role in the integrated management of municipal solid waste (MSW), where the 'organic' fraction can range from between 20 to 40 per cent in high-income countries and to between 50 to 70 per cent in low-income countries (UNEP 2016).

Organic waste derived from municipal sources is predominantly food and garden/yard waste, including tree and shrub prunings, dead flowers, bedding plants and wood; however, in cities, food waste is the dominant fraction. Food waste can be particularly problematic for municipal authorities due to its high-water content (c. 50-95 per cent on a mass basis) and high bulk density (c. 500 kg/m^3). It is therefore heavy and wet, so can create significant problems if it is not managed effectively (see BOX 1).

BOX 1: PROBLEMS CAUSED BY ORGANIC WASTES

It is important to manage organic wastes effectively to harness their benefits while minimising potential negative environmental impacts. They can cause a range of environmental, health and social problems when they are improperly dumped or not effectively managed. Some of the key issues include:

Odour and Aesthetic Concerns: Organic wastes, when left to decompose in open or uncontrolled environments, can produce strong and unpleasant odours. These odours can negatively impact the quality of air in surrounding areas, leading to discomfort for residents and visitors.

Pathogens and Disease Spread: Organic wastes can contain harmful pathogens, such as bacteria, viruses and parasites, that can cause diseases in humans and animals. When organic waste is dumped inappropriately, these pathogens can spread and contaminate water sources, soil and even food crops, posing significant health risks.

Pest Infestations: Improperly managed organic wastes attract pests like rodents, insects and flies. These pests can spread diseases, cause damage to property and create unsanitary conditions.

Water Pollution: When organic wastes are dumped into water bodies like rivers, lakes, or oceans, they can degrade water quality by consuming oxygen during decomposition. This process, known as eutrophication, can lead to the death of aquatic life and disrupt the balance of ecosystems.

Greenhouse Gas Emissions: When organic wastes decompose in landfills without sufficient oxygen (anaerobic conditions), they produce methane, a potent greenhouse gas that contributes to climate change. Methane has a much higher global warming potential than carbon dioxide over a short period of time.

Soil Contamination: Dumping organic waste directly onto soil can introduce contaminants and pathogens into the environment, disrupting the natural soil ecosystem and potentially impacting the health of plants, animals and humans.

Waste Accumulation and Aesthetics: Improper dumping of organic waste can contribute to the buildup of waste piles in public spaces, roadsides and urban areas, leading to an unsightly and unhygienic environment. This can reduce property values, hinder economic development and deter tourism.

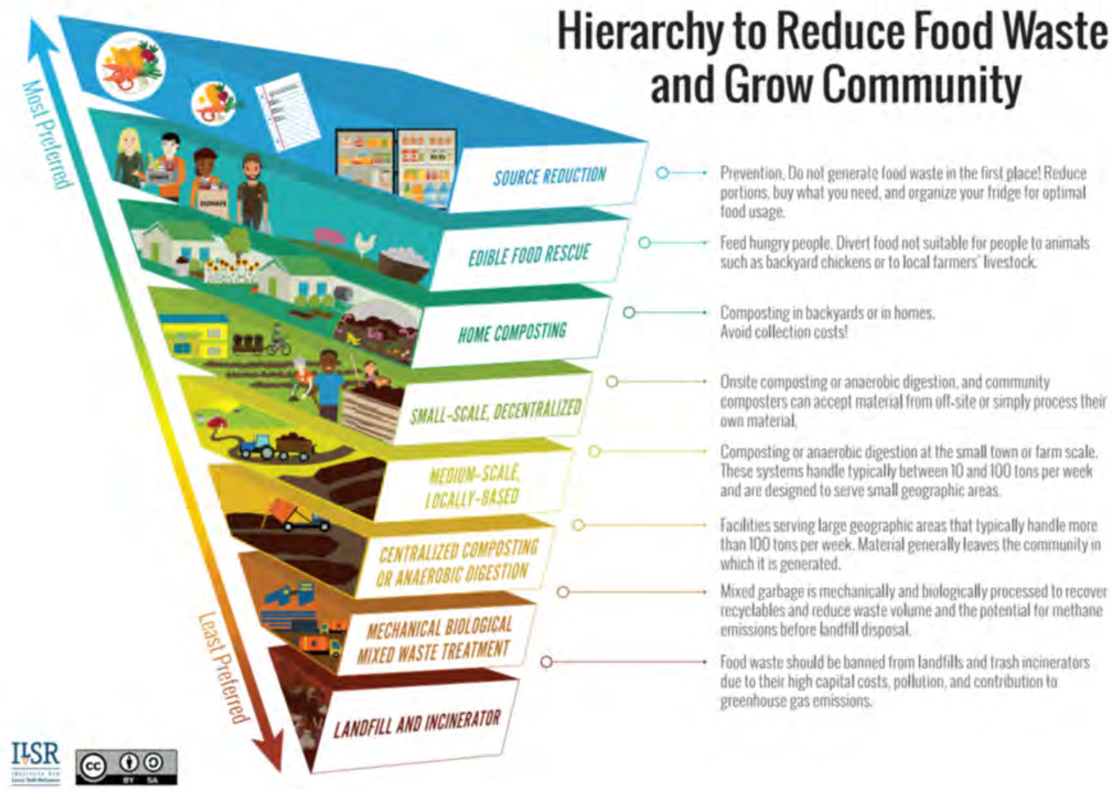
Resource Waste: Organic wastes, if not properly managed, represent a lost opportunity to recycle nutrients and organic matter. Instead of enriching soils through composting or other waste management techniques, valuable resources are wasted.

Social and Economic Disruptions: The presence of improperly managed organic waste can lead to social tensions, conflicts and increased costs for local governments. Communities may suffer from health issues, reduced quality of life and decreased economic opportunities.

Collecting organic waste separately from dry recyclables and residual non-recyclable waste, offers a number of advantages, including:

- Keeping dry recyclables clean, especially the paper/cardboard fraction that easily absorbs water;
- Choosing collection bin/receptacle types best suited to the different categories of waste. For example, as food waste has a high bulk density compared to plastic packaging, smaller volume containers can be used;
- Tailoring collection frequencies according to the different categories of waste. Due to food waste's high moisture content, it requires more frequent collection than dry recyclable fractions, for example. This can offer cost and logistical benefits for dry recyclable collections;
- Reducing the methane generating potential of residual landfilled waste; and
- Increasing the calorific value of residual waste sent for incineration or waste-to-energy.

Cities can promote a number of different composting options in line with the waste hierarchy, as shown schematically in Figure 1.



Source: https://ilsr.org/food-waste-hierarchy/

Figure 1: Hierarchy for the management of food waste

There are a wide range of different types of composting systems, ranging from small, simple structures that can process very small quantities (less than a tonne) of organic waste at a time, to large multi-million-dollar facilities capable of processing in excess of 100,000 tonnes a year.

Small-scale composting is often carried out by individuals, households, community groups, schools, and small businesses. It is generally managed manually without the need for mechanical equipment. These small-scale composting efforts contribute to reducing the amount of organic waste going to landfills, enriching local soils, and promoting sustainable practices at the community level.

Medium-scale composting is typically undertaken by a variety of entities that generate a moderate amount of organic waste, such as farms and agricultural operations, schools and universities, restaurants and food service providers, public parks and green spaces, and community gardens. These operations are larger than what an individual or household might manage but smaller than industrial-scale composting facilities, and will utilise some mechanical equipment, such as a front-end loader or a composting container.

Large-scale composting facilities are often managed by municipalities and local governments or their contractors, including commercial composting companies and waste management companies. Some agricultural operations and food processing industries may also compost large volumes of organic waste in order to reduce disposal costs. These facilities often use specialised equipment and technology to optimise the composting process and ensure efficiency, environmental sustainability and the production of high-quality compost.

Images: © Freepik | AI Generated

2.3. Composting Examples

This section summarises some of the underlying legislative instruments and composting practices carried out in selected countries that are relevant to the context of West Asia.

The Hashemite Kingdom of Jordan

The National Agricultural Research Centre (NARC) carried out research on making compost from the wastes generated at the Zaatari refugee camp. They studied the effect of the compost on the growth of forage and field crops, trees and plants in rangeland areas (FAO 2020).

Policies and Legislation:

- Management of Solid Waste Regulation No. 27/2005
- Instructions for the Management of Solid Waste (2006)
- National Solid Waste Management Strategy (2015)
  - Based on the '3R' approach
  - Aims to minimise landfilling of biodegradable waste (Decision 11392/02, 2015)
  - Aims to divert 75 per cent (using 2014 as the baseline) of biodegradable waste from landfill by 2024.

The State of Qatar

An integrated anaerobic digestion and composting facility is operated at the Domestic Solid Waste Management Centre in the city of Mesaieed, about 36 km south of the capital city, Doha. The facility accepts source segregated green (yard) and food waste to produce a Grade A compost; and mixed MSW to produce a Grade B compost. The facility has been in operation since 2011.

Composting is also being promoted by the Qatar Green Building Council (QGBC).

Policies and Legislation:

- The overarching plan for the management of solid waste in Qatar was set out in its first National Development Strategy 2011-2016 (Mariyam *et al.* 2022). This established a solid waste management plan that aimed to recycle 38 per cent of solid waste and limit per capita waste generation.

The Republic of India

Most composting facilities treat mixed municipal solid waste as the input feedstock, making compliance with the Fertiliser Control Order difficult.

The latest annual report on the Implementation of the Solid Waste Management Rules (2016) (Central Pollution Control Board 2021) suggests that there are the following operational treatment facilities:

- Composting: 4,102
- Vermicomposting: 474
- Anaerobic digestion: 530

There are similar number of new facilities being set up.

Policies and Legislation:

- The Solid Waste Management Rules (2016) set out the obligations of different stakeholders with regard to the collection and treatment of organic waste.
- The Municipal Solid Waste Management Manual Part II (2016) describes different composting options and detailed information on how to set up and operate a facility (Central Public Health and Environmental and Engineering Organisation 2016)
- The Fertiliser Control Order (1985, fifth amendment 2021) sets minimum quality criteria for compost.

The Democratic Socialist Republic of Sri Lanka

The ‘Pilisaru’ programme led to the distribution of almost 18,000 compost bins to householders; this increased to 70,000 by 2011. However, it also led to the development of many small, medium and large-scale mixed MSW composting plants that suffered from odour and vermin problems, resulting in protests by citizens (Dandeniya and Caucci 2020).

Most of the composting facilities in Sri Lanka use simple windrows with the aim of reducing the volume and biodegradability of the organic fraction of mixed MSW (Samarasinha, Bandara and Karunarathna 2015). In 2019 there were thought to be just over 150 composting facilities.

Policies and Legislation:

- In 2008, the ‘Pilisaru’ government programme aimed to promote the sorting of waste, which included composting.
- Standards for compost produced from municipal organics and agricultural wastes were introduced in 2003.

2.4. Alternative Treatment Methods

In addition to composting, a number of other treatment techniques can be used to create products from organic waste streams. These include anaerobic digestion (sometimes also called ‘biomethanisation’ or ‘biogas’ plants), pyrolysis, the production of a refuse-derived fuel (RDF) and using organic waste to grow black soldier fly larvae. These are described in Table 1 .

Over the past two decades, anaerobic digestion has grown in popularity in many European countries to treat commercial and municipal food wastes. It is also widely used in North America for on-farm wastes, such as animal manures and slurries. Although these systems tend to rely on high capital cost infrastructure, there are many examples in Asia where small-scale systems are used at a household level to generate biogas for cooking and heating purposes.

Table 1: Disaster types and their waste characteristics

	Composting	Anaerobic Digestion	Pyrolysis	Refuse-derived Fuel	Black Soldier Fly (BSF) Processing
Operational Principles	Decomposition of organic wastes by micro-organisms in the presence of oxygen to produce a solid, organic matter rich material.	Decomposition of organic wastes by micro-organisms in the absence of oxygen to produce biogas (a mixture of methane and carbon dioxide) and a solid or semi-solid nutrient-rich material (digestate).	Heating of biomass to high temperatures in the absence of oxygen to create a carbon-rich solid material (biochar).	Various steps (dependent upon configuration of the plant) are used to extract high calorific fractions (e.g. plastics) from MSW. If the organic fraction is included, this will need to be dried to remove water. Produces a solid material that is used as a fuel.	Decomposition of organic waste by Black Soldier Fly (Hermetia illucens) larvae.
Main product(s) & their use	**Compost** – used as a soil improver to add organic matter and plant nutrients to soil to improve its properties.	**Biogas** – used as a fuel to generate electricity and/or heat, be upgraded and compressed into a transport fuel or injected into a gas grid as biomethane. **Digestate** – can be used as a biofertiliser or composted to create nutrient-rich compost.	**Biochar** – used as a soil amendment to increase soil properties.	**RDF** – may be used as a fuel in a coal-fired power station or in cement kilns.	**BSF larvae** – harvested for use as a protein-rich feed source for animals, particularly poultry and fish. **Frass** – this is the solid residue and consists of consists of the undigested substrate, exoskeletons, and metabolic by-products of the black soldier fly larvae. It needs to be further treated by composting or AD.
Benefits	Increase soil organic matter and nutrient levels. Increase soil biota. Sequester carbon in soil. Offset the use of inorganic conventional fertilisers.	Replace fossil fuel-derived energy sources. Offset the use of inorganic conventional fertilisers.	Sequesters carbon in soil.	Reduces landfilling of waste. The biogenic portion of the RDF is carbon neutral and may be used to offset greenhouse gas emissions under trading schemes.	Creates a nutrient-rich animal feed using recycled resources. The organic residue can be treated and used to create a soil improver and/or biogas.
Suitable types of organic waste (examples)	Food waste, garden waste, wood waste, manures and crop residues.	Food waste, manures, crop residues, sludges, and fats, oils and grease. Not suitable for woody/garden waste	Wood.	Organic fraction of MSW, paper, wood and plastics (excluding poly vinyl chloride).	Food waste, manures, slaughterhouse waste, spent grains.
Required waste quality	High (Only low if being used to treat MSW prior to disposal)	High (Only low if being used to treat MSW prior to disposal)	Medium (Should not include treated timber)	Low	High
Project scale	Small to large	Small to large	Small	Medium to large	Small to medium
Investment	Low to high	Medium to high	Low	Low to medium	Low to medium

Chapter 3

The Composting Process

Composting is a natural process involving the controlled decomposition of organic materials by naturally occurring micro-organisms into a nutrient-rich humus. Composting mimics the biodegradation processes that occur in nature but is managed to optimise the conditions for efficient and controlled decomposition. This chapter describes the process and the main factors that affect composting.

3.1. The Science of Composting

All composting processes rely on bacteria and fungi to decompose organic wastes and convert them into compost. These micro-organisms are typically found in soil and the natural environment, so do not need to be bought or cultured separately.

Organic waste serves as a source of food for these microbes, with different types dominating at different stages of the composting process. As these microbes consume organic waste, they release heat energy, which in turn, increases the temperature of the composting mass. They also need oxygen (as composting is what is called an 'aerobic' process) and an appropriate amount of water. Other by-products of the composting process include carbon dioxide, water and some volatile substances that can be odorous. This is shown schematically in Figure 2.

Adapted from (Rynk *et al.* 2022)

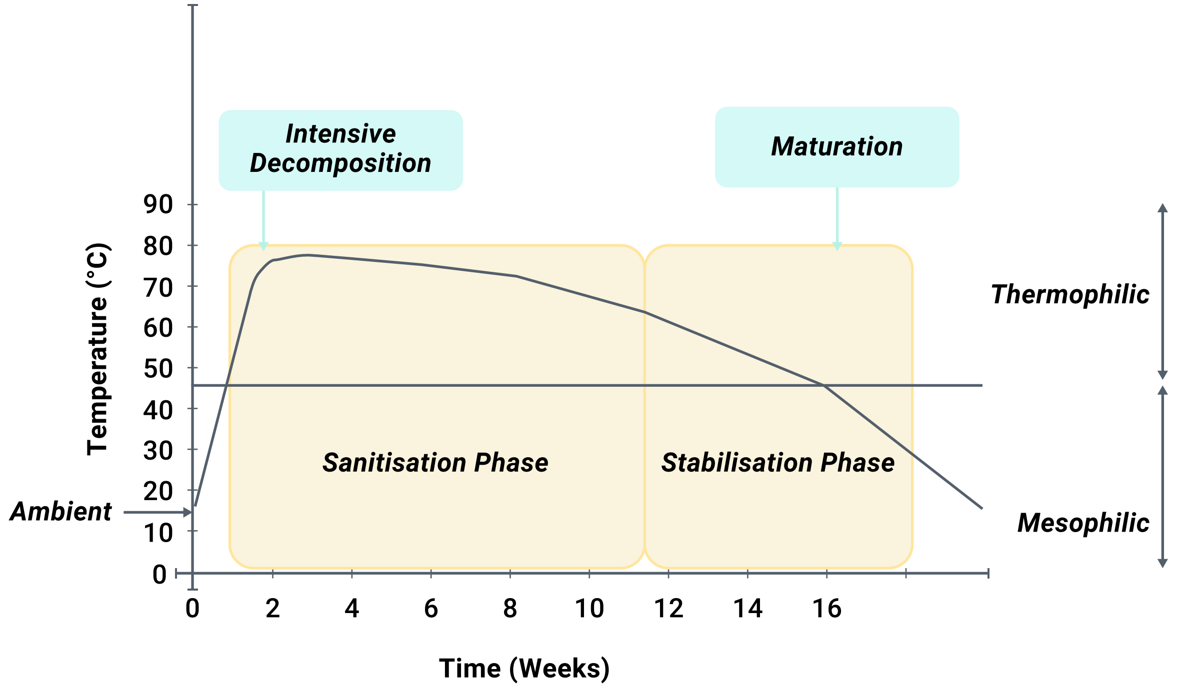
Figure 2: The composting process

Composting processes generally consist of at least two different phases:
During the first phase of composting, bacteria predominate, processing readily decomposable nutrients like proteins and sugars. In doing so, they release heat energy which increases the temperature of the composting mass. As the temperature rises, different types of microbes begin to thrive, whilst others start to die off or become dormant. In general, microbes that thrive in the temperature range of 20-45 °C are termed mesophiles, whilst those that thrive above 45 °C are called thermophiles.

The thermophilic composting phase (i.e., when temperatures are above 45 °C) is characterised by fewer bacteria and more fungi. This is where complex nutrients (such as cellulose) are metabolised and humification starts to take place. This phase is important as it is when the composting materials are sanitised; that is, when any harmful pathogens and weed seeds are killed off by high temperatures.

As the nutrients begin to be used up, the rate of microbial activity starts to fall, resulting in a corresponding decrease in temperature. This final phase is called the maturation or curing phase; it is where soil microbes begin to recolonise the compost, humification continues and inorganic nitrogen forms are oxidised to nitrate. Maturation is an important, but often overlooked, phase of the composting process and is essential to produce high-quality compost.

The main composting phases are shown in Figure 3.



Source: Jane Gilbert, personal communication

Figure 3: The main composting phases

3.2. Composting Parameters

As composting is a biological process, it is important to ensure that a number of key parameters are managed carefully to ensure the successful decomposition of organic waste. The main parameters are described below and summarised in Table 2.

Table 2: Optimal composting parameters

Parameter	Optimum Range	Importance
Carbon-to-Nitrogen (C:N) ratio	25:1 - 40:1	• Ensures that the micro-organisms have the necessary nutrients for decomposition.
Oxygen	> 10%	• Prevents the formation of malodours. • Maintains high-rate composting.
Moisture	50 - 60%	• Needed for effective microbial metabolism. • If too high, leads to the formation of malodours.
Temperature	55-70 °C	• Ensures effective destruction of pathogens and weed seeds (sanitisation).
Particle size	2.5 – 5.0 cm	• Ensures that there are sufficient free air spaces (FAS) to allow gases to diffuse.
pH	6.5 – 8.0	• Ensures effective microbial growth and metabolism.

3.2.1. Carbon-to-Nitrogen Ratio

A balanced C:N ratio ensures that micro-organisms have the necessary nutrients for decomposition. Too much nitrogen (and not enough carbon) will result in some of the nitrogen being lost to atmosphere, whilst insufficient nitrogen will result in slow composting.

The ideal C:N ratio for composting is typically around 25-40:1. Organic materials with a high carbon content, like leaves and straw, therefore need to be balanced with materials rich in nitrogen, such as food scraps or manure. Examples of the C:N ratios of organic wastes are listed in Table 3.

Table 3: Average carbon-to-nitrogen ratios of common feedstocks in municipal solid waste

Feedstock		Average C:N Ratio
	Food	15:1
	Green grass	10:1
	Leaves	55:1
	Woodchips	200:1
	Newsprint	400:1
	Cardboard	560:1

Source: Environment Canada, 2013

3.2.2. Aeration

Introducing fresh air into the composting mass is important to ensure that sufficient oxygen levels are maintained (i.e., the conditions are kept 'aerobic'). This is especially important during the initial stages of composting when microbial activity is at its highest.

Aeration can be achieved in a number of different ways:

- **Turning** – This involves systematically mixing ('turning') the composting material Turning can be done simply by hand (using a garden fork), by using a tractor or by using a specialist turning device.
- **Forced aeration** – This involves forcing air through perforated pipes lying underneath the composting mass.
- **Passive aeration** – This relies on the natural diffusion of gases into and out of the composting pile.

3.2.3. Moisture

Moisture is required to support the metabolic activity of the micro-organisms involved in the composting process. Too much moisture, and the hollow spaces in the composting mass become filled with water preventing gasses from diffusing and leading to the formation of odours. Too little moisture and microbial activity slows down.

Ideally, the moisture content should be between 50-60 per cent (m/m) at the start of the process. As composting progresses, water is lost through evaporation, whilst some is also released by the microbes as a by-product of their metabolism. Generally, the moisture content decreases during composting, making the final product drier and easier to handle.

3.2.4. Temperature

Heat released by the composting microbes causes the temperature to rise. During the initial 'sanitisation' phase (see Table 4), it is important to keep the temperature of the composting mass above 55 °C for a minimum period of time. This is to ensure that there is adequate destruction of pathogens and weed seeds. The minimum temperature-time profiles set out in the EU Fertilising Products Regulations (European Union 2019) are shown in Table 4. During this sanitisation phase, turning/mixing of the composting mass is recommended to ensure that all of the material is subjected to these high temperatures.

Table 4: Minimum temperature-time profiles for composting set in the EU Fertilising Products Regulation, 2019

Temperature	Minimum Residence Time
55 °C	14 days
60 °C	7 days
65 °C	5 days
70 °C	3 days

3.2.5. Particle size

Organic materials should be shredded or chopped into smaller pieces for two reasons: Firstly, to increase the surface area for microbial activity, as smaller particle sizes facilitate faster decomposition; and, secondly, to create free air spaces (FAS) in the composting mass to allow for the diffusion of gases. Therefore, it is important to ensure that the materials are not too large or too small; with the ideal range being between 2.5 to 5.0 cm.

3.2.6. pH

Ideally the initial pH of the composting feedstocks should be as close to neutral (pH 7) as possible; however, this is particularly difficult to control in practice. Additionally, the pH of the material also varies naturally during the composting process due to the release of metabolic by-products, such as organic acids and ammonium.

As most feedstocks will buffer large changes in pH, this parameter is rarely monitored during the process. However, should a facility accept highly acidic (e.g., citrus residues) or alkaline feedstocks, then these should be blended with other suitable feedstocks before composting.

All of the above parameters are important for the successful operation of a composting process. However, the emphasis placed on each parameter can be varied from composting plant to plant, depending on the feedstock types, the composting technology used, and operator’s knowledge and experience of the composting process.

3.3. Processing Stages

Irrespective of the size of the composting system, the same basic processes are involved (Figure 4). These processes include:

- **Shredding:** Larger organic materials are often shredded into smaller pieces to increase the surface area, which accelerates the decomposition process.
- **Mixing:** The shredded organic waste is then mixed to create a balanced blend of materials (C:N ratio, moisture content etc.).
- **Aeration:** This can be achieved by 'turning' or agitating the compost pile regularly, which helps maintain the required oxygen levels and prevents the pile from becoming compacted, or by forcing air through the composting mass.
- **Monitoring:** The composting process is closely monitored for factors like temperature, moisture and oxygen levels. Regular testing ensures that the conditions are conducive to efficient decomposition and the production of high-quality compost.
- **Maturation:** After the active composting phase, the material is allowed to mature for several weeks to several months. During this period, the compost stabilises and any remaining undecomposed materials continue to break down.
- **Screening and Quality Control:** Once matured, the compost is screened to remove any remaining large particles and contaminants. The final product is inspected for quality and adjustments may be made to the process if necessary.
- **Distribution and Use:** The finished compost is then ready for distribution and use. It can be sold to gardeners, landscapers, farmers and other end users to improve soil structure, fertility and water retention.

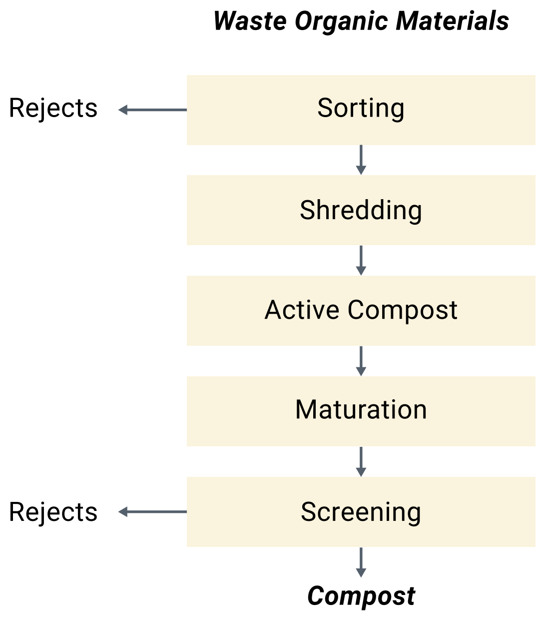


Figure 4: Flow of materials at a composting facility

Chapter 4

Composting Feedstocks

4.1. Organic Wastes

Organic wastes are biodegradable materials that originate from living organisms, primarily plants and animals and can be decomposed by natural processes. They are rich in carbon and typically contain a variety of compounds, including carbohydrates, proteins, fats and nucleic acids. Organic wastes are an essential part of the natural nutrient cycle, as they contribute to soil fertility and support the growth of new plants. These are some of their properties:

- **Biodegradability:** Organic wastes are capable of being broken down by micro-organisms, such as bacteria and fungi, into simpler substances through the process of decomposition. This process releases nutrients and energy back into the environment.
- **Carbon-Rich:** Organic wastes contain a significant amount of carbon. This carbon content contributes to the organic matter present in soils and helps improve soil structure, water-holding capacity and nutrient availability.
- **Nutrient Content:** Organic wastes contain essential nutrients such as nitrogen, phosphorus and potassium, along with micronutrients required for plant growth. When these wastes decompose, the nutrients are released into the soil, enriching it and supporting plant growth.
- **Moisture Content:** Organic wastes often have a high moisture content, which can impact their decomposition rate. High moisture levels can promote the growth of decomposing micro-organisms, while excessively wet conditions might impede decomposition.
- **pH and Acidity:** The pH and acidity of organic wastes can vary depending on their source. Some organic wastes may be more acidic, while others might be closer to neutral. The pH can influence the rate of decomposition and the type of micro-organisms involved.
- **Texture and Consistency:** Organic wastes can have varying textures, from fibrous to more gelatinous. The texture can influence how easily the waste breaks down and how it interacts with other materials in the composting or decomposition process.
- **Odour and Gases:** During decomposition, organic wastes can produce gases such as carbon dioxide, methane and volatile organic compounds. These gases can contribute to odours, especially in poorly managed decomposition systems.
- **Pathogens and Contaminants:** Depending on the source of the organic waste, it might contain pathogens (harmful micro-organisms) and contaminants that can impact human health and the environment. Proper handling and treatment are essential to minimise these risks.
- **Composting Potential:** Organic wastes can be used in composting processes to create nutrient-rich compost that can be added to soils to improve fertility and structure. Proper composting can help reduce waste volumes and produce a valuable soil amendment.

Examples of organic wastes include food scraps, yard trimmings, agricultural residues, manure, sewage sludge and various by-products from food and beverage production.

4.2. Identifying Feedstocks

Most composting facilities enter into long term contracts with local city authorities as part of an integrated waste management strategy. As such, the feedstocks usually consist of food waste and garden/yard trimmings, although this depends upon the local circumstances and housing type.

Across Asia, the ‘organic’ fraction of municipal solid waste is often over 50 per cent by mass of total municipal solid waste arisings, with the majority of this being food waste. Targeting this fraction, alongside food waste information campaigns aimed at reducing the overall quantity, can prove an effective strategy.

Furthermore, it is important to remember that organic waste feedstocks may vary in both quantity and quality throughout the year. This may be due to seasonal variations in the growth of some plants and crops, festivals at certain times of the year, or leaf fall during autumn/winter. These variations need to be considered when planning collection schemes and the composting facility.

Issues associated with balancing the carbon-to-nitrogen ratio and annual variations are discussed in Section 5.3.

4.3. Segregating and Collecting Organic Wastes

Successful organic waste recycling operations rely upon the manufacture of high-quality compost. This means that organic wastes need to be kept apart from other wastes that have the potential to cause contamination.

Contamination in compost refers to the presence of materials that are not intended to be part of the composting process and can negatively impact the quality of the final product. Contaminants can affect compost quality, nutrient content and potentially harm plants, animals (including humans), or the environment when the product is used. Potential compost contaminants are detailed in BOX 2.

BOX 2: POTENTIAL COMPOST CONTAMINANTS

Physical items: These include plastics, glass, metals, synthetic materials and other non-biodegradable substances that do not break down during composting/anaerobic digestion. Non-organic materials can remain in the compost and decrease its quality.

Plastic contamination is increasingly becoming a cause for concern, not only because of its longevity in the environment, but also because of the formation of microplastics. These are particles of plastic that are less than 5 mm in size and are formed from a wide range of plastic products, with car tyres and synthetic textiles being the two largest sources. Once in the environment they fragment even further, becoming smaller and smaller, eventually becoming nanoplastics (< 1 μm).

Due to their very small size these plastics are of concern, as there is evidence that they can be eaten by animals and become concentrated as they pass up the food chain. Humans are known to ingest microplastics when eating shellfish and sardines. There is also evidence that some chemicals and pathogenic micro-organisms can bind onto microplastics, so the effects these plastics exert are not solely physical as chemical and biological effects are known to occur.

Organic chemicals: These are chemicals such as pesticides, herbicides, plasticisers used in plastics manufacture, cleaning products and the products of incomplete combustion (such as dioxins). In recent years, a certain group of chemicals referred to as PFAS (per- and polyfluoroalkyl substances) have become cause for concern. They have been referred to as 'forever chemicals' due to the long length of time it takes them to breakdown. Moreover, they are toxic and have been shown to accumulate in food chains, raising concerns about the impacts they have on animals, including humans.

Inorganic chemicals: These are the heavy metals, such as lead, cadmium and mercury, which can be harmful to plants and animals. Using contaminated compost or digestate means that these metals can accumulate in the soil over time, causing toxicity problems.

In order to minimise (and ideally prevent) contamination, it is essential that organic waste be kept separate from other waste right from the point at which it is generated. This is termed 'source segregation' or 'source separation', with the terms being used interchangeably.

Not only does the collection of organic waste separately from other waste streams offer advantages for the overall management of municipal solid waste (MSW) as noted in Section 2.2, but it also significantly reduces capital and operational costs at the composting facility. Some of the advantages and disadvantages of separate versus mixed organic waste collections are listed in Table 5.

Table 5: Advantages and disadvantages of collecting source separated organics vs mixed MSW

Collection System	Advantages	Disadvantages
Collect source separated organics	• Significantly reduced levels of contamination • Results in higher quality compost products • Less money and time spent handling and separating waste at the facility • Potential to encourage residents to take actions to reduce waste	• Can be less convenient for residents at the start of new collection schemes • Requires dedicated collection vehicles and equipment • Requires additional labour for waste collection, awareness raising and monitoring
Collect mixed waste & sort at the composting site	• No need for additional equipment and labour • Does not require citizens to separate their waste	• High potential for contamination, including plastics and hazardous organic chemicals • Low quality compost, that may need to be disposed of (rather than sold) • High processing costs at the facility

Source: Based on (US EPA 1994)

Composting the organic fraction of mixed municipal waste therefore has the following limitations:

- Elaborate pre-sorting equipment is required, which carries a significant capital and operational cost.
- Twice the surface area is required compared to composting separately collected organic waste.
- The removed non-biodegradable fractions are usually soiled, so that their value for further recycling or sale is reduced.
- The compost will be heavily contaminated with physical and chemical contaminants, as noted in BOX 2.
- The yield of compost would be lower compared to that at a facility composting separately collected organics. This is because many organic wastes adhere to contaminating items such as plastics and metals, so a fraction is inevitably lost during contaminant removal.

Apps have been developed for generating real time data regarding the collection of different waste fractions and exporting such data to centralised data collection systems. Application of such apps would ensure appropriate collection of source-segregated material from the source, giving data about weight of each designated fraction. Such data would also provide real time data about waste composition in a city in every season, as well as during festivals and holiday periods. An example is the SEWAC[1] app developed in India.


© Freepik | AI Generated

[1] https://www.ecoparadigm.com/SEWAC

Chapter 5

Planning a Composting Facility

5.1. Factors to Consider

When planning a composting facility as part of a city's solid waste management plan, several key factors need to be taken into account. These considerations are essential to ensure the facility's efficiency, sustainability and compliance with environmental regulations. They include:

1. **Site Selection**
    - Choose a suitable location that complies with zoning regulations and is accessible for waste collection vehicles.
    - Assess soil conditions, drainage and groundwater proximity to prevent environmental contamination.

2. **Facility Design**
    - Design the composting facility layout to accommodate the expected waste volume and processing capacity.
    - Include designated areas for waste drop-off, processing, curing and storage of finished compost.
    - Implement measures to control odour, dust and noise.
    - Ensure that all composting facilities and processes adhere to health and safety standards that protect all workers, with attention to the specific needs of women, such as appropriate sanitation facilities.

3. **Technology and Equipment**
    - Select appropriate composting technology (e.g., aerated windrow, in-vessel or static pile) based on available resources and the local climate.
    - Procure necessary composting equipment such as shredders, turners and screens to optimize the process.

4. **Feedstock Management**
    - Model predicted variations in quantity and quality of feedstocks throughout the year e.g., leaf fall in autumn and festivals such as Eid and Diwali.
    - Specify guidelines for acceptable feedstock materials, including source separation of organic waste from other waste streams.
    - Educate residents and businesses on proper waste separation and collection methods.

5. **Process Management**
    - Develop a composting process that ensures efficient decomposition of organic materials while complying with regulatory requirements.
    - Monitor and control temperature, moisture levels and aeration to facilitate composting.

6. **Regulatory Compliance**
    - Ensure compliance with national and local environmental regulations, including air quality, water quality and land use permits.
    - Establish protocols for regular reporting and compliance monitoring.

7. **Safety Measures**
    - Implement safety protocols for facility staff and visitors, including training on equipment operation and handling of organic waste.
    - Provide necessary gender appropriate safety equipment and signage considering the different sizes and fittings needed by women workers to ensure their safety and comfort.

8. **Quality Assurance**
    - Establish quality control measures to produce high quality compost free from contaminants.
    - Conduct regular testing for contaminants and ensure compliance with compost quality standards.

9. **Waste Collection and Transportation**
    - Plan efficient waste collection routes to minimize transportation costs and emissions.
    - Determine the frequency of waste collection and establish collection schedules.

10. **Community Engagement**
    - Engage with the local community including women groups to gain their support and address concerns regarding the composting facility.
    - Promote women's involvement in decision-making, consider roles in planning, and offer flexible training schedules or childcare services to accommodate women's household responsibilities. Conduct outreach and education campaigns that are inclusive and accessible to the local community including women, to promote composting and waste reduction.

11. **Economic Viability**
    - Develop a sustainable financial model for the composting facility, including cost recovery mechanisms, fees and potential revenue streams from the sale of compost.

12. Monitoring and Reporting

- Implement a monitoring system to track facility performance, including compost production rates, waste diversion rates and environmental impacts.
- Include gender-sensitive indicators in the monitoring and evaluation framework to track the participation and impact of composting programs on women. This data can help in making informed adjustments to improve women participation in composting.
- Prepare regular reports to assess progress and identify areas for improvement.

13. Environmental Impact Assessment

- Conduct an environmental impact assessment to evaluate the facility's potential effects on air and water quality, wildlife and nearby communities.

14. Emergency Response Plan

- Develop a comprehensive emergency response plan to address potential accidents, spills, or other unforeseen events.

15. Long-Term Sustainability

- Consider the long-term sustainability of the facility, including plans for expansion, maintenance and closure.

Incorporating these considerations into the planning process will help ensure the successful establishment and operation of a composting facility as part of a city's solid waste management plan while minimizing environmental impacts and maximizing the benefits of organic waste recycling.

An example of the way in which the city of Karbala in Iraq planned its pilot composting facility is explained in BOX 3.

BOX 3: EXAMPLE OF PLANNING A PILOT COMPOSTING FACILITY IN THE CITY OF KARBALA, IRAQ

The city of Karbala, the capital of Karbala Governorate in the Republic of Iraq, had a population of half a million in 2008, that increased to 0.9 million by 2012. Its municipal solid waste (MSW) arisings consequently grew by an estimated 4 per cent annually, increasing from 100,000 tonnes in 2008 to 300,000 tonnes by 2012. Moreover, the large number of religious pilgrims who visit the city every year, add an additional 15 per cent to the city's MSW. As almost two-thirds of the city's MSW is organic waste, this highlights the significant potential for composting.

In 2021, a pilot composting plant was developed. A steering committee including officials from the Ministry of Environment, Karbala Municipality and Governor's office, and expert organisations oversaw the design, procurement and implementation of the project.

The chosen location was within an area planned for a new landfill site, with sufficient space for it to be scaled up in future; however, its rural location meant that the site was not serviced by roads, water or electricity. As electricity was identified as being required for the operation of the facility, a solar photovoltaic array was included in the facility's design.

Temperature, rainfall, humidity, wind speed and wind direction were all considered during its planning and design. Although the Karbala winter is cool, its summer months are hot. The area also receives little rainfall, with June to September receiving almost none. Consequently, maintaining moisture levels in open-air composting piles was identified as potentially problematic, so the decision was made to use a covered system.

Following approval of an environmental impact assessment by the Middle Environmental Directorate and a successful tender, a private sector company was contracted to carry out all construction works, including earth works, road construction and security fencing. The pilot facility has been designed to compost up to 150 tonnes of organic waste a year, including waste from 100 households, with farmers receiving the compost for agricultural purposes.

The pilot composting facility was officially handed over to Karbala Municipality in 2022. A partnership between the Karbala Municipality and Karbala Governor's Office ensured that the project was implemented successfully with a six-month timeframe.

5.2. Site Location

Choosing the right site for a composting facility requires a thorough analysis of a number of factors to ensure that the facility complies with regulations, minimises its environmental impact and serves the needs of the community. In practice it is often very difficult to find an 'ideal' location, with compromises needing to be made on a number of fronts. Early dialogue with regulatory authorities and key stakeholders is therefore essential to ensure that a proposed facility will comply, at a minimum, with all legal requirements. A checklist of the factors to consider are shown in Figure 5.

1. Zoning and Regulatory Compliance:
   - Verify that the site complies with local zoning regulations and land use policies.
   - Ensure compliance with national and regional environmental regulations.

2. Proximity to Waste Sources:
   - Evaluate the distance to major sources of organic waste, such as residential areas, businesses and markets.
   - Minimise transportation distances to reduce costs and emissions.

3. Accessibility:
   - Confirm that the site is easily accessible for waste collection vehicles.
   - Assess road conditions and transportation infrastructure.

4. Environmental Impact Assessment:
   - Conduct an environmental impact assessment to identify potential impacts on air quality, water quality, and wildlife.
   - Avoid environmentally sensitive areas.

5. Soil and Topography:
   - Assess soil strength for assessing suitability for installation of compost plant.
   - Consider topographical features that may affect facility design, especially, drainage.

6. Water Resources:
   - Determine the availability of water sources for composting operations.
   - Ensure responsible water use to avoid straining local resources.

7. Odour Control:
   - Analyse wind direction and potential odour dispersion.
   - Plan for odour control measures, such as buffer zones.

Cont. on next page.

8. Transportation Infrastructure:
   - Evaluate proximity to major transportation routes for efficient waste and compost transportation.
   - Assess transportation logistics for feedstock and finished compost.

9. Community Proximity:
   - Consider the distance to residential areas, schools, hospitals, and other sensitive locations.
   - Minimize potential disruptions to communities.

10. Utilities and Infrastructure:
    - Ensure access to essential utilities, including electricity, water supply, and wastewater treatment facilities.

11. Buffer Zones and Setbacks:
    - Establish buffer zones and comply with setback requirements to mitigate potential nuisances.

12. Permitting and Regulatory Compliance:
    - Identify and adhere to all necessary permits and regulatory requirements, including air and water quality permits.

13. Land Availability and Size:
    - Confirm that the site offers adequate space for composting operations and future expansion, if needed.
    - Assess the suitability of adjacent land for potential expansion.

14. Emergency Access and Response:
    - Plan for emergency access routes and develop a comprehensive emergency response plan.

15. Community Engagement and Consultation:
    - Engage with the local community to gather input, address concerns, and build support for the facility.
    - Conduct public outreach and information sessions.

16. Cost and Feasibility:
    - Evaluate the overall cost of land acquisition, site development, and infrastructure improvements.
    - Assess the feasibility of the chosen location within budget constraints.

Figure 5: Site Selection Checklist for a Composting Facility

5.3. Feedstock Blending

The types of feedstocks and their collection were discussed in Section 4. However, when planning a facility, it is prudent to ensure that diversified sources of materials are delivered to the site on a year-round basis. Depending on the climatic zone, some feedstocks predominate at certain times of the year, leading to an imbalance in the carbon-to-nitrogen ratio of the composting mix. For example, in temperate regions, autumnal leaf fall and winter tree prunings can result in a predominance of carbon-rich materials being delivered to site; whilst festivals such as Eid and Diwali can increase food waste arisings.

Care also needs to be taken when considering composting food waste, as this needs to be mixed with carbon-rich bulking materials to balance the C:N ratio, and adjust the porosity and moisture levels. Suitable bulking materials include wood chip, straw, palm leaves, banana stems and tree prunings. A minimum ratio of 1 part food waste to 1 part bulking material is needed in order to enable effective composting and prevent the formation of malodours.

A balanced source of composting feedstocks throughout the year is therefore an essential component of the facility's plan.

5.4. Financial Aspects

The economics of composting are complex and prudent financial management is essential for guaranteeing the long-term sustainability of the facility. In general, the cost of composting includes both design/capital expenditure (CapEx) and operational expenditure (OpEx) as set out in Figure 6.

DESIGN/ CAPITAL EXPENDITURE	OPERATIONAL EXPENDITURE
• Planning and design of the facility (feasibility studies, siting costs) • Investment (capital costs for land, buildings, machinery, vehicles) • Planning and design of the operation, management and marketing strategies • Obtaining necessary approvals and permits • Risk assessments	• Raw materials (feedstock transportation) • Administrative and overhead (personnel, labour) • Other production costs (water, energy) • Marketing • Residual management and disposal • Other environmental and social (pollution control, odour, community awareness) • Training • Personal protective equipment • Any other hidden costs

Figure 6: Indicative items of expenditure associated with the design, construction and operation of a composting facility

While costs are largely based on local circumstances and the selected composting processing systems, the following issues are key to a sustainable composting project and should be considered:

- Ensuring that appropriate planning, feasibility studies, design and construction are carried out.
- Planning on the concept of a 'lifecycle cost' rather than immediate costs until the facility has been commissioned.
- Ensuring that the design should have sufficient built-in flexibility to accommodate improvements in technology and changes in the legislative framework (e.g., the national compost standard).
- Ensuring that there is provision for operation and maintenance expenditure for the whole of the operating period, including major repairs, change of spares, plus cost of marketing the product (compost).
- Creating a 'Sink Fund' to cover the costs of major repairs and maintenance, site expansion, technology modification, capacity building etc.

- Identifying appropriate financial sources, such as debt and equity financing. This would depend on local circumstances and whether the composting facility is being established by the public or private sectors, or a public-private partnership.
- Maximising harnessing of solar energy from panels located on the facility's roofs. Depending on the location of the facility and the potential to connect to sell surplus electricity to the grid, this could provide additional revenue and could be an effective contributor to the 'Sink Fund'.
- Establishing a marketing strategy (see Section 7.5) for sale of the compost. This step should be taken seriously, and sound preparations need to be made before starting to market the compost.
- Investigating subsidies and grants (e.g., Certified Emission Reductions under the Clean Development Mechanism).

Income can come from two sources:

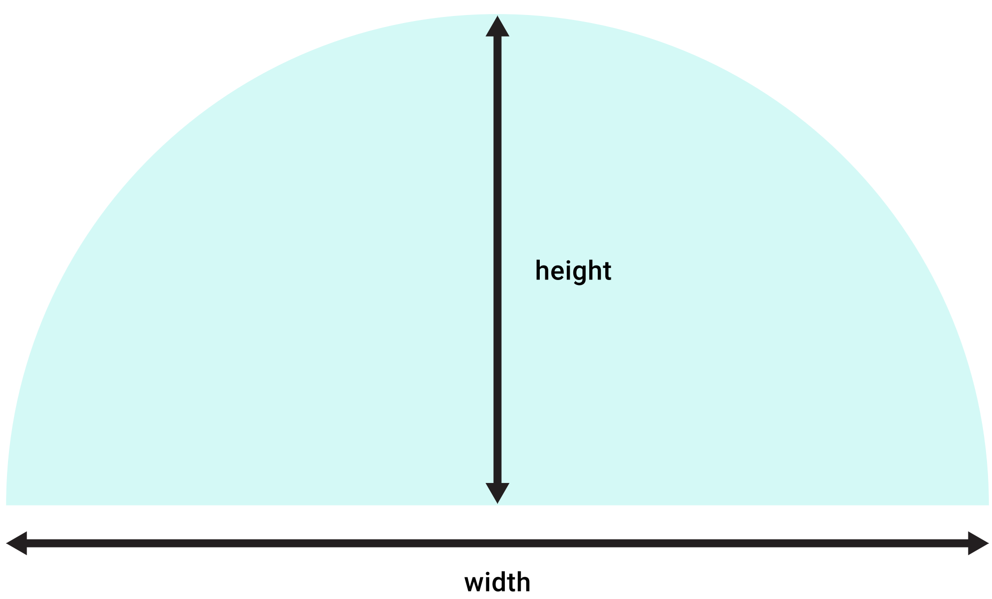
- A gate fee levied on every tonne of feedstock delivered to the site, and
- From the sale of the composted products.
- Overall, most composting operations receive 75 per cent of their income from gate fees and only 25 per cent from compost sales.
- It also needs to be remembered that, due to mass losses during the composting process and the removal of contaminants and oversized fragments, that compost products comprise about 30-40 per cent of the total input mass.

5.5. Composting Pad Size Calculations

The anticipated mass (weight) and volume of incoming feedstocks need to be estimated. This information should help in the design of the facility and, in particular, the sizing of the reception area and quantity of materials (and rejects) that need to be handled. However, these figures should not be used to calculate the total area of the composting pad. This is because the composting process results in a loss of carbon dioxide and water, causing the composting piles to become lighter and smaller i.e., there is both a mass and volume shrinkage. The extent to which this happens depends on the type of feedstock and the composting duration. In the absence of specific data, it can be assumed that the mass and volume will halve, leading to an overall shrinkage factor of 0.75.

Calculating the size of a composting pile depends upon its shape. Unless a dedicated compost turner is used, it can be assumed that a cross section of the windrow or ASP is similar in shape to a parabolic arch. It is then simple to calculate the area of the cross section and multiply this by the length of the pile to calculate the volume (Figure 7).

Cross sectional area = 2/3 x width x height



Volume = cross sectional are x length

Figure 7: How to calculate the volume of a windrow

The height of the pile will be limited by the machinery used to move and create the windrow. Tractors and skid steer loaders will generally be able to create piles up to 2.5 metres in height, whilst some front-end loaders can create piles up to 4 metres high. The width at the base of the pile is generally just under twice its height. Bear in mind that the larger the pile, the harder it is for gases to diffuse into and out of the composting mass. This not only slows the rate of composting but also increases the risk of odour generation and fire. Calculating the anticipated size of the composting pad is shown in BOX 4.

BOX 4: HOW TO CALCULATE THE AREA OF THE COMPOSTING PAD

1. **Calculate the total volume of material to be composted at any one time.** This will depend upon the anticipated weekly feedstock inputs and the length of time active composting plus maturation will take. Anticipated increases in feedstock quantities may vary seasonally due to festivals, leaf fall and growth patterns of vegetation etc. A 'buffer' therefore needs to be considered to accommodate anticipated feedstock uplifts throughout the year. The length of time to produce compost may typically be anywhere from six to 12 weeks, although this may be influenced by ambient temperatures. Additional storage of mature compost before sale and distribution may also be required.
2. **Apply a shrinkage factor of 0.75.** This assumes that the volume of material will reduce to 50 per cent of the incoming value during composting.
3. **Calculate the dimensions of the windrows.** This will depend on the machinery that will be used to create the piles.
4. **Calculate the volume of each windrow.** This involves calculating the cross-sectional area of the pile, then multiplying it by the windrow length.
5. **Calculate how many windrows/piles will be needed at any one time.** It is sensible to include a 'buffer' in the event that composting takes longer than anticipated.
6. **Calculate the area of each windrow then multiply it by the estimated total number required at any one time.** Spaces between the windrows, vehicle turning points, perimeter fencing, buffer distances, offices and machinery storage will also need to be taken into account.
7. **Create a scale drawing to visualise the plan.**

5.6. Composting Systems

A number of composting methods and technology models have been developed to operate at different scales in different countries. These range from very simple systems to sophisticated, computer controlled, patented methods (Table 6).

In essence, they all provide the same basic conditions needed for effective composting, namely:

- A solid base for composting to take place on
- Adequate aeration to supply oxygen
- Mixing and size reduction of feedstocks
- Removal of contaminants
- Temperature and moisture management, and
- Maturation and final processing of the compost.

The main types of composting system are summarised in Table 6, although there are many variations too numerous to describe here. They essentially differ in the following ways:

- Open to the air or enclosed (in-vessel)
- Passive or active aeration
- Manual or computer-controlled process management

Table 6: Examples of different types of large-scale composting systems

System Type	Operational Principles	Advantages	Disadvantages
Passively Aerated Piles 	• Composting materials may be laid out in small piles or windrows, or • Specialised bins/boxes are used. • Aeration may be acheived through the use of perforated pipes inserted into the materials, or by manually mixing the materials periodically.	• Simple to operate. • Cheap to construct. • Dedicated equipment is not required. • Minimal training and competence of operatives is required. • Can be carried out in gardens and community spaces.	• Low levels of processing control. • High potential for odour and attraction of vermin. • Temperature distribution is unlikely to be even, so sanitatsation may be problematic.
Vermicomposting 	• Selected species of leaf litter worms (e.g., Eisenia fetida) are introduced into food waste and other non-woody organics. • Composting takes place in shallow trays covered with leaves or compost.	• High nutrient compost is produced that has a good structure. • Sale of worms also provides a secondary income.	• Process is highly dependent upon temperature of the composting materials. If it becomes too high the worms will die. • High surface area requirements.
Open Air Turned Windrows 	• Composting materials are laid out in long rows called 'windrows'. • They are mixed periodically using either a front-end loader or a specialised windrow turner.	• Relatively simple system to operate compared to in-vessel options. • Tried and tested technique used globally. • Can be operated with simple equipment.	• Low levels of process control. • As it is not enclosed, emissions may be problematic. • Operation may be dependent on weather.
Aerated Static Piles 	• Composting materials are laid out in long rows over a pipe or plenum connected to a fan. • Air is forced through the composting materials to facilitate aeration. • A semi-permeable membrane (e.g. Gore®) may be placed over the piles to reduce odours and manage moisture and temperature.	• Positive and/or negative pressure may be employed at different stages of the composting process. • Odour control is possible.	• Needs good structural material. • Works best with homogeneous feedstocks (e.g., biosolids mixed with woodchips). • Air will follow the 'path of least resistance', so some turning is required. • Not enclosed.
Silos 	• Composting materials are contained in concrete silos. • Air is forced through a plenum in the bottom of the silo. • Materials are covered with a semi-permeable membrane.	• Modular system. • Insulated, so less affected by weather than open systems. • Spent air can be channelled through a biofilter to reduce emissions.	• Height of the silo may limited by the mechanism used to cover the composting materials. • External maturation of compost is required.
Electromechanical 	• Materials are actively mixed and aerated inside the unit through action of rotating augers. • Typically used for small-scale on-site composting.	• Short processing times. • High level of process control. • Can be used with an odour control system.	• Cost per tonne of material composted is high. • Moving parts may become damaged and require replacement. • External maturation of compost is required.

Images: © Authors

System Type	Operational Principles	Advantages	Disadvantages
Tunnels 	• Operate on a similar basis to the silo system, except the composting material is contained in a concrete tunnel with roof. • Often used for food and green waste co-composting on a large scale. • Developed by the mushroom growing industry.	• High levels of process control. • Highly engineered. • Tried and tested composting method. • Process air can be treated through a biofilter.	• High capital infrastructure costs.
Bays and Enclosed Halls 	• Composting materials are placed in concrete bunkers or large halls. • Mechanical augers move along the materials to mix and aerate. • Used on a large scale, often with non-segregated organics.	• Highly engineered.	• Moving parts may become damaged and require replacement. • Not often used for woody wastes. • High capital infrastructure costs. • Difficult to isolate batches due to size.
Towers 	• Composting materials are fed into the top of the vertical unit and work their way through the system by gravity. • Used at medium-scale facilities.	• Modular. • Low footprint, so useful where land is limited.	• Low levels of process control. • Low levels of emissions management. • External maturation of compost is required.
Rotating Drums 	• Composting materials are fed into the higher end of a rotating drum with projections in to mix it. • The drum is placed at an angle and rotates allowing the materials to fall through the drum over a number of days.	• Some process control is possible such as odour control. • Effective to mix materials well, especially if heterogenous.	• Moving parts may become damaged and require replacement. • External maturation of compost is required.

Images: © Authors

Examples of different composting approaches in different countries are shown in Boxes 5 and 6.

BOX 5: COMPOSTING IN SRI LANKA USING STATIC PILE BOXES

The composting facility located in Matale, Sri Lanka, was established in 2007 through the collaborative efforts of the local non-governmental organisation, Sevanatha, with the support of UNESCAP and Waste Concern in Bangladesh. Initially designed to manage two tonnes of organic waste daily, the project expanded in 2010 with the backing of the Pilisaru Programme. Macro Enrich Compost (Pvt) Limited Company, a Sevanatha business venture, plays a pivotal role in the composting operation.

The core activities of the project involve educating the community on the separation of waste at its source, conducting door-to-door collection of separated waste, and transporting it to the composting facility. Upon arrival at the facility, the waste goes through a rigorous process that includes weighing, sorting, mixing, piling in containers for composting, maturing, screening, storage, and eventually, bagging and marketing.

Employing a box composting method, the Matale Compost plant adheres to stringent controls with the objective of producing high quality compost meeting national standards. The produced compost is then distributed within the city through mobile sales outlets. In addition to the revenue generated from compost sales, Sevanatha also derives income from selling recyclable materials and collecting user fees from households and businesses in the project area.

Transportation

Segregation

Pilling (Box Method)

Packaging

Screening

Heat Measure

Images: © Authors

BOX 6: COMPOSTING IN THE KINGDOM OF THAILAND USING A ROTATING DRUM

In Bangkok, approximately 44 per cent of its Municipal Solid Waste (MSW) comprises organic materials, with plastic, paper, glass, metals and other materials making up the rest. The moisture content is between 44 to 60 per cent, volatile solids between 32 per cent and 43 per cent, and the ash content varies between 6 to 17 per cent. This high proportion of organic waste has driven the development of an integrated solid waste management system in Bangkok, encompassing waste collection, transfer stations, composting and final landfilling.

The Bangkok Metropolitan Administration (BMA) is responsible for collecting just over nine thousand tonnes of waste per day and has outsourced the disposal management to a private sector entity. Out of this waste, approximately 60 per cent, equivalent to 5,600 tonnes a day, is deposited in a landfill located in Kampaeng Saen District, Nakhon Pathom, while the remaining 40 per cent is transported to the On-Nut Waste Transfer Station. Among the transported waste, about 5 per cent undergoes composting, and the remaining 35 per cent is directed to the disposal site at the Panom Sarakham District.

Since 2006, a privately-owned company has operated the composting facility in Bangkok utilising a rotary drum to process mixed MSW. This plant has a daily capacity of 1,000 tonnes, with average daily compost production of 250 tonnes (25 per cent of the input material). The produced compost is distributed to farmers throughout Thailand through a contract with a fertiliser company. Furthermore, the composting facility receives tipping fees from the BMA, calculated at 21 USD per tonne of waste received.

Sorting

Rotary Drum

Making Windropiles

Resudual to Landfill

Ready for Sell

Screening

Images: © Authors

5.7. Equipment and Resources Requirements

Hardstanding

Composting is always best carried out on a hard surface, with associated drainage and leachate control measures. Appropriate traffic routes to ensure the safe movement of vehicles, odour control systems, site security measures (e.g., fencing and signage), weighbridge/ record keeping, and water management systems are also key requirements. Most of these depend on local conditions, such as climate (temperature and levels of precipitation), regulatory requirements and proximity of the site to housing and businesses (so-called 'sensitive receptors'). As such, generic guidance regarding sizing and specifications for the four scenarios may be misleading. Worked examples for the four composting scenarios are detailed in Appendix 1, alongside specifications taken from operational composting facilities.

With regard to hardstanding, reinforced concrete should be specified wherever possible. This is because subsidence and compaction of underlying earth may occur as a result of repeated heavy vehicle movements, leading to ponding of water and potential safety problems. Moreover, the surface directly underneath composting materials is subjected to prolonged high temperatures and the release of potentially corrosive chemicals. For these reasons, suggested concrete specifications are listed in Table 7.

Table 7: Suggested concrete specification

Parameter	Specification
Type	Reinforced HA-25/P/20/IIa concrete Fiber content with a structural function of 6 kg/m^3
Depth	40 cm
Permeability	To contain a water-repellent additive that ensures a permeability of 10-9 m^3/second

Weighbridge

A weighbridge is an essential component of any medium to large scale composting facility and is used to measure the weight of a vehicle plus its contents. By routing all vehicles over a weighbridge when entering and leaving the facility, the weight of the contents can be calculated. This is important when calculating gate fees (fees levied per tonne of feedstock delivered to the site) and also when selling compost.

Modern weighbridges are linked to computer systems so that an electronic record of vehicle movements and deliveries can be kept. Moreover, it allows the weighbridge operator the ability to link the vehicle's registration number with the load. Accurate weighbridge data are important for regulatory compliance and operational management. An example of an above ground weighbridge is shown in Figure 8.

Figure 8: An above ground weighbridge

Materials Handling Vehicle

A materials handling vehicle is needed to:

- Load the incoming feedstock into the feeder conveyor,
- Turn the windrows, and
- Move compost to the screen, 'curing' and bagging areas.

The anticipated volume of feedstock influences the type and size of the vehicle. Small facilities may only need a small skid steer loader, whilst larger facilities may require front-end loaders with larger-sized buckets (Figure 9).

Figure 9: A front-end loader with backhoe

Windrow Turner

Windrow turners come in various sizes and configurations, including tractor-mounted (via the tractor's power take-off;) and self-propelled models, to accommodate different composting needs and scales. They have an axle that is usually positioned horizontally and runs the length of the windrow turner's working width. A series of blades or drums are attached to this axle, which turns when the machine moves along the window. As they rotate, they dig into the compost pile or windrow and lift the material from the bottom to the top. This action effectively turns and mixes the organic material.

Figure 10: A tractor-mounted windrow turner

Shredder

Shredders are used to reduce the size of incoming feedstocks so that they are of an appropriate size for composting. Depending upon the feedstocks and composting process, they can come in a variety of shapes and sizes. Hammer mill shredders or tub grinders are the two most common types, although woodchippers may also be used at small-scale facilities.

Figure 11: A shredder breaking up woody waste

Trommel Screen

A trommel screen is a cylindrical drum-like machine used to separate materials by size (Figure 12). It consists of a large cylindrical mesh steel drum that is mounted at an angle. Material is fed into the top end of the trommel using a conveyor belt. The trommel drum rotates at a controlled speed, driven by an electrical motor. As the drum rotates, the material inside tumbles and moves along the length of the drum. Larger materials like plastic bags and pieces of wood are unable to pass through the holes in the screen and are discharged at the end of the trommel. Materials that are smaller than the openings in the screen pass through it and are collected in a separate area or conveyor belt below the trommel. This allows for the separation of different-sized materials based on the size of the screen openings.

Figure 12: A trommel screen

Conveyor System

Conveyor systems are needed to move materials into and out of trommel screens (see next section).

Depending on the size of the facility up to four conveyors may be needed as follows:

- To move incoming feedstocks into a screen to remove contaminants before composting,
- To move rejected material out of the trommel screen into a rejects collection bay,
- To move matured compost into a trommel screen for final product preparation,
- To move rejected material from the trommel to into a rejects collection bay.

An example is shown in Figure 13.

Figure 13: A conveyor system at a facility

Electricity

Electricity will be required to power some of the equipment, and to provide lighting inside the composting shed, office, laboratory, toilets and other utility areas.

An electrical control panel is essential. Its function is to control all connected electrical equipment and safety modules to ensure their safe and smooth operation. It should consist of:

- A compact centralised control station,
- A three-phase, 440 Volts, 50 Hertz electrical supply,
- Emergency stops at three different locations,
- A variable frequency drive (VFD) for the feed conveyors, and
- An illuminated enclosure for easy maintenance and safety.

The current output will depend upon the power rating of the installed machinery, so this will need to be taken into account when sizing the control station.

Water

Water is required for providing moisture, cleaning machinery and areas of hardstanding, flushing toilets, drinking water, and functioning of the laboratory and office. Depending on local weather conditions, rainwater can be harvested and used for cleaning purposes, reducing the need for imported clean water.

Human Resources

Managing and operating a composting facility requires a team of trained, knowledgeable and competent persons, with each having specific roles and responsibilities. Every facility should, have as a minimum a:

- Site manager
- Site operator
- Weighbridge operator
- Driver
- Labourer

In addition to full-time staff, additional resources will be required to cover:

- Accounting,
- Human resource management,
- Compost sampling and testing (may be outsourced if sufficient resources are not available for setting up dedicated laboratory in the composting facility),
- Site security,
- Vehicle maintenance and repair, and
- Compost sales and marketing.

Given that some of these roles would may not necessitate full-time staffing, they may consequently be outsourced to external companies.

Further details, including indicative job descriptions and experience are set out in Appendix 2.

5.8. Decision Making Criteria

Composting facilities can be established and operated at different scales, ranging from small, simple systems to complex and highly controlled methods that are used at medium and large-scale facilities.

The choice of facility depends on many different factors, of which the main ones include:

- The anticipated type and quantity of feedstocks to be processed.
- Availability of financial resources, including capital and projected operational expenditure.
- Availability of human resources.
- Availability of land and its proximity to housing, businesses, schools and other ‘sensitive receptors’.
- Market for the product (compost)

Some of these factors are listed in Table 8.

Table 8: Summary of composting system decision making criteria

Composting System	Scale	Land Required	Buffer Zone Required	Complexity/ Skill Set Required	Relative capital investment	Relative operational & maintenance cost	Main resources equired	Additional factors to consider
Passively aerated composting	Small	Low	Low	Low	<<x	<<y	Bin, Cage or Container Shovels/ Forks	Odour control and vermin
Vermi-composting	Small to Medium	Low to Medium	Low	Medium	<<x	<y	Bin, Cage or Container Worms Shovels/ Forks	Sensitive to quality of feedstock and temperature changes, special precaution required if ambient temperature goes above 370C
Turned windrow	Small to Large	High	High	Medium	x	y	Land, equipment, continuous supply of feedstock, labour and market for compost	Siting requirements, zoning, regulatory enforcement, odour, buffer zone proportional to size of operation
Aerated static piles with semi-permeable cover	Medium to Large	Medium to High	Medium	Medium	3x	1-1.5y	Land, equipment, investment costs, continuous supply of feedstock, labour and market for compost	Siting requirements, zoning, regulatory enforcement, odour can be better controlled than open windrow
In-vessel	Medium to Large	Medium	Medium	High	6-7x	2y	Power, skilled labour, financial requirements	Consistent power requirements, financially intensive, technical expertise to operate

Note to table: Estimates of land requirements, capital and operational costs depend upon many criteria including operational throughput (i.e., number of tonnes of feedstock composted every year). The information presented in the table has been provided for indicative purposes only.

Chapter 6

Operating a Composting Facility

6.1. Process Steps

Irrespective of the size of the composting facility, the everyday activities are broadly similar, as described previously in Section 3.3. They include:

1. Receiving feedstocks over a weighbridge and recording their weight and waste type,
2. Unloading feedstocks into a designated reception area,
3. Removing any large undesirable items (contaminants),
4. Shredding woody/large waste items,
5. Mixing and blending different feedstocks where appropriate,
6. Forming the mixed feedstocks into windrows or laying the material over an aeration pipe/plenum,
7. Turning the materials using either a front-end loader (as described previously) or dedicated windrow turner. The frequency of turning will depend on site specific conditions and may need to be adjusted according to changes in ambient weather conditions (e.g., between dry and rainy seasons),
8. Moving the fresh compost out of the active composting area and into a maturation area,
9. Screening mature compost to remove remaining contaminants and over-sized fragments,
10. Bagging, blending (if required), selling and distributing the final product.

6.2. Timescales

The time taken to create mature, quality compost will depend upon a number of different factors, such as:

- The type and properties of the processed feedstocks,
- The intensity to which the process is managed, in particular whether it is actively or passively aerated,
- Whether an open or closed (in-vessel) composting system is used,
- The ambient temperature and extent of precipitation at the site, and
- The anticipated end use of the composted product.

Overall:

- The active composting phase usually takes between 4-8 weeks, and
- The maturation phase usually takes between 4-12 weeks.

However, these timescales are only indicative as some sites prefer to create compost in only six weeks, whilst other tend to adopt a much longer timeframe (up to a year). Normally in warm climate, turned windrow composting takes 8 weeks. In general, the longer the material is left to compost, the better its quality. However, for commercial purpose, the time allotted for composting has a direct ramification on space requirement and O&M cost. A balance has to be struck to achieve the quality of compost according to the prescribed compost quality standard of the concerned country in the minimum time possible.

It is worth noting here that some small-scale composting system suppliers claim that their products create 'compost' in 24 hours. Whilst this may provide some level of processing, the biological decomposition necessary to create compost takes much longer; practically, six weeks would be the minimum timeframe.

The following sections describe the main activities necessary to manage a composting operation. They are necessarily generic, as operational aspects will need to be tailored to the site's specific conditions and regulatory requirements. Specific examples of the ways in which the process is operated at the four worked examples are described in Appendix 1.

6.3. Management Information Systems

For all but the smallest composting facility, a management information system (MIS) is essential in order to adequately capture operational, monitoring and maintenance information. Examples include:

- Weighbridge data for incoming feedstocks so that gate fees can be accurately charged, and windrow/pile batched can be linked to specific deliveries. This is important for traceability purposes.
- Temperature and moisture data, linked to specific batches.
- Maintenance and repair of vehicles.
- Staff training.

All of these should form part of the site's quality management system (QMS) and should align with its standard operating procedures (SOPs).
Example data are listed in Table 9.

Table 9: Example on-site data collection requirements

Data Required	Frequency	Data Use and Analysis
Designed hours of operation and actual hours of operation	Weekly	• Efficiency of operation. • Regulatory compliance.
Quantity and type of waste received at the plant	Daily	• Calculation of percentage of production. • Gate fee invoicing. • Traceability.
Batch location linked to incoming feedstocks.	Whenever windrows are formed.	• Quality assurance and traceability.
Windrow/pile temperature & moisture levels	Daily	• Quality control and sanitisation. • Regulatory compliance. • Link to specific batches of incoming feedstocks.
Quantity of compost produced daily	Daily	• Calculation of percentage of production
Quantity of compost sold/ distributed for use	Daily	• Marketing Efficiency and inventory
Inventory (stock) of compost	Monthly	• Inventory status. Usually, bulk sale of compost is linked to cropping season. Accordingly warehousing facility may be needed. • Efficiency of production. • Marketing effectiveness.
Quantity of rejected material	Daily	• Efficiency of source segregation. • Contractual compliance with waste collectors.
Quality of the compost (analysis report)	Minimum monthly	• Quality control. • Efficiency of composting process.
Number of staff reported for duty	Daily	• HR and administration.
Any issue regarding HR, safety and security in the compost plant	Weekly	• Regulatory compliance. • Health & safety review and subsequent improvement. • HR and administration.

6.4. Monitoring the Process

This involves regular inspection and control of temperature, moisture levels and aeration to ensure optimal conditions for decomposition. Ideally, the temperature of the piles should be monitored daily using a long stem temperature probe during the first few weeks of composting, with the frequency reducing as the material becomes more stable. This is particularly important to ensure the material has been adequately sanitised as described in Section 3.2.

Moisture levels can be monitored in a simple laboratory, or by using the hand squeeze test (see BOX 7). In dry climates water may need to be added to composting piles at frequent intervals to adjust the moisture levels, whilst in wetter areas, water may not be required at all.

Monitoring also includes assessing the carbon-to-nitrogen ratio and turning the compost as needed. Precise oversight helps maintain efficient decomposition and high-quality compost output while minimising potential issues.

BOX 7: HAND SQUEEZE TEST TO MEASURE MOISTURE

The hand squeeze test is a straightforward and practical method to assess the moisture content of compost. It constitutes a hands-on approach that does not necessitate any specialised equipment. The process can be described as follows:

1. Sample Collection: Start by selecting a representative sample of the compost. Pick up a handful of compost material is gathered, ensuring that it is drawn from various depths and areas within the compost pile or container. This diversity ensures an accurate representation of moisture levels throughout the compost.

2. Squeeze the Sample: With the compost sample in hand, squeezed it firmly. Adequate pressure is needed to compact the material, but not to the extent of wringing out excessive moisture.

3. Observe Texture and Moisture: Focus on the feel and appearance of the compost as it is squeezed:

Excessively Dry: If the compost exhibits a dry, crumbly texture and easily disintegrates, it indicates insufficient moisture. In such instances, introduce water into the compost pile to elevate its moisture content. Inadequate moisture can impede the decomposition process.

Optimal Moisture: Ideally, when pressure is applied to the compost, it should retain its shape and possess the characteristics of a damp sponge. It should neither be dripping with water nor so dry that it readily falls apart. The objective is to attain a "damp sponge" texture, signifying well-balanced compost.

Excessively Wet: If the compost feels excessively wet, causing water to drip from the hand upon squeezing, it indicates an overabundance of moisture. In such cases, the remedy involves the addition of dry, carbon-rich materials such as leaves or straw to absorb excess water and enhance aeration.

It is important to bear in mind that achieving the appropriate moisture level in compost is crucial for effective decomposition and for mitigating issues such as foul odours or poor compost quality.

6.5. Managing Contaminants

This involves rigorous screening of incoming feedstocks to remove non-compostable items like plastics and metals. Once removed, contaminants should be stored in a container or secure location before being sent for disposal. This is particularly important with any potentially hazardous materials and plastic film (e.g., bags) to prevent them being dispersed around the site where they may cause harm or blow off site.

6.6. Preventing and Managing Odours

Regular monitoring of moisture and temperature, as well as regular turning/aeration should help prevent the formation of odours. However, due to problems with the composting process or the receipt of smelly feedstocks, odour issues may arise.

If the site is located close to homes or businesses, complaints may be received. In this regard, the old adage that ‘prevention is better than cure’, is worth taking note of. Once neighbours have been sensitised to an odour problem, they are far more likely to complain a second time (or more).

Walking around the perimeter of the site every day is advisable, noting where any odours are detected, their strength and how they smell. It is important that the person noting the odours should do this as soon as they arrive at the site, so that they haven’t had time to acclimatise to the site’s smells. The results of the perimeter walk should be noted in the site diary.

Furthermore, a small weathervane or weather station should help the site manager assess if neighbours may be affected by the site’s activities.

6.7. Cleaning the Site and Equipment

Maintaining cleanliness at the facility is vital for hygiene and efficiency. Composting facilities should have scheduled cleaning routines for equipment and work areas, in particular the feedstock reception area should be cleaned daily. This includes removing residual compost, preventing build-up of organic matter, and sanitising equipment to prevent cross-contamination. In areas that receive high levels of rainfall, puddles and ponds may also become an odour source, so their formation should, wherever possible, be prevented.

6.8. Managing Leachate

This involves the collection and treatment of liquid run-off from the composting process, which may contain dissolved organic compounds and nutrients. Proper management ensures that leachate does not contaminate surrounding soil or water bodies. This is achieved through containment systems, treatment processes and compliance with environmental regulations.

Moreover, leachate containment systems need to be regularly emptied and cleaned in order to prevent odour formation. Where appropriate, leachate can be sprayed back onto windrows, but only during the early stages of composting before sanitisation has taken place.

6.9. Preventing Fires

Fires can start at composting facilities for a number of reasons, and in most cases, they can be prevented through good site management practices. The commonest reason results from stockpiling fine, dry materials or creating very large windrows. As materials at the centre of these pile heat up, spontaneous combustion can occur, which then starts to spread. Smaller, moist piles are therefore safer.

All sites should have an Emergency Response Plan, setting out how fires should be managed and how the emergency services involved. The Plan should also include provision for fire breaks (i.e., gaps between windrows and buildings), access to fire extinguishers, water hoses and so forth.

The entire area of the composting site should be a no smoking zone, and this should be enforced. Additionally, all equipment that has potential to become hot or create sparks should be kept away from dry materials.

Good quality fire extinguishers should be placed at different points including in the office and, where appropriate, the laboratory. These need to be routinely checked and repaired/replaced when required.
Finally, all staff should be trained in safety protocols, including fire prevention measures and emergency response procedures.

6.10. Managing Health and Safety

Composting facilities are hazardous places, due to the frequent movement of large vehicles, the composting process itself and associated emissions. All facilities should therefore have a written Health and Safety Policy, that includes basic risk assessments for all identified hazards (see BOX 8). Control measures should then be introduced to reduce the risk of people being harmed.

All people who work at a composting facility should be provided with a copy of the Health and Safety Policy, receive appropriate training and be provided with suitable Personal Protective Equipment. These include:

- High visibility jackets, vests and trousers,
- Non-slip work boots with steel toe caps and midsoles,
- Hard hats, helmets for risky areas,
- Puncture proof gloves,
- Eye protection, and
- Respirators for those involved in materials handling, including windrow turning.

The Policy should be accompanied by the site's Standard Operating Procedures (SOPs), that should set out Safe Systems of Work for each job function, including the safe routing of vehicles, and approved vehicle maintenance/repair procedures.

Where contractors are required to visit and work on the site, they should also receive a copy of the policy, sign to confirm this and receive specific training depending on their role. Approved contracts should only then be provided with a time-limited Permit to Operate.

Due to the nature of the composting process and the high level of microbes on-site, all personnel and visitors should follow good hygienic practices, including:

- Washing hands before eating and drinking,
- Only eating and drinking in the designated office,
- Not smoking on site.

The provision of sanitising hand gel and face masks used during the COVID-19 outbreak should be available for use.

Furthermore, regular health checkups should be considered for all personnel.

Should an accident occur, then a suitably equipped first aid kit (including a sterile eye wash) should be available in the site office. As a minimum, the site manager and site operator should be trained in basic first aid. All accidents, however small and seemingly innocuous should be recorded in the site's Accident Book and be reviewed periodically.

BOX 8: HAZARDS, RISKS, ASSESSMENTS AND CONTROL MEASURES

Hazard: A hazard refers to any source of potential harm or danger in the workplace or in any other setting. Hazards can be physical, chemical, biological, ergonomic, or psychosocial in nature. They have the potential to cause injury, illness, damage to property, or other adverse effects.

Risk: Risk is the likelihood or probability of a hazard causing harm or damage. It quantifies the chance of an adverse event occurring as a result of exposure to a hazard. Risks are typically assessed by considering factors such as the severity of the potential harm, the frequency of exposure, and the number of people exposed. Risks are often classified as low, medium, or high based on these factors.

Risk Assessment: This is a systematic process used to identify, evaluate, and manage potential risks or hazards. It involves several key steps, typically conducted in the following order:

1. Identify hazards
2. Assess risks
3. Introduce control measures
4. Document the findings
5. Communicate with relevant stakeholders
6. Review and monitor
7. Continuous improvement

Control Measure: A control measure, also known as a risk control measure, is a strategy or action taken to mitigate or reduce the level of risk associated with a hazard. These measures are put in place to prevent accidents, injuries, or damage. Control measures can take various forms, including engineering controls (physical modifications), administrative controls (procedures and policies), and personal protective equipment (PPE). The selection of control measures depends on the specific hazard and the level of risk involved.

6.11. Training Personnel

All personnel should receive relevant training. This should be carried out when they first start working on-site, and include as a minimum:

- Basic information about the composting process,
- Safe systems of work relevant to their job description,
- Health and safety, and
- Emergency procedures.

Periodic training should then be scheduled, with attendance forming part of their contract of employment. One simple way to keep staff engaged and to discuss safe working practices is to hold weekly or fortnightly Toolbox Talks (see BOX 9). These need only take 15-30 minutes, usually at the start of the day. Every person should sign their attendance, with copies of the talk and attendance sheet filed by the site manager.

BOX 9: TOOLBOX TALK

A toolbox talk is a short, informal safety meeting or discussion that takes place among workers and supervisors at the beginning of a work shift or before a specific task begins. The primary purpose of a toolbox talk is to address safety concerns and raise awareness about potential hazards in the workplace, particularly those related to waste management or disposal.

1. During a toolbox talk at a composting site, the following topics may be covered:
2. Hazard Identification: Discuss potential hazards associated with waste materials, such as chemical, biological or physical hazards. This includes identifying the types of waste present and their associated risks.
3. Safe Working Practices: Emphasize the importance of following established safety protocols and procedures when handling, transporting, or disposing of waste materials.
4. Personal Protective Equipment (PPE): Ensure that workers are aware of the specific PPE required for their tasks, such as gloves, respirators, or protective clothing, and stress the importance of wearing them.
5. Equipment and Machinery: Discuss the safe operation of machinery and equipment commonly used at waste sites, including waste compactors, forklifts, and shredders.
6. Emergency Procedures: Review emergency response procedures, such as what to do in case of chemical spills, fires, or accidents, and the location of emergency equipment like eyewash stations and fire extinguishers.
7. Waste Segregation: Explain the importance of segregating different types of waste to prevent contamination and ensure proper disposal.
8. Reporting Procedures: Encourage workers to report any safety concerns, incidents, or near-misses promptly to their supervisors.
9. Communication: Stress the importance of clear communication among team members to ensure everyone is aware of their roles and responsibilities.
10. Environmental Considerations: Highlight the need to minimize environmental impact through responsible waste management practices, such as recycling and waste reduction.
11. Questions and Discussion: Allow time for workers to ask questions, share experiences, and engage in a discussion about safety concerns and best practices.

It's essential that toolbox talks are conducted regularly and are specific to the tasks and hazards present at the waste site. They help create a safety-conscious culture among workers and contribute to reducing accidents and incidents composting sites.

Chapter 7

Compost Products And Markets

7.1. Compost Properties

Compost typically consists of:

- Humus: The stable, dark, and organic fraction of compost that enhances soil structure and nutrient-holding capacity.
- Nutrients: Compost contains essential plant nutrients, such as nitrogen, phosphorus, and potassium, as well as micronutrients required for plant growth.
- Organic Matter: Compost is rich in organic carbon, which improves soil fertility and microbial activity.
- Microbial Biomass: It contains a diverse population of micro-organisms, which continue to benefit soil health when incorporated into the soil.
- Beneficial Micro-organisms: Compost can also contain beneficial microorganisms that aid in disease suppression and nutrient cycling in the soil.

All of these attributes make compost a valuable soil improver or component in a potting mixture. Typical chemical-physico properties of a green waste-derived compost are shown in Table 10.

Table 10: Typical chemical-physico properties of a green waste compost

Parameter	Value	Unit
Carbon-to-Nitrogen Ratio	15:1	-
Dry matter	70	%
Moisture	30	%
Organic matter	30	% dry matter
Organic carbon	17	% dry matter
pH	7.5	-
Electrical conductivity	2	dS/m
Total nitrogen (N)	10	kg/tonne (fresh mass)
Total phosphate (P_2O_5)	4	kg/tonne (fresh mass)
Total potash (K_2O)	7	kg/tonne (fresh mass)
Total magnesium (MgO)	4	kg/tonne (fresh mass)
Total sulphur (SO_3)	3	kg/tonne (fresh mass)

7.2. Compost Benefits

When incorporated into soil, compost improves soil health, promotes plant growth, and enhances the vitality of soil ecosystems. These benefits include:

Enhancing Soil Structure: Compost contributes to the enhancement of soil structure by binding soil particles together. This promotes soil aggregation, consequently improving soil porosity, water infiltration and drainage. The improved soil structure also reduces the risk of soil erosion.

Improving Water Retention: Compost increases the soil's ability to retain water, enabling it to preserve moisture for extended periods. This proves particularly advantageous in arid or dry regions and during periods of drought.

Nutrient Enrichment: Compost serves as a source of vital nutrients, including nitrogen, phosphorus, potassium and micronutrients. These nutrients are gradually released as the compost decomposes in the soil, providing a steady supply of nourishment to plants and diminishing the likelihood of nutrient leaching.

Microbial Activity: Compost introduces beneficial micro-organisms like bacteria, fungi, and other soil-dwelling organisms to the soil. These microbes contribute to nutrient cycling, the decomposition of organic matter and overall soil well-being.

pH Regulation: Compost can help stabilise soil pH, rendering it less susceptible to drastic fluctuations. This proves particularly crucial in maintaining an optimal pH range for plant growth and nutrient accessibility.

Reducing Soil Erosion: The improved soil structure and increased water-holding capacity delivered by compost aid in curbing soil erosion, which is pivotal in averting topsoil loss and sustaining the productivity of agricultural land.

Suppression of Soil Diseases: Certain components within compost have demonstrated disease-suppressing qualities. Specific beneficial microbes present in compost can hinder the proliferation of harmful pathogens in the soil, thus lowering the risk of soil-borne diseases in plants.

Carbon Sequestration: The incorporation of compost into the soil can contribute to carbon sequestration, aiding the mitigation of climate change by storing carbon within the soil and reducing atmospheric carbon dioxide levels.

Reducing the Need for Synthetic Fertilisers: By providing a natural source of nutrients, compost can reduce reliance on synthetic fertilisers, which can have adverse environmental consequences when manufactured and used.

Plant Growth and Productivity: Ultimately, the enhanced soil structure, increased nutrient availability and favourable microbial environment fostered by compost culminate in healthier plants with heightened growth, vigour and productivity.

7.3. Compost Products

Compost is a versatile product that can be used in a variety of different ways. Compost facility operators may blend screened, mature compost with other materials, such as coir or bark to create mixtures best suited to different applications. The main ways in which compost is used are as follows:

Soil Amendment: Compost can be incorporated into garden soil to enhance its texture, moisture retention, and nutrient content, thereby improving overall soil quality for plant growth.

Mulch: Gardeners and landscapers can apply a layer of coarse compost to the soil surface surrounding plants and trees. This acts as a mulch, serving to conserve soil moisture, regulate temperature, and suppress the growth of weeds.

Topdressing: Finely screened compost may be applied to lawns as a topdressing to foster healthy grass growth. This practice enhances soil structure and encourages beneficial microbial activity.

Potting Mixture: Compost can be blended with other materials, such as coir, perlite, vermiculite and sand to create a potting mixture in which to grow plans in containers. Only very mature compost should be used.

Compost Tea: Compost can be steeped in water to create a nutrient-rich liquid known as compost tea. This liquid can then be employed as a natural fertilizer and soil conditioner when applied to plants.

Erosion Control: In areas prone to soil erosion, compost can be utilised to stabilise the soil. Its ability to bind soil particles helps prevent erosion and soil loss.

Planting: Compost can be placed in the bottom of a hole in the soil into which new trees or shrubs are planted. This provides essential nutrients to support root growth and helps establish the plant.

Vegetable Gardens: Compost can be added to vegetable garden beds to enrich the soil with nutrients, resulting in healthier and more productive crops.

Flower Beds: Gardeners may choose to incorporate compost into flower beds and borders to improve soil quality, leading to more vibrant and robust blooms.

Compost for Trees and Shrubs: Established trees and shrubs can thrive when compost is applied around their bases, enriching the soil and supporting their overall health. Compost is particularly valuable when used with fruit trees.

Compost as a Soil Conditioner: To improve soil drainage and alleviate compaction, compost can be used as a soil conditioner.

7.4. Quality Parameters

The importance of manufacturing quality compost cannot be overstated. It is important not only for marketing, but also for environmental protection purposes. Compost quality depends on the physical, chemical and biological characteristics of the material, including:

- **Physical parameters** - particle size, colour, odour, moisture, bulk density, and levels of physical contaminants such as plastics and metals.
- **Chemical parameters** - organic matter content, pH, electrical conductivity, nutrient levels and presence of potentially toxic elements (i.e., heavy metals).
- **Biological and microbiological parameters** - presence of pathogens and weed seeds.

In addition, the stability and maturity of the compost is also important, as this will influence the way in which the compost can best be used.

7.4.1. Standards

National compost quality standards have been set in many countries, primarily to protect soil and crops grown for human and animal consumption. These standards usually stem from a precautionary principle, in which prevention of harm to the environment and people has been prioritised. Standards therefore set limits for contaminants. They also set key parameters in order to prevent dilution or partially composted materials from being sold.

Standards may be developed by industry groups, standards setting bodies, regulatory authorities or government. Some standards in use in some Asian countries are listed in Table 11.

Table 11: Compost standards in some Asian Countries

	Sri Lanka (2019)	Thailand (2005)	Bangladesh (2008)	India (2016)
Physio-chemical Properties				
pH	6.5-8.5	5.5-8.5	6.0-8.5	6.5-7.5
Electrical Conductivity (dS/m)	4	<5	–	<4
Colour	Brown, grey or dark black	–	Dark grey to black	Dark brown to black
Storage	Not less than 12 months at room temperature	–	–	–
Moisture (% by mass)	<25% (dry basis)	<35%	<15%	15-25%
Odour	Should not have any foul odour	–	Absence of foul odour	Absence of foul odour
Bulk Density	–	–	–	<1
Particle Size	Should not leave residue >2%, when passed through 4 mm standard sieve	< 12.5 x 12.5 mm	Non-granular form	Minimum 90% material should pass through a 4 mm sieve
Sand / Inert Content	<20%	< 2%	≤1%	–
C: N Ratio	10-25	< 20:1	< 20:1	< 20:1
Organic Carbon (% by mass)	>20	Organic matter >30%	10-25	>12

	Sri Lanka (2019)	Thailand (2005)	Bangladesh (2008)	India (2016)
Contaminants				
Plastics, glass, metal	–	<0.01%	–	–
Arsenic (ppm)	≤3	≤50	–	≤10
Cadmium (ppm)	≤3	≤5	≤5	≤5
Chromium (ppm)	≤50	≤300	≤50	≤50
Copper (ppm)	-	≤500	≤0.05%	≤300
Lead (ppm)	≤50	≤500	≤30	≤100
Mercury (ppm)	≤0.5	≤2	–	≤0.15
Nickel (ppm)	≤50	–	≤30	≤50
Zinc (ppm)	–	–	≤0.1%	≤1000
Number of viable weed seeds	Should not contain more than 16 viable weed seeds per square meter	–	–	–
Fecal coliforms	Free	–	–	–
Salmonella	Free	–	–	–
Pathogens	–	–	–	0

	Sri Lanka (2019)	Thailand (2005)	Bangladesh (2008)	India (2016)
Plant Nutrients				
Nitrogen (N) (% mass)	≥1.0	≥1.0	≥0.5-4.0	≥0.8
Phosphorus (as P2O5) (% mass)	≥0.5	≥0.5	≥0.5-1.5	≥0.4
Potassium (as K2O) (% mass)	≥1.0	≥0.5	≥1.0-3.0	≥0.4
Magnesium % (% mass)	≥0.5	-	-	-
Calcium % (% mass)	≥0.7	-	-	-
Sulphur % (% mass)	-	-	≥0.1-0.5	-

7.4.2. Product Specifications

In addition to national standards, producers or industry groups may develop their own product specifications. These may describe the type of compost and its characteristics, as well as the way in which it should be used. In Europe, for example, the European Compost Network has developed a specification for using compost as a component in a growing medium (potting mix) (Siebert and Gilbert 2018). This, amongst other parameters, specifies very stable compost having a low electrical conductivity.

7.4.3. Quality Assurance and Certification

A national standard is insufficient in itself, to provide customers with the assurance that a composted product is fit for purpose and safe to use. Self-declaration by a producer therefore relies on marketing honesty and intermittent compost testing. This is why quality assurance and certification are so important.

All composting facility operators should ideally implement a quality management system (QMS) that covers all on-site activities (see Section 3.3) necessary to consistently manufacture quality compost, meeting relevant standards and specifications. The QMS needs to include specific quality control (QC) measures at all stages of the composting process to ensure that hazards are reduced to acceptable levels, and relevant corrective actions are implemented when parameters fall outside of pre-determined levels. Examples of specific QC measures include:

- Visual inspection of all incoming feedstocks to confirm that levels of contamination are below pre-agreed levels. In the event that excessive contamination is present, the site operator should either reject the load, or ensure that a greater level of contaminant removal (e.g., through hand picking) is carried out before composting.
- Monitoring windrow temperatures daily. This provides evidence that compost has been subjected to the appropriate time-temperature profiles (see Section 3.2) to ensure that limit levels for pathogens and weed seeds are not exceeded.
- It is, therefore, important to determine what the appropriate quality control measures should be and ensure that they are included in the facility's QMS. All employees need to be adequately trained and instructed to carry out these activities as part of the site's standard operating procedures. Furthermore, recording and evaluation of these controls needs to be carried out to provide consistency and continuous improvement.
- Some countries, such as the Belgium (Flanders), Germany and the United Kingdom, operate a third-party certification scheme for composting operations. Here an independent and impartial certification body audits a site's quality management system, including record keeping, laboratory test results and staff training. The certification body will then assess whether or not an operator has consistently met the requirements of the relevant compost standard. This way end users are provided with assurance that compost bought from a certified composting site are fit-for-purpose and meet minimum quality criteria. Where compost is used on land on which food for humans and animals is grown, this is particularly important.

© Freepik

7.5. Compost Marketing

The sustainability of a composting business depends, in part, on the successful sale of its products. A comprehensive marketing strategy should therefore be developed during the planning stage before the facility becomes operational.

First a market assessment needs to be carried out to provide a holistic overview of the local market and its competitors. A well-structured compost market assessment checklist will help ensure that all critical aspects of the market have been thoroughly researched and evaluated. An example checklist is shown in Figure 14.

1. Market Overview: Describe the compost market's size and significance.
2. Market Segmentation: Identify and categorise market segments (types of compost, applications, regions).
3. Market Trends: List and analyse current market trends.
4. Market Drivers: Identify factors driving market growth.
5. Market Challenges: Outline challenges faced by the compost industry.
6. Competitive Landscape: Analyse key market players, their strategies, and market share.
7. Consumer Behaviour: Understand consumer preferences and willingness to pay.
8. Regulatory Environment: Discuss relevant regulations and standards.
9. Supply Chain Analysis: Examine the compost supply chain for inefficiencies.
10. Market Size and Growth: Provide market size data and growth projections.
11. SWOT Analysis: Conduct a SWOT analysis of the compost market.
12. Market Entry Strategies: Recommend strategies for new entrants.
13. Price Analysis: Analyse pricing strategies.
14. Environmental Impact: Assess the environmental benefits of composting.
15. Future Outlook: Discuss future prospects and emerging opportunities.
16. Case Studies: Include relevant case studies.
17. Conclusion and Recommendations: Summarise findings and provide actionable recommendations.
18. References: Cite all sources and references used.

Figure 14: Compost market assessment checklist

Once the assessment has been completed, a marketing strategy can then be developed. This should not only form part of the facility's overall business plan, but it should also be a dynamic document that is reviewed periodically and updated as the economic environment changes. The key components that should be included are as follows:

1. Market Analysis:
   - Market Segmentation: Identify and define the target audience by demographics, psychographics and behaviour.
   - Market Size and Growth: Analyse the size of the target market and its growth potential.
   - Competitor Analysis: Assess competitors, their strengths, weaknesses, and market positioning.
2. Unique Selling Proposition (USP):
   - Clearly define what sets the composted product(s) apart from the competition.
3. Marketing Objectives:
   - Establish specific, measurable, achievable, relevant, and time-bound (SMART) marketing goals.
4. Marketing Mix (4Ps):
   - Product: Describe the product, including its features, benefits, and any unique attributes.
   - Price: Determine the pricing strategy, considering factors like cost, competition, and perceived value.
   - Place: Define the distribution channels and how the compost will be made available to customers.
   - Promotion: Outline promotional strategies, including advertising, public relations, sales promotions and digital marketing.
5. Target Audience and Buyer Personas:
   - Develop detailed buyer personas that represent ideal compost customers, including their needs, preferences, and pain points.
6. Marketing Budget:
   - Allocate resources and budget for each marketing activity, considering both short-term and long-term needs.
7. Marketing Channels:
   - Determine which marketing channels (e.g., social media, email, content marketing, traditional advertising) are most effective for reaching the target audience.
8. Content Strategy:
   - Plan a content creation and distribution strategy to engage and inform your audience.
9. Sales and Distribution Strategy:
   - Define how to sell and deliver the compost, including sales team structure and distribution partners (if appropriate).
10. Marketing Tactics:
    - Specify the specific marketing tactics and campaigns to achieve the objectives.

11. Timeline:
    - Create a marketing calendar that outlines when each marketing activity will be carried out.
12. Key Performance Indicators (KPIs):
    - Identify the metrics to use to measure the success of the marketing efforts (e.g., conversion rate, ROI, website traffic).
13. Risk Analysis:
    - Assess potential risks and challenges that may impact the marketing strategy and develop contingency plans.
14. Testing and Optimization:
    - Include a process for testing different marketing approaches and continuously optimizing the strategy based on data and feedback.
15. Team Roles and Responsibilities:
    - Assign roles and responsibilities to team members involved in executing the marketing strategy.
16. Legal and Regulatory Compliance:
    - Ensure that the marketing activities comply with relevant laws and regulations, including data protection and advertising standards.
17. Monitoring and Reporting:
    - Outline how to track and report on the performance of the marketing activities to stakeholders.
18. Budget Allocation and Return on Investment (ROI) Analysis:
    - Describe how to allocate the budget across various marketing channels and measure the return on investment for each.
19. Sustainability and Ethics:
    - Consider sustainability and ethical considerations in the marketing strategy, especially if these aspects align with the brand values.
20. Contingency Plans:
    - Develop contingency plans for unexpected situations, such as a crisis or sudden changes in market conditions or natural calamities due to which the normal cropping pattern is stalled.
21. Executive Summary:
    - Provide a concise summary of the marketing strategy for quick reference.

A well-structured marketing strategy should serve as a roadmap for achieving business objectives and help adapt to changing market conditions and customer preferences. It should be flexible, data-driven and aligned with overall business goals.

An example of the way compost is sold in Dhaka, Bangladesh, is described in BOX 10.

BOX 9: TOOLBOX TALK

A toolbox talk is a short, informal safety meeting or discussion that takes place among workers and supervisors at the beginning of a work shift or before a specific task begins. The primary purpose of a toolbox talk is to address safety concerns and raise awareness about potential hazards in the workplace, particularly those related to waste management or disposal.

1. During a toolbox talk at a composting site, the following topics may be covered:
2. Hazard Identification: Discuss potential hazards associated with waste materials, such as chemical, biological or physical hazards. This includes identifying the types of waste present and their associated risks.
3. Safe Working Practices: Emphasize the importance of following established safety protocols and procedures when handling, transporting, or disposing of waste materials.
4. Personal Protective Equipment (PPE): Ensure that workers are aware of the specific PPE required for their tasks, such as gloves, respirators, or protective clothing, and stress the importance of wearing them.
5. Equipment and Machinery: Discuss the safe operation of machinery and equipment commonly used at waste sites, including waste compactors, forklifts, and shredders.
6. Emergency Procedures: Review emergency response procedures, such as what to do in case of chemical spills, fires, or accidents, and the location of emergency equipment like eyewash stations and fire extinguishers.
7. Waste Segregation: Explain the importance of segregating different types of waste to prevent contamination and ensure proper disposal.
8. Reporting Procedures: Encourage workers to report any safety concerns, incidents, or near-misses promptly to their supervisors.
9. Communication: Stress the importance of clear communication among team members to ensure everyone is aware of their roles and responsibilities.
10. Environmental Considerations: Highlight the need to minimize environmental impact through responsible waste management practices, such as recycling and waste reduction.
11. Questions and Discussion: Allow time for workers to ask questions, share experiences, and engage in a discussion about safety concerns and best practices.

It's essential that toolbox talks are conducted regularly and are specific to the tasks and hazards present at the waste site. They help create a safety-conscious culture among workers and contribute to reducing accidents and incidents composting sites.

Chapter 8

Awareness Raising

Awareness about recycling of organic waste into compost and its significance in promoting sustainable agricultural practices has dwindled over the past century. This decline can be attributed to the prevalence of urbanisation and the widespread use of synthetic fertilisers by farmers. As a consequence, there is often little understanding of the composting process and how compost can be used. Facility operators therefore have a big role to play in engaging actively with relevant stakeholders including women, in order to improve their knowledge and understanding, as well as 'winning hearts and minds'.

There are three broad stakeholder groups to which awareness raising and information could be usefully targeted:

1. **Technical professionals:**
   This group would include, for example, urban planners, civil engineers, architects and government representatives. By having an understanding of what is involved in the composting of organic waste, its benefits and importance, it is hoped that informed decisions and professional advice will be made. Additionally, encouraging women's participation in waste segregation education programs can empower them to effectively separate organic waste for composting.

2. **Farmers, agricultural advisers, landscapers and marketing professionals:**
   This group would consider gender representation including women benefiting from hands-on training and information about the benefits of applying compost to soil, its role in sustainable agricultural practices and how it can be used as part of annual crop cycles.

   As the benefits of using compost are often not fully realised in the first year following application, longer term demonstration plots alongside a control should be considered. This could usefully be incorporated into the compost marketing strategy and could include providing limited amounts of free compost to local farmers in return for using their land for training purposes. Additionally, composting can lead to cleaner environments and potentially reduce the burden of waste collection, which can often fall on women and children.

3. Citizens

The public is an important stakeholder in the matters of municipal waste management, and their co-operation in organics recycling programmes is pivotal to ensure effective source segregation. This is essential in order to minimise contamination levels and maximise diversion of organics from disposal.

Furthermore, it is imperative that the public is kept informed about planned processing and disposal facilities within their city, including designated locations for such activities. Collaboration and support from the public in this regard are integral to the effective implementation of the waste management plan and composting activities.

Citizens can be reached through traditional marketing routes, such as newsletters and advertising; however, as social media networks now play a big role in most peoples' lives, innovative ways of creating online content can be developed.

Finally, promotional activities linked to national and local festivals, holiday events and fairs offer the opportunity to engage directly with people. This may, for example, involve hiring a stall at a summer fete which will involve compost competitions and free giveaways. International Compost Awareness Week, held over the first week in May, is a useful initiative to exploit. As the theme and accompanying resources are available online (see BOX 11 below), this could provide a cost-effective opportunity.

BOX 11: INTERNATIONAL COMPOST AWARENESS WEEK

International Compost Awareness Week (ICAW) is the largest and most comprehensive awareness initiative promoted by a number of compost organisations in many countries, ranging from North America (US Composting Council and Compost Council of Canada) to Europe (ECN European Compost Network) up to Australia (AORA Australian Organics Recycling Association).

It is celebrated each year during the first week of May to raise the awareness of consumers and non-experts about the importance of bringing back organic matter to soil by means of compost and to promote the link between compost, soil health and food production. For details see:

https://www.compostfoundation.org/ICAW/ICAW-Home

Source: CREF

References

- **Azadi, S., Karimi-Jashni, A., Talebbeydokhti, N., Khoshbakht, R. & Binaee Haghighi, A.** (2020). Industrial Composting of Commingled Municipal Solid Waste: A Case Study of Shiraz City, Iran. Journal of Environmental Treatment Techniques, 8(4): 1292–1303. https://doi.org/10.47277/JEET/8(4)1303
- **Bidlingmaier, D.W. & Diaz, D.L.F.** (2022). Annals of Composting. Independently published.
- **Central Pollution Control Board.** (2021). Annual Report 2020-21 on Implementation of Solid Waste Management Rules, 2016. Delhi, Ministry of Environment, Forestry and Climate Change. https://cpcb.nic.in/status-of-implementation-of-solid-waste-rules/
- **Central Public Health and Environmental & Engineering Organisation.** (2016). Municipal Solid Waste Management Manual Part II. Delhi, Ministry of Urban Development, Government of India.
- **Dandeniya, W.S. & Caucci, S.** (2020). Composting in Sri Lanka: Policies, Practices, Challenges, and Emerging Concerns. In: H. Hettiarachchi, S. Caucci & K. Schwärzel, eds. Organic Waste Composting through Nexus Thinking. pp. 61–89. Cham, Springer International Publishing. https://doi.org/10.1007/978-3-030-36283-6_4
- **Environment Canada.** (2013). Technical Document on Municipal Solid Waste Organics Processing. Government of Canada. https://publications.gc.ca/site/eng/9.697250/publication.html
- **European Union.** (2019). Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 (Text with EEA relevance).
- **FAO.** (2020). Compost from organic bio solids – Production, socioeconomics and impact on soil productivity. FAO. https://doi.org/10.4060/ca9916en
- **Mariyam, S., Cochrane, L., Zuhara, S. & McKay, G.** (2022). Waste Management in Qatar: A Systematic Literature Review and Recommendations for System Strengthening. Sustainability, 14(15): 8991. https://doi.org/10.3390/su14158991
- **Premakumara, D., Mazumdar, N., Suttibak, S., Damanhuri, E., Guodi, Z., Jayaratne, K., Eusuf, M. & Shawkat, O.** (2014). Promoting Municipal Solid Waste Management through Composting in Asia. Kitakyushu Urban Center Institute for Global Environmental Strategies.
- **Rupani, P., Maleki Delarestaghi, R., Asadi, H., Rezania, S., Park, J., Abbaspour, M. & Shao, W.** (2019). Current Scenario of the Tehran Municipal Solid Waste Handling Rules towards Green Technology. International Journal of Environmental Research and Public Health, 16(6): 979. https://doi.org/10.3390/ijerph16060979
- **Rynk, R., Black, G., Gilbert, J., Biala, J., Bonhotal, J., Schwarz, M. & Cooperband, L., eds.** (2022). The Composting Handbook: a how-to and why manual for farm, municipal, institutional and commercial composters. London San Diego Cambridge Oxford, ElsevierAcademic Press.
- **Samarasinha, G.G. de L.W., Bandara, M.A.C.S. & Karunarathna, A.K.** (2015). Municipal solid waste composting: Potentials and constraints. HARTI research report. Colombo, Hector Kobbekaduwa Agrarian Research and Training Institute.
- **Siebert, S. & Gilbert, J.** (2018). Specification for the Use of Quality Compost in Growing Media. Guideline. European Compost Network. https://www.compostnetwork.info/download/180901_ecn-guidelines-for-use-of-quality-compost-in-growing-media/
- **UNEP, I.** (2016). Global Waste Management Outlook. United Nations. https://doi.org/10.18356/765baec0-en
- **United Nations Environment Programme & Climate and Clean Air Coalition.** (2021). Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi, United Nations Environment Programme. https://www.ccacoalition.org/resources/global-methane-assessment-full-report
- **US EPA.** (1994). Composting of Yard Trimmings and Municipal Solid Waste. United States Environmental Protection Agency.

Appendix 1: Worked Examples

1. Scenarios

This section provides basic information about four different composting scenarios based on experience gained in a number of developing countries in Asia. They are as follows:

- Five tonnes per day (TPD) using a turned windrow system (5 TPD-W)
- 50 TPD using a turned windrow system (50 TPD-W)
- 150 TPD using a turned windrow system (150 TPD-W)
- 50 TPD using an aerated static pile system with a breathable cover (50 TPD-ASP)

The feedstock in all four scenarios is separately collected organic waste from a municipal source, which is predominantly food and garden waste. The bulk density of the waste is assumed to be 0.75 tonnes/m^3. This is summarised in Table 12.

Table 12: Composting scenarios

<table>
<tr><th>Scenario</th><th>Composting System</th><th>Feedstock</th><th>Quantity (tonnes/day)</th><th>Feedstock Density (tonnes/m³)</th><th>Scale</th><th>Throughput (tonnes/year)</th></tr>
<tr><td>5 TPD-W</td><td rowspan="3">Windrow</td><td rowspan="4">Separately collected organic waste</td><td>5</td><td rowspan="4">0.75</td><td>Small</td><td>1,825</td></tr>
<tr><td>50 TPD-W</td><td>50</td><td>Medium</td><td>18,250</td></tr>
<tr><td>150 TPD-W</td><td>150</td><td>Large</td><td>54,750</td></tr>
<tr><td>50 TPD-ASP</td><td>ASP</td><td>5</td><td>Medium</td><td>18,250</td></tr>
</table>

Note to table: ASP = Aerated Static Pile

2. 5TPD Turned Windrow Scenario

2.1. Site Plan

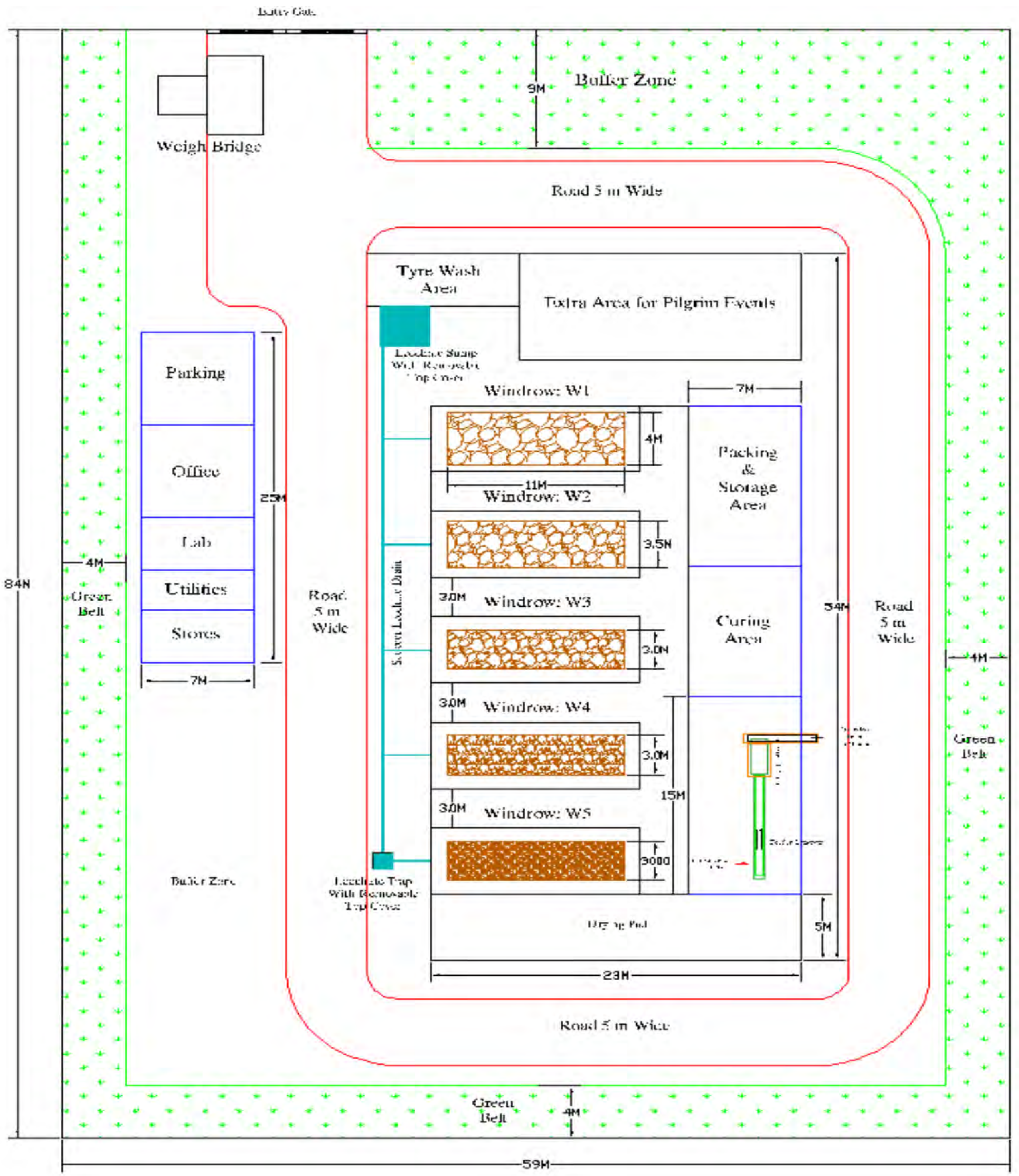


Figure 15: Site plan for a 5 tonne per day windrow composting facility

2.2. Infrastructure

- Average total area of the composting facility: 5000 m^2
- Concreted composting platform (composting pad): 1242 m^2
- Roof with steel columns, truss, purlin and corrosion resistant sheets: 1242 m^2
- Drain length for the composting pad ('saucer' drain, 30 cm wide, 10 cm deep with smooth plaster and cement punning): 180 m
- Drain length for the compost plant ('saucer' drain, 45 cm wide, 15 cm deep with smooth plaster and cement punning): 160 m
- Leachate traps 2 nos. as per drawing, 0.5 m deep, 0.5 m diameter, masonry structure with plaster and neat cement punning. The bottom should be curved for better cleaning. Location: inside shed, as per drawing.
- Length of internal road (3 m wide, black top with camber): 160 m
- Fence: 2 m high masonry structure with intermittent concrete columns for strengthmportant.
- Planting rows of indigenous plants (sturdy) which grow to about 3 m height to provide a good green screen and buffer.
- Height of shed: 7 m on the windrow side, 5 m on the office side, 12 m in the middle (as per section drawing).
- The gap between the two sections of the shed would facilitate ventilation.
- Rainwater harvesting for the storm water from the roof.
- Solar PV panels on roof top.

2.3. Operational Steps

1. Unloading and picking out any large and undesirable item followed by mixing.
2. Laying of the windrow with a trapezoidal cross section (windrow 1).
3. Turning off the windrow after one week to the next space slot (windrow 2).
4. Turning off the windrow after one week to the next space slot (windrow 3).
5. Turning off the windrow after one week to the next space slot (windrow 4). The 4th and 5th windrows need to be under a shed even if the first three windrows are in the open.
6. Turning off the windrow after one week to the next space slot (windrow 5).
7. After completion of 5 weeks, the composted material is screened using a trommel having a 10 mm mesh.
8. The material >10 mm is taken out through the 'rejects' conveyor. This material can be used as a cover over the fresh material in the 1st windrow, which would help in controlling birds, flies and odour to some extent.
9. The material <10 mm is the material fit for further 'curing' for 3 weeks.
10. The 'cured' material is ready for packing / bagging and storage as compost.

11. The product is around 20 per cent of the feedstock, which means about one tonne per day. When the input material is more due to festivals / religious events, more compost would be produced proportionally.
12. For this size of compost plant, one month's storage in the compost plant is recommended. The storage area is also indicated in the drawing.

10.2.4. Input Mass and Volume

	Per day		Per week	
	Mass (tonnes)	Volume (m^3)	Mass (tonnes)	Volume (m^3)
5 TPD-W	5	7	35	47

10.2.5. Windrow Size Calculations

Scenario	Width (m)	Height (m)	Length (m)	Volume (m^3)
5 TPD-W	4	2	9	47

10.2.6. Materials Handling Vehicle

Scenario	Vehicle
5 TPD-W	Skid steer loader or a tractor with a front-end loader and backhoe. The front shovel should have a minimum capacity of 1 cubic metre. The backhoe should have a minimum capacity of 0.1 m^3.

10.2.7. Trommel Screen Sizes

Scenario	Screen Function	Minimum Throughput (tonnes/hour)	Minimum Throughput m^3/hour	Mesh Size (mm)
5 TPD-W	Pre-composting	0.5	0.7	25
	Post-composting	0.5	0.7	10

10.2.8. Power and Daily Water

Scenario	Per day	Per week
5 TPD-W	23	15,000

10.2.9. Full-time Personnel

Scenario	Site Manager	Site Operator	Weighbridge Operator	Driver	Labourer
5 TPD-W	1	1	1	1	3

3. 50 TPD Turned Windrow Scenario

3.1. Site Plan

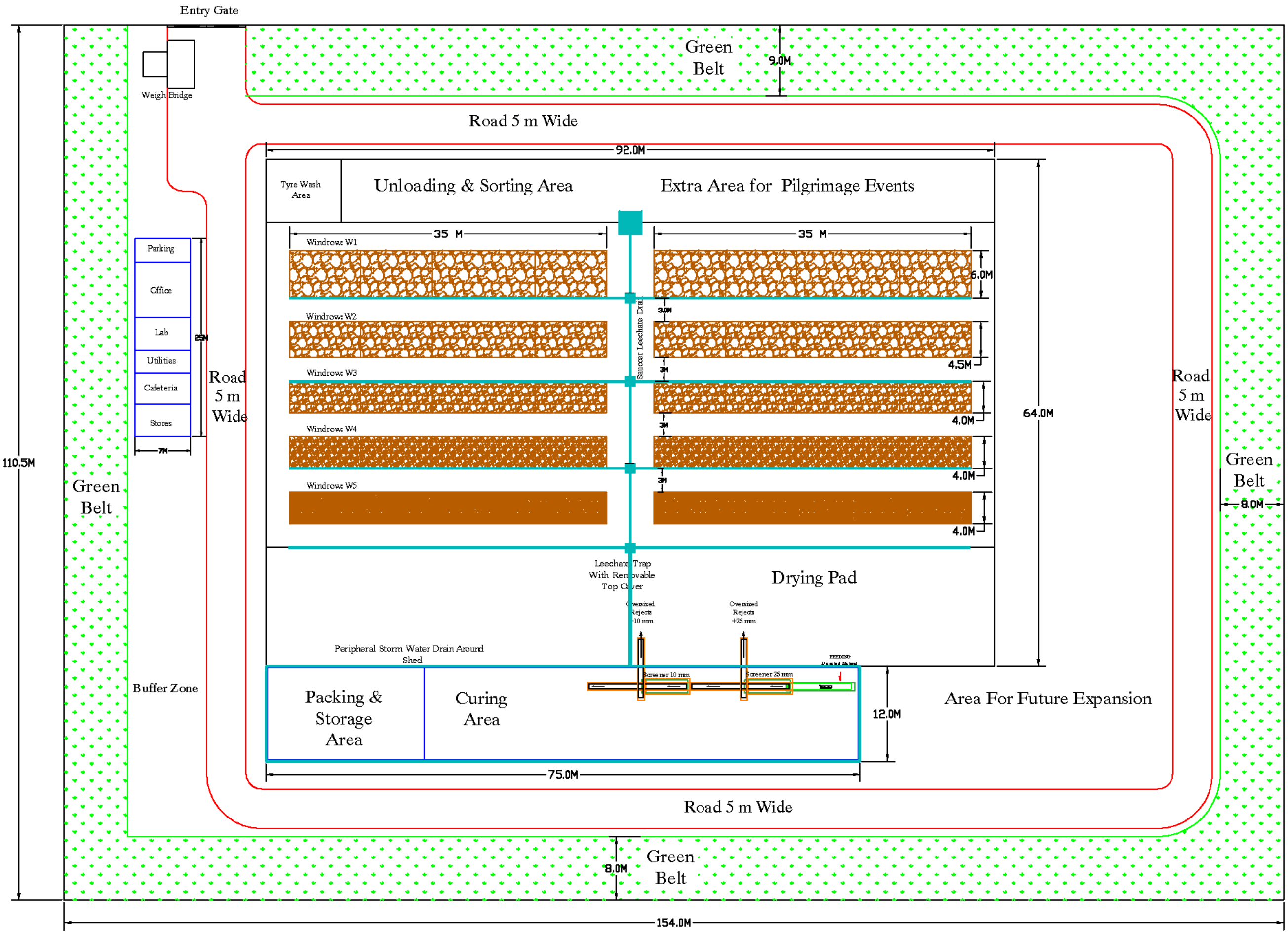


Figure 16: Site plan of a 50 tonne per day composting facility

3.2. Infrastructure

- Total area of the facility – 17,000 m², (1.7 hectare)
- Concreted composting platform (composting pad) – 5900 m²
- Roof with steel columns, truss, purlin and corrosion resistant sheets – 5900 m²
- Drain length for the composting pad ('saucer' drain, 30 cm wide, 10 cm deep with smooth plaster and cement punning) – 390 m
- Drain length for the compost plant ('saucer' drain, 45 cm wide, 15 cm deep with smooth plaster and cement punning) – 300 m

- Leachate traps two as per drawing, 0.5 m deep, 0.5 m diameter, masonry structure with plaster and neat cement punning. The bottom should be curved for better cleaning. Location – inside shed, as per drawing.
- Length of internal road (3 m wide, black top* with camber) – 300 m
- Fence – 2 m high masonry structure with intermittent concrete columns for strength
- Planting rows of indigenous plants (sturdy) which grow to about 3 m height to provide a good green screen and buffer.
- Height of shed – 9 m on the windrow side, 7 m on the office side, 15 m in the middle (as per section drawing).
- The gap between the two sections of the shed would facilitate ventilation.
- Rainwater harvesting for the storm water from the roof.
- Solar PV panels on roof top.

3.3. Operational Steps

1. Unloading area for picking out any large and undesirable item followed by mixing.
2. Laying of the windrow with a trapezoidal cross section (windrow 1 x 2 nos.)
3. Turning off the windrow after one week to the next space slot (windrow 2 x 2 nos.).
4. Turning off the windrow after one week to the next space slot (windrow 3 x 2 nos.).
5. Turning off the windrow after one week to the next space slot (windrow 4 x 2 nos.).
6. The 4th and 5th windrows need to be under a shed even if the first three windrows are in the open.
7. Turning off the windrow after one week to the next space slot (windrow 5 x 2 nos.).
8. After completion of five weeks, the composted material is screened using a trommel having 25 mm circular openings.
9. The material >25 mm is taken out through the ‘rejects’ conveyor. This material can be used as a cover over the fresh material in the 1st windrow or the ‘extra’ windrows, which would help in controlling birds, flies and odour to some extent.
10. The material <25 mm goes through the next process conveyor to the next screener trommel having 10 mm mesh.
11. The material >10 mm is taken out through the ‘rejects’ conveyor. This material along with material >25 mm can be used as a cover over the fresh material in the 1st windrow, or the ‘extra’ windrows, which would help in controlling birds, flies and odour to some extent.
12. The material <10 mm is the material fit for further ‘curing’ for three weeks.
13. The ‘cured’ material is ready for packing / bagging and storage as compost.
14. The product is around 20 per cent of the feedstock, which means about 1 (one) tonne per day. When the input material is more due to festivals / religious events, more compost would be produced proportionally.
15. For this size of compost plant, one month’s storage in the compost plant is recommended. The storage area is also indicated in the drawing.

3.4. Input Mass and Volume

	Per day		Per week	
	Mass (tonnes)	Volume (m^3)	Mass (tonnes)	Volume (m^3)
50 TPD-W	50	67	350	467

3.5. Windrow Size Calculations

Scenario	Width (m)	Height (m)	Length (m)	Volume (m^3)
50 TPD-W	5	3	47	467

3.6. Materials Handling Vehicle

Scenario	Vehicle
50 TPD-W	Medium sized tractor with a front-end loader and backhoe. The front shovel should have a minimum capacity of 1 cubic metre. The backhoe should have a minimum capacity of 0.5 m^3.

3.7. Trommel Screen Sizes

Scenario	Screen Function	Minimum Throughput (tonnes/hour)	Minimum Throughput m^3/hour	Mesh Size (mm)
50 TPD-W	Pre-composting	5	7	25
	Post-composting	5	7	10

3.8. Power and Daily Water

Scenario	Per day	Per week
50 TPD-W	50	30,000

3.9. Full-time Personnel

Scenario	Site Manager	Site Operator	Weighbridge Operator	Driver	Labourer
50 TPD-W	1	1	1	1	4

4. 150 TPD Turned Windrow Scenario

4.1. Site Plan

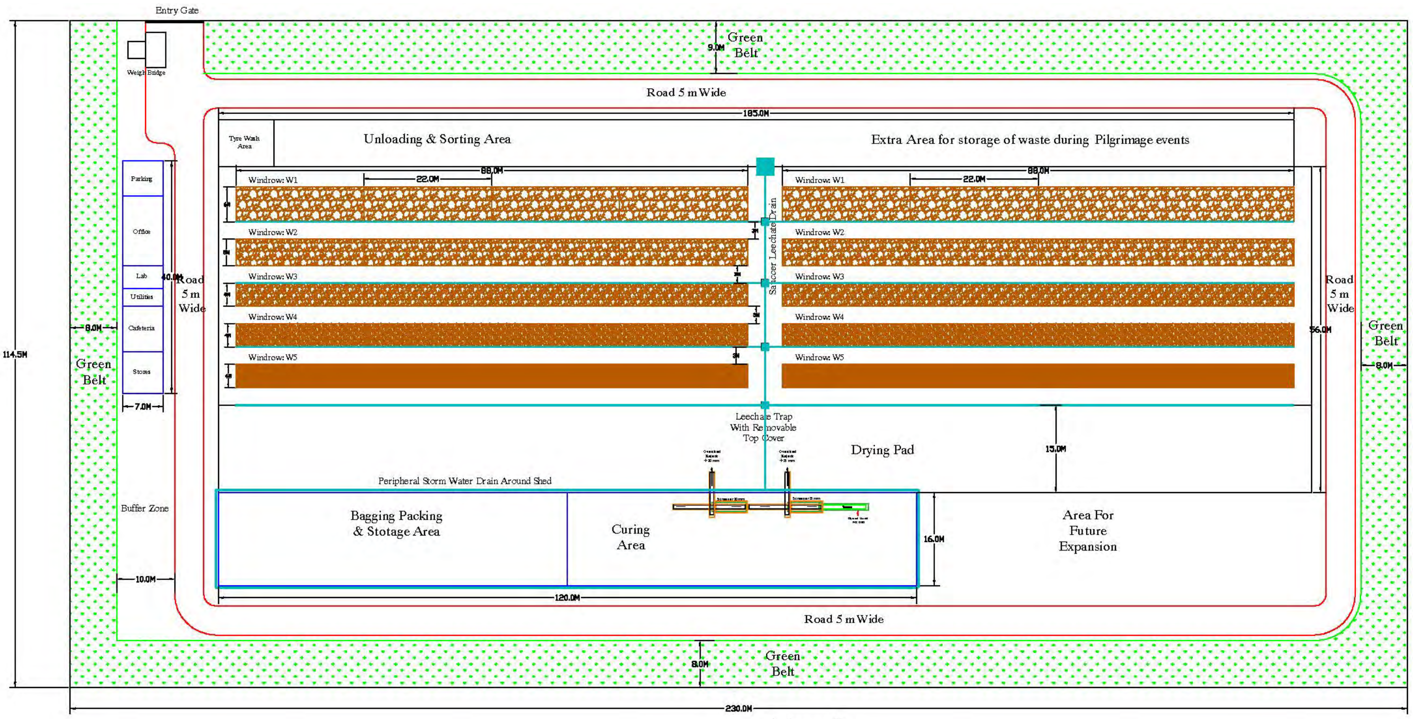


Figure 17: Site plan of a 150 tonne per day turned windrow composting facility

4.2. Infrastructure

- Total area is about 20,000 m^2 (2 hectare)
- Concreted composting platform (composting pad) – 10,360 m^2
- Roof with steel columns, truss, purlin and corrosion resistant sheets – 10,360 m^2
- Drain length for the composting pad ('saucer' drain, 30 cm wide, 10 cm deep with smooth plaster and cement punning) – 690 m
- Drain length for the compost plant ('saucer' drain, 45 cm wide, 15 cm deep with smooth plaster and cement punning) – 520 m
- Leachate traps 8 nos. as per drawing, 0.5 m deep, 0.5m diameter, masonry structure with plaster and neat cement punning. The bottom should be curved for better cleaning. Location – inside shed, as per drawing.
- Length of internal road (7 m wide, black top* with camber) – 520 m
- Fence – 2 m high masonry structure with intermittent concrete columns for strength

- Planting rows of indigenous plants (sturdy) which grow to about 3m height to provide a good green screen and buffer.
- Height of shed – 10 m on the windrow side, 8 m on the office side, 15 m in the middle (as per section drawing).
- The gap between the two sections of the shed would facilitate ventilation.
- Total area of the facility: 26,335 m^2 (2.63 ha)
- Rainwater harvesting for the storm water from the roof.
- Solar PV panels on roof top.

4.3. Operational Steps

1. Unloading area for picking out any large and undesirable item followed by mixing.
2. Laying of the windrow with a trapezoidal cross section (windrow 1).
3. Turning off the windrow after one week to the next space slot (windrow 2).
4. Turning off the windrow after one week to the next space slot (windrow 3).
5. Turning off the windrow after one week to the next space slot (windrow 4). The 4th and 5th windrows need to be under a shed even if the first three windrows are in the open.
6. Turning off the windrow after one week to the next space slot (windrow 5).
7. After completion of 5 weeks, the composted material is screened using a trommel having 25 mm openings, followed by a trommel having 10 mm openings.
8. The material >25 mm and >10 mm is taken out through the respective 'rejects' conveyor. This material can be used as cover over the fresh material in the 1st windrow, which would help in controlling birds, flies and odour to some extent.
9. This 'rejects' material would also be very suitable for the extra windrows or the material placed at the additional space during religious tourism.
10. The material <10 mm is the material fit for further 'curing' for 3 weeks.
11. The 'cured' material is ready for packing / bagging and storage as compost.
12. The product is around 20 per cent of the feedstock, which means about 1 (one) tonne per day. When the input material is more due to festivals / religious events, more compost would be produced proportionally.
13. For this size of compost plant, one month's storage in the compost plant is recommended. The storage area is also indicated in the drawing

4.4. Input Mass and Volume

	Per day		Per week	
	Mass (tonnes)	Volume (m^3)	Mass (tonnes)	Volume (m^3)
150 TPD-W	150	200	1,050	1,400

4.5. Windrow Size Calculations

Scenario	Width (m)	Height (m)	Length (m)	Volume (m^3)
150 TPD-W	8	4	66	1,400

4.6. Materials Handling Vehicle

Scenario	Vehicle
150 TPD-W	Medium to large sized front-end loader. The front shovel should have a minimum capacity of 2-3 cubic metres.

4.7. Trommel Screen Sizes

Scenario	Screen Function	Minimum Throughput (tonnes/hour)	Minimum Throughput m^3/hour	Mesh Size (mm)
150 TPD-W	Pre-composting	15	20	25
	Post-composting	5	7	10

4.8. Power and Daily Water

Scenario	Per day	Per week
150 TPD-W	70	40,000

4.9. Full-time Personnel

Scenario	Site Manager	Site Operator	Weighbridge Operator	Driver	Labourer
150 TPD-W	1	2	2	2	6

5. 50 TPD Aerated Static Pile

5.1. Site Plan

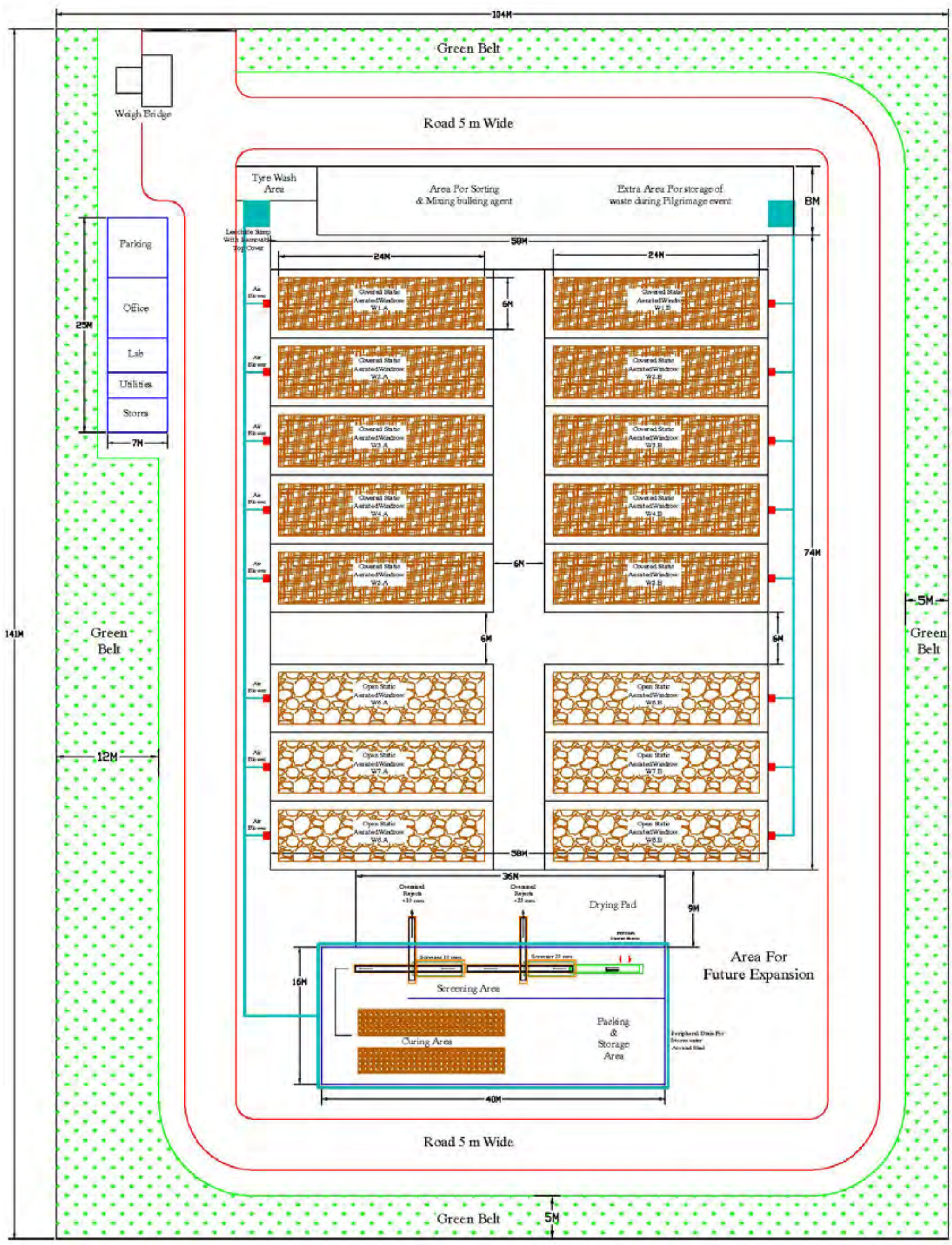


Figure 18: Site plan of a 50 tonne per day aerated static pile composting facility

5.2. Infrastructure

- Total area of the plant – 14664 m^2, say 14,700 m^2 (1.47 hectare)
- Concreted composting platform (composting pad) – 4300 m^2
- Roof with steel columns, truss, purlin and corrosion resistant sheets – 4300 m^2
- Drain length for the composting pad ('saucer' drain, 30 cm wide, 10 cm deep with smooth plaster and cement punning) – 390 m
- Drain length for the compost plant ('saucer' drain, 45 cm wide, 15 cm deep with smooth plaster and cement punning) – 300 m
- Leachate traps 2 nos. as per drawing, 0.5 m deep, 0.5 m diameter, masonry structure with plaster and neat cement punning. The bottom should be curved for better cleaning. Location – inside shed, as per drawing.
- Length of internal road (3 m wide, black top* with camber) – 300 m
- Fence – 2 m high masonry structure with intermittent concrete columns for strength
- Planting rows of indigenous plants (sturdy) which grow to about 3 m height to provide a good green screen and buffer.
- Height of shed – 9 m on the windrow side, 7 m on the office side, 15 m in the middle (as per section drawing).
- The gap between the two sections of the shed would facilitate ventilation.
- Two different configurations of the shed have been indicated in the section drawings (figures 6 and 7). When the detailed plan and engineering drawings would be made, a choice may be made between the two configurations, depending upon the prevailing wind direction at the site and directions of sun's movement.
- Rainwater harvesting for the storm water from roof.
- Solar PV panels on roof top.

5.3. Operational Steps

1. Unloading area for picking out any large and undesirable item followed by mixing.
2. Laying of the windrows with a trapezoidal cross section (windrows 1- 4 x 2 nos. each) over the identified area over the aeration pipes. The windrows are covered with breathable covers with the help of the mechanical contraption meant for the purpose.
3. Shifting of the windrows after 4 weeks to the next space slot (windrows 5-6 x 2 nos.) for 2 weeks.
4. After 6 weeks the composted material is screened using a trommel having 25 mm circular openings.
5. The material <25 mm goes through the next process conveyor to the next screener trommel having 10 mm circular openings.
6. The composted material <10 mm size is cured for two weeks.

7. The material >10 mm is taken out through the 'rejects' conveyor. This material along with material >25 mm can be used as a 'structural material' for the fresh material in the windrows of the 1st phase and the 'extra' windrows (during pilgrimage events), which would help in aeration of the material in the composting pile. Part of the organic structural material gets composted, and the rest is screened out in the next cycle of screening through 25 mm and 10 mm.
8. The product is around 20 per cent of the feedstock, which means about 1 (one) tonne per day. When the input material is more due to festivals / religious events, more compost would be produced proportionally.
9. For this size of compost plant, one month's storage in the compost plant is recommended. The storage area is also indicated in the drawing.

5.4. Input Mass and Volume

	Per day		Per week	
	Mass (tonnes)	**Volume (m^3)**	**Mass (tonnes)**	**Volume (m^3)**
50 TPD-ASP	5	67	350	467

5.5. Windrow Size Calculations

Scenario	Width (m)	Height (m)	Length (m)	Volume (m^3)
50 TPD-ASP	6	3	39	467

5.6. Materials Handling Vehicle

Scenario	Vehicle
50 TPD-ASP	Medium sized tractor with a front-end loader and backhoe. The front shovel should have a minimum capacity of 1 cubic metre. The backhoe should have a minimum capacity of 0.5 m^3.

5.7. Trommel Screen Sizes

Scenario	Screen Function	Minimum Throughput (tonnes/hour)	Minimum Throughput m^3/hour	Mesh Size (mm)
50 TPD-ASP	Pre-composting	15	20	25
	Post-composting	5	7	10

5.8. Power and Daily Water

Scenario	Per day	Per week
50 TPD-ASP	86	20,000

5.9. Full-time Personnel

Scenario	Site Manager	Site Operator	Weighbridge Operator	Driver	Labourer
50 TPD-ASP	1	1	1	1	4

Appendix 2: Personnel Requirements

Job Description	Desirable Qualifications/ Experience
Plant Manager	
To manage all aspects of composting facility operations, including receiving, processing, and composting of organic materials.	• Diploma in Civil / Mechanical Engineering. • Experience working as a manager / supervisor at a waste management site/ factory or similar for a minimum of 5 years. • Capable of administration and understand basic concepts of accounting. • Knowledge of relevant regulations & legislative requirements. • Human resource management skills. • Knowledge and experience of implementing health and safety measures. • Experience in vehicle / fleet management.
Plant Operator	
To support the plant manager and to co-ordinate the daily activities.	• High school certificate including technical subjects or a diploma from a technical training institute. • Experience in mechanics or electrical systems, including basic repairs to vehicles. • Experience of working as an operator in a relevant environment (e.g., waste site or factory) for a minimum of two years. • Knowledge and experience of implementing health and safety measures.
Weighbridge Operator	
To record the weight of all vehicles entering and leaving the facility and to ensure that adequate records are maintained.	• High school pass • Preliminary computer training • Knowledge and experience about weighbridge operations
Driver	
To operate the materials handling vehicles and other large equipment (e.g. shredder).	• High school pass • Must be able to read and understand road signs and traffic rules. • Trained to drive heavy vehicles with 3 years' experience. • Experience of driving front end loader-cum-backhoe preferable. • Good track record of driving (no convictions).
Labourer	
To assist staff in all site activities, including cleaning equipment and the site, removal and safe storage of contaminants.	• Practical knowledge about health and safety procedures. • Ability to take instructions from the plant manager or the operator. • Willingness to work in a team. • Diligence in all work activities.