

# Compost Facility Operator Study Guide



## **Compost Facility Operator Study Guide**

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# Glossary of Terms

The definitions of terms provided in this section are not necessarily the 'dictionary' definitions but are in the context of the subject matter.

**Active Composting Area** is the area where windrow or piles of feedstock are placed for active composting.

**Aerated Static Pile (ASP)** is a method of composting that involves mechanically moving air through the compost pile, either through suction or blowing air through the pile. Little or no agitation or turning is performed.

**Aeration** is the process by which the oxygen-deficient air in compost is replaced by air from the atmosphere. Aeration can be enhanced by turning the compost, by passive aeration, or by forced aeration using blowers.

**Aerobic** refers to any situation or process where oxygen is present. In the context of waste management, the term is frequently used to describe the process of composting, which **REQUIRES** that oxygen be present.

**Aerobic Conditions** is an environment that is conducive to the microbial degradation of organic solid waste in the presence of oxygen.

**Agitation** is the mixing of compost materials, often referred to as turning, which fluffs up the composting pile and re-establishes free air space, redistributes moisture, and generally accelerates the breakdown of materials.

**Agricultural composting facilities** are on-farm operations that compost only livestock manures. These facilities are regulated through Alberta Agriculture and Forestry or the Natural Resources Conservation Board. Non-agricultural composting facilities are regulated through AEP.

**Amendment** is a supplemental material mixed with compostable feedstock in preparation for composting to create a favourable condition for composting, either by adjusting the moisture content or the carbon to nitrogen (C:N) ratio.

**Anaerobic** refers to any situation or process where oxygen is not present. Anaerobic digestion of organic waste is a process that **REQUIRES** that oxygen not be present.

**Anaerobic Condition** is an environment in which microbial degradation of organic solid waste occurs in the absence of oxygen.

**Anaerobic Digestion (AD)** is a controlled and managed biological process that uses microorganisms to break down organics material in the absence of oxygen.

**Aquifer** means an underground water-bearing formation that is capable of yielding water, as through a water well.

**Biodegradation** is a process where organic materials are degraded by microorganisms.

**Biogas** is a gaseous by-product of the anaerobic digestion process. The major components of biogas are carbon dioxide and methane.

**Biosolids** are the organic sludges produced when sewage or other organic wastes are biologically 'digested' in an anaerobic process as part of the sewage treatment process. Biosolids are sometimes thickened and then composted as a means of recycling them into a useful soil amendment.

**BOD** is a measure of the amount of dissolved oxygen required to biochemically oxidize the degradable organics in a sample.

**Borehole** means a hole drilled into the earth to explore by observing and sampling the materials brought up by the drill and establish the hydrogeological setting and engineering characteristics of the formations below. Water sampling pipes are often installed as well, both to sample the water in the future and to measure the depth to the water level.

**Buffer zone** is the vicinity between the active composting area and the property boundary.

**Bulking agent** is an amendment added to a mixture of composting raw materials to improve the structure and free air space of the mixture. Bulking agents are usually rigid and dry, and often have large particles.

**Carbon-to-Nitrogen (C:N) Ratio** is the ratio of quantity of carbon (C) in a material (on a dry weight basis) to the amount of nitrogen (N) in the material (on a dry weight basis).

**COD** is a measure of all the organic and inorganic materials present in a sample that can be oxidized by heat and acid. Since it includes organic materials that are not normally biodegradable, the COD of a sample will always be higher than its BOD.

**Compost** is a stable, humus-like material that results from the biological decomposition and stabilization of organic materials under aerobic and thermophilic conditions. Compost is potentially beneficial to plant growth, and is sanitized to a degree that protects human and plant health.

**Composting** is a managed, biological process through which organic matter is degraded under aerobic conditions to a relatively stable, humus-like material called compost.

**Contaminant** refers to an element, compound, substance, or organism that, through its presence or concentration, causes an adverse effect on the nature of an environment or impairs human use of the environment.

**Contamination** is any introduction into the environment (water, air, or soil) of microorganisms, chemicals, wastes, or wastewater in a concentration that makes the environment unfit for its intended use.

**Contravention** is an act that involves breaking (contravening) a law, regulation or requirement.

**Curing** is the final stage of composting in which stabilization of the compost continues, but the rate of decomposition is slowed to a point where turning or forced aeration is no longer necessary. Curing generally occurs at lower, mesophilic temperatures. This term is used synonymously with maturing.

**Curing Area** is the area where composting materials are placed to stabilize to reach maturity.

**Digestate** is the solid or semi-solid material left over after anaerobic digestion.

**Digester** is a vessel or tank in which the anaerobic digestion process occurs.

**Emissions** generally refers to airborne materials such as gases from burning, from car tailpipes, and from landfills as landfill gas.

**Feedstock** is all materials that are accepted at the composting facility and used in the composting process, including amendments and bulking agents.

**Food Waste** is discarded animal and vegetable matter from food and food preparation; sources include residences and commercial establishments, such as grocery stores, restaurants, produce stands, institutional cafeterias and kitchens, and industrial sources

**Forced Aeration** is the practice of using fans to move air through the composting material in a pile or vessel.

**Foreign Matter** is any matter resulting from human intervention that includes organic or inorganic components, such as metal, glass, and synthetic polymers (e.g., plastic and rubber) that may be present in the compost.

**Free Air Space (FAS)** is a measure of the space between individual particles in the compost pile that are filled with air. FAS is fundamental to active composting and curing, as there must be

enough void space in the compost pile for oxygen. It is also critical that the spaces between the particles are interconnected so that air can move through the compost pile passively, or be forced through with aeration fans.

**Gasification** is a thermo-chemical process in which organic material, including waste, is partially combusted in a high-pressure chamber with limited oxygen. The material which does not combust is converted to synthetic gas, tars, and ash-like char. In the waste management industry, the syngas is typically used as fuel for power generation or heat, so gasification of waste is considered a form of waste-to-energy.

**Geological formation** refers to the types and thicknesses of soils and rock that are in an area.

**Geology** is the study of the earth, the materials of which it is made (soils, rock), the structure of those materials, and the historical processes (volcanic activity, sedimentation, etc.) that influenced their formation.

**Geotechnical** as in geotechnical investigation, is the exploration of soils and geological formations beneath the surface, generally undertaken by drilling boreholes and analyzing material samples.

**Greenhouse gases** are gases that trap heat in the atmosphere and are generally believed to contribute to climate change. There are many different gases that behave as greenhouse gases. The most common one is carbon dioxide, but methane is a stronger greenhouse gas that is produced by materials breaking down under anaerobic conditions.

**Groundwater** is water that is below the earth's surface, generally in the pore spaces of soils and bedrock.

**Hydrogeology** is the study of the relationship between water and geology with particular emphasis on the movement and chemistry of water.

**Humus** is the dark or black, carbon-rich, relatively stable residue resulting from the decomposition of organic matter.

**Infiltration** is the process by which liquid passes through soils or porous materials. In composting, infiltration generally refers to the passage of precipitation, surface water or leachate through a composting pile, through a working pad or through a liner system.

**In-vessel Composting** is a method of composting where the materials being processed are completely encapsulated during the composting process.

**Leachate** is a liquid that has percolated through or drained from solid waste or compost often containing suspended or dissolved waste materials.

**Leaf and Yard Waste (L&YW)** is vegetative matter resulting from gardening, horticulture, agriculture, landscaping, or land-clearing operations, including materials such as tree and shrub trimmings, plant remains, grass clippings, leaves, trees, and stumps.

**Liner** is a continuous layer constructed of natural or synthetic materials, beneath or on the sides of a structure or facility, which restricts the downward or lateral migration of the contents of the structure or facility.

**Mature Compost** is a stable compost that has little or no organic phytotoxic substances that can cause delayed seed germination when used as a soil amendment, and meets maturity compost quality requirements, as set out in the Guidelines for Compost Quality, published by Canadian Council of Ministers of the Environment (CCME), as amended.

**Mesophilic** is the temperature range most conducive to the maintenance of mesophilic microorganisms, generally accepted as between 20 and 45 degrees Celsius (°C).

**Microorganism** is a living organism so small that it requires magnification before it can be seen.

**Moisture Content** is the weight fraction or percentage water in a substance.

**Municipal Solid Waste (MSW)** is the solid waste discarded from residential, industrial, commercial, institutional, construction, and demolition sources; does not include hazardous waste.

**Overs** are oversized materials that have not completely broken down and are screened from the finished compost.

**Oxygen Demand** is the amount of oxygen required by the aerobic microorganisms to break down material at the various stages of the compost process.

**Passive Aeration** is naturally occurring air movement through compost windrows and piles caused by convection and that supplies air. No mechanical devices are used.

**Pathogen** is an organism, including some bacteria, viruses, fungi, and parasites, that can produce an infection or disease in a susceptible human, animal, or plant host.

**Permitted capacity** is the maximum quantity of feedstocks and amendments that can be accepted at the composting facility during a specific time frame (usually per year) as stated in the facility's authorization document from AEP. A facility's permitted capacity may be greater or less than its processing capacity.

**pH** is a measure of the concentration of hydrogen ions in a solution which determines if a material is acidic or alkaline. A pH of 7 is neutral.

**Phytotoxic** is an adjective describing a substance that has a toxic effect on plants. Immature or anaerobic compost may be phytotoxic if it contains acids or alcohols that can harm seedlings or sensitive plants.

**Porosity** is a measure of the pore space around individual compost particles, including the pore space filled by water. Calculated as the total volume of the pores in a sample divided by the total volume of the sample.

**Post-consumer** refers to materials that have served their intended use and have been recovered or diverted from disposal. Post-consumer organics (such as plate scrapings) usually come from residences, commercial kitchens in restaurants or hospitals.

**Pre-consumer** refers to materials that have not reached a consumer yet. These materials usually come from food processors, warehouses, supermarkets and other retailers prior to reaching consumers for use. An example of pre-consumer organic waste is food items that were deemed unfit for sale in grocery stores and discarded, or that made it to the grocery store but went bad on the shelves.

**Process to Further Reduce Pathogens (PFRP)** is a set of criteria used to define the time and temperature requirements needed to reduce pathogen levels in a material. For in-vessel and ASP composting, PFRP requires that materials be maintained at operating conditions of 55°C or greater for 3 consecutive days. For windrow composting, materials must be maintained at a temperature of 55°C or greater for at least 15 consecutive days, during which time, the windrow must be turned at least five times.

**Processing Area** is the combination of the feedstock processing and the active composting area.

**Processing Capacity** is the maximum amount of material that can move through the composting facility during a specific time frame. It is a function of the composting method used, the capabilities of processing equipment, the size of compost piles, and how long materials need to remain in place for biological processed to be completed. Usually expressed on an annual basis, but sometimes daily or weekly processing capacities are specified.

**Putrescible** is a substance that is organic and will rapidly biodegrade.

**Pyrolysis** is a process where organic material, which may be waste, is heated in a chamber in the absence of oxygen which results in its conversion into synthetic gas, oils, and a charcoal-like solid residual. The gas and oils can be used as an energy source, so in the waste management industry pyrolysis is generally considered a form of waste-to-energy. The solid is sometimes refined into a soil amending product called “bio-char”.

**Receiving Area** is the area used to receive incoming feedstocks.



**Residence Time** is the amount of time materials remain in a composting or AD system (e.g., vessel, windrow, or pile).

**Retention Pond** is a pond that is designed to store process water and runoff from storm events.

Runoff is any rainwater or meltwater that drains as surface flow from the receiving, processing, curing, and associated storage areas of a composting facility.

**Screening** is the process of mechanically separating particles based on size that is used to remove large particles or contaminants from compost to improve consistency and quality of the end product.

**Sharp Foreign Matter (sharps)** is foreign matter over 3 millimetres in dimension that may cause damage or injury to humans and animals during or resulting from its intended use. Sharps may consist of, but are not limited to, metallic objects, glass or porcelain.

**Source Separation** is the separation of the waste materials into two or more distinct components prior to collection to limit the possible contamination of one material stream by the other.

**Source-Separated Organics (SSO)** is the organic fraction of MSW that has been accumulated and pre-sorted by the generator, and collected separately from household hazardous material and non-compostable material.

**Stability (of Compost)** is the reduced rate of change or decomposition of compost as it approaches maturity. Usually, stability refers to the lack of change or resistance to change. A stable compost continues to decompose at a very slow rate and has a low oxygen demand.

**Stable Compost** is a compost that has a reduced rate of respiration and heat rise but may still contain organic phytotoxins.

**Static Pile** is a method of composting that does not involve turning the composting pile or otherwise using mechanical devices to introduce oxygen into the pile.

**Surface water** is water that is on the surface of the earth, as opposed to groundwater, which is below; generally refers to rivers, lakes, streams, ponds and wetlands.

**Thermophilic** is the temperature range most conducive to the maintenance of thermophilic microorganisms, generally accepted as being greater than 45°C.

**Tipping Fee** is a fee charged at the point of reception for treating, handling, and/or disposing of waste materials.

**Topography** is the form of a land surface. A topographic map is a detailed map of the surface features of land. It includes the mountains, hills, creeks, and other bumps and lumps on a particular part of the earth.

**Trace Element** is a chemical element present in compost at a very low concentration.

**Turning** is the action of mixing and agitating material in a windrow, pile, or vessel. Turning is done to increase free air space, introduce oxygen, redistribute moisture, or make the material more homogeneous.

**Vectors** in the context of composting, refers to 'disease vectors' such as birds, mice, rats, and insects, that can spread diseases.

**Vegetative matter** means source-separated organics that consist of plant matter, including but not limited to non-treated wooden material, leaf and yard waste, agricultural crop residues, vegetable processing plants, and pre-consumer meat-free food wastes.

**Volatile Organic Compound (VOC)** is a naturally occurring or synthetic chemical compound that has a high vapour pressure during ordinary conditions, causing large amounts of molecules to evaporate and enter the surrounding air, resulting in odours.

**Water Content** is the amount of water a material contains.

**Windrow** is a long, relatively narrow and low pile. Windrows have a large, exposed surface area that encourages passive aeration and drying.

**Working Surface** is an outdoor surface on which processing activities (e.g., grinding, mixing, composting, and screening) or material storage occurs. Typically designed to withstand the weight and wear of composting equipment.

# Acronyms and Abbreviations

<	less than
≤	less than or equal to
°C	degree(s) Celsius
AD	Anaerobic Digestion
ADR	Activities Designation Regulation
AEP	Alberta Environment and Parks
AIP	Acceptable Industry Practice
Alberta Recycling	Alberta Recycling and Management Authority
AOPA	<i>Agricultural Operation Practices Act</i>
ASP	aerated static pile
ASTM	American Society for Testing and Materials
BMP	best management practice
BNQ	Bureau de Normalisation du Quebec
BOD	biochemical oxygen demand
BSE	bovine spongiform encephalopathy
C	carbon
C:N	carbon-to-nitrogen
CCEMC	Climate Change and Emissions Management Corporation
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
cfm	cubic foot (feet) per minute
CFO	confined feeding operation
CH <sub>4</sub>	methane
CO <sub>2</sub>	carbon dioxide
CO <sub>2</sub> e	carbon dioxide equivalent
COD	chemical oxygen demand
COR	Certificate of Recognition
CQA	Compost Quality Alliance
CRD	construction, renovation, and demolition
D/T	dilutions to threshold

DAO	Delegated Administrative Organization
DO	dissolved oxygen
dw	dry weight
ECS	Engineered Compost Systems, Inc.
EPA	Environmental Protection Agency
EPEA	<i>Alberta Environmental Protection and Enhancement Act</i>
ERP	Emergency Response Plan
FAS	free air space
FOG	fats, oils, and greases
ft <sup>2</sup>	square foot (feet)
FWD	food waste disposer
g	gram(s)
GHG	greenhouse gas
GWP	Global Warming Potential
ha	hectare(s)
HDPE	high-density polyethylene
ICI	industrial, commercial, and institutional
ISWM	integrated solid waste management
K	potassium
kg	kilogram(s)
kg/ha	kilogram(s) per hectare
kg/L	kilogram(s) per litre
kg/m <sup>3</sup>	kilogram per cubic metre
kg/person/y	kilogram(s) per person per year
kpd	kilogram(s) per day
L	litre(s)
L&YW	leaf and yard waste
lb	pound(s)
lb/ft <sup>3</sup>	pound(s) per cubic foot
lb/yd <sup>3</sup>	pound(s) per cubic yard
LDPE	low-density polyethylene
LFG	landfill gas
m	metre(s)

m <sup>2</sup>	square metre(s)
m <sup>3</sup>	cubic metre(s)
m <sup>3</sup> /h	cubic metre(s) per hour
m <sup>3</sup> /s	cubic metre(s) per second
MBT	mechanical-biological treatment
MC	moisture content
mg	milligram(s)
mg/kg	milligram(s) per kilogram
mL	millilitre(s)
mm	millimetre(s)
MOR	Managed Organic Recycling, Inc.
MPN	most probable number
MRF	Materials Recovery Facility
MSW	municipal solid waste
N	nitrogen
NL	not listed
NRCB	Natural Resources Conservation Board
O <sub>2</sub>	oxygen
OH&S	Occupational Health and Safety
OM	organic matter
OU	odour unit
P	phosphorus
PAW	passively aerated windrow
PAYT	Pay-As-You-Throw
PFD	process flow diagram
PFRP	Process to Further Reduce Pathogens
PHA	Public Health Act
PIR	Partnerships in Injury Reduction
PPE	personal protective equipment
ppm	part(s) per million
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control

RBL	reclaimable bioreactor landfill
RFP	recycled food products
RPE	Respiratory protection equipment
SC	solids content
SECOR	Small Employer Certificate of Recognition
SRM	specified risk material
SSO	source-separated organic
t/m <sup>3</sup>	tonne(s) per cubic metre
TKN	total Kjeldahl nitrogen
tpd	tonne(s) per day
tpm	tonne(s) per month
tpy	tonne(s) per year
TMECC	Test Methods for the Examination of Composting and Composts
USC	United States Customary
USDA	U.S. Department of Agriculture
VOC	volatile organic compound
WCB	Workers Compensation Board
WCR	Waste Control Regulation
Wright	Wright Environmental Management Inc.
WtE	waste-to-energy
WWTP	wastewater treatment plant
yd <sup>3</sup>	cubic yard(s)
yd <sup>3</sup> /h	cubic yard(s) per hour

# Introduction

In Alberta, at least one person working at or supervising a composting site is required to be a Certified Compost Facility Operator. To become certified, the person must pass a certification exam and have at least one year of relevant experience.

Alberta's Operator Certification Program was established to verify that composting facility operators have the knowledge needed to:

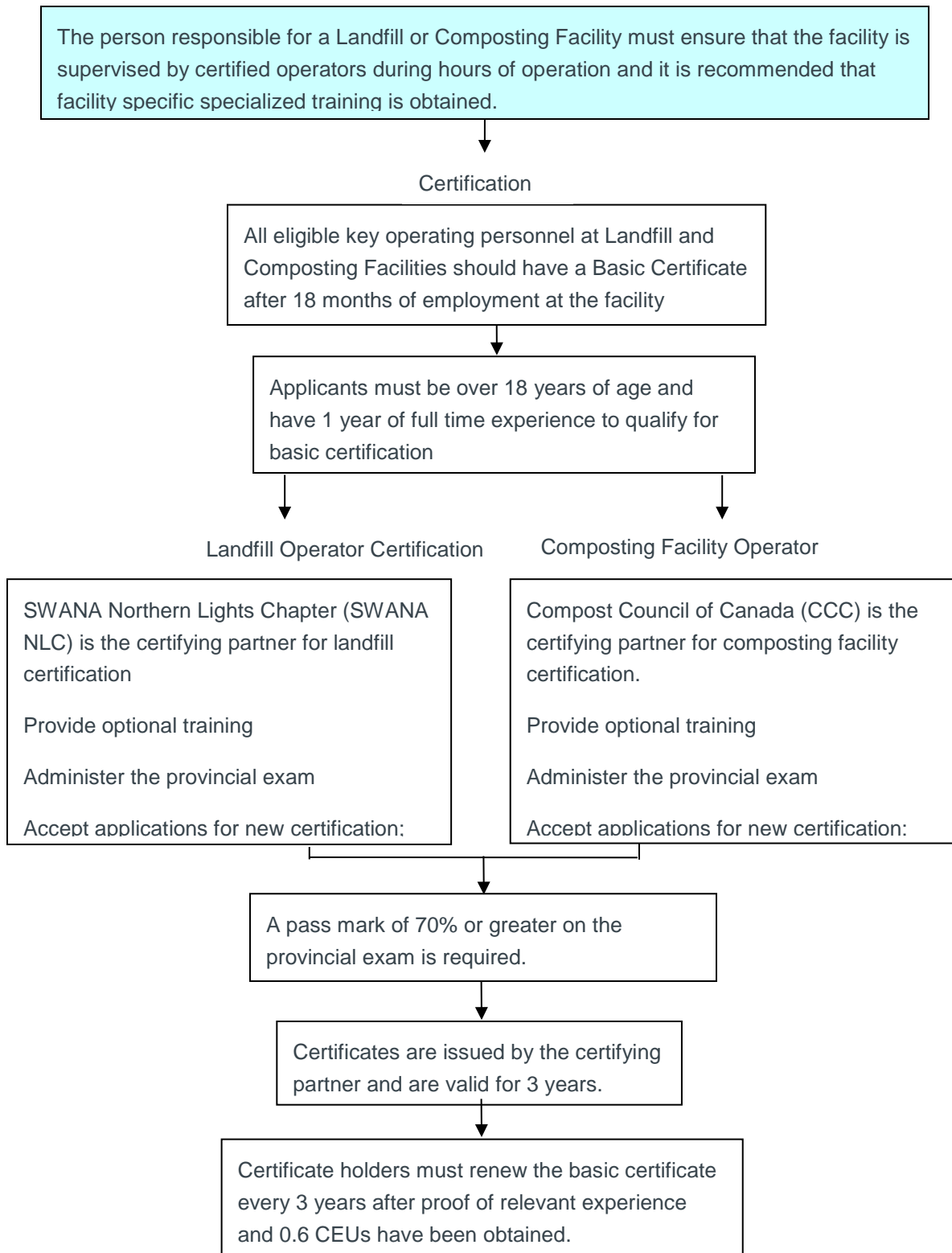
- Protect the environment
- Protect public health and provide for public safety
- Achieve regulatory compliance
- Efficiently operate their facilities
- Protect employee safety and well-being
- Meet waste reduction and resource conservation objectives
- Follow the waste management hierarchy of reduce, reuse, recycle, and recover

Figure 1 provides an overview of the structure of the program and the steps involved in obtaining and maintaining an Operator Certificate. This study guide addresses only certification of composting facility operators; landfill operator certification, while part of the same program, is not covered. The compost operator certification program is currently administered by the Compost Council of Canada. Landfill operator certification is administered by the Northern Lights Chapter of the Solid Waste Association of North America.

To meet program goals, it is important that the Certified Operator understands applicable Alberta Environment and Parks (AEP) approvals processes, provincial and federal regulations relating to operations and product quality, and principles of facility operations and site safety.

This document is intended to assist individuals working towards obtain their initial certification. An operator preparing to challenge the Operator Certification exam will find value in this manual, classroom courses, and on-the-job training.

As indicated in the program overview diagram in Figure 1, in order to renew their certification, operators must continue to learn about facilities and the environment. This ongoing education is called Continuing Education Units or CEUs. The Continuing Education Unit Policy is available on AEP's website. It includes a list of currently recognized training courses.



**Figure 1. Operator Certification Program Structure**

Source: AEP, 2016



# Chapter 1 – Composting and Integrated Solid Waste Management

## 1.1 Learning objectives

It is important for composting facility operators to understand the current setting of the waste management industry. Composting facility operators can influence how their operations align with society's objectives in waste reduction and management.

This chapter provides an overview of:

- Waste generation in Alberta
- The waste management hierarchy
- Integrated solid waste management
- Sorting and processing technologies
- The role of composting in an integrated system

## 1.2 An Overview of Integrated Solid Waste Management

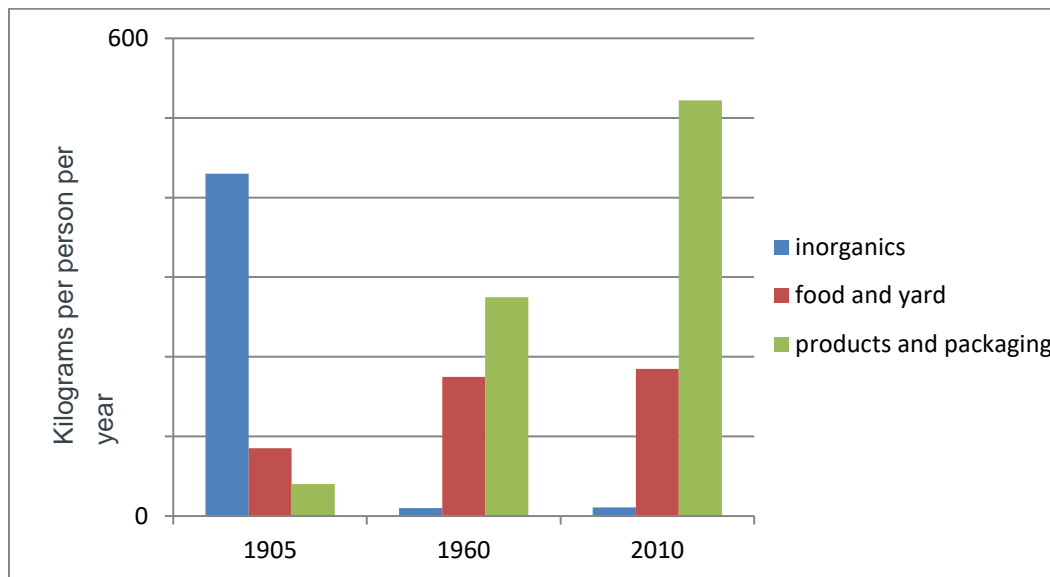
The term integrated solid waste management refers to a strategic approach to sustainable management of solid wastes, covering all sources and all aspects. It considers generation, segregation, transfer, sorting, treatment, recovery, and disposal combined, with an emphasis on efficiency. This chapter provides background and history that is useful in understanding the evolution of today's integrated approach to waste management. It goes on to describe the tools and approaches typically used in waste management systems in Alberta.

In the early 1900s, municipal solid waste (MSW) was largely made up of inorganic material - ashes and street debris. Little packaging was used, purchased goods were not discarded, and food was seldom wasted. Today, the waste stream is made up of more packaging, such as plastics, cardboard, and metals. More products purchased today are considered disposable, and more food is wasted.

## 1.2.1 Challenge of Managing Solid Waste

Managing solid waste is challenging, as waste volumes grow along with the population, and society's dependence on packaging, manufactured goods, and products of convenience. Our waste stream is continually changing as new products enter the market and are eventually discarded. Continuing growth and change requires new approaches to maintain effective waste management and minimization.

Figure 1.1 is a visual representation of the change in waste types over the past 100 years. As new consumer goods enter the market, the waste stream is expected to continue to change in the decades ahead.



**Figure 1.1. Changing Waste Stream**  
*Adapted from Spiegelman and Sheehan, 2005*

Poor or uncontrolled disposal of solid wastes can lead to a variety of problems, including:

- Land pollution created by litter and by contamination carried from a landfill or from stored loose trash in runoff water
- Landfill gas emissions to air – both an air quality and greenhouse gas (GHG) issue
- Property damage, air pollution, and downwind soil contamination from trash fires
- Pollution of surface water bodies caused by contaminated runoff water
- Groundwater contamination from seepage of leachate or contaminated surface water

- Public health concerns and effects due to ineffective control of chemical and biological contaminants and irritants, including odours
- Conflicts with, and impacts on, wildlife

The aesthetics of a poorly managed landfill can also cause issues with neighbours and stakeholders.

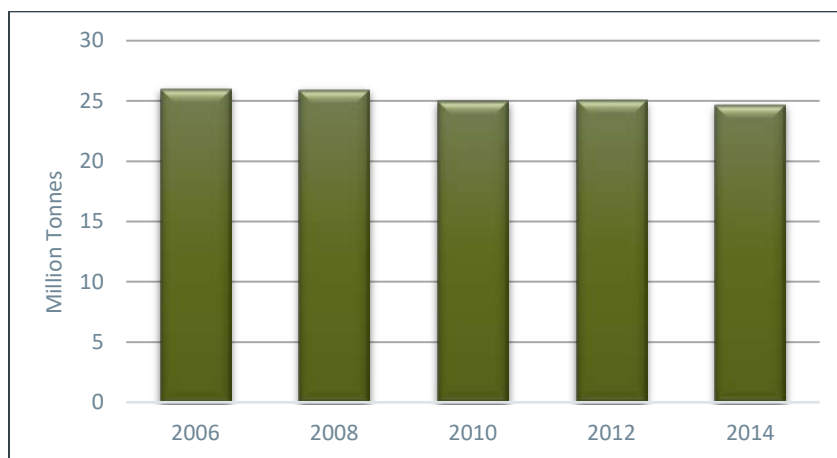
Governments develop initiatives to reduce waste and regulations to prevent pollution and protect public health. Despite reduction efforts, landfills remain an essential part of the waste management industry, so must be built and operated to mitigate these risks.

Comprehensive planning and development of solid waste systems is needed to store, collect, transport, process, and dispose of our discards. An effective solid waste system requires training and education programs to develop the skill sets needed to understand waste management systems and operations.

## 1.2.2 Waste Generation

[Statistics Canada](#) maintains a database of Canada’s waste management generation, diversion, and disposal. Statistics Canada’s web page [Waste Management Industry Survey](#) provides this information.

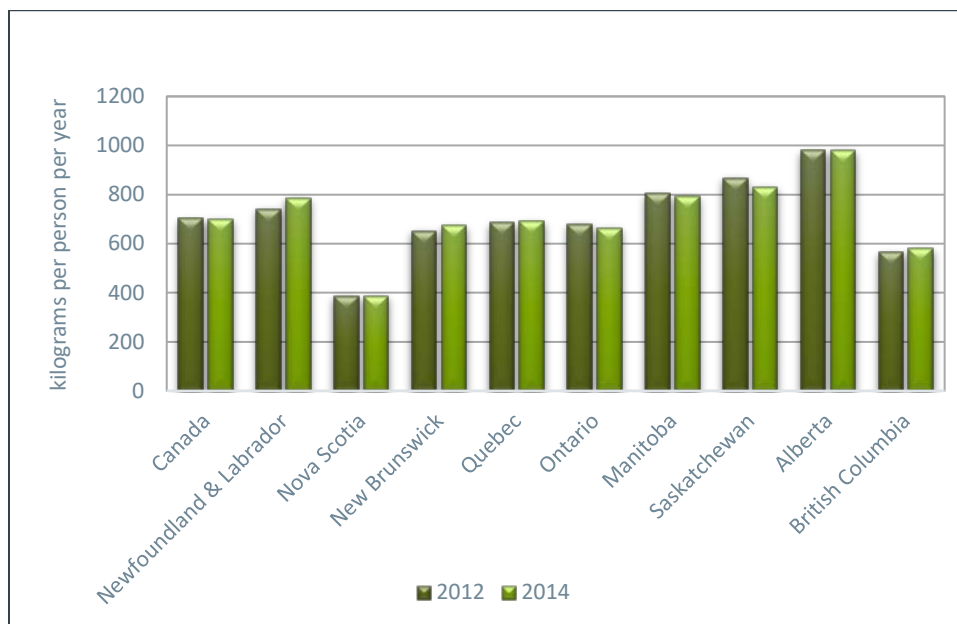
Since 2006, waste disposal in Canada has been quite steady, at between 24 and 26 million tonnes per year (tpy) (Figure 1.2). Disposal volumes are influenced by factors such as the state of the economy and population growth and shifts.



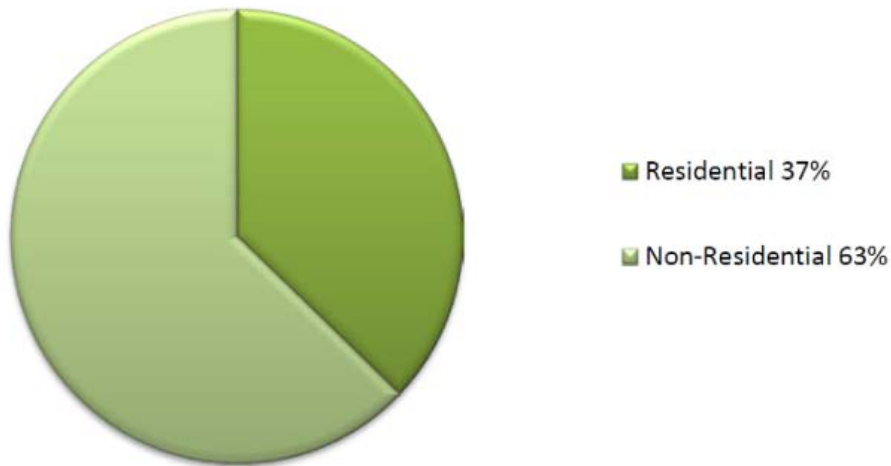
**Figure 1.2. Annual Municipal Solid Waste Disposal (All of Canada – 2006 to 2014)**  
Based on published data from Statistics Canada, 2016

The population served and the amount of resources recovered and diverted from the waste stream affect the amount of waste finally disposed of in a landfill. Alberta disposes of nearly 4 million tpy, while Ontario, with a larger population, disposes of over 9 million tpy (Statistics Canada, 2016). By calculating a per person rate of disposal, a better comparison can be made between provinces (Figure 1.3). By this measure, Alberta is the highest waste generator on a per person basis. These figures include not just waste from homes, but also waste from industrial, commercial, and institutional (ICI) sources, as well as the debris from construction, renovation, and demolition (CRD) work. Provinces and communities with different diversion policies and programs will have lower disposal rates. As shown in Figure 1.3, Nova Scotia has achieved a rate of less than 400 kilograms (kg) per person annually.

In 2010, residential waste made up about 37% of the total municipal solid waste (MSW) stream in Canada. The remaining 63% was non-residential waste generated from ICI and CRD activities as indicated in Figure 1.4.



**Figure 1.3. Provincial per Person Disposal, 2012 and 2014**  
Based on published data from Statistics Canada, 2017



**Figure 1.4. Residential Portion of Non-hazardous Waste in Canada**  
*Adapted from Giroux Environmental Consulting, 2014*

As a rule of thumb, in Alberta, about 1 tonne of discards (waste, compostables, and recyclables) is generated for every person in a community (example: 10,000 people = approximately 10,000 tonnes of materials). We can quickly estimate waste portions using the 30-30-30 rule: 30% residential, 30% ICI, and 30% CRD materials (AEP, 2016). The remaining 10% may be either ICI or CRD waste, depending on individual community activities. This approach is useful only for early discussions when deciding on a waste management project or facility. Every community is different, and a comprehensive evaluation of waste generation rates and waste quantities should be completed for further planning purposes.

Some of the top producers of ICI waste include:

- Hotels and food service providers
- Health care institutions (hospitals, social services)
- Manufacturing
- Retail stores

Sources of CRD waste include:

- Building construction
- Home and building renovation
- Building demolition and street rehabilitation

### 1.2.3 Municipal Solid Waste Organics

Organic materials found in MSW are typically food waste and leaf and yard waste. Examples of organic wastes that can be diverted from landfills include:

- Table scraps
- Bread and dough products
- Pasta and rice
- Coffee grounds and tea bags
- Eggs and egg shells
- Fruits and vegetables
- Meat and bones
- Nuts and nut shells
- Solid dairy products
- Grass, leaves, and weeds
- Tree prunings and brush

Encouraging home composting and grass-cycling reduces the amount of material that needs to be collected at the curb and disposed.

### 1.2.4 Integrated Solid Waste Management

Integrated solid waste management (ISWM) is a comprehensive system that includes elements of waste reduction and reuse, recycling, composting, energy production, and final disposal. ISWM considers the environmental and public health benefits, social commitments, and economic sustainability of the system. A system that works for one community may not work for another. A well-planned ISWM system considers the community's particular needs, economic capacity, and community and political support. The system's components work together to achieve the goals of minimizing the amount of waste materials remaining for safe processing or disposal.

Some discards include materials that are recyclable, compostable, recoverable, and disposable. With effective programs to make use of discarded materials, less waste is disposed.

The solid waste management hierarchy illustrated in Figure 1.5 defines the preferred order of actions in waste reduction and management.

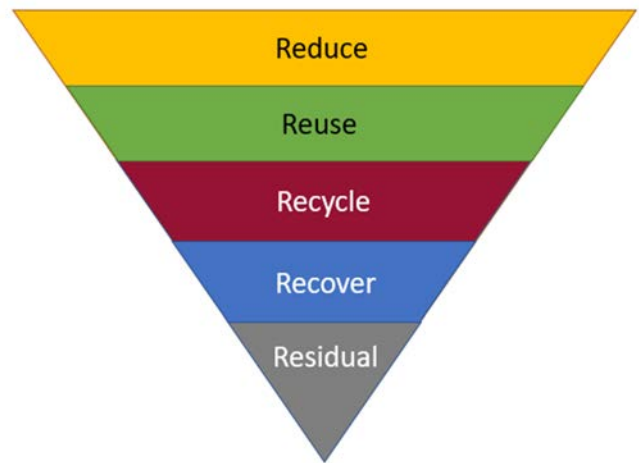
“**Reduce**” refers to waste prevention or source reduction. It focusses on actions that minimize the amount of waste produced, such as reducing packaging, extending product life (repair instead of replace), and reducing manufacturing wastes through process improvements (lean

manufacturing). For a household, backyard composting and grass-cycling are considered reduction strategies. Waste prevention can be extended to retail businesses, institutions, and homeowners to reduce consumption and waste of products. Waste prevention can reduce the requirements for collection, transport, processing, and disposal.

“**Reuse**” refers to giving a product a second life, either for its original purpose (examples include used clothing, furniture, and appliances) or re-purposing the product (examples include reuse of re-fillable containers).

“**Recycling**” involves collecting discards and using them as raw materials in the manufacture of new materials or products. Commonly recycled materials include metals, glass, plastics, and paper products. Recycling programs can be an economic stimulus, as they create employment and markets, and supply raw materials for industry. Photo 1.1 shows a recycling depot where residents can drop off recyclable materials.

Composting is generally considered a form of recycling. It is the conversion of organic materials, such as food waste, leaves, and yard waste, through biological decomposition, into a rich soil amendment. Anaerobic digestion is a form of recycling for the same reason, but it also serves as recovery technology as it captures the gas produced by the decomposition of the organics. By diverting organic materials from landfills to composting facilities, methane (CH<sub>4</sub>) gas that would be generated in the landfill is avoided; thus, there is an overall reduction in GHG emissions. Photo 1.2 shows one method of composting, which is discussed more fully in Section 1.2.10.



**Figure 1.5. Waste Management Hierarchy**  
*Source: JL Technical Services*



**Photo 1.1. Recycling containers**  
*Source: JL Technical Services*



**Photo 1.2. Windrow composting**  
*Source: JL Technical Services*

“**Recovery**” refers to the use of technologies that recover at least some of the energy value of waste that cannot be reused, recycled, or composted. It is often associated with waste-to-energy (WtE) facilities. Large-scale WtE plants are typically incineration systems (Photo 1.3) with heat recovery and electrical power generation. Other forms of recovery are becoming more popular. Examples are gasification and anaerobic digestion, both of which produce energy and, in the case of the former, the possibility of producing industrial chemicals.

“**Residual**” refers to the material that remains as waste once the higher-level processes in the ISWM hierarchy have been applied, and which must be disposed of in a properly designed and managed landfill (Photo 1.4). Current standards for landfills are based on best practices for siting, design, construction, and operation to minimize impacts to land, air, and water. A landfill must be operated in a controlled and professional way to protect the environment. Landfills require long-term care and monitoring to provide this assurance for generations.



**Photo 1.3. High-temperature incineration**  
*Source: JL Technical Services*



**Photo 1.4. Compactor at a landfill**  
*Source: JL Technical Services*



## 1.2.5 Components of an Integrated Solid Waste Management System

There are several core components to a municipal waste management system that must be fully integrated to be economical and efficient.

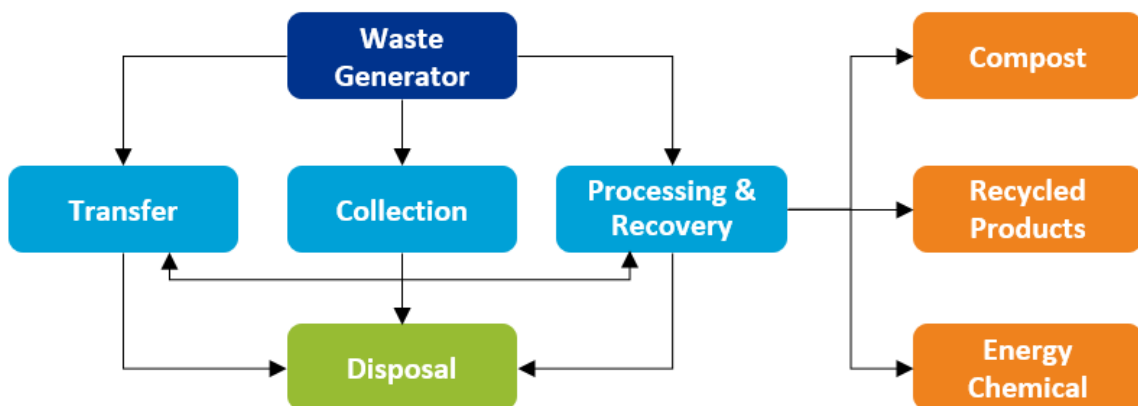
Components for a given community may include:

- Curbside collection
- Transfer and haul
- Community drop-off points for hazardous waste, recyclables, and trash
- Composting operations
- Recycling plant
- WtE or other advanced recovery technologies
- Community reuse or 'take-it-or-leave-it' depots (free stores)
- Other programs and facilities that meet community needs

A municipal waste management system can be influenced by many factors, such as:

- Size of community
- Distance to recycling markets
- Available landfill space
- Economics
- Community concern for the environment

Some municipalities only provide waste collection and disposal. Others have more complex systems that include waste transfer to distant landfills and processing of recyclable materials or organics for composting. Still others may include recovery technologies. Figure 1.6 illustrates the potential pathways of material flow from generator through to final disposal or to recycling or recovery solutions.



**Figure 1.6. How Components in a Municipal System Connect**

Source: JLTechical Services

It is important in program and facility design to be aware that, within each component of the municipal waste system, there are opportunities to include programs to reduce waste disposal.

These can include:

- Source separation by residents and businesses
- Multi-material collection (examples include blue box, green bin, and waste bin collection)
- Curbside collection or central drop-off locations for reusable and recyclable materials
- Separation at transfer stations or community depots for recycling or composting
- Separation at disposal sites for recycling or composting
- Education about consumer choices and options provided by the community's waste management system
- Policies

Existing ISWM systems that achieve low per person waste disposal rates typically incorporate many of these programs.

Programs to manage products listed in regulations can further improve waste diversion. In Alberta, examples of these include beverage containers, used oil and oil containers, used paints, electronics, and tires. Municipalities in Alberta can participate in these programs.

Besides these government-mandated programs, there are other opportunities available through industry-supported programs:

Municipal governments influence how much waste diversion happens in a community through policies such as:

- Green procurement policies
- Banning of specific materials from landfill disposal (some have banned cardboard and yard waste)
- Adoption of a Pay-As-You-Throw (PAYT) cost of service strategy

- [Health Products Stewardship Association](#) – Called ENVIRx in Alberta, this program is managed by the Alberta Pharmacists Association. Residents can return prescription drugs, over-the-counter medications, and natural health products to pharmacies for proper disposal.
- [Recycle My Cell](#) – In Alberta, a partnership between the Government of Alberta and the Canadian Wireless Telecommunications Association has established over 500 locations where cell phones can be returned for recycling.

**Zero Waste** is a goal that aims to have no waste going to landfills. It calls for the use of all of approaches described, along with others that call for broad social and regulatory change. There are communities in Canada that have set long-term zero waste goals. Some communities in Europe are close to achieving their zero waste goals.

### Impact of Diversion on Landfills

ISWM systems put a lot of effort into diverting waste from landfills. Besides the clear benefits of

The [Alberta Recycling and Management Authority](#) (Alberta Recycling) is the non-profit Delegated Administrative Organization (DAO) that administers the tire, electronics, used oil materials, and paint recycling programs in Alberta. Alberta Recycling also coordinates household hazardous waste round-ups, along with AEP.

The [Beverage Container Management Board](#) is the DAO mandated under the Beverage Container Recycling Regulation to regulate and enhance the extensive beverage container recycling system in Alberta.

## 1.2.6 Solid and Organic Waste Collection

Residential organic wastes are often collected at drop-off depots or through curbside collection programs. Alternatively, they can be hauled directly to processing facilities by generators. Since all the work is delegated to waste generators in this second approach, it is the most cost-effective collection method available to a municipality.

While there are definite cost advantages for municipalities to implement a direct-haul program, there are also disadvantages. Among these is the increased infrastructure required at the

processing facility to manage the higher expected traffic levels. Because there is a variety of collection vehicle types, there might also be a need to change the design of the facility's receiving area to accommodate them. At facilities where direct-haul loads are accepted from residential customers, it is recommended that they be provided with an unloading area separate from the area used by commercial traffic.

Drop-off depots are also cost-effective, as much of the collection work is delegated to the waste generators. However, due to the lower level of convenience for waste generators, drop-off collection programs often collect less than 50% of the available material; diversion rates in the range of 10 - 25% are more common (CH2M, 2013).

Due to the potential for odours and attraction of birds and animals, drop-off depots are more suited for collection of leaf and yard waste (L&YW), brush, and tree branches and limbs. It is recommended that materials be emptied at least weekly, and more frequently during periods of hot or wet weather. Good roads and working surfaces should be provided so that the site is accessible during wet weather.

Curbside collection of organic wastes from residents increases convenience, which can significantly increase participation and diversion rates. For example, in established curbside collection programs with supporting education programs, participation rates of 80 to 90% is common.

Residential collection programs offered by municipalities for organic wastes are generally limited to single-family homes and row houses. Most municipalities do not provide collection services to apartments and condominiums. Instead, these other types of dwellings are normally serviced like commercial businesses.

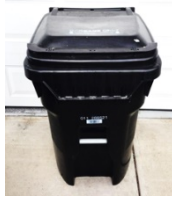
Historically, curbside collection was done manually, with collection crews physically loading bags and materials into collection truck hoppers. Over the past 10 to 15 years, there has been an increasing trend to use collection trucks with semi-automated and fully automated unloading systems. This approach offers many benefits over manual collection methods used for residential waste collection, including fewer injuries and reduced absenteeism amongst collections staff, and potentially increased efficiency (CH2M, 2013).

The type of curbside collection equipment used (that is, manual, semi-automated, or fully automated) dictates the type of collection containers that can be used. Manual collection allows for pickup of bagged or bundled material; traditional garbage cans (Photo 1.5); or small, standardized carts. However, the weight of the bags, bundles, and containers must be limited to prevent back injuries among collection workers. Semi-automated and automated systems are typically used with larger, standardized carts (Photo 1.6) that are provided by the municipality. Popular cart sizes are 120, 240, and 360 litres (L).



**Photo 1.5. Bag and garbage can used for manual collection**

*Source: CH2M*



**Photo 1.6. Standard cart for automated collection**

*Source: CH2M*



**Photo 1.7. Kitchen scraps collection pail**

*Source: CH2M*




Many municipalities that collect food waste from residents provide small, 4-L collection pails (Photo 1.7) to each household as part of their programs. The pails are intended to serve as the central receptacle for food and other kitchen organic wastes within the home. They are provided to increase convenience and cleanliness, as well as program participation.

Different types of residential materials are often collected and delivered to the waste management facilities separately. Three variations are described in Table 1.1.

### Pay-As-You-Throw (PAYT)

PAYT can take various forms. The basic idea is a financial incentive to reduce the amount of waste one produces for disposal. Communities who collect waste set out in garbage bags might require that each bag have a pre-paid tag affixed to it (tag-a-bag). More bags = higher cost. Communities with cart-based collection may offer small, medium, and large carts – with the monthly fee for service increasing with the size chosen.

**Table 1.1. Examples of Common Multi-Stream Collection Systems**

Single Stream	Two Stream	Three Stream
 <p>All materials are set out in the same container(s). They are collected in one vehicle and disposed at a landfill, or delivered to a mixed waste processing facility for recovery of recyclable materials.</p>	 <p>Recyclable materials and waste are set out in different containers. Recyclables are collected in one vehicle, and waste is collected in a second vehicle. Some two-stream collection systems may use compartmentalized collection vehicles for both.</p>	 <p>Waste materials, recyclable materials, and organics for composting are set out in separate containers and collected separately.</p>

In the two- and three-stream examples, the different materials will be taken to different facilities. In the case of three-stream collection, organics would be tipped at the composting site; recyclables at the Materials Recovery Facility (MRF); and trash at the landfill, transfer station, or, in some cases, at a WtE facility or other advanced recovery process.

There are many variations of residential organic waste collection systems. Of most interest to composting facility operators is the way the waste is delivered to their facility, and the nature of the organic waste in the load.

ICI wastes are typically collected in larger bins using front-load trucks. Mixed waste in these bins is delivered to the landfill, transfer station, or processing plant. In some communities, the municipality or the commercial hauler may offer separate collection of recyclable materials or organic waste, which are delivered to a processing plant.

## 1.2.7 Waste Transfer

Transfer stations are used where landfills or processing facilities are far outside of an economical direct-haul trucking distance. Waste is unloaded from collection vehicles at the transfer station, and reloaded into larger-capacity vehicles that allow for more economical transport to the landfill.

Transfer stations are also often used to provide a convenient facility for residents and small businesses to directly dispose of their wastes. These transfer stations often include designated bins or areas to receive materials suitable for recycling and for household hazardous waste collection.



**Photo 1.8. Rural transfer station**  
Source: JL Technical Services

In some cases, small transfer stations that use roll-off bins are built at landfill sites so that the public can drop off their wastes without having to go to the tipping face (the place where waste is ultimately dumped and compacted). In these situations, the landfill operator will use roll-off trucks to transfer the waste a short distance to the tipping face. Photo 1.8 shows a typical simple open-air transfer station.

The [Alberta Transfer Station Technical Guidance Manual](#) includes an in-depth description of the various types of waste storage, collection, and transfer systems used in Alberta.

## 1.2.8 Reuse Initiatives

Municipalities and businesses can encourage reuse of materials. Reuse businesses include Goodwill and Salvation Army stores, clothing consignment stores, and stores that sell used sports equipment. Local organizations, such as the Foothills Salvage and Recycling Society, have shown that by accepting donated goods for sale or exchange, they can divert materials from landfill disposal. Another example is the City of Edmonton's Reuse Centre.



**Photo 1.9. "Take It or Leave It" Centre**  
Source: Tom Moore, Slave Lake

While scavenging from an active landfill face is unacceptable, landfill operators can develop opportunities for controlled salvaging with facilities where customers can drop off usable items they no longer need, and can look over items left by others and take what they can use. Photo 1.9 is an example of a “Take It or Leave It” facility that encourages reuse.

### 1.2.9 Food Salvage, Food Waste Reduction and Reuse

Redirection of food and food waste is an option that should be considered before the material is collected and composted or otherwise treated. There are generally two options that can be pursued:

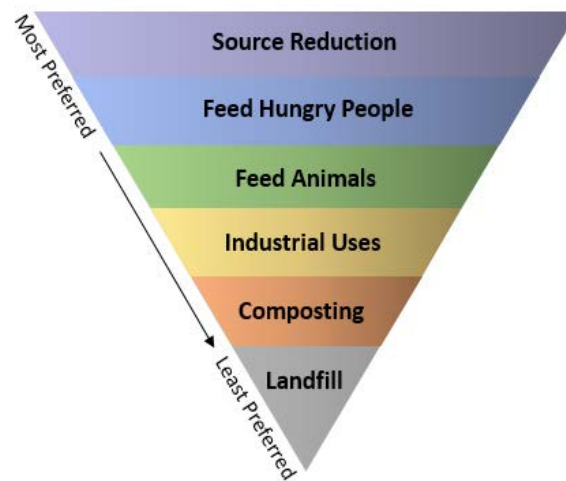
Donating non-perishable and unspoiled food to agencies such as food banks, soup kitchens, and shelters that can feed people in need.

Diverting food and food waste for use directly as animal feed, or as an ingredient in the manufacture of animal feed. This is a common place, but is not often talked about in the municipal organic waste management industry.

Both options are more suited to food and food waste from retail or manufacturing sources (that is, grocery stores, conference centers and banquet halls, and food packaging plants) than from households, restaurants, and other post-consumer sources. For example, food processors, grocery distributors, and grocery stores are among the largest group of donators to the Calgary Food Bank.

Several provinces have passed “Good Samaritan” laws that protect food donors from liability. Alberta has the Charitable Donation of Food Act and the Alberta Health Services Guidelines for the Distribution of Donated Food, which can help promote food donation. However, this information must be distributed to potential food waste generators and donors.

Diverting food and food waste for use directly as animal feed, or as an ingredient in the manufacture of animal feed, has been done in North America, Europe and other parts of the world, particularly in the hog industry, since the late 19th and early 20th centuries. However, due to concerns over the potential transmission of diseases and increasing regulations worldwide, as



**Figure 1.6. Food Recovery Hierarchy**  
*Adapted from EPA Website*



well as consumer opinion regarding this practice, it has become less common and more regulated.

In Canada, food waste and food processing by-products are referred to as recycled food products (RFPs). RFPs may appear in poultry feed, commercially produced dog and cat food, pig rations, and cattle rations. Food reuse as feed is regulated by the Canadian Food Inspection Agency (CFIA) under the federal *Feeds Act*. CFIA has a number of requirements that must be met so RFPs can be used for animal feed (or, more specifically, livestock feed). These regulations ensure that RFPs have a nutritional value and are not simply degraded or contaminated foodstuffs.

CFIA also administers feed-related portions of the federal Health of Animals Regulations. These regulations primarily deal with the possible transfer of infectious diseases via feedstuffs, and prohibit the feeding of specific proteins from mammals to ruminants (cattle, sheep, antelopes, deer, giraffes, and their relatives). The regulation underwent a major amendment in 1997 in response to the Bovine Spongiform Encephalopathy (BSE), commonly known as “mad cow disease”, situation in Europe, and a second major amendment in 2006 in response to the appearance of BSE in Canadian cattle herds in 2003 (Library of Parliament, 2005).

In addition to the spread of diseases, there are additional risks involved with the redirection of food waste for use as animal feed. These additional risks were summarized by the New Zealand Ministry for Primary Industries (New Zealand Government, 2017) with respect to hogs, but they equally apply to other livestock:

- Spoiled food waste may contain organisms, such as salmonella, that could infect livestock if the food waste is stored for too long or is not properly processed
- Cereal or grain based food waste may contain toxins that could impact the health of animals
- Food waste may contain foreign objects (including glass and wire) that could injure animals

If these risks are appropriately managed through regulations and application of best practices, diverting RFPs to animal feed offers a practical and sustainable method of disposal for food waste generators.

### **1.2.10 Composting**

Composting is a managed biological process where microorganisms decompose organic materials under aerobic conditions, converting it into a biologically stable, humus-like product. During the active composting stage of the process, temperatures reach 55 to 65 degrees Celsius (°C) and are sustained for several days or weeks. Sustaining the temperature of materials in this

range is necessary to reduce pathogens and weeds seeds to safe levels in the final compost product.

Typically, feedstocks are inspected and pre-processed before the active composting stage. This may involve removing feedstocks from containers or bags, removing non-compostable materials, and preparing the materials to provide the best conditions for composting. This feedstock preparation may involve grinding to a certain particle size, adding coarse amendments to increase free air space in the material, blending together feedstocks to optimize nutrient ratios or pH, and adding water to increase moisture content of the feedstock.

Once feedstocks have progressed through the active composting stage, they will have significantly degraded, but are not yet stable enough to qualify as finished compost. Further “curing” of the material is needed so that the material is fully degraded and mature enough to be used without causing odours or impacting plant growth

Curing can take anywhere from a few weeks to several months to complete, and is normally done outdoors in piles or windrows.

Once the compost is matured, it is normally screened or otherwise refined prior to being sold to end-users. This step removes materials, such as larger compost particles, stones, and any remaining physical contaminants that will detract from the quality of the product. Screening may also be necessary to meet particle size criteria for certain compost uses (for example, top dressing of sports field or erosion control applications).



**Photo 1.9. Windrow composting in Jasper, Alberta**

*Source: Scott Gamble*

## **1.2.11 Other Organic Waste Management Methods**

### **1.2.11.1 Maceration and Sanitary Sewer Disposal**

Onsite treatment of food scraps with a food waste disposer (FWD) and then discharging them to the sanitary sewer is a commonly used technique for managing food scraps in both residential and commercial settings. The relative cost of diverting food waste using FWDs is low compared to some other management methods, since this option takes advantage of pre-existing investments in sanitary sewer systems. In municipalities with advanced wastewater treatment plants (WWTPs) that include anaerobic digesters, the addition of food waste to the sanitary sewerage can boost biogas generation and energy recovery.



**Photo 1.10. Producing colored mulch from ground wood waste**

*Source: Scott Gamble*

### **1.2.11.2 Mulch Production**

Mulch is a protective layer applied over soils to reduce the amount of soil moisture lost to evaporation, balance changes in soil temperature during the day and night, and control weed growth. It is usually applied early in the growing season.

Mulch produced from shredded wood and bark has become popular for landscaping applications in recent years, due to its durability and consistency, as well as aesthetic value. Often, the mulch is “colored” with vegetable oil-based pigments to make it a consistent shade of black, brown, or red.

Wood-based mulches are often produced from the residuals from the forestry industry, pulp mills, and wood-fabrication businesses. In some areas, the demand for colored mulches has expanded programs that collect and grind clean pallets and dimensional lumber, logs, and stumps.

### **1.2.11.3 Biomass Production**

Biomass is the broad term applied to renewable energy sources produced from biological material that are burned to generate heat or electricity. Biomass can also be used as a feedstock to produce other forms of energy, such as biogas and biodiesel.

Common biomass sources include wood waste from land clearing and forestry operations, wood from urban sources (for example, construction and landscaping), and agricultural crop residuals. In the southeastern United States, storm debris from hurricanes is a significant source of biomass. There are also some instances where biomass crops, such as fast-growing willows, are purpose-grown and harvested to provide renewable biomass sources for energy production.

In areas where there are established facilities that consume biomass, significant volumes of wood waste can be diverted to this use. Producing biomass from wood debris typically involves shredding it to the appropriate size, and removing contaminants.

#### 1.2.11.4 Anaerobic Digestion

The anaerobic digestion (AD) process can be used to break down organic wastes. It is a controlled and managed biological process that uses microorganisms to break down organic material without oxygen. As well as stabilizing organic wastes and reducing their volume, AD produces biogas, which is composed primarily of methane (approximately 60 %) and carbon dioxide (approximately 40%). Biogas can be captured and refined into boiler fuel, fuel for electrical generators, or fuel for vehicles.

There are many AD systems available for processing organic components from the solid waste stream. Typically, these systems are proprietary and are provided as a technology package by vendors.

AD systems are often categorized based on the solids content (or also the water content) of the feedstocks as they are placed into the system. Because solid waste digester technology is continuously evolving, there is inconsistency in the terms used by the industry to describe various types of AD systems. This manual adopts the terms “high solids” and “wet” as the primary categories.



**Photo 1.11. Small scale AD system**

*Source: CH2M*

Feedstocks fed to high-solids systems typically have less than an 80% moisture content (more than 20% solids). Feedstocks are typically handled as a solid material with front-end loaders (high-solids-stackable systems), or processed into a slurry (high-solids-slurry systems) and handled using specialized pumping systems. In a wet AD system, feedstocks are dissolved or suspended in a liquid form and are handled as a liquid. Feedstocks in wet systems have a moisture content higher than 80% (less than 20% solids).

AD technologies are also classified according to whether the steps of the AD process occur in a single vessel or in two (or more) sequential vessels.

The material left over at the end of the AD process is called digestate. The digestate can be a solid, semi-solid, or liquid, depending on the type of AD system used. With proper authorizations from AEP, liquid digestate can be applied to agricultural land. Solid and semi-solid digestate is usually composted. Digestate management is a key consideration in AD system selection and overall facility costs.

### 1.2.11.5 Co-digestion

Anaerobic digestion is a well-established process for stabilization of liquid manures, as well as the solids removed from sanitary effluents at WWTPs. Co-digestion is generally a new development in the organic waste management field. It refers to the introduction of food waste from the solid waste stream or fats, oils, and greases (FOG) into an on-farm manure digester or the digestion system at a WWTP.

Co-digestion takes advantage of existing digestion and biogas handling infrastructure, and potentially allows for a reduction in overall capital investments. This is particularly true if the digester has extra capacity, as is often the case in the early years of WWTP operation before wastewater loads approach design capacities.

Co-digestion offers potential advantages, including improved nutrient balance, increased gas production, and dilution of waste streams (thereby reducing the potential impacts of toxic compounds, such as free ammonia and hydrogen sulphide).

On the other hand, co-digestion likely requires the addition of new waste receiving, pre-processing and feeding facilities. Additional material volumes being sent to dewatering systems, biogas systems, and recycle streams may also require money to be spent on upgrades to existing infrastructure. However, increased biogas production and revenues from tipping fees can offset a portion of the investment needed for modifications and upgrades to the existing plant.

### 1.2.11.6 Bioreactor Landfills

The term “bioreactor landfill” broadly refers to a solid waste landfill that is intentionally operated to enhance the biodegradation (breakdown) of the organic wastes it contains.

This contrasts with a traditional “dry tomb” landfill where the breakdown rate is very slow. The optimized waste breakdown that occurs in a bioreactor landfill results in more rapid generation of landfill gas (LFG) from the waste compared to traditional dry tomb landfills, and to landfills that only recirculate leachate for leachate management purposes. LFG is generated at a high rate in the bioreactors, and can be extracted and used to generate power.

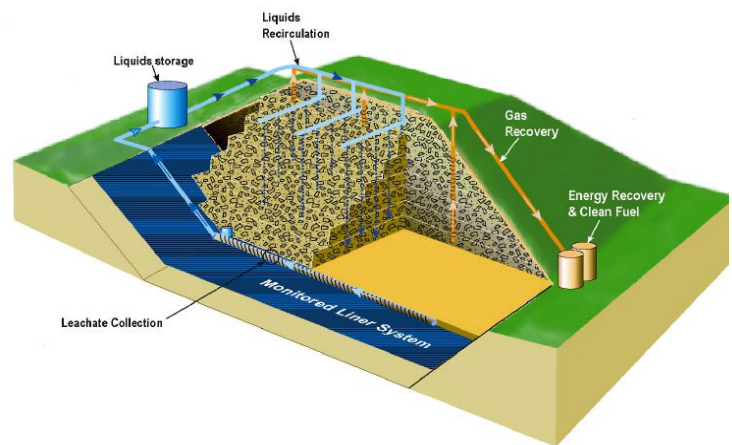


Figure 1.8. Cut-away view of a bioreactor landfill

Bioreactor landfills are not exclusively anaerobic (without oxygen). It is possible to degrade the material aerobically by injecting air into the waste contained in the bioreactor through vertical or horizontal wells.

One of the key benefits of bioreactor landfills is the speed at which waste breakdown occurs. As a result, the apparent settlement of the landfill surface occurs over a period of years rather than decades. Other potential advantages of bioreactors identified by EPA (2017) include:

- Lower waste toxicity and mobility due to both aerobic and anaerobic conditions
- Reduced leachate disposal costs
- Reduced post-closure care

A variation of the bioreactor described is the concept of a “reclaimable” bioreactor landfill (RBL). This is a unique application where the bioreactor landfill is designed and operated so that individual cells can be excavated once the contents have been sufficiently degraded or maximum LFG has been harvested. If the RBL has been filled with mixed solid waste, the stabilized material that is excavated would presumably be used as daily, intermediate, or final cover elsewhere within the landfill. Alternatively, an RBL could be filled exclusively with organic wastes, and the stabilized material removed could be further processed via composting into a soil amendment product.

#### **1.2.11.7 Mechanical-Biological Treatment**

Mechanical-biological treatment (MBT) is a loosely defined term, but generally refers to series of processes (first mechanical and then biological) used to handle MSW. The mechanical treatment involves use of waste processing equipment to pre-process or prepare the MSW for a later biological step. The biological treatment may simply stabilize organic materials in the MSW prior to disposal, or it may capture energy in the form of biogas or produce a soil amendment product. Typical biological treatment involves anaerobic digestion, composting, or both. Photo 1.11 shows an MBT facility in Edmonton.

A common feature in MBT facilities is the use of separation techniques as part of the upfront processing to recover recyclable materials; and remove bulky items, hazardous wastes, and other non-organic components from the MSW. Usually, some form of manual inspection or sorting is done prior to mechanical separation. This can be as simple as inspecting and removing undesirable materials as the MSW is unloaded from collection vehicles in a tipping area. Manual sorting conveyors, similar to those used in the recycling industry, have also been used.



**Photo 1.12. The Integrated Processing and Transfer Facility and Co-composting Facility in Edmonton is an example of a large-scale MBT system**

*Source: City of Edmonton*

Mechanical processing methods vary, and can involve equipment that separates MSW components based on size (for example, trommel and disc screens) or density (for example, air classifiers). Equipment that removes ferrous material using magnets, or non-ferrous material using eddy-current systems, can also be used. Bag opening and shredding equipment is sometimes used prior to these processing steps.

In addition to the processing equipment described, it is also possible to use wet processes, such as flotation and hydro-pulping, to separate MSW components and remove contaminants. However, these wet processing methods are generally only used when a wet anaerobic digester is used for the later biological treatment step.

MBT systems can also be used to produce refuse-derived fuel for use in WtE systems. This application is popular in Europe, but is much less common in North America.

#### **1.2.11.8 Thermal Hydrolysis (Lystek)**

Thermal hydrolysis is a process patented by Lystek International Inc. that uses a combination of heat, alkali, and high-shear mixing to produce a high-solid, pathogen-free liquid by-product. The by-product has considerable concentrations of nitrogen, phosphorous, and potassium, which make it valuable as a fertilizer.

While Lystek's corporate information prominently mentions organic wastes, the technology has only been commercially proven with processing of municipal biosolids so is not applicable for the management of food waste.

The liquid by-product produced from biosolids meets the EPA's Class A biosolids standard. A Lystek facility in Ontario is capable of producing by-product that can be registered with the CFIA under the Fertilizer Act.

#### **1.2.11.9 Alkaline Stabilization**

Alkaline stabilization is a common method for treating municipal biosolids. It involves the addition of alkaline materials to dewatered biosolids to raise the pH level, creating conditions unsuitable for the growth of microorganisms. Other benefits of this process are that trace elements in the biosolids are immobilized, and the end-product that is much less odorous than untreated biosolids. The chemicals traditionally used for alkaline stabilization are quicklime or hydrated lime.

In general, alkaline stabilization is a non-proprietary process. However, numerous patented processes are available. For example, Advanced Alkaline Stabilization with Subsequent Accelerated Drying is a method patented by Walker Industries and called N-Viro for treating municipal biosolids. It involves the addition of alkaline materials to dewatered biosolids to raise the pH level, creating conditions unsuitable for the growth of microorganisms, and subsequent heating and drying.

N-Viro has been used to treat food waste from the solid waste stream on a trial basis at a facility in Banff, Alberta. Results from this pilot have not been made public at the time of writing.

### **1.2.12 Waste-to-Energy and Conversion Technologies**

WtE is a term used to describe a variety of technologies that treat waste to produce energy in the form of heat or power. The most common technology today is incineration. In a modern incineration system, waste is burned at high temperatures, and air is controlled to optimize the process. Sophisticated air scrubbing equipment is used to clean the exhaust air before it is released to meet regulated air quality standards. The combustion heat is commonly captured and used for heating or generating electrical power. Photo 1.12 shows a WtE facility.



Emerging technologies, often referred to as “conversion technologies”, include gasification and pyrolysis. Gasification technology uses a thermo-chemical process to convert prepared waste to a synthetic gas (or ‘syngas’) used as a fuel for energy production, or to industrial chemicals. Pyrolysis is a process that involves the thermal decomposition of feedstock at high temperatures (400 to 815°C) in the absence of oxygen. The resulting end-product is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide). The oils and fuel gases can be used directly as boiler fuel or refined for higher quality uses, such as engine fuels, chemicals, adhesives, and other products. The solid residue contains most of the inorganic portion of the feedstock, as well as large amounts of solid carbon or char.



**Photo 1.13. Waste-to-Energy facility**  
*Source: JLT Technical Services*

## 1.3 Past, Present, and Future of Organic Waste Management in Alberta

Historically, waste was a local issue, and there was little to no cooperation between municipalities, and no provincial involvement. Today, we see increasing cooperation and coordination between municipalities and regions to accomplish waste reduction goals.

In 1996, regulation of waste management in Alberta was transferred from the Public Health Act to the Environmental Protection and Enhancement Act (EPEA), with stricter requirements. Waste facilities today must be carefully located and designed with engineering features to minimize impacts on land, water, and air. Landfills and composting facilities must be supervised by trained and certified employees, and monitored to demonstrate environmental protection. Current standards and how they are satisfied are described in later chapters of this manual.

The amount of attention given to organic waste management in Alberta has changed over the years. In the late 1980s, organic waste diversion was uncommon and limited to a few small L&YW composting site. In the 1990s, L&YW composting became more common, and some facilities began to experiment with food waste and municipal biosolids.

Since the turn of the century, food waste and biosolids composting have become much more common, and there has been an upswing in the use of forced aeration systems at small and medium sized composting sites.

Those in the industry should expect more changes for organics management in the future, such as:

- Continuous strengthening of regulations and standards
- Technology advances
- Increased waste diversion through reduce, reuse, recycle, and recovery initiatives
- Continuation of the trend to larger regional facilities and multi-use waste management centres

Landfill sites are increasingly being expanded into multipurpose waste management centers that incorporate recycling and composting operations, hazardous waste depots, and reuse stores.

# Chapter 2 – Composting Process and Principles

## 2.1 Learning Objectives

There are many organic wastes that can be diverted and composted. It is important for compost operators to understand the characteristics of the feedstocks they accept so they can implement proper receiving, processing, and composting practices. With some feedstocks, more careful processing is needed to manage pathogens or avoid nuisance issues during composting.

It is also important that compost operators have a basic understanding of the biological principles of composting, as well as how they can control the compost pile to create the best conditions for microorganisms, and to minimize odours and nuisances.

## 2.2 Common Compost Feedstocks

The section describes the characteristics of some of the more common feedstocks accepted at composting facilities. There are many other organic materials that may be appropriate for composting but are not discussed. It is recommended that before accepting a new feedstock, facility operators determine whether or not the material will be beneficial. Specifically, the following issues should be considered:

- Biodegradability of the feedstock
- Potential of the feedstock to contain physical contaminants or pathogens
- Potential for the feedstock to contain hazardous chemicals
- Pre-processing requirements of the feedstock (for example, grinding, screening, mixing)

### 2.2.1 Leaf and Yard Waste

Leaf and yard waste (L&YW) refers to a wide range of materials, which includes vegetative matter resulting from gardening, horticulture, agriculture, landscaping or land clearing operations including:



**Photo 2.1. Leaf and yard waste**  
*Source: CH2M*

- Grass clippings
- Leaves
- Flowers
- Weeds
- Pine needles and cones
- Small prunings from bushes and trees

L&YW produced by residents, businesses, and institutions are the most common feedstock at composting facilities. A survey of existing composting facilities by the Compost Council of Canada in 2007 found that 66% of facilities in Canada composted leaves or L&YW exclusively.

L&YW collected through curbside programs in Alberta is generally small enough that it does not require pre-processing (that is, grinding) before composting. L&YW collected at drop-off depots is more likely to contain larger materials (for example, limbs, trunks) that require grinding. Often, brush and other larger materials are separated at drop-off depots so that all of the L&YW received does not need to be ground.

L&YW is usually relatively free of contaminants. As a result, many regulatory agencies in North America have relaxed the permitting requirements for L&YW composting facilities and the product distribution limitations on compost made from L&YW. Despite this reputation, there is still the potential for contamination. Some of the common contaminants found in L&YW include plastic bags, pet wastes, rocks, and fertilizer containers. Operators should always be vigilant and inspect feedstocks for contaminants, particularly items that might damage equipment or risk health and safety.

L&YW generation rates vary over the year more than most other components of the municipal solid waste (MSW) stream. In Alberta, there is a very small amount of L&YW generated from November through March. The exception is Christmas Trees collected in December and January, which some municipalities consider to be part of the L&YW stream.

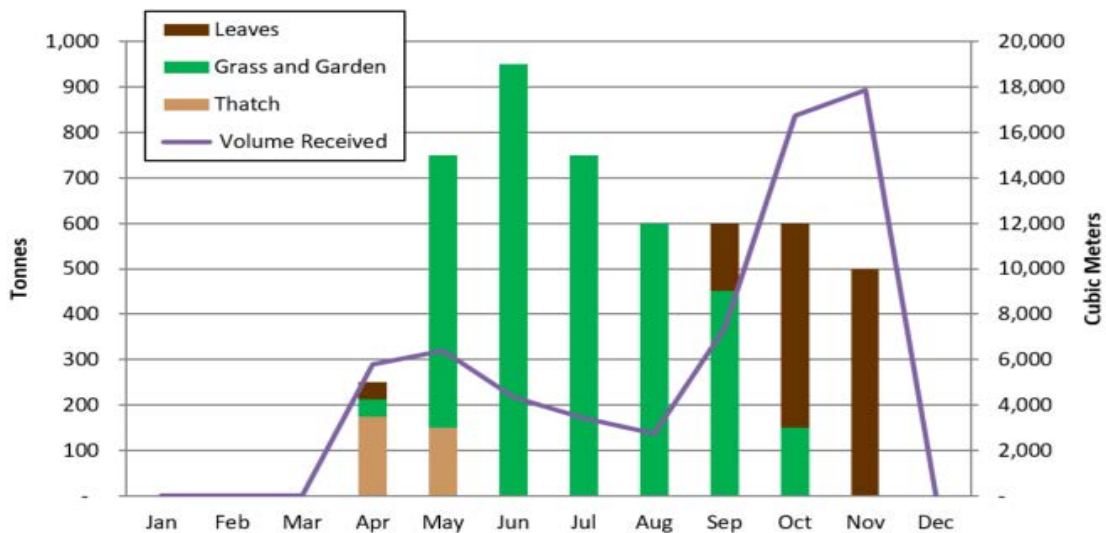
The characteristics of this feedstock also change over the year. In Alberta, L&YW quantities begin to increase in the spring (usually during mid to late April), and the material consists mainly of leaves left over from the previous season and dead grass (thatch) raked from lawns.

Green grass clippings appear by the end of May, and continue to be a major component of the L&YW stream into September. In late-September and October (and sometimes into November), the L&YW stream is mostly leaves, with lesser amounts of garden debris and brush trimmings. Typically, the first snowfall signals the end of the L&YW collection season.



**Photo 2.2. Stumps, logs, concrete and bricks can damage equipment and cause injuries**  
 Source: CH2M

A typical month-by-month generation curve for L&YW in Alberta is shown on Figure 2.1. This figure also shows how the composition of the L&YW varies during over the year.



**Figure 2.1. Typical L&YW Generation Curve**

Understanding these seasonal variations in L&YW generation rates and characteristics is important for composting facilities. Composting pads and systems must be able to handle all feedstocks received during peak periods within a reasonable time after being received at the facility (for example, within 1 to 2 days); a facility with a capacity design based on the average weekly delivery rates may be very undersized.

Pure green grass has a very low free air space, but a high moisture content and C:N ratio. If it is not mixed with enough amendment, offensive odours can be generated during composting usually used.

Since composting systems are often designed based on the volume of material to be processed rather than its weight, changes in the bulk density of a feedstock over the year must also be understood. With L&YW in particular, the peak period for volume may not equal the peak period for weight, as shown on Figure 2.1.

Operators must recognize and understand the impacts of seasonal variations in the quantities and characteristics of L&YW and other feedstocks so they can prepare for changes rather than being surprised by them. At certain times of the year, extra staff may need to be brought in to help, the facility's receiving hours may need to be extended, extra watering may be required, or composting recipes may need to be altered.

Seasonality of L&YW quantities can also affect finished product handling and sales activities. For example, at a facility that produces finished compost in 8 months, the material received during May and June will be ready in January and February of the following year. Since there are generally no sales at this time of the year, a product storage area will be required to store product before it is sold, and there might be extra material handling costs.

Another example of operational impacts that seasonal variations could have would be at a facility that takes 12 months to produce finished compost. In this case, the material received during the peak period in May and June will not be ready for the following year's peak sales period, which, in Alberta, generally occurs in April and May.

In addition to within-year variations, L&YW quantities can also vary from year to year within a given area. These changes can be from weather changes that directly affect the growth rate of grass and trees. Things to consider include changes in temperatures, precipitation (rain or snow fall), and hours of sunlight. Weather changes are somewhat balanced in the city by irrigation and fertilization practices. For example, the effects of a dry summer season on residential lawns can be offset by watering on a regular basis.

The age of residential and commercial developments, and the resulting maturity of trees used in landscaping, can lead to differences in L&YW quantities within a municipality. For example, the amount of leaves generated by 50 or 75-year-old trees in older neighbourhoods is more than the quantities in newer subdivisions where trees are younger and smaller.

Snowfall can also impact L&YW quantities, since snowfall contributes to soil moisture, which affects growing conditions during the following season. Snowfall can also affect quantities in a less obvious way. For example, an early snowfall can disrupt leaf collection activities, so leaves are not collected until the following spring. This will have the effect of reducing annual quantities in one year, and increasing it in the next. The delay can also increase seasonal peaks and affect a composting facility's processing capabilities.

Snow storms and other major storm events can also increase L&YW quantities. When snow storms happen late in the spring or early in the fall while tree still have their leaves, more tree limbs will break from the weight of the snow.

Tree diseases (such as Dutch elm disease), insect infestations, and the need for pruning and other control measures, can also affect the amount of L&YW generated. L&YW debris resulting from control of diseases and infestations is sometimes managed outside of diversion programs for other L&YW due to concerns over the spread of diseases. Some municipalities specifically ban the acceptance of elm wood in a composting operation.



**Photo 2.3. Typical contaminants in L&YW materials**

*Source: CH2M*

The concept of “peaking factors” is commonly used to express the change in the amount of a waste generated during a certain time frame compared to the period's average amount over the year. Typically, weekly or monthly peaking factors equal the average. In the composting industry, weekly or monthly peaking factors are usually used.

## 2.2.2 Food Waste

Food waste is a large component of the MSW stream. These organic wastes are generated in large quantities by households, grocery stores and markets, restaurants and cafeterias, and hospitals and long-term care facilities. It also includes spoiled, off-grade, or unsold produce and food from warehouses, grocery stores, and restaurants.

This feedstock generally has a high moisture content, which can lead to leachate production during composting. Anaerobic conditions and offensive odours can rapidly develop during collection and handling of this feedstock.

The following are examples of specific food wastes that are typically included in diversion programs:

- Bread and baked goods
- Coffee grounds and filters
- Tea bags and loose tea
- Milk and dairy products
- Eggs and egg shells
- Fruits and vegetables
- Meat, chicken, and bones
- Fish and shell fish
- Pasta and rice
- Table scraps and plate scrapings



**Photo 2.5. Food waste from residential generators**

*Source: CH2M*



**Photo 2.4. Food waste from commercial generators**

*Source: CH2M*

Food-soiled paper products are often included within food waste diversion programs. Food-soiled paper products (for example, paper towels, napkins, pizza boxes, soiled or waxed cardboard, soiled newspaper, and tissues) cannot be recycled. However, these materials do not normally have any harmful or toxic characteristics and are readily degradable. Including food-soiled paper in collection programs is also beneficial because it helps to absorb free-liquids during collection.



Many municipal collection programs advocate lining kitchen bins and curbside carts with newspaper instead of compostable plastic bags.

Food waste can be categorized as either “pre-consumer” (that is, coming from food processors, warehouses, and supermarkets), or “post-consumer” (that is, originating in residences and commercial kitchens in restaurants or hospitals). Post-consumer food waste typically has more physical contaminants.

The food waste stream is significantly less variable than the L&YW stream: Quantities during peak periods are generally only 10 to 20% higher than average.

### Compostable Liner Bags

Many collection programs allow participants to use compostable liner bags in their kitchen bins and collection carts. The intention of these liner bags is that they increase cleanliness and convenience, and thus boost participation in the program.

Compostable liner bags can cause problems for operators at composting facilities. The bags can wrap around rotating parts of shredders, mixers and windrow turners. The bags also tend not to break down completely during the short active composting stage that is typical at mid and large-size facilities. The residual that is left over can blow around during curing and screening activities, and contribute to litter.

## 2.2.3 Biosolids

Biosolids, less commonly called sewage sludge, are the non-degradable and partially degraded solids that are separated from wastewater at municipal treatment facilities. The characteristics of biosolids vary with the characteristics of the wastewater, the type of wastewater treatment system, and the treatment system's efficiency. Biosolids are often further classified into three groups: undigested biosolids, digested biosolids, and lagoon biosolids.

Undigested or "raw" biosolids are made up of unprocessed sludges from primary and secondary wastewater treatment systems. Primary sludges are usually grey and slimy, and



**Photo 2.6. Compostable plastic liner bag after three weeks of active composting**  
*Source: CH2M*

have an offensive odour and very high water content. They contain inorganic solids and courser-grained organic colloids (particles less than 0.001 millimetre [mm] in size). Secondary sludges are composed primarily of biological solids. Biosolids from primary and secondary processes are typically combined at the treatment plant to simplify subsequent handling and processing.

Undigested biosolids pose a biological hazard due to the high levels of a variety of pathogens, and are often stabilized at the wastewater plant through anaerobic digestion or other pathogen-reducing processes. Digestion also reduces the volume of biosolids that require handling. The resulting digested biosolids have fewer pathogens (but are still biologically hazardous) and are easier to handle. Since digested biosolids are a source of plant nutrients, organic matter, and inorganic elements, they are often land-applied to agricultural soils.

Solids that accumulate in wastewater lagoons over a period of many years must eventually be removed so as not to interfere with lagoon operation. Upon removal, these biosolids have characteristics similar to undigested biosolids from a wastewater treatment plant (for example, high pathogen content, low solids content).

Because of the very high moisture content (that is, usually more than 95%), biosolids need to be dewatered before they can be composted. The most common dewatering methods are belt presses and centrifuges aided by chemical coagulants (polymers) added to the biosolids. Belt presses reduce moisture content down to the 85% range. Centrifuges typically reduce moisture content to between 75% and 80%.

#### **2.2.4 Septage**

Septage is the combination of liquid and solid sewage material that is removed from septic tanks, portable toilets, and holding tanks. Depending on the source, it may contain grease, grit, hair, and debris. Septage usually has an offensive odour and can foam when agitated.

Septage is most commonly transported to a nearby wastewater treatment facility for disposal. It is uncommon to accept septage at composting facilities. If composted, special care must be taken to manage the receiving and processing of the material to prevent offensive odours and leachate. Like biosolids, the temperature of the compost process must also be closely managed so that pathogens in the septage are reduced to safe levels. Depending on the amount of debris, extra screening of the finished product may also be required.

## 2.2.5 Animal Manures

Manures are primarily generated by agricultural operations, including farms, ranches, and feedlots. Manures are also generated in smaller quantities by zoos, wildlife parks, fair and rodeo grounds, and veterinary clinics.

In addition to quantity, it is important to consider the moisture content of the material before accepting manures for composting. The moisture content of manure varies, depending on the type of animal and the age of the manure. How the animals are housed, and the types and volumes of bedding material used also affect moisture content of the manure. For example, manure from free stall dairy barns can have a moisture content as high as 95%, and will require dewatering prior to composting. On the other hand, manure removed from a horse stable could be mostly made of woodchips, wood shavings, straw, or sawdust, and have a moisture content of 20 to 35%.



**Photo 2.7. Dairy barns and feedlots are one of the largest sources of manure in Alberta**  
*Source: Scott Gamble*

## 2.2.6 Slaughterhouse Waste

Waste materials and by-products generated by slaughterhouse and packaging plants are primarily organic due to their animal origin. Typical wastes and by-products include:

- Blood meal
- Bones and meat scraps
- Condemned meat and carcasses
- Hair and feathers
- Hides
- Paunch manure
- Viscera and body parts

Much of the waste and by-products from meat and poultry operations can be used in the composting process with some amount of pre-processing. For instance, bones, horns, hoofs, and large meat scraps must be ground prior to composting, and blood should be dried to produce blood meal.

Wastes generated by the fishing industry can include:

- Fins
- Heads

- Shells
- Tails
- Viscera
- Whole fish and shellfish

Much of this material can be converted to products such as fish meal and oil. The ability to successfully compost these wastes and produce a high-quality product has also been demonstrated in several locations in Canada.

### **2.2.7 Animal Mortalities**

Composting of deadstock from agricultural operations, and animals killed by collisions with highway vehicles, is a common practice.

As outlined in Chapter 6, deadstock must be managed in accordance with provincial and federal regulations to prevent transmission of livestock diseases, and protect air and water quality. If an animal is known or suspected to have died from certain diseases, the death must be reported to authorities and specific disposal procedures followed. The rules for handling cattle carcasses are very specific and strict, due to the potential for the spread of bovine spongiform encephalopathy (BSE).

## **2.3 Amendments**

Amendments are normally added to the organic waste(s) during composting. This is done to adjust the moisture content, carbon to nitrogen (C:N) ratio (or both) upwards or downwards into the desired range, or to provide structure and free air space to the mixture to improve the movement of oxygen. While the necessary adjustments can often be made using one amendment type, two or more amendments can be mixed with the organic wastes to get the desired results.

Woodchips produced through diversion and grinding of untreated dimensional lumber and logs, stumps, and brush are the most commonly used amendment. Grass, leaves, and brush from residential L&YW collection programs can also be used, but the characteristics of these materials vary over the growing season, which can lead to operational challenges. Cardboard (including wax-coated cardboard), sawdust, and straw can also be used, but are often less desirable because they will not provide the structure required throughout the composting process.

It is also normal practice to recycle a portion of the oversized material screened from the finished compost back into the initial mixture of feedstocks. In addition to inoculating the bacterial

population, these “overs” help adjust moisture levels and nutrient ratios. The amount of overs recycled back into the mixture depends on many factors and can vary through the year.

## 2.4 Process Overview

Composting is a managed biological process in which various microorganisms or “microbes” decompose organic material, converting it into a biologically stable material used as a soil amendment. Although the end-result is the same, composting differs significantly from the natural decay process that occurs in the natural environment.

Composting can be used to produce compost. Alternatively, the composting process can be used as a waste treatment method to stabilize organic wastes prior to further treatment or disposal.

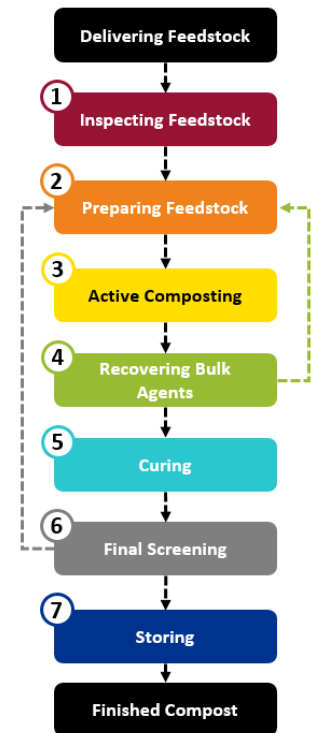
It is often helpful when describing the composting process to break it down into distinct steps. The process model shown on Figure 2.2 is based on the model developed by the US Composting Council, which has become widely accepted by the industry.

**Feedstock Recovery and Inspection** involves removing feedstock materials from any bags or containers they are delivered in and inspecting them for non-compostable materials and contaminants. When found, these contaminants need to be safely removed to improve the quality of the final product, to prevent damage to processing equipment, and prevent injuries to staff.

Once non-desirable items are removed, the remaining materials are prepared for composting.

**Feedstock Preparation** involves changing the physical and chemical characteristics of the feedstock to provide the best conditions for microbes during the composting process. Preparation may include grinding to change particle size, mixing in amendments to increase free air space, blending together various feedstocks to optimize nutrient ratios or pH, adding water, or adding partially composted materials from another pile to inoculate the fresh feedstock with beneficial microbes.

Prepared feedstocks are then placed into the pile, windrow, or vessel where the **Active Composting** process begins. The active composting process is sometimes described as having two stages: high-rate and stabilization. In reality, this distinction is theoretical, as the transition between stages is gradual enough that it may not even be noticed.



**Figure 2.2. Composting Process Model**

The initial high-rate stage of the composting process involves the rapid decomposition of the most readily degradable material. It is characterized by the generation of a significant amount of heat; enough to raise the temperature of the feedstocks into the 55°C – 65°C range. Production of heat provides several important benefits:

- Most pathogenic bacteria, viruses, and parasites are inactivated when exposed to temperatures of 55°C or greater in a compost pile for several days
- Most weed seeds are also inactivated by exposure to high temperatures

This stage of the composting process generally requires the closest monitoring, as it has the greatest chance to result in odours and nuisance conditions.

The high-rate composting stage is followed by a stabilization stage. During compost stabilization, there is still a high demand for oxygen, and pile temperatures remain in the thermophilic range. But as the easily degradable materials are decomposed, there is a decline in bacterial activity and a corresponding decline in pile temperatures.

Once the easily degradable feedstock materials are consumed and the compost is stable, the biological process slows down even more and enters the **Curing** stage. During curing, microbes convert extra carbon into carbon dioxide and humus, and extra nitrogen into nitrates. Microbes also decompose more complex organic structures, such as lignin and cellulose.

The curing stage is complete when the level of biological activity in the material is less than acceptable thresholds, and the compost is mature. Maturity is a measure of the organo-chemical condition of compost, used to describe the presence or absence of phytotoxic effects, usually caused by ammonia or organic acids.

**Screening and refining** removes oversized materials, such as large compost particles, stones, and un-composted amendments, and creates a product that can be used for the selected end-use. Physical contaminants that may be present, such as large pieces of glass, plastic, or metal

Stability” and “maturity” are sometimes used interchangeably. However, stability and maturity are two separate indicators that measure different properties.

Stability indirectly measures the level of decomposition of the organic material by measuring biological activity. Maturity is affected by stability, but it also measures whether there are other impacts (that is, phytotoxic effects) on plant germination and development.

Because of the differences, it is possible for compost to be stable but not mature. However, a mature compost is always stable.

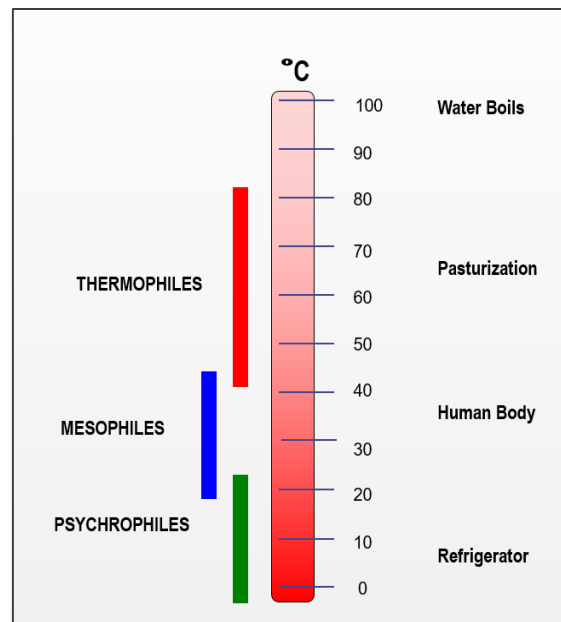
are also removed. Screening and refining is typically done after curing. However, at some facilities, screening is done before curing to **Recover Amendments** so they can be reused in the active composting stage, to remove larger particles (for example, plastic, partially degraded paper) that might cause litter, or to reduce the volume of material to be cured, which reduces space requirements.

Refining may also include mixing the compost with other products (for example, topsoil, peat, sand) to produce soil blends. At some larger facilities, the compost or blends may be bagged for distribution through the retail market.

**Storage** of the finished product is the final stage of the process. Compost production does not always match the sales schedule, and product may need to be stored for several months.

**Odour Controls** are required to capture and treat or otherwise manage odorous off-gases generated by receiving, preparation, active composting, and curing activities. In outdoor operations, there are few options to capture odours. The trend in the industry is towards incorporating best management practices (BMPs) and technologies that allow odorous process gases to be collected and treated.

In addition to odours, impacted runoff water and leachate that results from the composting operation has to be managed. **Process Water Controls** are necessary, since the runoff and leachate may contain nutrients, solids, or other contaminants that can negatively impact groundwater or surface water quality. Similarly, **Nuisance Controls** are needed to manage dust and litter that might result from composting activities, and wildlife that might be attracted to the facility.



**Figure 2.3. Temperature ranges of various types of microbes**

## 2.5 Compost Microbiology

Many different types of microorganisms are involved with decomposing feedstocks during the composting process. The different stages of the process are controlled by different types and species of microorganisms, which are adapted to the process temperatures that exist at the time. The microorganisms consume the feedstocks, as well as the by-products left behind by previous microorganisms, and the remains of these previous microbes.

The three main groups of microorganisms found in composting piles are bacteria, fungi, and actinomycetes.

Bacteria are the most numerous organisms in the composting pile and are found in many forms. These microorganisms are small and tend to be generally faster decomposers than other microbes. They dominate the early stages of the composting process, but as the simpler compounds in the feedstock (sugars, starches, fats, and proteins) are consumed, bacteria populations decline.

Bacteria are sometimes classified according to the temperature at which they can survive and reproduce. Using this classification scheme, the three main types of bacteria are:

- Psychrophilic bacteria, which thrive at temperatures below 20°C
- Mesophilic bacteria, which thrive at temperatures between 10°C and 45°C
- Thermophilic bacteria, which thrive at temperatures above 40°C

Actinomycetes are a type of bacteria that grow in colonies and have a long, branching, filamentous (thread-like) structure, similar to a fungal mycelium. In the composting pile, actinomycetes typically become noticeable during the transition phase between high-temperature composting and curing, and are more often found in drier parts of the pile.

They can be recognized as a grayish, cobwebby growths that appear 2 – 5 centimetres (cm) below the outer surface of the compost pile. Actinomycetes are more tolerant of mesophilic temperatures and can also break down more complex lignaceous (wood-like) compounds.

Fungi are larger microorganisms and are also present in many forms. Fungi take over in the final stages of composting when the organic material has been changed to a more digestible form. They tend to thrive in a lower pH range and are tolerant of low-moisture conditions. Fungi can break down the more complex substances (for example, polysaccharides, lignins, cellulose) and their populations are higher during the curing stage.





**Photo 2.8. Actinomycetes located just under the surface of a compost pile**

*Source: CH2M*

## 2.6 Process Parameters

A composting facility operator does not directly control the microorganisms that break down materials in the compost pile. Instead, the operator's job is to provide the right conditions for the desired microbes to flourish. By providing the best conditions, the operator helps composting proceed in an efficient and nuisance-free manner.

There are several parameters that operators monitor and control during the various stages of the composting process:

- Free air space
- Moisture content
- Nutrients
- Oxygen concentration
- Particle size
- pH
- Temperature

A summary of ideal ranges for these parameters is provided in Table 2.3 at the end of this chapter.

## 2.6.1 Nutrients and the Carbon-to-Nitrogen Ratio

Carbon (C), nitrogen (N), phosphorus (P), and potassium (K) are the primary nutrients required by the microorganisms involved in composting. In most feedstocks, there is enough phosphorus and potassium to not limit the composting process. More often, carbon or nitrogen is the limiting factor. Microorganisms use carbon for energy and growth, while nitrogen is used for protein and reproduction. There must be enough of these two nutrients in a form available to the microbes for composting to proceed properly.

The carbon to nitrogen ratio, or C:N ratio, is a commonly used measure of the amount of nutrients in a composting feedstock. The ideal C:N ratio is between 25:1 and 35:1. If the C:N ratio is less than 20:1, the available carbon may be fully used before the nitrogen is stabilized, which results in release of ammonia. At C:N ratios greater than 40:1, the composting process begins to slow down, as the microorganisms are limited by the lack of nitrogen.

The C:N ratio is determined by dividing the amount of carbon in a sample of material by the amount of nitrogen in the sample, as shown in Chapter 5. The amounts of carbon and nitrogen are expressed on a dry weight basis.

Feedstocks do not always have a C:N ratio that falls within the ideal range. To overcome this, different feedstocks are often blended together in different amounts as part of the feedstock preparation stage to achieve the best balance of carbon and nitrogen. For instance, a feedstock containing large amounts of nitrogen (for example, manure) could be blended with one that has a high carbon content (for example, straw, woodchips).

To guide the actual blending process, a recipe is usually prepared in advance. Developing a recipe involves calculating the required amounts of individual feedstocks and amendments required to produce a mixture with an optimal C:N ratio. The calculations can be done manually (as shown in Chapter 5), using computer spreadsheets, or using internet-based or commercial software packages. Recipe development also involves checking moisture content and bulk density of the feedstock mixture.

To calculate the C:N ratio of a material or blend of materials, it is necessary to know the carbon and nitrogen concentrations. This information can be obtained from compost reference books, internet resources, or by submitting a sample of material to a laboratory for analysis. Examples of C:N ratio information for some common feedstocks is provided in Table 2.1.

**Table 2.1. C:N Ratio of Composting Feedstocks**

<b>High Nitrogen</b>	<b>% N dry weight (dw)</b>	<b>C:N Ratio</b>
Dairy Manure (free stall)	4.6 – 8.2	4.0 – 5.4
Digested sewage sludge	3.7	13
Fish wastes	6.5 – 14.2	2.6 – 5.0
Garbage (food waste)	1.9 – 2.9	14 – 16
Grass clippings	2.0 – 6.0	9 – 25
Mixed slaughterhouse waste	7 – 10	2 – 4
Poultry carcasses	2.4	5
Swine manure	1.9 – 4.3	9 – 19
Tree trimmings	3.1	16
<b>Balanced</b>	<b>% N (dw)</b>	<b>C:N Ratio</b>
Fruit wastes	0.9 – 2.6	20 – 49
Horse manure – general	1.4 – 2.3	22 – 50
Paper mill sludge	0.56	54
Paunch manure	1.8	20 – 30
Shrub trimmings	1	53
<b>High Carbon</b>	<b>% N (dw)</b>	<b>C:N Ratio</b>
Corrugated cardboard	0.1	563
Bark – softwoods	0.04 – 0.39	131 – 1,285
Corn cobs	0.4 – 0.8	56 – 123
Leaves	0.5 – 1.3	40 – 80
Sawdust	0.06 – 0.8	200 – 750

Source: NRAES/On farm Composting Manual

If the steps are followed to develop an appropriate recipe, and the blending of materials done well, re-adjustment of nutrient levels is not normally required during composting. If adjustments are necessary, it usually involves adding the required amount of nitrogen- or carbon-rich material into the existing material, and making sure it is thoroughly mixed.

Calculating the C:N ratio is useful when deciding on composting blends, but it does not provide a complete picture. The availability of the nutrients (carbon, in particular) must also be considered. Microbes work on the surface of the feedstock particles, and cannot get to nutrients in the centre of large particles. Material breakdown can be improved by reducing the particle size, but if the particles are too small, it can affect oxygen transfer into the compost pile.



**Photo 2.9. Adding water to a windrow during turning**

*Source: CH2M*

## 2.6.2 Moisture Content

Adequate moisture levels must be maintained throughout the material being composted to keep the microorganisms alive and active. Water is essential for the microbe's metabolic and reproductive functions, as well as for transferring nutrients, chemicals, and wastes to and from the microbes.

The optimal range for moisture levels will vary, depending upon the type of feedstock being composted, the technology being used, and climate impacts, but is generally between 55 and 65%.

If moisture levels are too high, the spaces between individual feedstock and amendment particles will become filled with water, making it hard for air to move through the pile. This can lead to anaerobic conditions and offensive odours. Excess moisture can also drain from the base of the composting pile and contribute to leachate. Leachate that accumulates around the base of piles will become an odour source, and can attract flies and other insects.

If there is not enough moisture, the metabolic and reproductive functions of the organisms will slow down,



**Photo 2.10. Leachate from composting piles can attract flies and release offensive odours**

*Source: CH2M*

resulting in reduced activity or death. Low moisture content can also result in an increase in the amount of dust generated when compost is turned, moved, or otherwise handled.

It is easier to manage the composting process when the moisture is evenly distributed throughout the compost mass. Uneven moisture distribution can lead to pockets of anaerobic activity, or dry areas through which air can short-circuit (flow along the path of least resistance). Uneven moisture distribution is often caused by poor mixing, but can also be caused by poor working surface grading (that is, water collecting in low spots) or faulty aeration systems.

Moisture content is usually modified during the feedstock preparation stage as part of the blending process. If the feedstocks are too wet, dry materials, such as woodchips or sawdust, can be added. If feedstocks are overly dry, water or leachate can be added to raise the moisture content.

During the composting process, moisture can be lost from the pile through evaporative cooling. It is a common practice to add additional water during composting to maintain moisture levels within the optimal range. The moisture addition should be accompanied by mixing or turning to evenly distribute it throughout the composting material.

At times, it may also be necessary to remove excess moisture from material being composted. Often, this is done towards the end of the active composting or curing stages as a preparatory step to screening and other refining operations. Removal of moisture is normally done by increasing the amount of air or mechanical agitation.

The moisture content of materials in a compost pile can be measured in several ways. The simplest method to gauge moisture content, and one that all compost operators should know, is the hand squeeze test. An experienced operator can take a sample of material in their hand and,

### Calculations for Determining Moisture Using Drying Methods

1. Record the weight of the sample container ( $M_c$ ).
2. Place a sample of material onto the sample container. Record the weight of the sample and container ( $M_{start}$ ).
3. Calculate the initial sample weight ( $M_{wet}$ ).

$$M_{wet} = M_{start} - M_c$$

4. Dry the material in the oven, microwave, or Koster Moisture Tester.
5. Record the weight of the dried sample and plate ( $M_{finish}$ ). Calculate the weight of the dried sample ( $M_{dry}$ ).

$$M_{dry} = M_{finish} - M_c$$

6. Calculate the moisture content (MC).

$$MC = (M_{wet} - M_{dry}) \div M_{wet}$$

by giving it a gentle squeeze to see how much water is released and how the material sticks together, can estimate the moisture to within 5%.

The most reliable method, and the one used by commercial laboratories, is to place a sample of the material in a drying oven for at least 24 hours to completely evaporate the water from it.

The difference in the weight of the sample before and after drying represents the water that was evaporated. With this information, the moisture content can be calculated.

The drying method used by laboratories requires a specialized oven, and this is too costly for most composting facilities. However, the oven drying method can be copied at the composting facility using a microwave oven or a Koster Moisture Tester. These methods are quick (15 to 30 minutes) and inexpensive, but are not as precise as the method used by commercial laboratories. Operators must also be careful when handling the heated samples to prevent burns or small fires.

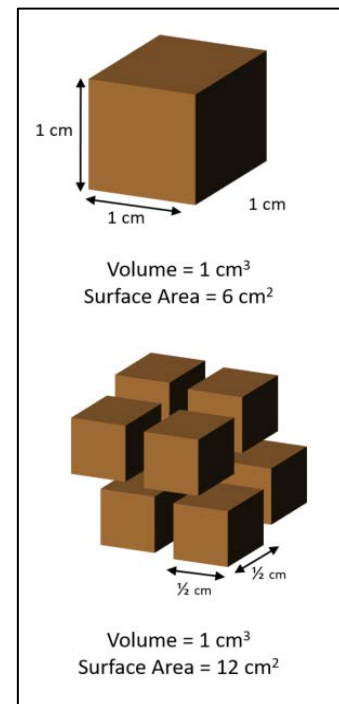
The formulas for calculating moisture content using microwaves and Koster Moisture Testers is the same as that used for laboratory drying ovens.

### 2.6.3 Particle Size

The microbes in a composting pile live and work on the surface of the individual feedstock particles, and decompose them from the outside in. If more surface area is available, the compost pile can support more microbes, and decomposition will happen faster.

A material with a small particle size has more surface area compared to the same volume of material with a larger particle size. On this basis, it seems that grinding feedstocks into fine particles would be the best solution. However, if the particles are too small, they are more likely to pack together, and the space between the particles will become smaller. As discussed in the following section, if the space between the particles is too small, the compost process can slow and offensive odours can be generated. Therefore, it is recommended that the pile contain a range of different sized particles, from 3 or 4 mm up to 75 mm.

Particle size is measured using a set of sieves that have openings ranging in size from 6 mm ( $\frac{1}{4}$  inch) up to 76 mm (3 inches). A pre-weighed sample (for example, 1,000 grams [g]) is passed through the set of sieves, and the amount left on each sieve is weighed.



**Figure 2.4. Illustration of the Impact that Particle Size has on Surface Area**

These weights are used to calculate the size of each fraction on a percent basis. This information is then used to prepare a gradation chart similar to the one shown in Table 2.2.

## 2.6.4 Free Air Space

Free air space refers to the available space between individual feedstock and amendment particles in the compost pile that are not filled with water. It is expressed as a percentage of the entire volume of the composting matrix (e.g., particles and voids). Having enough free air space is key, as the air necessary to transfer air into, and remove heat from, the pile. If there is not enough free air space, air movement and oxygen transfer can be reduced, leading to anaerobic conditions. Lack of air movement can allow heat to build up in the composting pile, which can lead to more evaporation of water.

A free air space between 40 and 60% is generally recommended. Compost piles that are actively aerated with a fan can have less free air space than piles that are passively aerated since the fan can overcome the increased resistance to air flow.

Due to their small particle size and high moisture content, feedstocks, such as food waste, biosolids, and manures, do not have enough free air space to sustain composting, and require that a bulking agent be added. A bulking agent is an amendment added to increase the amount of free air space in the composting pile. Coarse woodchips and oversized materials recovered when screening compost are the most common bulking agents.

Since the purpose of adding a bulking agent is to increase free air space, it is important to consider a material's structural characteristics when considering using it as a bulking agent. Woodchips are an ideal bulking agent because they do not break down quickly (that is, get smaller), or soften and deform when they get wet. Shredded cardboard is an example of a poor bulking agent: for the first few days in the compost pile, it will retain its shape, but once it gets wet, it will compress and not provide free air space.

It is possible to directly measure the free air space in a sample of material. However, the methods and equipment are generally too complicated to use in the field. Therefore, bulk density is commonly used as a substitute measure of free air. Bulk density can quickly and easily be measured in the field using what is commonly called a bucket test.

**Table 2.2. Gradation Chart Example**

Particle Size Range	Percent (%)
Less than 9.5 mm (3/8")	20
9.5 mm to 19 mm (3/8" to 3/4")	50
19 mm to 38 mm (3/4" to 1.5")	10
Greater than 38 mm (1.5")	10

### Method for Determining Bulk Density

1. Record the weight an empty 19-litre (L) (5-gallon) pail ( $M_{\text{pail}}$ ).
2. Determine the volume of the pail ( $V$ ). If the volume is not known, calculate it from measurements of the pail height and diameter, or by filling the pail to the brim with water, and weighing the container and water (density of water = 1 kilogram per litre [kg/L]).
3. Fill the pail one-third full of material. Drop the pail 10 times from a height of 15 cm (6 inches) onto a firm, flat surface to compact the material.
4. Add more material until the pail is two-thirds full. Drop the pail 10 times from a height of 15 cm (6 inches).
5. Fill the pail to the top. Drop the pail 10 times from a height of 15 cm (6 inches).
6. Fill the pail to the top (do not heap or over-fill the pail). Do not drop the pail to compact the material.
7. Weigh the pail and sample ( $M_{\text{total}}$ ). Subtract the weight of the pail ( $M_{\text{pail}}$ ) from the total weight ( $M_{\text{total}}$ ) to calculate the weight of the sample ( $M_{\text{sample}}$ ).
8. Calculate the bulk density of the sample.

$$\text{Bulk Density} = M_{\text{sample}} \div V = (M_{\text{total}} - M_{\text{pail}}) \div V$$

The typical bulk density in a compost pile that is passively aerated would be around 300 to 400 kilograms per cubic metre ( $\text{kg}/\text{m}^3$ ). The bulk density of material in an aerated static pile can be a bit higher (for example, 500 to 700  $\text{kg}/\text{m}^3$ ) since the centrifugal fans can force air through the material.



Screening after the active composting stage is often done to reduce the volume of material that needs to be cured. The oversized material from the screening step can also be reused and an amendment, and will help to inoculate fresh feedstocks with beneficial bacteria.

However, screening and removing oversized material also reduces free air space. This can reduce the flow of air through curing piles and affect oxygen concentrations.

A good compromise is to coarsely screen the material after active composting using a 20 mm to 30 mm screen, and then fine screen the material (e.g. 10 to 15 mm) after curing is completed.

## 2.6.5 Oxygen Concentration

The composting process is aerobic which means that it occurs in the presence of oxygen. The opposite of aerobic is anaerobic (that is, occurring in the absence of oxygen). Aerobic processes, such as composting, decompose organic waste much more quickly than anaerobic processes. The odours released by aerobic decomposition are generally less offensive than the odours from anaerobic decomposition.

During composting, having enough oxygen is critical to ensuring the desired species of microorganisms are present and can efficiently breakdown the organic feedstocks. If there is not enough oxygen, the microbes will slow down, or they will die off and be replaced with anaerobic microorganisms. When this occurs, the pile is said to have “gone anaerobic” or “gone sour”.

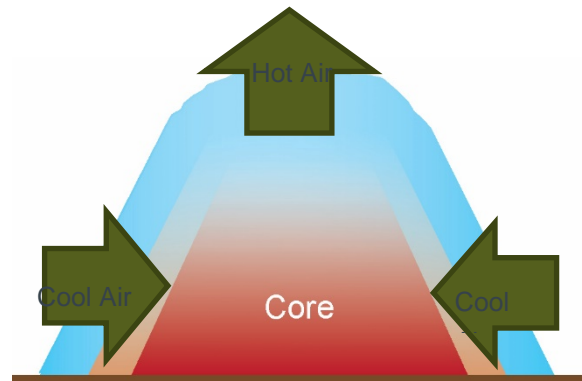
Oxygen levels are maintained in the composting pile by moving air through the pile, a process known as “aeration.” Oxygen is a major component (21% by volume) of air. Aeration supports aerobic microbial metabolism, and removes heat and water from the composting mass.

As outlined in Chapter 3, aeration can occur passively or actively. In a compost pile that does not have aeration fans (that is, passively aerated), air moves naturally through the pile because of convective heat transfer. Temperatures throughout a composting pile vary: material is hottest in the core of the pile where the microbes are most active, and cooler at the outside surfaces of the pile.

This temperature gradient causes the air in the core of the pile to heat up and rise upwards through the free air spaces until it is released through the top surface of the pile. Fresh air is drawn into the pile through its sides and travels into the core of the pile to replace the hot air

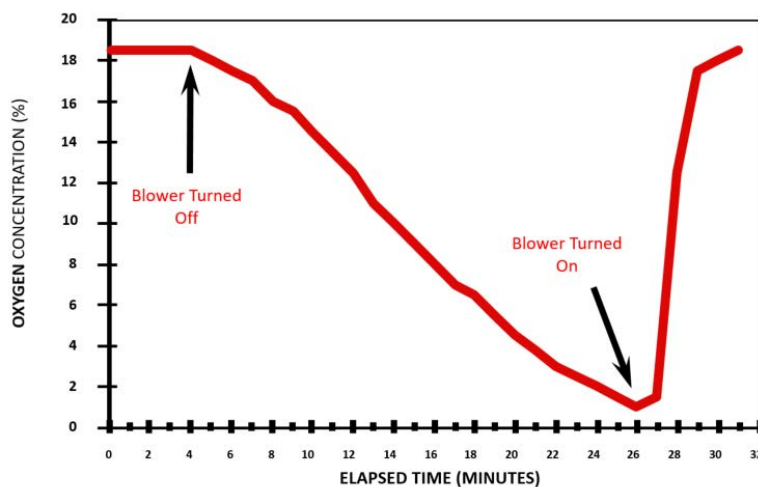
released through the top of the pile. This passive movement of air is otherwise known as the chimney effect.

In an actively aerated composting system, the compost pile is built overtop a network of perforated pipes, floor grates, or trenches with perforated covers. Centrifugal fans are used to force air through the composting pile via the pipes, grates, and trenches. If the air is forced up and through the pile, the pile is said to be positively aerated. If the fans are used to suck air down through the compost pile and into the pipes, grates, and trenches, the pile is said to be negatively aerated.



**Figure 2.5 Temperature variation in a compost pile**

In both passively and actively aerated systems, the amount of oxygen required in a composting pile varies over time. The most oxygen is required during the high temperature stage at the start of the composting process, when there are the most microbes. As the compost process continues into the stabilization and curing stages, the number of microbes decreases, and the amount of oxygen needed also decreases. The amount of oxygen required at the various stages of the process is called the oxygen demand, and can be measured in milligrams of oxygen ( $O_2$ ) per gram of solid material ( $mg O_2/g$  total solids). The more biological activity there is in a compost pile, the more oxygen is needed.



**Figure 2.6. Example Showing How Quickly Oxygen is Consumed in an Active Compost Pile**

While it is possible to measure the oxygen demand of a sample of material from a compost pile, the methods and equipment required to do this are not well-suited to use in the field. Instead, it is a common practice to measure the concentration of oxygen in the free air spaces within the composting pile using a specialized measurement device. The device consists of a long, hollow sampling probe connected by rubber tubing to an oxygen sensing unit. The hollow probe is inserted into the compost pile and used to extract a sample of air. The air sample is passed over the sensor, which measures the amount of oxygen in the sample, and provides a reading of the oxygen concentration between 0 and 21%.

The governing principle with this device is that when the compost pile's oxygen demand is being met, there will be extra oxygen in the pile's free air spaces. If the oxygen demand of the pile is not being met, there will be no oxygen in the free air spaces (that is, anaerobic conditions). This approach works through all stages of the composting process.

In practice, an oxygen concentration between 12% and 18% is considered a properly aerated pile. A concentration of 5% or less is generally considered to be an indication of poor aeration.

## 2.6.6 Turning and Agitation

Many composting methods and systems involve mechanically agitating the compost pile. In most passively aerated composting methods, the piles are agitated with a front-end loader or with a specialized windrow turner. This is often called “turning” the pile. Some actively aerated systems also rely on front-end loaders or turners for periodic agitation. Others agitate the material using automated paddle or auger systems, or by rotating the drum in which the materials are contained.

It is an often-held misconception that the purpose of turning or agitating a compost pile is to provide oxygen. It is true that agitation does introduce oxygen into the pile. However, this oxygen can be quickly consumed by the microbes. If there is not enough free air space in the pile, the oxygen will not be replenished, and conditions within the pile can become anaerobic.

It is more correct to say that turning and agitation indirectly assists oxygen levels by fluffing up the material in the compost pile. This re-establishes the free air space in the pile that was lost due to settling or compaction, and allows more air to flow through the pile.

Periodic turning will not overcome problems in a pile that result from initial lack of free air space caused by not adding enough amendment.



**Photo 2.11. Glass is extremely difficult to remove once it has been broken into small pieces.**

*Source: Scott Gamble*

Agitation also has other benefits that are not related to oxygen levels. It breaks up clumps and further mixes materials and redistributed moisture, all of which makes the compost pile more homogeneous and leads to more consistent process conditions. It also releases heat from the pile.

Regular turning during the initial high-rate stage is also critical to reducing pathogens in the material. Turning the material exposes more of the pile to the high temperatures in the core.

If a flail-type windrow turner is used, the turning action also physically breaks down large particles into smaller particles. This helps if the pile contains branches, brush, and other woody material that were not ground prior to composting. However, if the pile contains glass, hard plastics, and other inert contaminants, they may be harder to screen from the compost once they are broken into smaller pieces.

## 2.6.7 pH

pH is a measure of the acidity or alkalinity of a material and is measured on a scale of 0 to 14. Material with a pH of less than 7 is acidic, while a pH of greater than 7 means the material is alkaline. A pH of 7 is considered to be neutral. The pH scale is logarithmic, which means that a change in pH by one unit is equal to a change in acidity or alkalinity of 10 times. For example, pH 5 is 10 times more acidic than pH 6.

The pH of the composting mass is important, as microorganisms cannot survive if the environment is too acidic or too alkaline. As the pH of most feedstocks is within the desirable range of 6.0 to 8.0, pH adjustment prior to composting is not normally necessary. However, some feedstocks, such as cannery waste and distillery mash, may require adjustment with a more neutral feedstock or with lime.

Once started, the composting process is essentially self-regulating in terms of pH, and requires little monitoring or adjustment from the operator. However, during the initial few days of the process when the oxygen demand is the highest, it is possible for the pH of the material to drop significantly if there is not enough oxygen available. In an extreme case, the pH can drop to between 4.8 and 5.0. This can be a cause for concern, as certain trace elements will become more mobile (soluble) at a low pH, and can adversely affect the chemical quality of the finished product.

Historically, pH of liquids was measured using litmus paper. Now, a pH meter and electrode are most commonly used. Measuring the pH of a solid material like compost requires that an extract liquid be prepared. With compost, this is done by mixing prescribed amounts of compost and distilled water together, allowing them to sit for a certain length of time, and measuring the pH of the solution.

## 2.6.8 Temperature

Activity by the microbes involved with the composting process generates tremendous amounts of heat. Provided other process parameters (for example, C:N ratio, oxygen concentration, moisture content) are within their optimal ranges, monitoring the temperature of a composting pile provides operators with a good indicator of how the composting process is progressing.

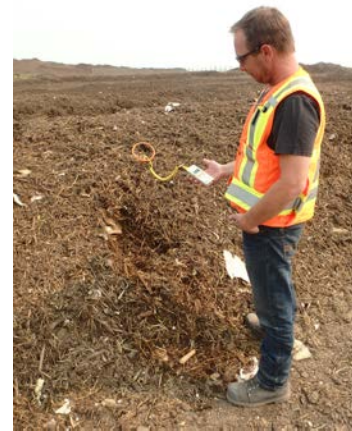
Temperature can easily be measured in a compost pile with a bimetal or digital thermometer. The thermometers used are typically 120 – 180 cm (48 – 72 inches) long and are often called temperature probes. The long probes are necessary to obtain temperatures in or near the core of the composting pile where the most biological activity occurs. Normally, there is a temperature gradient in the pile, and the outside of the pile is significantly cooler than the core.

During the active composting period, the operator's job is to promote rapid decomposition by keeping temperatures within composting piles between 55°C and 65°C. If temperatures are allowed to rise and stay higher for extended periods of time, the thermophilic microbes needed for efficient decomposition are less active or are unable to survive, and the composting process will slow down. If temperatures are allowed to stay below this range, the composting process will be dominated by slower acting mesophilic microbes, and the rate of decomposition decreases. Lower temperatures during the active composting stage can also result in incomplete destruction of pathogens and weed seeds that might be present in the feedstocks, thus affecting the quality and usability of the final compost product.

Without proper control, temperatures in a compost pile can climb quickly, assuming there is adequate moisture and nutrients. Compost piles with extra nitrogen (that is, the C:N ratio of the material is less than 20) can see rapid rises in temperature in the first 24 to 48 hours of the composting process.

In composting systems that have fans and forced aeration systems, temperature is controlled by moving more or less air through the pile.

In composting piles that do not have a forced aeration system, temperature is controlled by maintaining adequate free air space in the pile. The heat generated by microbes in the core of the composting pile will heat up the air in the pile, causing it to rise and escape through the top of the



**Photo 2.12. Measuring temperatures in a windrow**

*Source: CH2M*

pile. The movement of air up and out of the pile causes cooler fresh air to be drawn into the pile's core through the sides of the pile. This flow of air through the composting pile is known as "passive aeration" or the "chimney effect."

Agitating a composting pile, by turning it with a front-end loader or specialized windrow turning equipment, will expose the material in the core of the pile and release heat. Equally as important, the agitation fluffs up the material in the pile and helps to maintain free air space needed for passive aeration.

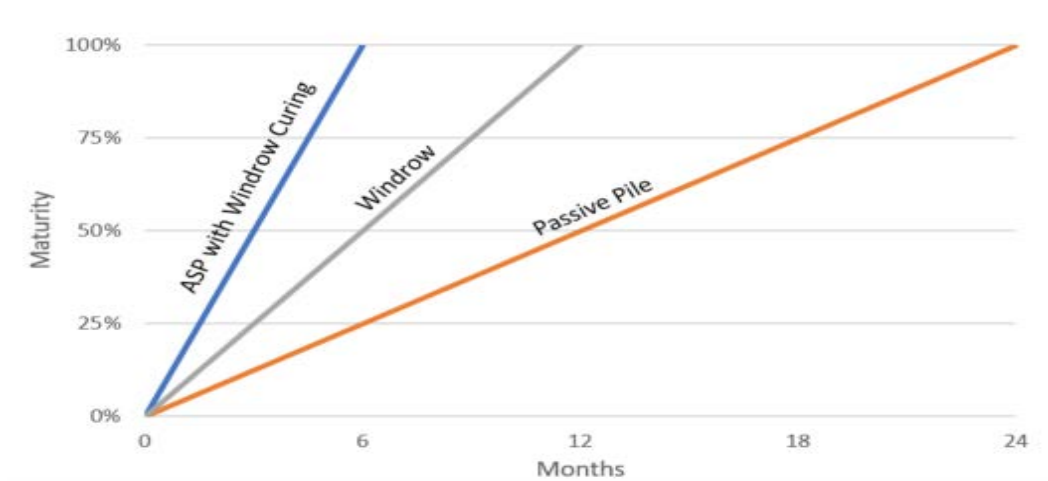
When the degradation rate begins to fall, so does heat production. Operations that monitor pile temperature at regular intervals should see a decrease in temperature over time.

### **2.6.9 Time**

Even though an operator can improve conditions in the compost pile, the complete breakdown of feedstocks and their change into stable and mature compost takes time. In Alberta, feedstocks taken to a composting facility are considered to be waste products until they are converted to finished compost, and the compost has been tested and proven to be mature.

Typically, two or more tests are required to accurately determine the maturity and stability of a compost. The most common maturity test is a plant bioassay, but ammonia concentration and volatile organic acid concentration also provide a measure of maturity. Stability is most commonly determined by measuring the amount of carbon dioxide from microbes in a sample.

The time required to produce finished compost is usually measured in months. With an actively aerated composting system and tight management, finished compost can be made in as little as 3 months during the summer from a feedstock such as biosolids. Outdoor composting in windrows during the late fall and winter can extend the amount of time required to 12 months. Feedstocks with a high amount of carbon (such as dead leaves) can take 2 to 3 years to completely break down if they are composted by themselves. Of course, these timelines will all be extended if the composting process is poorly managed by the operator.



**Figure 2.7. Example of how technology impacts the amount of time required for make mature compost**

## 2.6.10 Summary

The following table provides a summary of the optimal ranges for the key process parameters.

**Table 2.3. Summary of Optimal Ranges for Process Parameters**

Optimal Process Parameters	
Carbon to Nitrogen Ratio	25:1 to 35:1
Moisture Content	55 to 65%
Particle Size	3 or 4 mm up to 75 mm
Bulk Density (Free Air Space)	300 to 475 kg/m <sup>3</sup>
Pore-space Oxygen Concentration	>10%
pH	6 to 8
Temperature	50 to 65°C (>55°C during pathogen reduction stage)

# Chapter 3 – Composting Methods and Equipment

## 3.1 Learning Objectives

Organic wastes can be composted in different ways, from simple backyard operations to large, central facilities. The biological and process control principles are the same even though there are differences in the composting rates, control methods, and composting vessels. Composting is generally divided into three levels:

1. Home or backyard composting
2. Centralized composting
3. Onsite composting

**Home or backyard composting** is common in municipal waste reduction strategies across North America. By encouraging and assisting residents to compost their organic wastes at home, municipalities can divert waste from landfills, and reduce overall waste collection costs. Because these programs are so popular, there are many backyard compost containers available on the market. Many municipalities also provide plans for homemade compost bins.

**Centralized composting** involves collecting organic wastes from several different places and processing them at a single facility. These facilities are usually large, with capacities ranging from a few tonnes per day (tpd) up to several hundreds of tpd.

Centralized composting has been practiced in Europe and North America for many years. Many technologies and techniques have been developed, ranging from simple and inexpensive, to complex and costly.

**Onsite composting** refers to waste generators composting organic waste on their own sites. Examples of where onsite composting might take place include:

- Airports
- Apartment buildings
- Cafeterias
- Hospitals



**Photo 3.1. Backyard composting bin**

*Source: Scott Gamble*



- Office buildings
- Restaurants
- Schools and universities
- Shopping malls

The benefits of onsite composting are avoiding the costs of transporting organic wastes offsite for disposal or processing, and creating a supply of compost that can be used at the facilities where the organics are composted. The disadvantage is that not all generators have enough space or resources to actively compost and cure the material at their sites.

This chapter provides:

- A brief overview of common centralized composting techniques and technologies
- Examples of different onsite composting systems
- A discussion of material handling equipment used at composting facilities for pre- and post-processing

## 3.2 Centralized Composting Systems

Many methods and technologies are available to compost food and other organic wastes. Descriptions of the most common composting methods and technologies are provided in the following sections. A summary of the advantages and disadvantages of these options is provided in Table 3.2 at the end of this section.

In this guide, centralized composting technologies are sorted into two groups: passively and actively aerated systems, as shown in Table 3.1. In actively aerated systems, fans are used to force air through the free air spaces in the compost pile.

**Table 3.1. Types of Composting Methods and Systems**

Passively Aerated	Actively Aerated
Static Pile (un-aerated)	Agitated Bed
Bunkers	Agitated Containerized Systems
Windrow	Aerated Static Pile
Turned Mass Bed	Covered Aerated Static Pile
Passively Aerated Windrow	Channels
	Rotating Drum Systems
	Static Containerized Systems
	Tunnel Systems
	Turned and Aerated Mass Bed

In passively aerated systems, convective heat transfer created by the temperature changes within the compost pile cause air to move naturally through the free air spaces. In composting, this convective heat transfer process is known as the chimney effect, and is discussed further in Chapter 2.

## 3.2.1 Passively Aerated and Turned Composting Systems

### 3.2.1.1 Static Pile Composting

Static pile composting (that is, no forced aeration, and limited or no mechanical turning) is the simplest and least expensive composting option available. However, it is usually only used for feedstocks with high carbon to nitrogen (C:N) ratios, such as leaves, brush, and wood. This method does not work well for processing feedstocks with low C:N ratios, such as food waste and biosolids, because the oxygen required by the microbes that break down these materials cannot be met by passive aeration. Static pile composting also does not work well in the city, since odours can constantly escape from the pile. When older material in the pile is moved, it releases odours as the breakdown process starts again.

Feedstocks are formed into large, outdoor piles. Once built, the piles are passively aerated (exposed to natural air movement) via convection (when gravity causes hotter air to move up and colder air to move down, heat gets transferred) and diffusion (the natural, random movement of air or material spreading to take up available space), and decompose (break down) over a period of 2 to 3 years. Since there is little or no mixing or turning during aeration, it is very important that materials initially be mixed with enough amendment (something added to improve the compost process) to provide enough free air space to allow air to move within the pile.



**Photo 3.2. Static pile composting of L&YW**

*Source: CH2M*

Static piles should not be more than 5 metres (m) high. When piles are too large or there is not enough passive aeration, anaerobic conditions (lack of air) can develop, and offensive odours can be generated that may affect the surrounding community. The weight of overburden materials

in tall piles can also compress materials in the pile's base, which leads to further problems related to lack of free air space, air flow, and odours.

Problems can occur with static piles that are too small, particularly during the winter in cold climates. Due to the large amount of surface area (compared to the pile's volume), heat from the composting process can be lost to the environment faster than it is generated. This will result in the core temperatures of the composting pile not being high enough to kill pathogens and weed seeds. In extreme cases, small piles can freeze solid, and they cannot be turned, screened, or otherwise managed until they thaw.



**Photo 3.3. Overly-large static pile that has been compacted by heavy equipment**

*Source: Scott Gamble*

Composting materials using the static pile method takes much longer to complete than other methods because materials are typically not well mixed, and there is a lower aeration rate. The longer residence time (the time the material is breaking down in the pile) means that more space is needed compared to other methods that compost materials more quickly.

### **3.2.1.2 Bunker Composting**

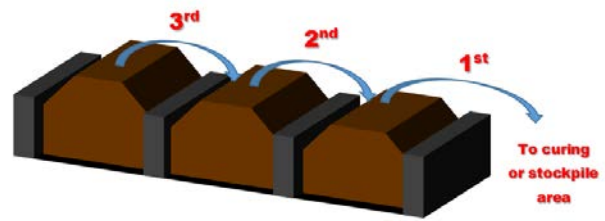
Smaller quantities of materials can be composted using static piles enclosed in small bunkers. The bunkers can be constructed from cast-in-place concrete, concrete lock-blocks, jersey barriers, and even wood. Depending upon the location and climate, the bunkers can be located outdoors, covered by a simple roof structure, or contained within a building.



**Photo 3.4. Bunker composting facility**

*Source: CH2M*

A typical installation consists of three separate bunkers. The first bunker is used for receiving fresh materials every day. When this bunker is filled (typically after 1 to 2 weeks), the third bunker is emptied, and refilled with material from the second bunker. The material from the first bunker is then moved into the second bunker to make room for fresh materials. Active composting occurs in the second and third bunkers. The movement of material from bunker to bunker mixes it and redistributes moisture. It also fluffs the material and re-establishes free air space within the pile, which is necessary for passive aeration.



**Figure 3.1. Movement of material through an unaerated bunker system**

Depending upon the size of the composting operation, materials can be moved from bunker to bunker using a skid steer or small front-end loader.



**Photo 3.6. Windrow composting**

*Source: Scott Gamble*

Due to their simplicity, bunker systems can be custom designed to match a specific application and rate of feedstock generation. Individual bunkers can range in size from 2 to 3 cubic metres ( $m^3$ ), to as much as 20  $m^3$ . Larger bunkers can be equipped with forced aeration systems to provide better process control and control over odours.

### **3.2.1.3 Windrow Composting**

Windrow composting is the most common composting method. It requires minimal infrastructure and has low installation and operating costs compared to many other composting methods. Feedstocks and amendments are placed into long, low piles (windrows) that are regularly turned using mobile equipment (such as front-end loaders, skid steers, or farm tractors and manure spreaders) or a specially designed windrow turner.

The turning process re-establishes the free air space in the material, mixes it, and re-introduces oxygen into the windrow. However, the oxygen introduced can be quickly consumed; in some cases, oxygen is consumed so quickly that anaerobic conditions can develop in a few hours. Therefore, it is critical to maintain enough free air space in the material being composted to allow for passive aeration.

Turning the windrows will also mix and homogenize the material in the pile, resulting in more consistent composting conditions. The size of feedstock and amendment particles will also be reduced, particularly if a specialized compost turner is used. Windrows are typically 1.5 – 3 m high and 3 – 6 m wide. The size of the windrow depends on the type of equipment used to turn it. There must be a balance between keeping a small enough cross-section to maintain aerobic conditions (through passive aeration), and a large enough pile to retain heat and reach temperatures high enough to reduce pathogens levels.



**Photo 3.7. Windrow composting facility in British Columbia**

*Source: CH2M*

The amount of land required for windrow composting is determined by windrow size and spacing, which is determined by the type of turning equipment used.

Generally, facilities that rely on straddle-type windrow turners can manage more material in the same amount of space than a site that uses a towed windrow turner or manure spreaders to turn the windrows. Using a front-end loader for pile turning can match the capacity of a large straddle turner, but only if no space is left between windrows.

Every time a windrow is turned, heat, water vapour, and gases trapped in the free air space are released into the atmosphere. If the facility is outdoors, there is little that can be done to capture the water vapour and gases. Therefore, windrow turning should not be done during stagnant air conditions, during temperature inversions, or if the wind is blowing directly towards neighbours. Similarly, it is often recommended that turning be done earlier in the day so that odours will not be detected by downwind neighbors during meal times or in the evenings when homeowners are more likely to be outdoors.

Normally, the temperature of the outdoor air gets colder as elevation increases. A “temperature inversion” is the meteorological term that refers to the phenomenon where air temperature increases with elevation. In effect, a layer of cool air at the ground surface is trapped by an overlying layer of warmer air.

The inversion results in odours, smog, and other air pollutants being trapped close to the ground instead of rising and dispersing. Temperature inversions can also result in freezing rain in cold climates.

Composting materials in windrows typically takes 6 to 12 months, depending on factors like:

- Type of feedstock(s)
- Weather conditions
- Frequency of turning
- Moisture levels in the material being composted

#### 3.2.1.4 Turned Mass Bed Composting

Turned mass bed composting is a type of windrow composting that relies on a very specialized type of turner. These turners allow for the creation of mass beds that have the same length and height as traditional windrows (that is, 30 – 100 m long, 1.5 – 3 m high), but are significantly wider.

The turners used for this compost method differ from normal windrow turners which throw material backwards behind the turner as it moves forward along the windrow. Mass bed turners are equipped with rear discharge conveyors that catch the material as it is thrown backwards, and redirect it sideways. The sideways throwing action of the turner allows it to work sequentially from one side of the mass bed to the other. Each time the turner makes a pass through the bed; it picks up the material to its right and throws it to its left, and in the process, creates a new drive aisle to its right. The unit then backs up, moves to the right, and repeats the process down the newly created aisle. Once the mass bed has been completely turned, it will have been physically relocated 6.0 – 7.5 m to the left.



**Photo 3.8. Self-propelled mass bed turner with discharge conveyor**

*Source: CH2M*

Mass beds can be operated in two ways: as a continuous flow system, or as a batch system. In a continuous flow system, the operator always adds fresh material to one side of the bed, and removes old material from the opposite side; every time the bed is turned, space is made available for new material. In a batch operation, the operator alternates the direction of turning each time, resulting in the bed moving back and forth within the same footprint.

Typical residence times in the bed are similar to those for turned windrow composting.

The turned mass bed composting method can be further improved by combining it with an in-floor positive or negative aeration system, and can be situated outdoors or housed within a building.

Although unaerated turned mass bed systems are becoming more popular, they are still not as well-known as windrow composting systems. The Cities of Edmonton and Calgary, and the Regional Municipality of Wood Buffalo, all use unaerated mass beds at their curing sites.



**Photo 3.9. Mass bed composting pile**  
*Source: CH2M*

### **3.2.1.5 Passively Aerated Windrow Composting**

In a passively aerated windrow (PAW) system, a network of perforated pipes is installed in the base of a windrow to enhance the natural convective flow of air through the compost pile. The pipes are installed as the windrow is built, and are placed perpendicular to its length, with a spacing of 0.5 – 1 m. The ends of the pipes are open and extend beyond the sides of the windrow, allowing more air to reach the windrow core. Sometimes, a 250-mm base layer of finished compost, straw, or woodchips is placed overtop the pipes to further enhance airflow through the pile. A 250-mm-thick layer of finished compost is normally placed overtop the surface of the windrow to discourage pests and to help retain heat and moisture in the pile. The outer layer also helps to manage odours.

The increased amount of passive aeration theoretically allows for quicker processing times compared to the traditional static pile method. However, there is limited experience with this method, so it cannot be confirmed. Processing times are estimated to be between 1 and 2 years.

### **3.2.2 Actively Aerated Composting Systems**

Actively aerated composting systems are also referred to as forced aeration system, because air is forced through the composting pile using centrifugal fans. They are usually designed with a much shorter residence time than passively aerated composting systems. This is because only the first part of the composting process (that is, the high temperature stage) is completed in the composting system. Once the material has gone through this stage, it is typically removed from the system and further composted and cured in windrows or static piles.

There are numerous vendors that offer pre-engineered aerated systems, including Green Mountain Technologies, Engineered Compost Systems, W.L.Gore, MOR Inc., BDP Industries, Christiaens Group, and Transform Compost Systems.

The references to specific vendors in the following sections are not intended to be an endorsement. Instead, they are provided as current examples of composting systems. Owners and operators are encouraged to explore other vendors before making procurement decisions.

### 3.2.2.1 Aerated Static Piles

Developed in the early 1970s, this method has been successfully used to compost:

- Animal manures
- Animal mortalities
- Biosolids
- Food waste
- Industrial waste composting
- Leaf and yard waste

ASP composting offers less exposed pile surface; less agitation; and, when designed to operate using negative aeration and treatment of the off-gasses, much more odour control than windrow or other passively aerated composting methods.

Feedstocks are mixed and piled to depths between 1.5 and 3.6 m overtop an air distribution or collection network. There is no standard width or length for ASPs; the configuration often depends on site-specific situations, feedstocks, and land availability.

The air distribution network can include solid and perforated pipes laid on the ground and bedded in woodchips, or a below-grade air system, such as narrow trenches with perforated covers or buried pipes with spigots or grates at the surface. Below-grade systems cost more to construct, but piles are quicker to build and tear down, and operations are more efficient. They also eliminate the risk of damage or the need to replace aboveground piping. With aboveground ASP piping systems, new replacement pipes are typically required after two to four cycles of pile construction and tear down. Some ASP systems use high-density polyethylene (HDPE) pipe, with walls 15 – 25 mm thick to minimize damage.



**Photo 3.10. Typical ASP system with aboveground piping**

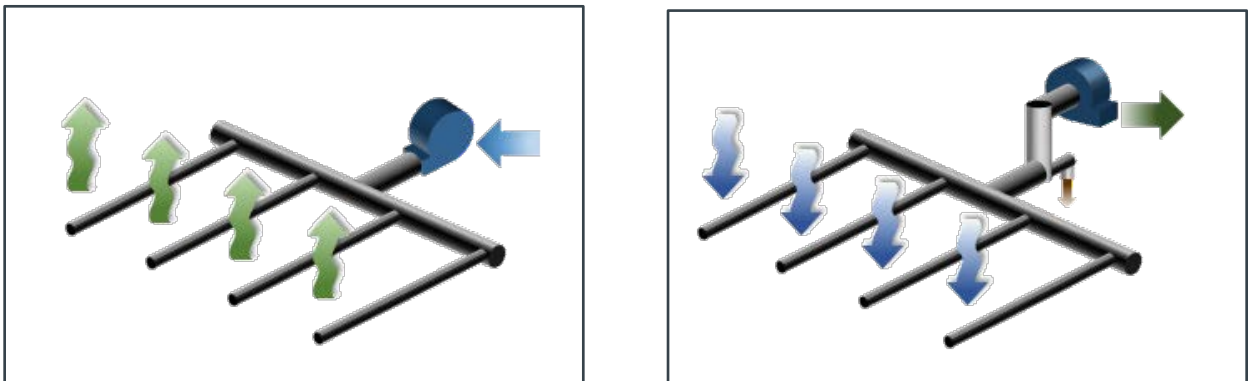
*Source: CH2M*



Air is forced through the distribution network using fans (sometimes called blowers). Aeration can be either positive (that is, air is blown by the fan through the piping network and into the pile) or negative (that is, air is sucked down through the pile and into the piping network and fan).

Negative aeration allows for better odour control, since process air is captured and can be treated. Aeration fans must be constructed with corrosion-resistant materials. When negative aeration is used, the air coming from the pile will have a much stronger smell, so some form of treatment is needed. The most common practice is to exhaust the air from the pile through an odour treatment system.

Negative aeration may also compact the feedstock more, and requires fans with slightly more horsepower than positive aeration to create the same amount of air flow.



**Figure 3.2. Comparison of Positive Aeration (Left) and Negative Aeration (Right)**

Air flow can be continuous or intermittent. Blowers that run all the time allow for lower air flow rates, but the pile may then be too cool to kill pathogens if the system is not carefully designed and managed. Temperature feedback to variable frequency drives that control aeration fans is needed to maintain pile temperatures at desired levels. A major benefit of continuous negative aeration is that odorous process air is continuously drawn from the pile for collection and treatment through biofiltration.

It is more common for blowers to be turned on and off. Aeration fans are typically controlled by a timer, or by a computerized system that measures temperatures in the piles and turns the fans on and off – much like a home thermostat.

ASP systems are often designed to use individual piles spaced 1- 2 m apart, or contained within three-sided bunkers. A variation is to design an extended pile configuration where piles are built up against each other with no physical separation. This configuration allows for more material to be processed in a given area.

Since ASPs are not turned regularly, care must be taken during the blending of feedstocks with structural amendments to maintain enough free air space throughout the composting period. It is important to achieve a homogeneous mixture and not compact the material with machinery while constructing the pile, so that air is evenly distributed and no anaerobic areas develop. Otherwise, there could be poorly composted material sections and more odours.

Typical residence times are 3 – 8 weeks, followed by a period of curing to produce finished compost.

Although they are more commonly installed outdoors, ASP composting systems can also be enclosed inside buildings.



**Photo 3.11. Mechanical timer used to control aeration fans**

*Source: Scott Gamble*



**Photo 3.12. ASP system with a bunker configuration**

*Source: CH2M*

The composting process can release a lot of heat, dust, and water vapour. Buildings that house ASPs (or other open vessel systems) that are positively aerated may have a rainforest-like environment, with interior fog making it hard to see and condensation dripping from the ceiling interior. This is particularly true when positively aerated systems are used in colder climates.

Due to these operating conditions, the interior environment and materials used to construct the buildings are critically important for sustaining safety and building integrity. Some enclosed facilities have inadequate corrosion protection, interior visibility, and indoor air quality. These problems are often related to low air exchange rates in the building, or to questionable ventilation system design.

#### 3.2.2.2 Covered Aerated Static Piles

The concept of using covers overtop of ASP composting systems is a natural progression that has evolved over the past 25 years. Covers provide protection from precipitation; reduce evaporative loss of water from the compost pile; contain litter that may be in the compost pile; and reduce pests. Some cover systems also help to control odours and volatile organic compound (VOC) emissions.

One of the early adoptors of covered ASP system employed the use of “compost pods” or “EcoPods” made from polyethylene film, and vary in lengths up to 60 m. The compost pods resemble plastic silage tubes, and are either 1.5 or 3 m in diameter. The tubes have large holes near the top and holes on the bottom that allow air movement and leachate drainage. Feedstocks are injected into the tube as it is unrolled using a special piece of equipment that also places one or two flexible, plastic aeration pipes in the bottom of the tube. When the pods are filled, the ends are sealed, and the pipe(s) in the base are connected to a positive aeration system. When the composting is complete, the plastic tubes are cut open, and the materials are removed.



**Photo 3.13. Positive ASP composting system inside at building**  
*Source: Scott Gamble*



**Photo 3.14. Composting system using polyethylene covers**  
*Source: Scott Gamble*

A covered ASP system called AC Composter was introduced to the composting marketplace in the mid-2000s. The system used negative ASP systems but incorporates a heavy-duty, impermeable tarp that has dozens of large perforations air can flow into.

Another type of covered ASP, which entails micro-porous covers, was first used in Europe, and was introduced to the North American market in the late 1990s. The emergence of this covered ASP system spurred the development of additional covered systems, and renewed interest in the use of various high-tech fabrics to cover outdoor composting systems.

These compost covers rely on a micro-porous membrane sandwiched between protective layers in the tarp. The membrane allows gases to pass through, but not liquids. The operational theory is that most of the intermediate odorous compounds formed during composting remain in the liquid phase. These compounds do not pass through the membrane; instead, they remain in the compost pile and break down as the composting process continues.

The microporous covered ASP System is based on a positive ASP composting system. Depending upon the installation, it uses in-ground aeration trenches or aboveground aeration piping to push air through the composting pile. The aeration fan is controlled by temperature and oxygen sensors via a control computer. Once the compost pile is built, it is covered by a large semi-membrane tarp that measures up to 10 m wide and 50 m long. The micro-porous membrane within the tarp helps to treat odorous process air as it diffuses through the tarp.

Although covers on these various systems can be placed manually, some vendors provide mechanical winders. Weights (for example, sandbags, tires, or water-filled hoses) are used around the perimeter of the piles to seal the edges of the tarp on the ground and prevent process air from short-circuiting (taking the path of least resistance out of the pile).

Typical residence times are 3 to 8 weeks, followed by a period of curing to produce finished compost.



**Photo 3.15. Mobile tarp winder used to place and remove compost covers**

*Source: CH2M*

### 3.2.2.3 Channel System

A channel composting system is like a turned windrow sandwiched between two long, parallel concrete walls. The walls are typically up to 3 m high, and between 3 and 6 m apart. Unlike outdoor turned windrows, which form a natural triangular cross-section, the compost fills the rectangular space between the walls, allowing for more efficient use of space.

Operationally, feedstocks are mixed with amendments, and the combined material is placed in the receiving end of the channel. The materials are then moved down the length of the channel by a specialized turning machine. The turning machine rides along the tops of the concrete walls, and has either an inclined conveyor, augers, or drum-mounted flails that extend down into the material. Every time the turner passes down the channel, materials are physically lifted and moved 3 to 4.5 m down the length of the channel. As the turning machine makes repeated passes down the channel over time, it gradually moves the material from the receiving to the discharge end. Normally, one turning machine is used to service multiple channels, and is moved between channels using a carriage system at the discharge end of the channels.

Residence time of materials in the channels is typically between 1 and 4 weeks. The system is normally designed so the active composting process is almost complete by the time that the compost is discharged from the end of the channel. At the end of the active composting period, the treated material is typically placed in outdoor windrows to cure.

A forced aeration system in the floor of the channel, similar to that used with ASP systems, is used to provide oxygen and manage temperatures. Positive aeration systems are most commonly used for channel systems.

### 3.2.2.4 Turned and Aerated Mass Bed

The turned mass bed system previously described in Section 3.2.1 can be improved by providing aeration to maintain oxygen concentrations and temperatures. The system can also be enclosed in a building which allows for more control over odours and other nuisances.

Aerated turned mass bed systems are becoming more common due to their space efficiency and process control. For many years, facilities were limited to the Seattle, Washington area. More recently, large-scale facilities have been constructed in British Columbia, Oregon, and Arizona.



**Photo 3.16. Channel composting system**

*Source: Scott Gamble*

Residence times are normally 3 to 6 weeks, followed by a period of curing to produce finished compost.



**Photo 3.17. Doppstadt mass bed compost turner**

*Source: Ecoverse*



**Photo 3.18. Vermeer mass bed turner operating inside a building**

*Source: Scott Gamble*

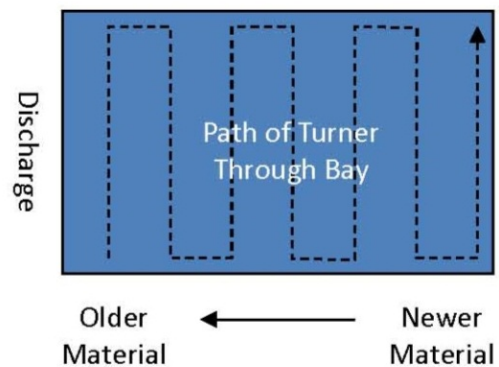
### 3.2.2.5 Agitated Bed

An agitated bed composting system is similar to a turned mass bed system, except it uses more automation. These types of systems are best for larger installations handling a lot of material.

The system consists of a large bed of composting material enclosed within a three- or four-sided bay. Perimeter walls around the bay allow for material depths of up to 3 m. The bay is equipped with an aeration system in the floor, similar to that used with ASP systems. Both positive and negative aeration can be used, but negative aeration is more common in North American installations.

Material in the bay is turned every 1 to 2 days by an automated system. The turner has an auger or paddle suspended from a bridge crane that spans the composting bay. The movement of the turner along the bridge crane, combined with the bridge crane's ability to travel up and down the length of the bay, lets the turning device access all areas of the bay.

Operationally, materials are placed along the receiving side of the bay using front-end loaders or conveyor systems. The materials are then moved across the bay by the turner, which follows an S-like path from the bay's discharge end to its receiving end. As the turner makes a lateral pass



**Figure 3.3. Schematic Showing Turner Movement and Material Flow in an Agitated Bay Composting System**

across the bay, the augers or flails physically lift material and move it towards the discharge end. Over time, as the turner makes repeated passes through the bay, the fresh material moves completely across the bay to the discharge end and is removed from the bay using front-end loaders or conveyors.

Residence time of materials in the bay is typically around 3 to 4 weeks. The system is normally designed so the active composting process is almost complete by the time the waste is discharged from the bed. The discharged materials are typically placed in outdoor windrows to complete the curing process.



**Photo 3.19. Agitated bay system in Lunenburg, NS viewed from discharge end of bay**

*Source: Scott Gamble*



**Photo 3.20. Bridge crane and suspended auger turning mechanism in Edmonton, AB viewed from discharge side of bay**

*Source: CH2M*

### 3.2.2.6 Static Containerized Systems

Static containerized systems are a type of aerated system that use one or more discrete composting vessels. These containers are very similar to the 30 m<sup>3</sup> (40 yd<sup>3</sup>) roll-off containers used in North America for handling commercial solid wastes. The size of the individual containers makes them portable, so they can be moved around the facility. They are also modular, as additional containers can be added as more capacity is required.

The containers are filled through sealable doors in the rear or roof of the container. Once filled, the



**Photo 3.21. Static container composting system**

*Source: Scott Gamble*

containers are connected to a stationary aeration system can provide air to multiple bins. Air exhausted from the vessels may be passed through a treatment system to reduce odours. As there is no agitation of the feedstock once it is loaded in the container, care must be taken to mix and homogenize it as much as possible before placement to keep air from short-circuiting.

After 2 to 4 weeks of composting, the containers are emptied by hoisting them onto a roll-off truck. The material is then tipped out the rear doors, much like a dump truck. This same truck is used to move empty and full containers around the composting site.

The material discharged from the systems must be further cured and matured before being used as a soil amendment. The curing time can take several weeks to several months, depending on the material being processed, the level of management, and external conditions.

### 3.2.2.7 Agitated Container and Vessel Systems

Agitated container and vessel systems are usually stationary and operate on a continuous feed basis rather than a batch basis. Like static containers, agitated container and vessel systems have smaller capacities and are modular. This makes them well-suited for facilities with smaller amounts of feedstock, or facilities that will be expanded over time.

Photo 3.22 shows a stationary, container-type system that relies on a moving floor system to slowly walk materials from the unit's inlet end to its discharge end. Parameters like temperature, moisture, and oxygen levels are monitored throughout the process. One or more sets of spinners are located along the length of the unit to agitate materials and break up clumps, and water can be added at these points also.

These agitated container systems are available in several sizes, from 450 kilograms (kg) per day, to several tpd, and additional processing capacity can be added by using a few units in parallel. The

size of the units is based on capacity; smaller units can fit inside a single parking stall, while larger units can be 3 to 5 m wide and be longer than 7 m. Installations of this system are



**Photo 3.22. Agitated container system composting system**

*Source: Scott Gamble*



commonly designed with a residence time of 14 days; however, longer residence times are possible by lengthening the unit.

Photo 3.23 shows an agitated container system that employs a continuous flow system that is similar to the Agitated container system shown in Photo 3.22 in that feedstocks are placed in one end, and stabilized compost is removed from the other end. The difference between the two systems is that rather than a moving floor, the agitated container system in Photo 3.23 uses an auger that runs along the length of the vessel to move materials towards the unit's discharge end.

The auger is driven by a motor and gearbox situated outside of the processing chamber, so they are easy to get to for maintenance.

The agitated container system in Photo 3.23 is available in four sizes, with capacities ranging from 500 kg per day to 11.5 tpd. Higher capacities can be obtained by operating multiple units in parallel. The smallest unit is approximately 8 m long and 1.5 m wide, while the largest unit is almost 22 m long and 5 m wide.



**Photo 3.23. Agitated container system**

*Source: CH2M*

### 3.2.2.8 Tunnel Composting Systems

Tunnel composting systems are provided by several vendors, including Gicom, ECS, Christiaens, and Herhoff. The technology is similar to a static container system, except on a larger scale.

A typical tunnel composter uses a positively aerated composting system with below-floor aeration pipes. The aeration floor and the composting pile are housed completely within a cast-in-place concrete enclosure. These enclosures are 4 – 6 m wide, 20 – 30 m long, and 6 m high; and are designed to allow front-end loaders to drive in and out of them to load and remove materials. A custom-designed door system is used to seal the front of the composting tunnel. These doors are slid manually and laterally on tracks (similar to a barn door) or are hinged and operated using hydraulics. Locking mechanisms and rubber door gaskets are used to keep the tunnel sealed while in use.



**Photo 3.24. Doors on tunnel composting system**

*Source: CH2M*

Like other aerated systems, residence times are typically between 2 and 4 weeks, and further curing of the compost is needed before it can be used.

Since there is no agitation of material within a tunnel, care must be taken with mixing and homogenizing the feedstock before its placement to minimize short-circuiting of the airflow fed into it.



**Photo 3.25. Interior view of tunnel composting system**

*Source: Scott Gamble*

### 3.2.2.9 Large-Scale Rotating Drum Systems

Large-scale horizontal rotating drum composting systems were developed in Denmark in the 1930s.

The first commercial-scale drum composting facility in North America was constructed in Big Sandy, Texas in the early 1970s. Other facilities were built in Oregon, Florida, Arizona, Tennessee, Georgia, Massachusetts, Alberta, and Quebec. Applications in North America have, for the most part, been limited to composting of mixed municipal solid waste (MSW).



**Photo 3.26. Large-scale drum composting system**

*Source: Scott Gamble*

Large-scale drum systems closely resemble cement kilns; the drums are usually 2 to 4 meters in diameter, and 21 to 73 meters long. The drums are positioned on a slight incline (less than 5%) and continuously rotate at a very slow speed (for example, 0.5 to 1 revolution per minute). The combination of the incline and the rotation causes material introduced into the drum's upper end to travel to the lower end, where it is removed through doors in the drum's shell or end wall. The shell and end walls of the drums are constructed of steel that, in some locations, is up to 100 mm thick.

The residence time of materials in the large-scale drums varies, but is usually between 1 and 3 days. Some systems use internal baffles to divide the drum into two or more compartments, allowing a lot of control over the flow of materials through the drum. Large drum systems are usually only used to initiate the composting process and must be accompanied by an additional technology to complete the active composting stage.

### 3.2.2.10 Small-scale Rotating Drum Systems

Several small-scale horizontal rotating drums systems have been developed during the past decade, modelled on the large-scale drum systems were established in the 1990s for composting mixed-municipal solid waste.

The small-scale systems use a steel drum with a diameter of 1.5 – 4.5 m, and a length of up to 10 m. The drums are positioned on a slight incline (less than 5%), so that gravity assists material injected into the drum's upper end in travelling to the lower end, where it is removed. Depending on the size of the drums, they are driven by large ring-gears, rubber trunions, or sprockets and chains.

Residence times of up to 7 days are common for drum systems. Following this, additional composting and curing is needed.



**Photo 3.27. Small-scale drum composting system**

Source: CH2M

**Table 3.2. Composting Technology – Advantages and Disadvantages**

Technology	Advantages	Disadvantages
Static Pile	<ul style="list-style-type: none"> <li>• Low capital and operating costs</li> <li>• Piles do not need frequent turning (low equipment and staffing requirements)</li> <li>• Works best when feedstock contains large amounts of wood chips or bark</li> <li>• No electric power needed</li> </ul>	<ul style="list-style-type: none"> <li>• Large area required</li> <li>• No means of controlling odours, which may drive a need for larger buffer areas around the site</li> <li>• Lower ability to manage pile moisture</li> <li>• Spontaneous combustion is more likely</li> <li>• Slow decomposition rate</li> <li>• Exposure to rain, wind, and cold can be problematic</li> </ul>
Passively-Aerated Pile	<ul style="list-style-type: none"> <li>• Same as static pile technology</li> </ul>	<ul style="list-style-type: none"> <li>• Same as static pile technology</li> <li>• Piles can be awkward to construct</li> </ul>
Windrow	<ul style="list-style-type: none"> <li>• Can handle feedstocks with lower Carbon to Nitrogen (C:N) ratios or free air space than static piles</li> <li>• Relatively-low capital costs and low technology requirements (windrow turners, front-end loaders, or farm equipment will suffice)</li> <li>• Relatively low operating costs</li> <li>• No electric power needed</li> <li>• Large amount of practical experience</li> </ul>	<ul style="list-style-type: none"> <li>• Large area required</li> <li>• More labour-intensive than static piles, particularly for feedstocks with low C:N ratio or free air space</li> <li>• No odour control, which may require larger buffer area between site and neighbors</li> <li>• More challenges to overcome if food waste or biosolids are included</li> <li>• Exposure to rain, wind, and cold can be problematic</li> </ul>

**Table 3.2. Composting Technology – Advantages and Disadvantages**

Technology	Advantages	Disadvantages
Aerated Static Pile	<ul style="list-style-type: none"> <li>• Forced aeration reduces land requirements</li> <li>• Use of negative aeration can help avoid odour problems</li> <li>• Moderate capital and operating costs</li> <li>• Smaller surface area relative to windrows reduces impacts of cold weather and rain</li> <li>• Lower operating costs and shorter processing times</li> <li>• Material handling requirements are less than windrow system (no turning required)</li> <li>• Lower risk of spontaneous combustion</li> </ul>	<ul style="list-style-type: none"> <li>• Slightly higher capital cost for forced-aeration equipment</li> <li>• No means of controlling odours</li> <li>• Over-aeration can remove moisture</li> <li>• Feedstock pre-processing requires a higher degree of care; feedstocks must be well mixed and properly sized and moistened</li> <li>• More operator skill required to manage aeration systems</li> <li>• Aeration systems generally require three-phase electrical supply</li> </ul>
Turned Mass Bed	<ul style="list-style-type: none"> <li>• Small surface area/volume improves heat retention</li> <li>• Efficient use of available space</li> <li>• Efficient material handling</li> <li>• Forced aeration can be used to reduce processing times and avoid odour problems</li> </ul>	<ul style="list-style-type: none"> <li>• Specialized windrow turner has higher capital cost than towed and smaller straddle-type turners</li> <li>• Capital cost is increased if forced-aeration system is used</li> <li>• Combination of over-aeration and turning can lead to excessive moisture loss from the piles</li> </ul>
Channel and Agitated Bed (enclosed)	<ul style="list-style-type: none"> <li>• Moderate capital and operating costs</li> <li>• Usually in buildings, so better odour control</li> <li>• Lower space requirements than windrow</li> <li>• Automation reduces labour and material handling requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Lacks flexibility in dealing with variable feedstock volumes</li> <li>• Large volume of foul process air to be managed</li> <li>• Operating and maintenance expertise required</li> <li>• Higher capital/operating costs than windrow</li> </ul>
Tunnel	<ul style="list-style-type: none"> <li>• Design of tunnel system leads to small headspace and high degree of odour control</li> <li>• Process air is contained within the tunnel which reduces building corrosion</li> </ul>	<ul style="list-style-type: none"> <li>• Moderate to high capital costs</li> <li>• Feedstock pre-processing requires a higher degree of care; feedstocks must be well mixed and properly sized and moistened</li> <li>• Less opportunity for automation</li> <li>• Specific operating protocols, PPE, and alarm systems may be necessary if the tunnels are designated as confined spaces</li> </ul>
Containerized	<ul style="list-style-type: none"> <li>• High degree of odour control</li> <li>• Low space requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Operating and maintenance expertise required</li> <li>• Higher capital and operating costs.</li> <li>• Generally has shorter residence time (1 to 4 weeks) and used in combination with another composting method/technology.</li> </ul>

## 3.3 Material Handling Equipment

Composting, regardless of technology, relies on equipment to handle materials, mix the feedstock, screen the product, and move the material through the process. Large volumes of material must be frequently moved, whether the material is in the feedstock preparation, composting, screening, curing, or product storage area. Because of this, a composting facility can only be as productive as its material handling equipment.



**Photo 3.28. Skid-steer loader**  
*Source: Scott Gamble*

### 3.3.1 Front-end Loaders

Front-end loaders are the workhorse of the composting industry. They are used for moving feedstocks, loading vessels or building windrows, turning and agitating piles, screening, and loading finished product on trucks.

Front-end loaders are available in many sizes. Where possible, front-end loaders should be closely matched, in size and operation, to their duties and other equipment at the facility. Waiting for hoppers or conveyors to unload, with an idling machine and operator, is inefficient and increases operating costs.

Ideally, the composting facility should be laid out with the size of front-end loader in mind, so space constraints and material-handling bottlenecks can be avoided. For example, receiving areas should have enough maneuvering room for the equipment even when waste is present.

Facility designers should also consider the surface front-end loaders are working on. A surface with uneven ground, bumps, or grade changes will cause a front-end loader bucket to spill as it carries its load. Not only does this detract from appearances, it decreases productivity. The spillage also causes lost product, mud accumulation, and dust generation.

Aside from selecting the size of the front-end loader, the size and style of bucket used should be considered carefully.

Front-end loaders equipped with oversized buckets can improve efficiency and save money in the composting and curing operations. Oversized buckets can usually carry double the volume of the lighter materials found in composting operations compared to the typical sand and gravel operations where the densities of the materials are much greater.

If speed is the highest priority and the extra height is not an issue, an oversized bucket is the most productive option. However, if the machine is also used to handle soil, rock, sand, or other heavy materials, it can be easily overloaded. Both operator training and signage on the bucket and in the cab should be mandatory. Training and signage will prevent unnecessary risks to people and machinery.

Roll-out buckets are becoming more popular in the topsoil and composting industries. Designed with a hinge at its front edge, the bucket can pivot forward from a level position to unload. The higher lifting height that results allows for loading of screens, grinders, and trailers with side walls up to 4 metres high without the use of a ramp. This greatly improves loading efficiency by reducing the loading time for each operation. Another advantage is that it allows storage piles to be stacked higher, saving floor space on the site.

To accommodate a roll-out bucket, the loader needs to be equipped with a third hydraulic valve to operate the additional hydraulic cylinder. Additional counter-weights are also required to make up for the additional weight placed on the front of the loader. Equipment operators will also require training for proper operation of a rollout bucket. If the operator does not have good control of the bucket as it reaches the end of its stroke, damage can be done to the bucket cylinder. Some bucket designs also require more maintenance in high-stress areas. These are minor concerns when compared to the overall productivity gains.

There are also various equipment attachments that can provide advantages to some applications. In areas where there is tight clearance and little room for loaders to manoeuvre, side- and ram-discharge buckets can improve machine performance. Side-



**Photo 3.29. Roll-out bucket on a front-end loader**  
Source: CH2M



**Photo 3.30. Front-end loader with an oversized bucket**  
Source: CH2M

discharge buckets scoop materials normally but discharge to the side by tipping off a hinge pin on the left or right. If a loader is retrofitted with this type of attachment, some drawbacks must be considered, including changes to the hydraulic system, uneven stresses on the loader, a greater risk of stress cracks to the bucket, and possibly more maintenance, especially to hinge pins and bushings. Ram-discharge buckets are well-suited in areas with low headroom, as the bucket does not need to tip to dump.

Another option that may work is a multipurpose or four-in-one bucket. This type of bucket has some additional vertical reach, particularly for loading trucks. It has a jaw assembly that allows the bucket to unload without rolling the bucket downward as is typical with a general purpose or light material bucket. It splits open to dump without actually rolling downward. Visibility is different for this type of bucket.

Other loader attachments that expand the capabilities of a loader include various teeth, grapples, clams, and pallet forks. ALLU offers an attachment with a series of rotating disks at the bottom of the bucket (without a solid bottom). The discs are hydraulically driven and can serve several functions, including screening, shredding, and pulverizing soft materials.

These specialty buckets are typically heavier due to the ram and hydraulics, which will significantly reduce the payload size of the bucket in comparison to conventional tip discharge buckets.



**Photo 3.31. ALLU bucket on a front-end loader**

*Source: CH2M*

### 3.3.2 Grinders and Shredders

There are many types of grinders and shredders available. The most commonly used types in the composting industry are tub grinders, horizontal grinders, slow-speed shredders, and chippers. They are typically used to reduce the brush brought in with yard waste feedstocks or for producing chips from wood waste stockpiles for use as a carbon amendment.

Tub grinders use a rotating tub to move material into a grinding chamber. The material is then broken down until it can pass through a discharge screen, or grating. Once through, the grating the material is moved up an incline conveyor and is discharged onto a pile.

Tub grinders are very mobile and can be relocated within a composting facility very easily.

Horizontal grinders use a metal chain conveyor built into the bottom of a loading deck to move material towards a rotating drum. Numerous teeth, knives, or both are mounted on the drum, which grabs the materials and forces them into the unit's grinding chamber. Inside, the material is reduced in size until it passes through grates and onto a discharge conveyor.

Horizontal grinders have an inherent damage avoidance advantage over tub grinders when grinding wood from stockpiles contaminated with metal. With a tub grinder, the front-end loader or excavator operator dropping material into the top of the tub may not be able to see any metal pieces already mixed into the bucket load. Conversely, a ground spotter may be able to stop and pick off any large pieces of metal dropped onto the conveyor feeding the cutting mill of a horizontal grinder before they get there.



**Photo 3.32. Horizontal grinder**  
Source: CH2M

Slow-speed shredders use two counter-rotating shafts that have discs or teeth welded onto the shafts. As the discs rotate, the teeth grab and pull the material down through the tight space between the discs where the material is cut or sheared into smaller pieces. Single shaft versions of these shredders are also available; rather than another rotating shaft with discs, the single shaft or disc cutter forces material against and through a metal “comb” fixed to the shredder's frame.

Chippers work by slicing materials into smaller chips, and are mainly used for tree trimmings and branches. Drum-style chippers have a horizontal infeed chute that sits a few feet off the ground. These chippers are manually fed, and are commonly used by tree service companies and public works departments. A drum inside the unit is mounted horizontally in the feed chute, and serves as a feed mechanism, as well as a cutter. Chips exit through an output chute, usually into a container, truck bed or pile.



**Photo 3.33. Shear shredder**  
Source: CH2M

Disc-style chippers have cutting blades mounted on a rotating disc oriented perpendicular to the material being feed through the unit's infeed chute. The blades cut the wood into chips, which are ejected out of the rear of the unit.



### 3.3.3 Mixing Equipment

Several types of mixers are available and suitable for compost feedstock blending. Compost mixers generally consist of a hopper with a mixing mechanism mounted on a shaft. Mixers are generally classified as horizontal or vertical mixers, depending on the orientation of the mixing shaft.

Mixing equipment can be further classified as batch or continuous flow. Batch mixers operate by receiving measured volumes of feedstocks and amendments according to the mix recipe. The feedstock materials are then blended for a period of 2 – 4 minutes, which is usually long enough to provide a thorough blend. Once mixed, a door on the back or side of the mixing vessel opens, and the action of the mixing device (that is, augers, paddles) discharges the material from the vessel into a pile or onto a conveying system.

Continuous flow mixers rely on a constant, steady flow of feedstock materials. The materials are introduced to the mixing chamber at the upstream end, advance through the machine through the action of the mixing devices, and are discharged at the downstream end into a pile or onto a conveying system.

Continuous mixers generally come in three basic varieties: pug mills, plow blenders, and screw conveyors. Pug mills and plow blenders are similar in construction materials and operation. They differ in that pug mills use rotating shafts with paddles that cut the feedstock materials, and plow blenders use rotating shafts with plow-shaped blending elements that lift and roll the materials. Both methods can be highly effective at mixing different types of materials.

### 3.3.4 Screens

Screens are used to separate materials based on particle size. They are used extensively in the composting industry to remove rocks, plastic, large wood particles, and other unwanted materials from finished compost. Screens are also used in some facilities during the preprocessing stage to remove contaminants and plastics from feedstocks prior to mixing and



**Photo 3.34. Horizontal auger mixer**  
Source: CH2M



**Photo 3.35. Loading a vertical auger mixer**  
Source: CH2M

composting. Material that passes through a screen is commonly referred to as the “unders,” while the larger material that does not pass through are known as the “overs.”

Screens can be stationary (that is, permanently mounted at one location) or mobile. Mobile screening systems are more common at small and mid-size composting facilities, and can be towed from site to site. Stationary systems are more common at larger composting facilities.

The two common screen types used in composting operations are trommel and star screens. Other screening systems are available, and are used extensively in gravel and mining operations. However, these have not been found to perform well with organic feedstocks and compost, which tends to be wetter and more cohesive (“stickier”).

Trommel screens consist of a horizontal rotating drum that screens are mounted around. Material is introduced to the inside of the drum at one end, and undersized material falls through the screens. Oversized material continues to travel through the drum and exits the opposite end. The drum rotates, which agitates the material and improves screen performance, and also helps to break up clumps. The drum is normally inclined to help oversized material work its way to the discharge end of the drum.

Star screens consist of a bank of rotating shafts fitted with rubber stars. The shafts and stars are spaced apart to allow material to pass through. The rotating stars convey any material down through the stars, and oversized material flows to the end of the screen deck.

When selecting a screen, it is important to consider the size of the screen openings. For finished compost, screen openings are generally in the range of  $\frac{1}{4}$  to  $\frac{3}{4}$  inches, depending on the intended use of the compost (for example, topdressing, erosion control). Many equipment manufacturers make trommel screens that allow the drum to be removed and replaced very



**Photo 3.36. Front-end loader feeding a portable trommel screen**  
*Source: Scott Gamble*



**Photo 3.37. Top view of star screen deck and side view of individual star**  
*Source: CH2M*

quickly (that is, in 15 to 30 minutes). Once removed, the screen panels can be replaced with others that have larger or smaller openings.

However, replacing the panels can be an awkward and time-consuming task, taking the better part of a day complete. To minimize the amount of downtime, some composting operations have two or more drums that are prefitted with different sized screens. This is particularly beneficial at operations that produce different grades of finished compost.



**Photo 3.38. Clogging of trommel screen**  
Source: CH2M

Changing the screening deck in a star screen is not possible. However, star screens provide a bit more flexibility in producing different sized finished product. This is achieved by changing the rotational speed of the shafts where the screening stars are mounted; a slower speed allows larger particles to fall through, creating a slightly coarser product. Star screens can also process material with a slightly higher moisture content (for example, 2 to 5% higher) than trommel or deck screens, which has helped them to gain increasing popularity in the composting industry. Operator skill, experience, and potentially some trial and error, is required to produce a uniformly sized product with a star screen, as the same settings on the unit will produce different results with batches of compost at different moisture contents.

Another practice used to produce compost products of differing sizes is to operate two or more screening units in series. In this case, the undersized material from the first screen is fed directly into the second screening unit for further processing.

The efficiency of screening equipment decreases as the moisture content of the compost being screened increases. If the compost is too wet, it will stick to the screen mesh and block the openings. This is also called “blinding”.

When screening compost to 12 mm or smaller, 40% to 45% is the preferred range. Moisture can be increased to the 50% range when using coarser screens (e.g. 20 to 30 mm).

### 3.3.5 Belt Conveyors

Belt conveyors are heavy-duty horizontal or inclined conveyors capable of transporting hundreds of tonnes of material per hour over long distances. In its simplest form, the belt conveyor consists of a head or drive pulley, a take-up pulley, an endless belt, and carrying and return idlers.

Conveyors are used instead of hauling materials from point to point with a front-end loader or trucks. Belt conveyors are very useful in composting facilities that have operations spread over large areas, or have processing equipment that is permanently located. Most often, they are used in association with stationary screening systems.



**Photo 3.39. Using horizontal conveyors to move material over longer distances can reduce operating costs compared to using front-end loaders**

*Source: CH2M*

### 3.3.6 Stacking Conveyors

Stacking conveyors or “stackers” are a cost-effective way to build finished product and amendment stockpiles. A stacker allows material to be placed into cone-shaped piles that are much higher than the piles made by the conventional discharge conveyor on a mobile screen or grinder, or with a front-end loader.

The stacking conveyors used at composting sites are normally specified by the length of the conveyor belt in imperial units. 60, 80 or 100-foot units are the most common sizes. This allows for pile heights that are, respectfully, of 8.5 m, 11.2 m and 13.7 m (28 ft, 37 ft, and 45 ft) high.



**Photo 3.40. Radial stacking conveyor used to make a large linear stockpile**

*Source: Scott Gamble*



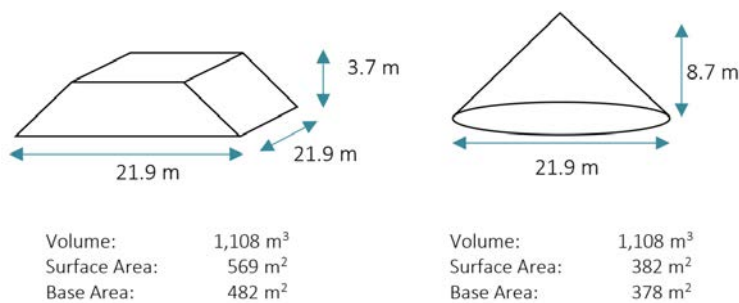
**Photo 3.41. Stacking conveyors allow tall piles to be made, without having to drive equipment on top of the material**

*Source: Scott Gamble*

More material can be stored in a tall conical pile, compared to a shorter pile with the same footprint. Using taller piles also reduces the surface area to volume ratio of the stored material.

The reduced surface area means less precipitation is absorbed into the material, or less moisture is lost to evaporation.

A radial stacking conveyor is a type of stacker that can pivot about its lower end. Once the stockpile reaches its maximum height, and operator manually rotates the conveyor so that additional material can be added onto the shoulder of the original pile. The end result is a windrow of material that is laid out in a semi-circular pattern.



**Figure 3.4. Storing finished compost in a conical stockpile built with a stacking conveyor results in less surface area than a stockpile with the same volume that is built with a front-end loader.**

# Chapter 4 – Facility Operation and Management

## 4.1 Learning Objectives

This chapter focusses on the operations of composting facilities in Alberta. Given the variety of composting methods and technologies available and the differences in feedstocks, it is very difficult to develop a full list of operating requirements that would apply to all composting facilities in the province. Having said that, all facilities should be operated to:

- Be safe
- Protect the environment
- Prevent odours and other nuisance conditions
- Comply with all relevant regulations
- Be well-maintained

To achieve these goals, an operations plan that reflects industry best practices and site-specific requirements should be developed for each facility.

In this chapter, you will learn about:

- The environmental risks composting facilities pose to air, land, and water
- Facility operation plans
- Feedstock receiving and preparation
- Composting and curing
- Product sampling, testing, and labelling
- Product handling, storage, and uses
- Monitoring tools and practices
- Nuisance management, including odours, vectors, noise, and dust
- Managing process water and stormwater
- Record keeping and reporting
- Weather issues, including how to deal with rain, wind, cold, and severe weather
- Equipment maintenance best practices

## 4.2 Understanding the Design Plan, Processing Capacity, and Permitted Capacity

Composting facilities are sited and designed by engineers to meet the standards set by AEP, and to incorporate industry best practices for controlling leachate, odours, and nuisances.

Construction of the facility should be carefully managed to meet the design, as outlined in the design plan, and follow specifications. Since the facility must also be operated in accordance with the design plan, it is important that managers and operators work with the engineer to understand the facility's design and its limitations. Deviating from the design plan can result in:

- Non-compliance with regulations
- Potential environmental impacts
- Odours or other nuisance impacts
- Strained relationships with neighbours

If departures from the original design plan or changes to the design of the facility are considered or needed, they should be reviewed by the original engineer or another qualified engineer before being implemented. This includes changes to the following:

- Types of feedstocks accepted
- Material residence times in active composting and curing processes
- Size of compost piles and stockpiles
- Mechanical aeration systems

Depending on the nature of change, authorization by AEP may also be necessary. A key component of the facility's design plan that needs to be understood by the facility's operators is its **processing capacity**. A typical composting facility has space for:

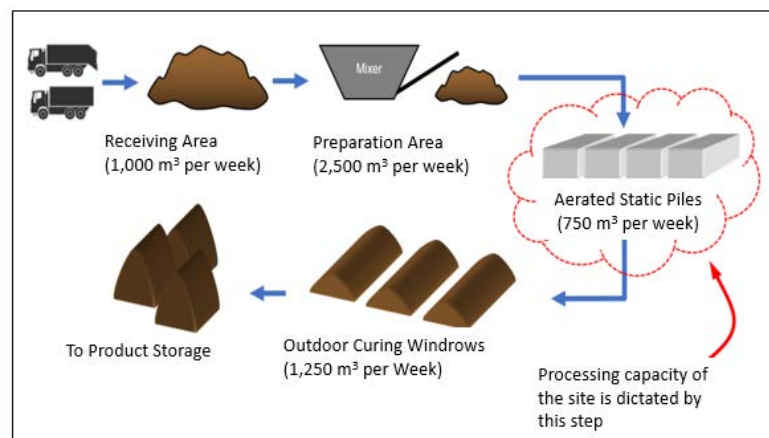
- Feedstock receiving and preparation
- Active composting
- Curing
- Finished product screening
- Storage

Material can flow through each of these processing areas at a certain rate, which is dictated by:

- The method of composting used
- Capabilities of processing equipment
- Size of compost piles and stockpiles
- How long materials need to remain in place for biological processes to be completed

The processing area with the lowest processing rate dictates the maximum rate at which material can flow through the entire site. Processing rates, and space requirements and equipment sizes by extension, are identified by a process flow diagram (PFD) and a mass and volume balance that are prepared by the engineer as part of the design process. The maximum processing rate (for example, usually expressed as volume processed on a per day or per week basis) can be calculated to determine the facility's annual processing capacity. For example, the annual processing capacity of the facility depicted by the PFD in Figure 4.1 would be:

$$750 \text{ m}^3 \text{ per week} \times 52 \text{ weeks per year} = 39,000 \text{ m}^3 \text{ per year.}$$



**Figure 4.1. Process Flow Diagram for a Composting Facility Showing Capacity of Each Operating Area**

### 4.2.1 Discrepancies between Processing Capacity and Permitted Capacity

A critical issue that owners and operators of small and mid-sized composting facilities need to understand is that their processing capacity (per the design plan) may be different than the **permitted capacity** stated in their authorization document from AEP.

The facility's processing capacity could be less than its permitted capacity. This is often the case when a composting facility is authorized by AEP through the registration process described in Chapter 6. Historically, composting facility registration documents issued by AEP were written with permitted capacities of 20,000 tonnes per year (tpy), rather than the actual processing capacity of the facility. AEP did this to streamline the registration process, and to reduce the need for a subsequent re-registration of facilities that increase their processing capacity. **Regardless**



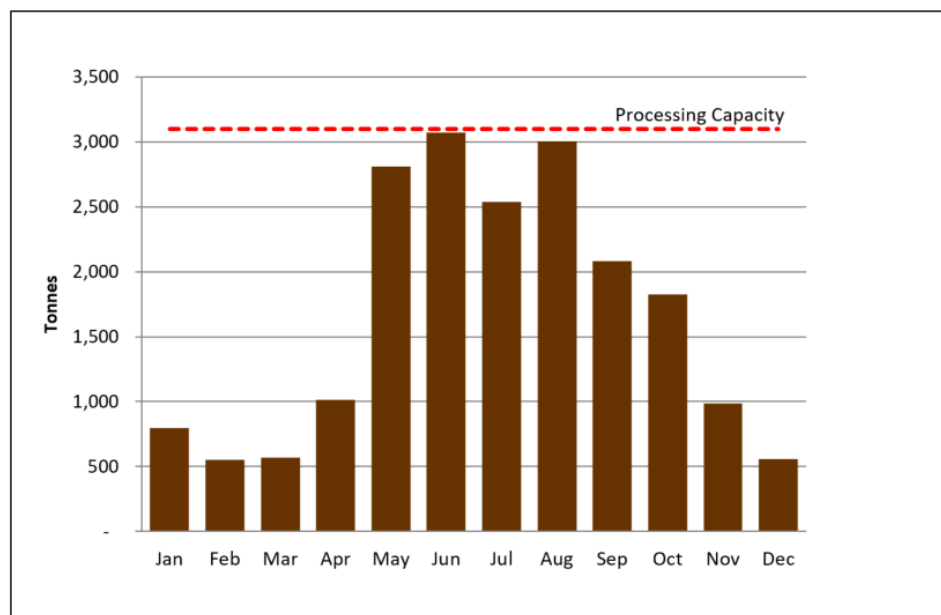
**of the permitted capacity in the registration document, the Code of Practice still requires that the facility not accept more materials than allowed for in its design plan.**

If the operator in this situation does not understand that they are limited by the facility's design plan and processing capacity, they could accidentally accept more material than their site can handle. Overloading the site can lead to several problems, including:

- Backlogs of unprocessed feedstocks and excessive compost pile heights (conditions that commonly lead to offensive odours)
- Attraction of birds and rodents
- Increased risk of fires

A facility's processing capacity can also be higher than its permitted capacity. This is commonly because of the design practices used to account for seasonal changes in the quantities of feedstocks accepted: composting facilities and systems are usually sized to handle the estimated peak monthly or peak weekly quantities.

Consider the example of a facility that is authorized by AEP to accept and process 20,000 tonnes of food waste, L&YW, and amendments that are distributed on a month-by-month basis, as shown on Figure 4.2. For the peak deliveries that occur in June, the facility would need to be designed with a processing capacity of 3,000 tonnes per month (tpm). Technically, this facility



**Figure 4.2. Example of Month-by-Month Processing Tonnages**

could handle that amount of material every month, so its annual processing capacity would be 36,000 tpy.

Due to the seasonal changes shown on Figure 4.2, the facility in this example would operate at only a fraction of its maximum capabilities in the winter months. If the operator decided to accept additional feedstocks to take advantage of the unused processing capacity during the winter, they would quickly exceed their permitted capacity, even though the facility is designed to handle the additional material. Exceeding the permitted capacity of 20,000 tpy for a registration compost facility will trigger an *Environmental Protection and Enhancement Act (EPEA)* approval. Thus, the facility will need an EPEA approval to operate at an annual processing capacity of 36,000 tpy.

## 4.2.2 Amendment Considerations

Many organic feedstocks are wet and not very porous, which can lead to odour and other problems if they are composted on their own. As outlined in Chapter 2, an amendment such as woodchips or oversized materials from the screening of finished compost is often added to the feedstocks to adjust the moisture content of the mixture, and to provide structure and free air space. In the case of food waste, biosolids, and some manures, the volume of amendment needed is usually two to four times the volume of the feedstock.

It is important to remember that AEP includes amendments accepted by a composting facility from offsite sources in all calculations of permitted capacity. Amendments that are screened out and re-used (that is, recycled) are not included in these calculations.

Operators must consider amendment requirements when interpreting processing capacities and permitted capacities, and whether they can accept feedstocks from new sources.

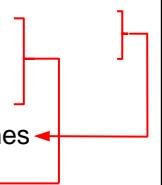
### How Amendments from Offsite Sources Affect Permitted Capacity Calculations.

Feedstocks accepted = 13,000 tonnes

Amendments from offsite sources = 5,000 tonnes

Amendments recycled within the site = 3,000 tonnes

**Permitted capacity = 18,000 tonnes**



**Figure 4.3. How Amendments from Offsite Sources Affect Calculation of Permitted Capacity**

## 4.2.3 Feedstock Type and Material Density Considerations

Permitted capacities of composting facilities are usually expressed in tonnes per year, and incoming feedstocks must be tracked to ensure the permitted capacity is not exceeded. However,

due to variations in the density and moisture content of feedstocks and amendments, it is easier and more appropriate to measure quantities on a volume basis once the materials are onsite. Volumes of composting piles, vessels and stockpiles are the basis by which engineers usually design each processing area.

To understand the impact of differing feedstocks and material densities, consider the example of a facility designed to process a maximum of 20,000 m<sup>3</sup> of feedstocks and amendments over the course of a year. As shown in the first row of Table 4.1, if the operator only filled this system with L&YW that has a density of 0.350 tonnes/m<sup>3</sup>, and needed no amendment because the L&YW had a balanced C:N ratio and enough free air space, the composting system could process 7,000 tonnes of L&YW during the year.<sup>1</sup>

However, if the operator accepted 7,000 tonnes of biosolids (density of 1.000 tonnes/m<sup>3</sup>), then 4,800 tonnes of woodchip amendment (density of 0.200 tonnes/m<sup>3</sup>) would need to be added to adjust the mixture's moisture content and free air space to acceptable levels (Row 2). The combined volume of biosolids and woodchips would be 31,000 m<sup>3</sup>, and the site would be exceeding its maximum processing capacity. To stay within the facility's 20,000 m<sup>3</sup> per year processing capacity, the operator would only be able to accept 4,500 tpy of biosolids and 3,100 tpy of amendment (Row 3).

**Table 4.1. Facility Capacity Example**

Feedstock	Amendment	Total Weight	Total Volume
7,000 tonnes of L&YW (÷ 0.35 tonne/m <sup>3</sup> = 20,000 m <sup>3</sup> )	None	7,000 tonnes	20,000 m <sup>3</sup>
7,000 tonnes of biosolids (÷ 1.0 tonnes/m <sup>3</sup> = 7,000 m <sup>3</sup> )	4,800 tonnes of woodchips (÷ 0.200 tonnes /m <sup>3</sup> = 24,000 m <sup>3</sup> )	11,800 tonnes	31,000 m <sup>3</sup>
4,500 tonnes of biosolids (÷ 1.0 tonnes/m <sup>3</sup> = 4,500 m <sup>3</sup> )	3,100 tonnes of woodchips (÷ 0.200 tonnes/m <sup>3</sup> = 15,500 m <sup>3</sup> )	7,600 tonnes	20,000 m <sup>3</sup>

<sup>1</sup> Formulas and additional examples for converting between mass and volume using density, and calculating feedstock and amendment ratios, are provided in Chapter 5.

## 4.3 Operations Plan

As previously mentioned, the composting facility must be operated in accordance with its design plan. The operational procedures required by the design, and the design's limitations, are captured in the operations plan. The operations plan is normally developed by the designer, with input from operations staff.

At a minimum, the operations plan needs to contain a description of the following:

- Sources and types of feedstock that can be accepted
- Acceptance procedures
- Procedures for feedstock preparation, aerating, and controlling moisture and temperatures in compost piles
- Plans for mitigating offensive odours and dusts

The operations plan also needs to contain an emergency response plan to deal with fires, environmental releases, and medical emergencies.

A more detailed operations plan based on best management practices (BMPs) is recommended and should contain:

- Prohibited waste handling procedures
- Site security and access control procedures
- Working surface maintenance program
- Liner maintenance program
- Process water management procedures
- Environmental monitoring program
- Compost quality monitoring plan
- Procedures for handling and disposal of residuals
- Contingency plans for reasonably foreseeable events
- Nuisance management plan
- Reporting procedures
- Composting process plan that includes:
  - Description of composting technology used
  - Procedures for maintaining aerobic conditions
  - Pathogens reduction plan
  - Composting temperature monitoring program
  - Quality assurance (QA) and quality control (QC) program
  - Procedures for curing compost to meet maturity requirements
  - Procedures for storage and management of final product
  - Procedures for preventing pathogen regrowth in final product

AEP recognizes that composting facilities will adapt and change over time, so it is expected that the operation plan will be a “living document” that will be reviewed and updated on a regular basis to incorporate changes in site practices, feedstocks, and technology. Any changes to the

operations plan must be included in the annual report prepared at the end of the year, as described in Section 4.28.

Changes made to the operations plan cannot conflict with the facility's design plan. If operations changes are required that result in conflicts, the changes should be reviewed by the original design engineer or another qualified engineer before being implemented. Depending on the nature of change, AEP authorization may also be necessary.

## 4.4 Feedstock Receiving, Inspection, and Storage

Feedstocks should be received in a designated area that is easily accessed and properly identified. This area is usually close to the entrance of the facility where the scale is located.

Ideally, the receiving area should have an asphalt or concrete surface that can withstand heavy truck traffic and be accessed during all weather conditions. Equally as important is the ability to remove feedstocks from the receiving area regularly, rather than allowing them to accumulate during poor weather conditions and cause odours or other nuisances.

If the unloading area does not have a solid working surface and is rutted or uneven, end dump trucks can tip over when they tip their boxes to unloaded. For safety reasons, end dump trucks should be kept at least 15 m from other vehicles and equipment while unloading.



**Photo 4.1. Bunkers for receiving and temporary storage of feedstocks**

*Source: CH2M*

It is generally recommended that areas frequented by customers be separated from other operating areas. Since customers are often not familiar with site practices and equipment, this separation helps to prevent injuries and accidents.

Traffic patterns to and from the receiving area should be established using signs, barricades, and traffic cones. One-way roads are best, but where this is not possible, it is preferable to route traffic in a counter-clockwise direction since this reduces the need for vehicles to cross in front of each other. During busy times, spotters may be needed to manage traffic.

Temporary and permanent signs used within the facility should have large text and use a minimal amount of writing so they are easy to read and understand. All signs should be constructed to the same standards and using the same style (for example, colours, fonts, size). Temporary signs (for example, hand-painted plywood) should be avoided, since they are often overlooked by customers, can cause confusion since they are not standardized, and they look unprofessional.

All signs should be regularly inspected for damage, cleanliness, and visibility. Signs should also be periodically checked to confirm their messages are still current.

The temporary storage area for incoming feedstocks should be large enough to hold the material delivered over a 1- to 3-day period. This allows for some flexibility to schedule day-to-day operations, or in the event of equipment breakdown. Storing feedstocks for more than a week is not recommended, and under normal practices, operators should try to process feedstocks on the same day they are received. Exceptions to these storage rules can be made for feedstocks that are very dry or have a high carbon content (e.g. leaves) and will not result in odour or other nuisance issues.

Stored feedstocks should always be staged in a “first-in, first-out” manner; that is, the material that has been stored the longest is accessible and can be removed first for processing.

It is a common practice at compost and other waste management facilities to inspect or screen materials for contaminants and unacceptable wastes as they are delivered. This often is done by the spotter who, in addition to directing traffic, watches materials as they are unloaded from delivery vehicles. Alternatively (or additionally), materials can be inspected by equipment operators as they are loaded into pre-processing equipment. However, this removes the ability to identify the source of the contaminant and work with the waste generator to eliminate contaminants in future loads.



**Photo 4.2. Manually inspecting feedstocks for contaminants**

*Source: CH2M*

When possible, deliveries containing unacceptable wastes should be rejected before being unloaded. If unacceptable wastes are unloaded or otherwise discovered, operators should segregate the waste from other feedstocks until it can be sorted or disposed of.

Unacceptable waste items include hazardous wastes and non-compostable wastes and debris that might impact the physical or chemical quality of the finished compost (for example, glass bottles, batteries). Operators should also be on the lookout for materials that could wrap around or damage equipment (for example, barbed wire, garden hoses), explode (for example, aerosol cans, propane cylinders), or that could be thrown by compost turners and become a dangerous projectile (for example, bricks, large rocks).

It may be useful to conduct random load inspections at larger composting facilities, or at facilities that accept feedstocks from many different sources. Random inspections can help identify and

divert prohibited or unacceptable wastes from the site, deter unscrupulous haulers, or help identify feedstock generators that need help with reducing contaminant levels in their feedstocks.

Staff doing random load inspections should take the following precautions:

- Notify other employees that a load inspection is taking place
- Isolate the load in an area that is away from traffic and other site operations
- Wear the proper personal protective equipment (PPE) (coveralls, safety boots, gloves, goggles)
- Document all actions and observations
- Be prepared to remove any hazardous or unacceptable waste to a safe area for later removal

All records of waste types observed during a random load inspection, including non-hazardous waste types, should be documented and maintained in the composting facility operating record. Photographs make a good record.

## 4.5 Feedstock Preparation

Depending on the feedstocks being processed and the composting method employed, feedstock preparation can consist of particle size reduction, screening, and/or blending.

As outlined in Chapter 2, particle size affects the composting process both by changing free air space, and by making more surface area available for biological action. Choosing the optimum particle size will depend on the composting technology, feedstock types, and the amendments used. By sizing feedstocks such as paper, tree branches, and cardboard to the right size, the composting process will be more efficient, and the material will require less handling.

The particle size of brush, branches, limbs, and tree trunks is adjusted by grinding the material before forming compost piles. Size reduction is normally done using tub grinders, horizontal grinders, or slow speed shredders.

Food wastes are typically mixed with amendments with a front-end loader or in a stationary mixer. This mixing process normally provides enough particle size reduction. However, food wastes with large amounts of cardboard may require more aggressive mixing, or grinding in a slow speed shredder.

It is generally easier to remove contaminants at the start of the composting process, before feedstocks are ground up or are adjusted for moisture content. Screening is sometimes used during pre-processing (before grinding or shredding) as a means of removing contaminants.

Feedstocks can be blended with amendments using equipment such as front-end loaders, manure spreaders, windrow turners, or horizontal or vertical mixers. Whatever the equipment and blending technique chosen, the goal should be to ensure that the final mixture of feedstocks and the amendments is as homogeneous as possible, and that moisture is evenly distributed. This will help to prevent pockets of varying biological activity within the material during the composting process.

When mixing materials with a front-end loader, a bed of amendment material is first laid out on the ground, and this is covered with the primary feedstocks. The materials are then mixed through a process of folding and back-blading the materials. This method of mixing relies greatly on the skill and experience of the equipment operator.

Mixing materials and forming windrows or piles using manure spreaders is common at smaller facilities and agricultural operations. The feedstock and the amendments are simply loaded into the manure spreader in the right amounts. The manure spreader is then taken to the site where the windrow or pile is to be formed, and the spreader is slowly pulled forward as it is unloaded to get the right pile height.

The preferred method when mixing with a windrow turner is to construct a windrow with alternating layers of feedstocks and amendments, beginning with a layer of amendment at the bottom. Once the windrow has been built to its full height, the windrow turner is used to mix and blend materials together. The windrow should be turned a minimum of two times for homogenization.



**Photo 4.3. Using a front-end loader to mix feedstocks and amendments**

*Source: CH2M*



**Photo 4.4. Mixing feedstocks and amendments with a manure spreader**

*Source: CH2M*



Like manure spreaders, horizontal and vertical mixers require that feedstock and amendments are loaded into the mixing hopper in the right amounts. Usually, the mixing paddles or augers are operating during the loading process. When the mixing process is completed, which usually takes 3 to 10 minutes, the material is discharged onto the ground via a conveyor belt. Mobile mixing units can also discharge materials directly into the composting windrow or pile.

Care must be taken when blending to not over-mix the materials, particularly when dealing with biosolids. Over-mixing can cause unwanted particle size reduction. With biosolids, over-mixing results in the formation of “sludge balls” that resist decomposition. These balls also roll off conveyor belts and out of compost piles during handling and turning, creating site cleanliness issues.



**Photo 4.5. Over-mixing biosolids can lead to large “sludge balls”**

*Source: Scott Gamble*

It is a good operating practice to always maintain a small supply of amendments onsite to mix with incoming feedstocks. Dry amendments, like straw, woodchips, and sawdust, are high in carbon and can normally be stored for longer periods of time without producing odours. However, these amendments should also be kept in a protected area or under cover so that they are not affected by the weather. Strong winds could carry the dry particles away and pose a nuisance to neighbours. As well, highly carbonaceous materials can catch fire if stored under very dry and hot conditions.

The odour potential of amendments with a higher moisture content and lower C:N ratio (for example, chipped brush and trees) is greater, and these materials should not be stored for long periods. As well, the size of the stockpiles for these materials should be managed due to the potential for spontaneous combustion, as discussed in Section 4.15.

## 4.6 Active Composting

As discussed in Chapter 3, there are many composting methods and technologies available. However, most composting facilities in Alberta use passively aerated static piles or windrows. Static piles with forced aeration systems are also becoming more popular for mid-scale facilities that process food waste and biosolids. The material handling operation of these systems is similar and is discussed in this section.

## 4.6.1 Initial Pile Construction

Initial construction of static or aerated composting piles and windrows is normally done using a front-end loader. Windrows might also be built with a manure spreader, or in some cases (for example, with L&YW), materials might be unloaded directly from delivery trucks into windrows. Regardless of how they are built, the piles and windrows should be oriented parallel to the slope of the underlying working pad so surface water drainage is not blocked.



**Photo 4.6. Using a front-end loader to build a pile in an ASP system**

*Source: CH2M*

Compost piles should be constructed with a consistent height. The height of windrows depends on the type of turning equipment, but is generally between 2 and 3.6 m (6 and 12 ft). Passively or actively aerated static piles are usually built with a height of 3 to 3.6 m (10 to 12 ft).

The width of windrows and static piles is normally 2 to 2.5 times their height. This is a good rule of thumb, since passive flow of air into the core of wider piles might be blocked. ASPs can be wider, since air is mechanically moved into the core of the pile via the underlying pipe network, rather than passively through the sides of the pile.

Windrows and piles higher than 3.6 m (12 ft) are not generally recommended. The weight of a high pile can compress material in the pile's base, affecting free air space and air movement. It is also more likely that operators will drive on portions of a large pile when constructing it, which will also compress materials and affect airflow.

If compost piles are too small, the pile may lose heat faster than heat is internally generated during colder weather periods, and it may be difficult to reach or maintain thermophilic temperatures.

There also needs to be enough spacing between and around compost piles to allow for movement of the equipment used for turning and watering. Generally, a 10 m (30 ft) wide aisle is recommended around the perimeter of the composting area to allow for access by site equipment and fire trucks. Space between adjacent piles can vary from 1 to 3.6 m (3 to 12 ft).

When long windrows are being built, it is important to keep the windrows straight and parallel with adjacent windrows. If the windrows are crooked (or spaced too far apart), the operator may not be able to build as many windrows as originally intended, and the processing capacity of the facility

might be reduced. Many operators find it helpful to place signposts, pylons, or some other marker at either end of the windrow's location as a guide while the windrow is being built.

Once constructed, each windrow or compost pile should be assigned a unique tracking number to allow it to be quickly identified and located by all site personnel. Tracking numbers can be written with a marker on a wooden stake or survey lathe and inserted into the pile.

The date that each windrow or compost pile is created should be noted in the operations log, along with the approximate amount of material added. The date(s) and amount of any additional feedstock or amendments added to a pile should also be noted.



**Photo 4.7. Compost piles should be labelled for easy identification**

*Source: CH2M*

## 4.6.2 Pile Turning

The composting method and feedstock will dictate how frequently piles need to be turned. Static piles and ASPs involve very little turning, while windrows might be turned once or twice a week during the initial stages of composting. Turning frequency during the initial stage of the composting process also must consider the pathogen reduction requirements outlined in Section 4.10.

Aside from pathogen reduction requirements, piles and windrows should be turned based on the results of temperature, moisture, and oxygen monitoring. Turning on a time-based schedule (for example, every Friday, or every other Tuesday) may result in piles being turned too often or not enough.

As outlined in Chapter 2, the purpose of turning and agitating the compost piles is to fluff up the material in the pile to re-establish free air space that may have been lost due to settling, compaction or material decomposition. This allows more air to flow through the pile. Turning also helps to break up clumps, further mix materials, redistributes moisture, and releases heat. This makes the compost pile more homogeneous and leads to more consistent process conditions.

The following can be used as guidance for determining when turning of windrows or passively aerated piles is required:



**Photo 4.8. Turning a windrow with a tracked excavator**

*Source: CH2M*

- Windrows should be turned when the temperature of materials exceeds 65°C or drops below 35°C
- Windrows can be turned following major rainfalls to evenly distribute moisture absorbed into the pile
- Depending on the weather conditions, active windrows can be turned after a snowfall event to incorporate moisture into the pile if required
- Windrows should be turned when visual observations or measurements indicate that the materials have become compacted or there is not enough free air space to allow for passive aeration
- Windrows should be turned when observations or measurements (for example, low oxygen concentrations) indicate that anaerobic conditions have developed

ASPs are typically not turned, or turned once after an initial two weeks of composting. Before turning, any labels should be removed and set aside. After turning, the labels should be reinserted into the pile.

Preferably, turning operations should be scheduled for the mornings so that any dust or odours that are released will dissipate before the end of the working day. Similarly, turning activities should not be undertaken during unfavourable wind conditions (that is, calm conditions or very slight breeze) that would increase the potential for offsite odour impacts.



**Photo 4.9. Turning a windrow with a front-end loader**

*Source: Scott Gamble*

When turning with a front-end loader, operators should either lift and fluff the pile from the side, “roll” it sideways to an adjacent location, or move it bucket-by-bucket to a new location. In either case, the operator should make sure that material from the outside of the old pile forms the inner core of the new pile, and the inside of the old pile becomes the outer layer of the new pile.

During all turning operations, site operators should avoid driving over any part of the pile, as this compacts the material, and the loss of free air space can lead to anaerobic conditions and odours.

After turning, the operator should walk along the sides of the pile to manually remove rocks, debris, and contaminants that may have been exposed. If space between the piles permits, a front-end loader or skid steer loader can also be used to touch up or straighten out the pile after turning.

The date and approximate time that each pile was turned should be noted in the operations log. Similarly, the date and approximate time that a pile is moved from one location to another should be noted in the operations log.

### 4.6.3 Combining Compost Piles

Decomposition results in the volume of materials being reduced as they are composted. This results in the gradual reduction in the size of compost piles. To make more processing space available at the facility, two or three smaller compost piles can be combined into a single larger pile.

The process of combining piles involves moving and turning. When turning is done with a front-end loader, site operators should follow the same procedures as when turning single piles: the outside of the old piles is used to form the inner core of the new pile, and the inside of the old piles becomes the outer layer of the new pile. When piles are turned with a windrow turner, one windrow can be placed on top of the other, provided the new windrow is subsequently turned with the windrow turner to mix the materials together.

The date and approximate time that the piles were combined should be noted in the Operations Log. For record-keeping purposes, it is usually easiest to assign the new pile a new tracking number, rather than referring to it by the old tracking numbers.

## 4.7 Curing

Depending upon the technology used and the facility design, the area designated for curing can be shared with the active composting area, or it can be a separate area where material is physically moved to complete the curing process. The first method is common with outdoor windrow facilities where composting and curing is all done in the same location. Separate curing areas are more common at sites that use ASPs and other aerated systems.

When curing areas are separated from active composting areas, they should be located so that drainage from receiving and active processing areas does not flow into or through the curing area. This is normally done by locating the curing area upslope from the active area, or providing separation with berms or ditching.

It is important to place curing windrows and piles in the proper direction relative to the grading of the working surface (that is, along the slope) to prevent the flow of runoff from being blocked and leachate from one pile draining into an adjacent pile.

## 4.8 Product Screening

Before use, finished compost is normally screened to remove oversized particles and remaining contaminants, recover amendments for re-use, and meet particle size specifications dictated by customers. Screening normally occurs after the curing process and before materials are placed in storage piles. However, materials are sometimes screened between the active composting and curing stages, or materials may be transferred to storage piles and screened later.



**Photo 4.10. Screening compost with a portable trommel**

*Source: Scott Gamble*

## 4.9 Product Storage and Distribution

At the end of the composting process, the matured material from several curing piles is normally combined into a single “lot” of finished product for management and distribution. The product lot should be assigned a unique tracking number to comply with the requirements of the Fertilizer Regulations (see Section 6.14.2).

Finished compost should be handled and stored to preserve product quality (for example, prevent weeds from spreading and pathogen re-introduction), and prevent it from becoming wet from snowmelt and rainfall. Stockpiling finished compost in 4-m-high piles built with a front-end loader, or 6- to 10-m-high cones built with stacking conveyors, are common practices.

Storage piles of finished compost should be physically labelled with their lot number so they can be quickly identified and located by all operators. Labels consisting of a 1-m-long wooden stake or survey lathe inserted into the storage pile, with the lot's unique identification number written on it, are recommended. Stakes should be placed in the same location on all piles so other staff can easily find them.

A clear aisle of approximately 5 m should be maintained between adjacent storage piles to allow for equipment access. An aisle of at least 10 m should be left around the outside perimeter of product storage areas to allow for access by site equipment, customer vehicles, and fire trucks. This perimeter aisle will also serve as a fire break from adjacent areas.

The moisture content of the finished compost storage piles should be periodically monitored by operators so that the material is not overly wet (more than 50%) or too dry (less than 35%). An overly wet product may lead to odours, and is more difficult to transport and use. An overly dry product can produce dust during handling, and can increase the potential for fires.



**Photo 4.11. Finished compost is often stored in large conical piles**

*Source: CH2M*

Water added to product storage piles should be evenly distributed over and throughout the pile. For smaller piles, it may be possible to add water using low-flow soaker hoses. Larger piles might require that water be sprayed on the product while it is being mixing and restacked.

Site operators should regularly inspect product storage piles for weeds and other vegetation. Any vegetation found growing in the storage piles should be manually removed. It is recommended that herbicides not be used to control vegetation and weeds on and around product storage piles.

Compost products are usually sold in bulk form (for example, truck-load quantities). Selling large amounts of compost in small (for example, 20- to 40-L) bags or 1 m<sup>3</sup> bulk bags is also common but involves significantly more planning, effort, and cost.



**Photo 4.12. Most compost is sold in bulk loads**

*Source: CH2M*

It is recommended that operators keep a log of product that is shipped offsite in orders of more than 3.8 m<sup>3</sup> (5 yd<sup>3</sup>). This Information is useful for reconciling invoices, and for refining marketing and sales programs. This also provides a means for product to be recalled, which is a requirement of the Fertilizer Regulations. The following information should be recorded in the log:

- Date and time the material is loaded
- The lot number(s) of the product shipped
- The amount of material shipped

- Customer name

### **4.9.1 Product Demand Curve and Storage Space Requirements**

With some exceptions (for example, greenhouses, medical marijuana growers), compost markets are normally seasonal and follow growing conditions. Sales can be characterized by a product demand curve, which takes the form of a table or graph that shows anticipated sales broken down on a month-by-month basis. In Alberta, the product demand curve is mostly limited to the period between late April or early May, and late September and early October. The start and end of the demand period varies from year to year based on weather conditions. The peak demand period is typically in May and early June.

At smaller outdoor facilities, storage requirements can be minimized by leaving materials in curing windrows over the winter months, and screening it in the spring before the start of the sales season.

Facilities that produce compost on a year-round basis typically have one or more dedicated areas for storing product during the winter months. At these sites, an understanding of the product demand curve is needed to determine the amount of product storage space needed at the composting facility. The product demand curve can be matched up with production curves to determine storage needs, as shown in Table 4.2.



**Table 4.2. Example Product Demand Curve**

	<b>Production (m<sup>3</sup>)</b>	<b>Expected Sales (m<sup>3</sup>)</b>	<b>Amount in Storage (m<sup>3</sup>)</b>
<b>Carryover from Previous Year:</b>			4,000
Jan	1,675	0	5,675
Feb	1,090	0	6,765
Mar	800	0	7,565
Apr	1,030	2,000	6,595
May	850	4,000	3,445
Jun	1,475	4,000	920
Jul	1,505	2,000	425
Aug	1,840	2,000	265
Sep	1,455	1,000	720
Oct	1,355	1,000	1,075
Nov	1,610	0	2,685
Dec	1,315	0	4,000
<b>Storage Area Capacity</b>			

## 4.10 Pathogen Reduction and Management

The commonly accepted practice for managing pathogens at centralized composting facilities is to expose the materials to elevated temperatures during composting for a specified amount time. This approach has been adopted from regulations developed in the United States by the Environmental Protection Agency (EPA). In the regulations, the EPA defined a set of Processes to Further Reduce Pathogens, or PFRPs. The PFRP methods for composting defined by the EPA were incorporated into the Canadian Council of Ministers of the Environment (CCME) Guidelines for Compost Quality, which have been adopted by AEP.

The PFRP requirements in the CCME guidelines are dependent on the composting technology or method employed, as follows:

- When composting using ASPs or an in-vessel technology, temperatures of not less than 55 degrees Celsius (°C) should be maintained in the composting pile for at least 3 days.

- When composting materials use the windrow method, temperatures in the composting pile should be maintained at 55°C or greater for at least 15 days, and during this 15-day period, the windrow should be turned at least five times

All composting piles, except those made up exclusively of L&YW, must be managed in accordance with these pathogen control practices. Following the completion of the composting and curing process, samples of finished product must also be sampled and analyzed for the presence of indicator pathogens (that is, fecal coliform or salmonella). Sampling and analysis of finished compost is discussed in further detail in Section 4.22.

From a regulatory perspective, operators who are composting only L&YW can choose to implement the PFRP requirements, or they can choose to sample finished products for pathogens. If they choose the second approach, samples must be tested for both fecal coliform and salmonella. Allowing operators to choose between meeting PFRP requirements and finished product testing makes complying with the CCME requirements easier for small facilities, and allows for the use of passively aerated composting methods, such as static piles, bunkers, and passively aerated windrow (PAW) systems.

Although it is not specifically mentioned, the 3- and 15-day periods referenced by the CCME guidelines should be consecutive days. Reducing pathogen populations to the levels intended by EPA requires material in the compost pile be exposed to the high temperatures for a minimum amount of time. If the minimum time requirements are not reached, the partially reduced pathogens populations could re-establish themselves once temperatures have dropped.

The number of turns specified by the PFRP requirements for windrow composting is needed so that materials throughout the compost pile are exposed to high temperatures. If the material were not turned, only material in the core of the pile would be exposed to the high temperatures, and pathogens would remain in the outside layers of the pile where temperatures are cooler. Turning mixes and moves materials from the outer layers to the core of the windrow. The specification for five turning events is based on what experience showed was needed to make up for imperfections in turning methods. It is implicit in the EPA requirements that the five turns be spread out over the 15-day period. This is so the core of the windrow is exposed to high temperatures for 3 days before the next turning event.

When ASP composting methods are used, it is recommended that the composting pile be covered with a 15 to 30-cm thick layer of screen overs, compost, or woodchips. This insulates the compost pile and helps to retain higher temperature in the outer layers of the pile. It is also often recommended that the composting pile be broken down and rebuilt at some point after the 3-day high-temperature period has been reached, and that temperatures in the rebuilt composting pile be maintained at 55°C for an additional 3 days. Like turning a windrow, tearing down and rebuilding the compost pile promotes more uniform exposure of the material to high temperatures. It also fluffs up the pile and helps re-establish free air space, and provides an opportunity to add moisture into the compost pile.



**Photo 4.13. Material at the bottom edges of an ASP pile is not likely to reach the temperatures needed for pathogen reduction. Turning the ASP “inside-out” at least once during active composting helps prevent pathogen regrowth**

*Source: CH2M*

High temperature is not the only condition pathogens and other unhelpful organisms are exposed to. Acid production early in the active composting stage can lower the pH of the compost mixture to 6.0 or lower. After this stage, increasing pH to 7.5 or higher makes the material more stable and the pH then approaches neutral. These pH shifts can reduce pathogen survival. Secondly, and perhaps even more importantly, because the pH shifts from slightly acidic to slightly basic, the amount of nitrogen given off in the form of ammonia increases. Ammonia can sterilize pathogenic microorganisms.

In addition to meeting pathogen reduction requirements, operators always need to take precautions to prevent composted materials in curing and product storage areas from being exposed to pathogen-contaminated materials. Exposure can lead to regrowth of pathogens in the materials. Typical precautions include:

- Trucks delivering feedstocks to the facility should be confined to the receiving area
- Trucks picking up finished product should not be allowed to enter or drive through receiving or composting areas on the way to the product storage area (a separate access to product storage and shipping areas is preferred)
- After material has gone through PFRP, it should only be handled with clean equipment, including front-end loaders (it may be necessary to wash equipment with a high-pressure washer before use or dedicate a loader to screening and product handling activities)

- To minimize cleaning, activities can be planned so that equipment is used first on pathogen-free material, and then on material that has not completed the pathogen reduction stage of composting (for example, when turning windrows, start with the oldest material and finish with the newest materials)
- Leachate may contain pathogens, and its re-use should be restricted to initial moisture conditioning of composting feedstocks (it should not be recycled back into composting piles that have started or gone through the pathogen reduction stage)
- Birds should be discouraged from roosting or nesting on composting, curing, and product storage piles to reduce the potential for pathogens to be re-introduced via bird droppings
- Runoff from receiving and active composting areas should not be allowed to drain into or through curing and product storage areas (if the site's design does not allow this, consider relocating operations so materials move from low to high ground as they progress through the composting process)



**Photo 4.14. Birds should be discouraged from nesting on compost piles**

Source: CH2M

## 4.11 Handling Residuals from the Composting Process

Residuals are the inorganic materials that do not break down during composting, or are not compatible with the composting method used. They are manually removed by operators and mechanical separation equipment during the different processing steps at the composting facility. Most residuals are removed during the initial feedstock inspection step, and during the final screening of the compost product.

Since most of the feedstocks delivered to the composting facility will be from source-separated programs, there should be relatively low levels of

### Common Contaminants in Composting Feedstocks

- Aerosol cans
- Automotive parts
- Bags of garbage
- Bathroom sinks
- Bricks and concrete blocks
- Cans and glass bottles
- Car jacks
- Carpet and floor mats
- Children's toys
- Coffee creamers and stir sticks
- Hockey sticks
- Household pesticide containers
- Lawn chairs
- Oil containers and filters
- Plastic bags
- Rope and wire
- Seedling and plant pots
- Shoes and slippers
- Small appliances
- Styrofoam (polystyrene)
- Video and audio cassettes

contaminants (typically less than 5% by weight). Operation of a composting facility does not normally result in a lot of residuals.

The primary concerns about managing residuals are litter, odours, and attraction of insects and wildlife. Residuals often contain large amounts of plastic film and other lightweight materials that can easily be blown about the facility or on to neighboring properties. Partially degraded organic materials may also be stuck to or mixed in with the residuals, and if they accumulate at the facility, they can become a source of offensive odours.

Smaller sites can store residuals in a covered container, such as a commercial garbage container or roll-off bin. Larger facilities might need multiple containers, or some type of enclosure or bunkers. Containers should be placed in a location that is accessible but does not interfere with processing operations. The residual storage container or areas should also be clearly marked so that other operators do not accidentally re-introduce these materials into the process.

The key principle for managing residual wastes is to not allow them to accumulate at the facility. Residuals should be removed regularly (for example, every 1 to 2 weeks) and disposed of appropriately. If a larger enclosure or bunker is used and it cannot be fully emptied each time, materials should be removed on a “first in-first out” basis so the most odorous residuals are dealt with first.

## 4.12 Water Addition

During composting, it is often necessary to add water to composting piles to replace moisture lost during the process or from evaporation during hot weather. Many enclosed composting systems incorporate some form of water addition system into the design of their vessels, and operators need only monitor the addition methods and rates to confirm it is operating properly. However, with windrow and static pile operations, water addition is a much more manual process.

Moisture addition techniques that allow water to be applied to thin layers of material are the most effective. An example is running the material on a conveyor under a spray bar. However, since many small and mid-size facilities do not use conveyors for material handling, this is not always possible.



**Photo 4.15. Spray bar installed on a horizontal conveyor**

*Source: Scott Gamble*

A common practice, but one that is not always effective, is to simply spray water over the compost windrow or pile using a fire hose or water truck.

While this can deliver a large volume of water quickly, it is often more water than the compost material can absorb. If too much water is supplied, much of the water runs off the outside of the pile, or rapidly percolates through it, and pools at its base or in the aisles between piles. The pooled water may be re-absorbed into the base of the pile, which can lead to the bottom layers becoming too wet, while the upper layers remain dry. Using water trucks also requires that a 3- to 5-m wide aisle be maintained between adjacent piles, which can reduce the number of piles that fit in the site, and can impact the site's processing capacity.

A much more effective method of remoistening the composting pile is to physically mix the water into the pile. This distributes the moisture evenly, and reduces the amount of water runoff. With windrows, the external material can be moistened with surface spray and then mixed in with one or more turning machine passes. Alternatively, the compost turners can be equipped with a spray bar that injects water into the material during compost turning.

Surface spraying of static piles may be helpful, but if not done carefully, can cause uneven moisture that may create process control difficulties. A system of low-flow sprinklers that distribute the moisture evenly over the surface and allow it to percolate in slowly has been shown to work, but can be labor-intensive if a large network of hoses is required. The date and amount of water added to compost piles should be noted in the Operations Log for future reference and troubleshooting.



**Photo 4.16. Pumping water onto a windrow with a water truck**  
Source: CH2M



**Photo 4.17. Spraying water onto a windrow during turning**  
Source: CH2M



**Photo 4.18. Using sprinklers to apply water to an ASP**  
Source: CH2M

## 4.13 Monitoring Tools and Practices

Measuring temperatures is the primary method used by operators for monitoring the progression and health of the composting process. Other key parameters that may be monitored include oxygen levels, moisture content, and bulk density. In combination, these parameters can be used to determine turning requirements or set and control aeration fans, identify additional amendment needs, and identify and diagnose process upsets.

Temperatures are normally measured using bimetal thermometers, which are readily available from several manufacturers. Digital thermometers, which use a thermocouple to measure temperatures, are also common. Digital thermometers are generally more expensive than a comparable bimetal thermometer, but provide a reading in much less time, and can be connected to datalogging units. Datalogging allows measurements to be taken at set intervals over a period of time, and later downloaded to a computer. Some datalogging units also allow time-stamped readings to be taken on-demand and associated with a location, eliminating the need for paper records.

Bimetal and digital thermometers used by operators to manually take measurements at composting facilities are normally equipped with a 120- to 180-cm (48- to 72-inch) stem constructed of 6- or 10-mm (1/4- or 3/8-inch) diameter stainless steel tubing. This allows temperature measurements to be obtained in or close to the core of the compost pile.

Thermometers with larger diameter stems (that is, 10-mm or 3/8-inch) are generally more robust, but can still bend easily if a hard object is encountered while pushing them into the compost pile, or during storage. For that reason, it is recommended that a probe guard be purchased to protect the thermometer from bending. Probe guards also make using the thermometer easier for the operator.



**Photo 4.19. Measuring windrow temperatures with a bimetal thermometer**

*Source: Scott Gamble*



**Photo 4.20. Using a datalogger to collect temperatures in an ASP**

*Source: CH2M*

A useful skill for operators is to learn to gauge composting temperature by feel. A person's natural reflex is to pull back from something that their body considers too hot. Knowing the temperature at which their body initiates this reflex action allows an operator to roughly gauge temperatures in a composting pile with their hand.

Of course, care should always be taken when manually handling compost from an active pile, as excessive temperatures or sharp objects (for example, sticks, glass, nails) can lead to injury. Open cuts or sores might also become infected.

Oxygen probes used at composting facilities are similar in appearance to a digital thermometer. They consist of a hollow stainless-steel probe that is inserted 1.2 to 1.5 m (48 to 60 inches) into the composting pile. Once the probe is inserted, a hand-operated or electrical pump draws a sample of gas from the compost pile through the probe and passes it across a sensor. The sensor determines the oxygen concentration and provides a digital read-out of the measurement.

Like thermometers, oxygen probes are subject to bending when inserted in to the compost pile. However, the stainless probe is much easier to replace, so this is less problematic. In comparison to thermometers, oxygen probes require more frequent calibration of the sensor. The oxygen sensor in the probe must be replaced every one to two years.

Measuring the moisture of a composting pile is more complicated than measuring temperature or oxygen, as it requires that a sample of material be taken. There are currently no field measuring devices available to operators that allow for reliable direct readings to be obtained within the compost pile. Most available probes used to directly measure moisture rely on electrical conductivity and do not function reliably in the higher moisture environment of a compost pile.

Fortunately, obtaining a compost sample to measure moisture is a straightforward process that involves digging into the surface of the composting pile with a shovel and extracting a small amount of material. The sample must be obtained from a sufficient depth within the compost pile, normally 0.3 to 0.6 m (12 to 24 inches). Once a sample is obtained, the moisture can be measured many ways. The



**Photo 4.21. Measuring oxygen concentration in a windrow**

*Source: CH2M*



**Photo 4.22. Judging moisture content with a squeeze test**

*Source: Scott Gamble*



quickest method, but also the least accurate, is the squeeze test. The operator squeezes a handful of material in their palm, and based on how much moisture drains out and how much the material clumps together, estimates the moisture content. With practice, an experienced operator can usually estimate the moisture content to within 5%. When doing hand squeeze tests, it is critical that the person confirm there are no pieces of glass, nails, sharp sticks, or other objects in the material before squeezing it.

The most accurate method of measuring moisture involves drying the sample in a laboratory oven for 18 to 24 hours at 70°C. The drying process drives off the moisture in the sample, leaving only the solid portion behind. By weighing the sample before and after drying, the moisture content can be calculated very precisely. A lower temperature is intentional when drying compost in this manner (as compared to drying soil), as compost typically has a high organic matter content, and drying it at higher temperatures can lead to loss of volatile compounds in addition to water.



**Photo 4.23. Oven used for measuring moisture content in a lab**

*Source: Scott Gamble*

A variation of the oven drying method is using a microwave oven to dry the sample. The concept is the same: weighing the material before and after drying allows the moisture content to be calculated. The advantage is that using the microwave oven speeds up the drying process considerably. The material is placed in the microwave and heated in 2- to 5-minute increments until the weight stabilizes. The disadvantage is that microwave drying drives off some of the volatile fraction of the sample, resulting in a less accurate number. Care must also be taken to confirm the sample is free of any metal. Finally, it is possible for the compost sample to ignite if it is heated for too long in the microwave. Despite these disadvantages, the microwave method allows operators to obtain quick measurements at a relatively low cost to make process control decisions.

A Koster Moisture Tester, commonly used to measure the moisture content of grains, can also be used to test the moisture in compost samples.



**Photo 4.24. Pail and hand-scale used for bulk density testing**

*Source: CH2M*

Although it is not a direct measure of free air space, bulk density can serve as a useful indicator of free air space, and is easily measured. However, like moisture, bulk density cannot be measured directly in the pile, and a sample of material must be obtained from a 25 to 30 cm depth. A quick test method has been developed to measure bulk

density in the field. It is simple, requiring only a small luggage or fish scale and a 20-L pail, and can be completed in a matter of minutes.

The frequency at which process measurements are taken varies widely based on the feedstocks being composted, the composting method, available labour resources, and the operator's experience. Monitoring frequency will also vary depending on the stage in the composting process; more frequent monitoring is generally required during the early stage of the process than later stages.

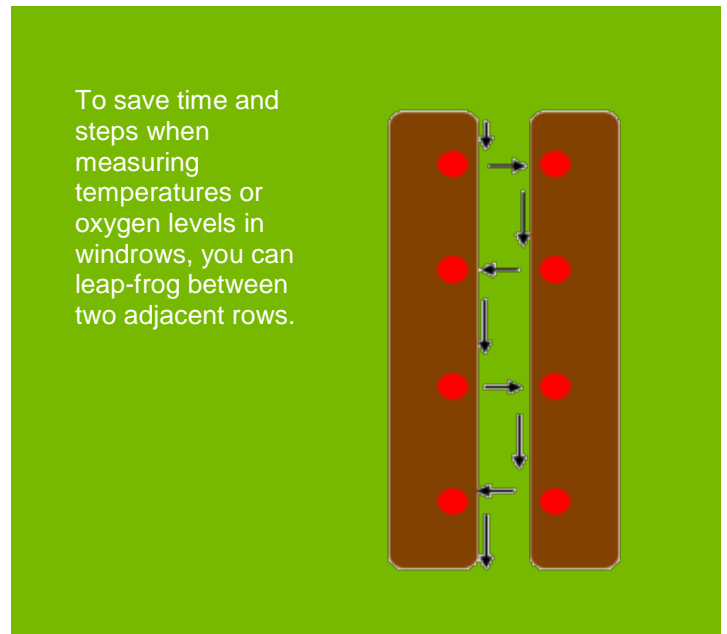
During the first few weeks of the process, monitoring should be done at least weekly. If pathogen reduction conditions are being documented, it may be necessary to take measurements daily, or insert digital probes into the pile that have datalogging capabilities. As the materials progress through the secondary composting stage, the monitoring frequency can be reduced. It can be further reduced during the curing stage.

There are no set guidelines on the number of points in a pile or windrow where measurements should be taken. This is a factor of the technology, the homogeneity of the material, and the operator's experience.

Monitoring allows operators to confirm that conditions at any given time are within optimal range. It is recommended that trends in data over time for a particular pile or windrow be reviewed, as should spatial variation within the pile or windrow. These spatial and time variations can be used to identify developing or existing problems that need to be addressed. For example, intermittent cool and hot spots along the windrow can indicate unevenly mixed material. Consistently low oxygen levels can indicate a malfunctioning forced aeration system or area that does not have enough free air space.

## 4.14 Composting of Weeds and Invasive Plants

Many guidance documents recommend that weeds and invasive plants be destroyed through burning or landfill disposal. In most jurisdictions, backyard composting of these materials is strongly discouraged, since the temperatures reached in backyard composting piles are often too low to destroy weed seed viability (for example, less than 50°C). Temperatures reached in piles



at centralized composting facilities are generally much higher and are sustained for longer periods. As a result, disposal of weeds and invasive plants at centralized composting facilities is an acceptable practice in some jurisdictions. For example, the Minnesota Department of Agriculture suggests that when burning, onsite management, or landfill disposal is not possible, processing the plants and their weed seeds through a certified compost operation may be the best alternative.

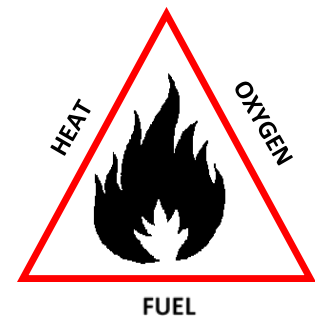
Several researchers have conducted field studies and laboratory trials to assess the impact of composting on weed seed and plant pathogen viability. Generally, higher compost temperatures, suitable pile moisture, and longer residence times have been found to equate to higher reductions in viability. Within the composting industry, following the previously described PFRP requirements is also considered to be the BMP for reducing the viability of weed seeds and plant pathogens in incoming feedstock materials.

## 4.15 Fire Prevention and Response

Fires have occurred at several composting facilities in Alberta. They have been caused by:

- Discarded cigarettes
- Hot equipment exhausts
- Welding and grinding
- Short-circuits of electrical equipment
- Spontaneous combustion

The fire triangle is a simple model for explaining and understanding the ingredients necessary for most fires. The sides of the triangle are fuel, oxygen, and an ignition source. Fires can be prevented by eliminating one side of the triangle.



**Figure 4.4. The Fire Triangle**

However, since composting is an aerobic process that requires oxygen, eliminating that side of the triangle is not possible. Similarly, most composting facilities contain a range of flammable materials, including some feedstocks, wood bulking agents, dust from grinding and screening activities, and vehicle fuels and lubricants. Maintaining a clean site properly storing fuels; cleaning up spills and leaks; and regularly removing dust from motors, engines, and engine exhaust systems (for example, with compressed air or leaf blowers) are some of the preventative measures that can be taken. But eliminating all fuel sources is not possible.

This puts composting facility operators in the position of having to focus most of their efforts on preventing ignition and heat sources.

## 4.15.1 Building and Equipment Fires

Fires can occur in buildings, vehicles, and equipment. These fires are often the result of:

- Arson
- Careless smoking
- Careless storage of flammable materials
- Faulty electrical wiring or equipment
- Poor housekeeping (for example, dust buildup in hot engine compartments)
- Sparks while fuelling equipment
- Welding and grinding

As shown in Table 4.3, there are several different classifications of fires. Different approaches to fighting a fire are used depending on the type of fire. Table 4.3 provides general information only. Staff should receive appropriate training to fight fires.

**Table 4.3. Classes of Fires and Extinguishing**

<b>Class A Fire</b>	<ul style="list-style-type: none"><li>• Burning wood, paper, rags, rubbish, or other combustible materials</li><li>• Use a water hose, pump-type water can, or fire extinguisher</li><li>• Soak the fire completely – even smoking embers</li></ul>
<b>Class B Fire</b>	<ul style="list-style-type: none"><li>• Flammable liquids, oil, and grease</li><li>• Use ABC extinguishers</li><li>• Start at the base of the fire, and use a swinging motion from left to right, always keeping the fire in front of you</li></ul>
<b>Class C Fire</b>	<ul style="list-style-type: none"><li>• Electrical equipment</li><li>• Use ABC extinguishers</li><li>• Use short bursts on the fire</li><li>• When the electrical current is shut off on a Class C fire, it can become a Class A fire if the materials around it are combustible</li></ul>

In the event of a fire, all site employees need to know the proper response, including building and site evacuation routes and procedures to get visitors, customers, and contractors to safety. It is advisable to call the fire department for all building and equipment fires. It is better to have fire services on the way to the site in case a small fire becomes uncontrollable. Site staff should only try to extinguish small fires when it is safe to do so and when they have had appropriate training.

Once they arrive, the fire department will take control over the situation and use their tools and equipment in combination with the site's own resources to manage the fire. Site staff are typically delegated to enforcing a safety perimeter around the area and redirecting customers. However,

they may be called and should be prepared to assist by operating site equipment, such as front-end loaders or water trucks.

Firefighters need a water supply to fight or contain building and equipment fires, and this should be a part of the site development plan. In rural locations or sites without municipal services, the surface water contained in onsite retention ponds is often used for firefighting. However, since they will often be soaked by the water when extinguishing the fire, firefighters should be made aware of possible contaminants in the surface water and their potential health effects, particularly the potential for the runoff to contain pathogens.

This is one of the reasons that designers often provide separate retention ponds for receiving and active composting areas, and curing and product storage pads. The runoff from pads should be much cleaner and pose much less of a risk to firefighters.

Prevention is the key to avoiding building and equipment fires. It is important to maintain buildings and enforce smoking rules for the site. Equipment and vehicles should be shut down while refuelling. Equipment should be kept in good repair. Engine compartments need to be cleaned regularly to remove dusty material and debris that could be ignited by hot engine parts. Before grinding and welding activities, dust and flammable debris should be removed from the work area, and fire extinguishers should be prepositioned. The areas where grinding and welding activities take place should be monitored for fires both during and after the work is completed.



**Photo 4.25. Dust that accumulates in buildings can be a fire hazard**

*Source: CH2M*

## 4.15.2 Compost Pile and Stockpile Fires

Compost operators must contend with fire caused by spontaneous combustion. Spontaneous combustion is when a pile of material self-heats to the point where a “thermal explosion” or “runaway reaction” begins. As heat continues to be generated in the pile faster than it can be dissipated, it causes the runaway reaction to accelerate. The reaction, in turn, releases energy that further increases the temperature in the

Fires in compost piles and stockpiles are seldom extinguished with only water. Effective fire response includes:

- Separating the burning material
- Isolating it and spreading it out
- Dousing with water or smothering with soil

pile, which further accelerates the reaction. At some point in this process, the auto-ignition temperature of the material in the pile is reached, and combustion occurs.

At composting facilities, spontaneous combustion usually occurs in poorly managed composting and curing piles, and stockpiles of yard waste awaiting processing. Stockpiles of bulking agents and finished compost are also susceptible to spontaneous combustion. In all these cases, the risk of a fire occurring increases when large piles are built or when piles are allowed to dry out. Piles that do not have enough free air space to allow air to move through them and heat to escape are also a higher risk.

As with other fires, the operator must focus on prevention to avoid spontaneous combustion fires. In this case, prevention means managing the compost process to prevent a thermal explosion from occurring. Limiting the height of piles, and managing moisture in compost piles and stockpiles are also best practices to avoid spontaneous combustion.

Spontaneous combustion does not generally occur in very dry materials, so there is a greater risk of fires breaking out in piles of ground brush and trees than from ground pallets and dimensional lumber. Spontaneous combustion is more likely to occur when the moisture content of materials is within the 30 to 40% moisture range. Keeping materials either drier or moister than this moisture range, as well as evenly moist, should prevent conditions for spontaneous combustion.

Because prevention is not always effective, operators must also be prepared to extinguish fires when they occur.

- Provide appropriate firefighting equipment at the site (many facilities have a dedicated pump and hoses that are stored in a secure and central location)
- Equip vehicles and mobile equipment with fire extinguishers
- Make sure there is adequate and accessible water supply
- Have a stockpile of soil available to smother fires
- Train all staff in the proper use of fire extinguishers, fire pumps and hoses, and how to respond to a fire in a compost pile or stockpile

### **4.15.3 Response Planning**

Operators should invite the local fire department to the composting facility and work through response procedures in advance, as not all firefighters are trained to extinguish compost and woodchip fires. Based on their previous training and experience, the initial instinct of firefighters may be to find a source of water, and use it to extinguish the fire. It may be necessary to help

them understand that the most appropriate method for dealing with compost and woodchip fires is to isolate the burning material, spread it out, and then wet it down or smother it.

Operators should also set up a response box for first responders at the facility entrance (and any secondary entrances) that contains an emergency call-out list and an up-to-date site map that shows fire hydrant and pond locations, fuel tank locations, storage facilities for oils and greases, and other hazardous areas.

Another important consideration is providing enough space within the site to fight a fire. During a fire response, there will be problems if piles are too close together, or there are no perimeter aisles and equipment and fire trucks cannot get to the burning pile. Similarly, there needs to be enough open space at the site to spread materials from the burning pile out and extinguish them.

Smoldering fires inside large piles are difficult to manage, since it is hard to know exactly how large they are and where they are.

- Call first responders in case the fire spreads to buildings, equipment, or grasslands, or in case someone gets hurt while putting out the fire. If the site is large, have someone meet first responders at the gate and direct them to the fire.
- Form a plan of attack. Make sure everyone understands their role. Make sure there is enough space to lay out the material.
- Break the stockpile down with a front-end loader, and spread the material out so it can cool. Smoldering and burning material needs to be watered or smothered with soil.
- Remove cool materials from around the exterior of the pile rather than digging straight into the heart of the pile.
- Use spotters who are in radio communication with the equipment operator.

Have pumps and hoses standing by to extinguish any open flames that develop, or to spray front-end loaders or staff who get trapped by flames.

## 4.16 Nuisance Control

Controlling nuisances is critical to avoiding conflicts with neighbours. The most common nuisance condition at composting facilities is offensive odours, but also include:

- Litter
- Dust
- Noise
- Weed growth
- Potential for attraction of flies, birds, and other wildlife

All facilities, regardless of size, should control nuisance conditions through design features and use of BMPs, and should have contingency plans that can be quickly implemented if nuisances occur.

### 4.16.1 Litter

Untidy sites due to poor controls for unloading and processing feedstocks or a lack of litter management programs can impact the public's perception of the site. If left unchecked, litter can become an eyesore, detracting from the overall impression of the facility, and can affect relationships with neighbours. While litter at composting facilities is generally not as large a problem as at landfill sites, it still needs to be managed.

Furthermore, government regulators will respond to public complaints regarding litter on and around composting facilities, and they can also form immediate opinions about site management based on how well litter is controlled. Poor litter control can create a negative image and lead the regulators to conduct a more in-depth inspection of all aspects of the operation.



**Photo 4.26. Poor litter control gives a negative image**

*Source: JL Technical Services*

The impact of litter on the environment goes beyond visual. Litter that escapes the site can be washed away in water drainage systems and impact water resources. It can have impact on farm animals and wildlife. Litter created by uncontrolled dumping of waste can create other issues, such as odours and animal scavenging.

Understanding wind patterns, where litter blows to, and under what wind conditions litter is picked up by the wind will help manage litter onsite. Note that at higher wind speeds, there can be safety concerns for both staff and customers due to flying debris.

The first step in controlling litter is to directly control the sources. This can involve enclosing feedstock receiving and debagging areas within buildings or fences, and keeping receiving building doors closed. At outdoor facilities, it may be necessary to stop unloading materials during very windy periods, or set up temporary fences downwind of unloading areas.

#### Litter Control Measures

- Using site design and enclosures
- Controlling incoming loads
- Using waste handling procedures
- Using permanent and temporary litter fences
- Limiting operations in high winds
- Retrieving litter on- and offsite



A second line of defense used at landfills that can also be applied to composting facilities is chain link or grid fencing around the perimeter of the site that is high enough to catch wind-blown litter, but not so high that it is aesthetically objectionable to neighbours. Trees and bushes around the perimeter of a site can also be used to capture litter, but it is more difficult to clean litter from them compared to fencing.

It is important that litter be regularly cleaned from any fencing. Not only do litter accumulations reflect poorly

on the facility, but they can increase the wind resistance of the fencing and lead to bending of posts, overturning of portable fencing, or other damage.

Daily patrols should be done around the site perimeter, access roads, and public roads leading to the site. The priority for picking litter should be on adjacent properties and farmland, public roads, and then starting at the entrance gate and working from the site perimeter towards the operating areas.

Offsite controls include by-laws and by-law enforcement of illegal dumping and securing loads in transport. Unsecured loads can be a major contributor to litter along roads leading to the compost site. Some waste management facilities have implemented surcharges onto tipping fees for unsecured loads. Many waste management sites work closely with by-law enforcement to encourage customers to secure loads.

Wind Description	Wind Speed (km/h)	Wind-blown Materials
Calm	Up to 10	Very light materials and dust
Light	10 to 20	Dry, crumpled paper; empty plastic bags
Moderate	20 to 40	Lightweight, empty boxes; flat cardboard; paper products; plastic film
Strong	40 to 60	Corrugated cardboard boxes, rigid or corrugated plastic sheets, plastic containers, paper products
Gale	60 to 90	Large boxes and flat sheets, brush, carpeting
Storm	90 to 117	Boxes; flat sheets; construction materials, including plywood
Hurricane	Over 118	Almost anything

## 4.16.2 Dust

Some of the most common sources of dust at composting facilities are:

- Unpaved or dirty roads and working surfaces
- Receiving and handling of dry feedstocks and amendments

- Grinding of dry materials (for example, wood waste)
- Turning or agitating dry compost piles
- Screening of finished products

Dust should be controlled for many reasons. From a health and safety perspective, dust can cause irritation of eyes and lungs. Dust can also get into the bearings and air intakes of site equipment, causing increased maintenance requirements or damage. Excessive dust can also settle on building ledges and in the engine compartments of site equipment, and pose a fire hazard. Dust can also limit visibility, which presents a hazard for people and machinery moving around the site.

Ideally, dust emissions caused by traffic should be managed by constructing roads with appropriate surfacing and by reducing traffic speed limits. Watering unpaved roads is a common means of controlling dust. However, this must be done with caution at a composting facility, since excess water can pond, become contaminated with organic materials, and lead to odour problems. If watering is to be used as a dust control method on roads, the level of housekeeping should be increased so that roads are kept clear of organic materials.

Grinding and otherwise handling dry feedstocks and amendments can usually be controlled by moistening the materials. Water misting systems or a system of sprinklers can be used to apply small amounts of water over a large area. Particular care must be taken that the materials are not watered to the point where anaerobic conditions occur.

Dust generation during composting operations should be controlled by maintaining optimal moisture conditions for the process. Handling of compost does not create a lot of dust when the moisture is more than 40%, which is less than the desirable level for the composting process.

The efficiency of screening equipment increases as the moisture content of the material being screened decreases. But the amount of dust generated also increases as moisture content decreases. Maintaining compost products at a moisture content of 40 to 45% provides a good balance between screening efficiency and dust generation. Under certain conditions, wetting dry materials during screening (with misting or sprinkler systems) can control dust.

### **4.16.3 Noise**

Noise can be caused by vehicles delivering feedstocks and amendments or removing products, site equipment (including front-end loaders and grinders), warning alarms on processing equipment, and aeration fans. These sources need to be managed both to prevent injuries to workers and to prevent impacts on neighbours.

Reducing speed limits on site roadways is one way to reduce noise. Repairing wash-boarded roads can also reduce the chassis noise that results from collection vehicles as they are travelling to and through the facility.

Truck drivers and heavy equipment operators should also run equipment at lower power levels whenever possible, and be discouraged from revving their engines to speed up the response of hydraulic systems. Site equipment should also be properly maintained. In particular, the mufflers on equipment should be regularly inspected, and any damage should be repaired immediately.

It may be possible to reduce noise from processing and aeration fans with some type of acoustical dampener. Otherwise, placing equipment within appropriately designed enclosures can be used to control noise. Developing and maintaining sound barriers, such as fences, earthen berms, or vegetation around the perimeter, can also be an effective means of reducing noise impacts on neighbours.

It may also be necessary to limit certain site operations to specific times of the day so that noises do not interrupt activities at neighbouring sites. For example, grinding can be done in the morning and early afternoon, rather than later in the day or during the evening if the site is close to residences.

#### 4.16.4 Noxious Weeds and Weed Control

Composting facilities provide a fertile environment for weeds to germinate and grow. If left unchecked, weeds will take over curing piles and finished compost stockpiles, and the weeds can quickly spread onto adjacent properties. Weed seeds can also contaminate compost products and affect product marketing and sales.

There are numerous weeds that are classified as “prohibited noxious” and “noxious” and must be controlled in accordance with the *Weed Control Act*. Prohibited noxious weeds must be destroyed, and noxious weeds must be controlled. Operators should work with local agricultural field personnel to identify and develop the appropriate controls for weeds to protect surrounding agricultural lands.



**Photo 4.27. Weeds can take root in curing and finished product piles and affect marketability**

Source: CH2M

### 4.16.5 Bird and Wildlife Management

Controlling birds and wildlife is necessary at any facility that handles food waste. Birds, rodents, or larger animals can grab food waste from composting piles and scatter it around the site or on adjacent properties. Birds, mice, and other animals can also spread diseases and pathogens.

Yard waste, biosolids, and manures generally do not attract birds and wildlife. However, birds may be attracted to the warmth of composting and curing piles (regardless of the type of feedstock) and roost or nest on top of the piles. Similarly, rodents may burrow into drier piles that are not regularly turned (for example, curing and piles) and establish nests. Some rodents (for example, deer mice) can carry Hantavirus, which raises the potential for workers to be exposed to the virus when dry piles are disturbed and the virus become airborne.

Controlling wildlife, and in particular, seagulls and other birds, can be a difficult task. Enclosing receiving and processing operations in buildings is very effective, but may not be appropriate or affordable for all facilities. Blending feedstocks quickly and incorporating them into windrows or piles at outdoor facilities will provide some degree of control, as will regular turning of windrows and piles.

Other means of controlling birds include:

- Balloons or kites
- Inflatable air dancers
- Propane cannons
- Pyrotechnics
- Recorded sounds of bird distress calls or predator birds
- Wires or nets suspended over operating areas

In extreme situations, dogs and birds of prey, such as falcons, can be used to make birds fearful of the site.



**Photo 4.28. An electric “air dancer” being used to scare birds at a landfill working face.**

*Source: CH2M*



**Photo 4.29. Winder system placing a tarp over a long windrow**

*Source: CH2M*

Covering piles with tarps can be used to control wildlife. However, manually placing and removing tarps and covers can be cumbersome and time-consuming. Some types of composting systems and windrow turning equipment are specifically designed to work with covers and tarps.



**Photo 4.30. Birds can be attracted to the heat given off by composting piles.**

*Source: CH2M*

Installing and maintaining electrified fencing around the perimeter of a site is commonly used to prevent large animals (for example, bears) from accessing the site. The Fish and Wildlife

Division of AEP has published a document entitled [Best Management Practices: Managing Waste Management Facilities for Bears and Wildlife](#) that provides guidance on electrical fencing.

#### **4.16.6 Flies**

Flies are a concern, since they can carry and spread diseases. Flies and fly larvae can be present in the feedstocks delivered to composting sites, particularly food wastes. Flies may also be attracted to the odours given off by decaying food waste and biosolids that are being temporarily stored or composted, to leachate puddles, or to the hot and moist conditions in a compost pile (regardless of the feedstock).

If materials are processed quickly after they are received and good housekeeping practices are implemented, flies are not normally a major problem at composting sites. However, infestations may occur from time to time despite an operator's best efforts. Some practices that can be used to control infestations include:

- Break the reproductive cycle of the fly population by turning active composting piles two to three times per week (this will bury fly eggs and larvae deeper into the pile, where they will be killed by the higher temperatures)
- Place a layer of partially finished or screened compost overtop compost pile(s) the flies are attracted to. (this prevents access, but also insulates the pile and helps raise the internal temperature high enough to kill off fly eggs and larvae)
- Deploy insecticide-free traps for adult flies

Fly populations can also be controlled using predator-insects that are native to Alberta (for example, parasitic wasps). These predator-insects can be purchased from Canadian vendors,

and released at the site. They are unlikely to eradicate the flies completely, but can reduce their populations to a more acceptable level.

Anytime there is a noticeable increase in the number of flies at the compost site, the operator should re-assess their operating practices to confirm that feedstocks are being promptly processed, conditions in the composting piles are optimal, and there is no excessive leachate accumulating around the base of compost piles.

## 4.17 Odour Control

Odours are the highest profile issue associated with composting. This issue is complicated by the fact that human's noses vary in sensitivity, and responses to odours are very subjective: an odour that one person considers acceptable may be very offensive to another person.

Failure to prevent odours, and to acknowledge or address their impacts on nearby neighbours, has resulted in strained relationships, lawsuits, environmental protection orders from regulators, and closure of facilities.

### 4.17.1 Sources of Odours at Composting Sites

A common mistake made by many novice compost operators is to focus all their attention and efforts on reducing odours from the active composting piles. While this can be one of the more significant odour sources, Table 4.4 clearly demonstrates that it is only one of many sources.

**Table 4.4. Typical Odour Sources at Composting Facilities**

<b>Waste material transport and storage</b>
Load trucks driving around and parking on the site
Feedstock unloading operations
Untreated emissions from temporary feedstock storage
Spillage from trucks
Spillage around storage facilities
Puddles from truck washing
Waste material tracked around site on truck tires
<b>Mixing</b>
Emissions from handling and moving feedstocks
Untreated emissions from pre-processing (mixing, shredding, grinding)
Material spilled during pre-processing
Residue on pre-processing equipment
<b>Compost pile building</b>
Emissions from handling and moving feedstocks
Spillage
Residue left on equipment
Large clumps of waste from poor mixing
<b>Processing</b>
Venting of tanks and sumps
Fugitive emissions from treatment vessels and aeration systems
Surface emissions from composting and curing piles
Leachate puddles at the base of composting piles
Leakage and ponding of condensate and leachate

Source: Environment Canada, 2013

### **4.17.2 Measuring Odours**

Odorous emissions from composting and other facilities can be measured by collecting and analyzing samples of air from in an around the facility. This analysis can identify the specific odour compounds that are present, and measure the concentrations, even when the concentrations are very low. However, there are two problems with this approach.

First is the cost of measuring odours in this manner: laboratory analysis to quantify the concentrations of specific compounds run in the hundreds and thousands of dollars. Secondly, odour emissions from composting facilities are dynamic: the compounds generated and their

concentrations can change from week to week, day to day, and even from hour to hour. The costs combined with the variability make it impractical for even the largest composting facilities to quantify the ranges in types and concentrations of odour compounds emitted.

To resolve this situation, scientists who study odours have devised five alternative parameters that measure human responses to odours. These measures have been adopted by several government agencies and are used in the composting industry, as well as by confined livestock operations, rendering plants, and wastewater treatment plants (WWTPs).

The five parameters are:

1. Odour Threshold
2. Odour Intensity
3. Odour Persistency
4. Hedonic Tone
5. Odour Character

Odour threshold and intensity are the parameters most commonly used.

**Odour threshold** is also known as odour concentration or odour strength. It is reported as a dimensionless dilution ratio, as dilutions to threshold (D/T), or using a pseudo-dimensional unit called an Odour Unit (OU). The measurement protocol involves a group of trained individuals (the odour panel) and a device called an olfactometer. The protocol is outlined in various international standards: The American Society for Testing and Materials International (ASTM) standard is the most commonly accepted methodology in Canada.

Two odour thresholds are measured by the test:

1. A detection threshold, where the panelists can determine there is an odour present in the air sample
2. A recognition threshold, where they can positively identify the character of the odour

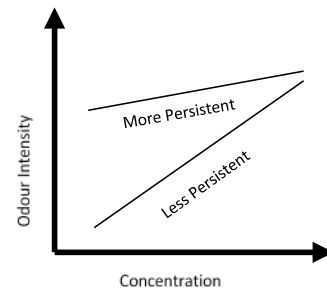
Basically, the olfactometer exposes each panelist to a sample of the odorous air that has been diluted with filtered non-odorous air. Panelists indicate when they can detect or recognize an odour in the sample. The person operating the olfactometer sequentially feeds samples to the panelists that are less and less diluted, and continues until half of the panelists indicate that they can detect or recognize the odour.

The results from all panelists are averaged, and odour strength is reported in terms of dilutions to threshold or odour units ( $1 \text{ D/T} = 1 \text{ OU}$ ). A higher D/T result means that more filtered air is required to dilute the original air sample to the threshold level, so the original sample is more odorous.



Third-party odour panelists are commonly employed for this type of testing because their certification and experience makes them more consistent, and they have no personal bias or sensitivity to a project (compared to locals who might have a vested interest in the facility or be opposed to it).

**Odour intensity** is a measure of the relative strength of the odour above the recognition threshold. Measuring intensity in accordance with the ASTM standard involves exposing panelists to a sample of the undiluted odorous air, and then exposing them to the odours from a series of increasing concentrations of butanol (also called butyl alcohol or n-butanol). The average assessment of all panelists is the reported intensity for the sample, and is expressed in units of parts per million (ppm) butanol equivalent. A higher butanol equivalence means the odour is more intense.



**Figure 4.5. Graph of Odour Intensity vs Concentration**

Butanol equivalent concentrations associated with intensity measurements can be converted to a numerical scale. For many people, this is an easier way to look at the results. Standardized reference scales with 5, 8, 10, and 12 reference points have been developed and are commonly used.

The intensity of an odour changes as the concentration of the odour compound increases or decreases.

Masking is the term used to describe when an intense odour prevents a person from detecting a less intense odour.

Ammonia is a common odour compound that comes from active composting piles. Ammonia is not very persistent, and as it drifts downwind from the facility and is diluted, it quickly becomes unnoticeable.

The intensity of ammonia generated by composting piles can sometimes mask another less intense odour. If the underlying odour is very persistent, it may still be detectable as it drifts downwind. Neighbours might complain about the underlying odour, but since it is being masked by the smell of ammonia at the site, the operator might mistakenly assume the composting facility is not the source of the odour.

Masking agents are chemicals with a pleasant smell (e.g., lemon, floral scents, bubble gum) that are intentionally released into the air to cover an unpleasant odour. The masking agent does not eliminate or reduce the unpleasant odour.

Car air fresheners, scented candles, potpourri, and scented oils are examples of everyday masking agents used by homeowners.

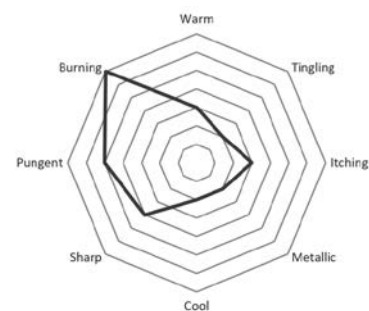
Masking agents can also be used at composting facilities, WWTPs, and transfer stations. In these

**Odour Persistence** is used to express how fast an odour compound's intensity changes relative to its concentration. It is measured in a lab and represented in a dose-response graph.

The rate of change is different for different odour compounds, and persistence is an important factor in the phenomena commonly known as odour masking.

Odour threshold and intensity do not distinguish between individual odours or measure how offensive an odour is. The **hedonic tone** is sometimes used with odour concentration to rate the pleasantness or unpleasantness of an odour sample. The hedonic tone is a subjective measure of odour offensiveness or pleasantness (on a scale from -10 to +10) that is made by odour panellists at the same time that odour concentration is measured.

**Odour character** is also known as odour quality. It is determined by an odour panel who describes what the odour smells like and what the odour feels like (for example, burning, cooling, itching) using a list of standard descriptors. The panelists also measure the relative strength of the characteristics they report. The results from the panelists are combined and summarized in descriptor graphs or "fingerprints."



**Figure 4.6. Radar Graph Used to Show Odour Character**

### 4.17.3 Collecting Air Samples for Analysis

Collecting representative air samples for odour analysis involves special equipment and techniques (including non-reactive, non-odorous sample bags), and is normally done by third-

party experts. Different techniques are used to collect air samples from pressurized vessels and air ducts, compost piles that are positively or negatively aerated with fans, and unaerated composting piles and windrows.

#### **4.17.4 Odour Modelling**

Computer-based atmospheric dispersion models can be used to predict where odours from a composting facility will travel under various weather conditions, and the magnitude of odour impacts on adjacent properties.

Dispersion models rely on weather data (for example, wind speed and direction, temperature) collected close to the site and digital models of the local topography. Information on the type and location of each specific odour emission source (for example, compost piles, vent stacks, leachate ponds) are also fed into the model, along with emission rates for each source. Odour emission rates can be determined by collecting air samples from similar sources at other composting facilities as described in the previous section, and measuring their odour characteristics (for example, odour threshold, intensity).

Using the various inputs, the dispersion model calculates what the overall odour impact from all sources will be at numerous points around the facility. The model output is normally shown as “isopleths” of different odour concentrations (odour units) overlain on an aerial photo or map of the site.

Dispersion modelling is normally used before construction of the facility. For example, early in the planning process when several potential host sites are being considered, modelling can be done to assess the number of impacted neighbours at each site and assist with the selection process. Due to cost and complexity involved, dispersion modelling is usually reserved for mid-sized and larger composting facilities, or facilities sited in high-density urban areas.

#### **4.17.5 Capturing and Treating Odours**

If odorous process air from composting piles can be captured, it can be treated to reduce the concentration of odour compounds. This is one of the benefits of using enclosed or in-vessel composting systems, or ASPs that incorporate negative aeration.

Enclosing feedstock receiving, pre-processing, and composting operations in buildings can also allow odorous emissions to be captured. In these cases, the ventilation system should be designed for high air exchange rates and capture of odours at their source (rather than allowing odours to permeate throughout the enclosed area).

While it helps from an odour control perspective, enclosing composting activities in buildings poses other challenges. Dust can accumulate in buildings used for receiving and shredding

feedstocks, which increases the risk of fire and can affect the quality of the air that staff working inside the building are exposed to. Alternatively, the interior of buildings that enclose active composting piles can be very humid, which can lead to faster corrosion of unprotected building components and equipment.

Two treatment methods are commonly used to treat odours air captured in composting facilities: wet scrubbers and biofilters.

Wet scrubbers use water or a diluted acid solution to remove odour compounds from the air stream. Depending upon the design, the water or acid solution is either sprayed downwards on a bed of porous, plastic media through which the air passes, or it is injected as a fine mist directly into the air stream.

Biofilters are the most popular choice for treating odorous airstreams from composting and other organic waste treatment facilities. Provided they are properly designed and operated, biofilters can remove a wide range of odour compounds, and have treatment efficiencies in the range of 90 to 95%. Treatment efficiencies for some odorous compounds, such as hydrogen sulphide, can be as high as 99%. The effectiveness of biofilter-based odour treatment systems may also be enhanced by coupling them with additional unit processes, such as a wet scrubber.

A typical biofilter consists of a bed of moistened organic media that sits overtop of a network of perforated pipes or aeration trenches, similar to a positive ASP. The organic media often consists of coarse woodchips with a small amount of compost mixed in, or the coarse, oversized material from screening of finished compost. Air is forced through the pipes and trenches and the media bed using centrifugal fans. As the air passes through the media, odour compounds are absorbed into the thin water film that surrounds the individual media particles, and are decomposed by bacteria and fungi that live in the media.



**Photo 4.31. Biofilters are commonly used to treat odours from composting systems**

*Source: CH2M*

The organic media in the biofilter slowly degrades and eventually reaches a point where it does not have enough free air space. When this occurs, typically after 2 to 4 years of operation, the media is removed and replaced with fresh media. Organic media biofilter systems are also usually segregated into different cells so that media can be replaced at different times to not leave a composting facility without any odour treatment as the changeout occurs in any one cell. Time is also required to cultivate the microbial population in a biofilter with fresh media to return the unit to its full odour treatment capacity.

Several manufacturers provide enclosed biofilter systems that use proprietary media manufactured from synthetic materials. These biofilters operate in the same manner as the previously described system, but the media used does not break down as rapidly and will last for 10 or more years before it is replaced.

Just like in a composting pile, operators must monitor and manage temperatures and moisture levels in the biofilter media. If the biofilter media is too dry (for example, less than 40% moisture content) or too hot (more than 40°C), it will not support the bacteria and fungi that break down the odour compounds, and treatment efficiency will be reduced. If the media is too wet, air flow can be impeded. It is generally recommended that the moisture content of the media be maintained between 40 and 60%, and that the temperatures do not exceed 40°C.

Carbon adsorption systems are effective for removing a wide range of odour compounds and are used in many other industries. They can be used to treat odours from small sources at composting facilities, such as leachate tanks and sumps, or biosolids storage hoppers. Carbon adsorption is not well-suited to treating odorous air captured from compost aeration systems due to the high levels of ammonia and amines that are typically present in the air stream. The capacity of commercially available carbon adsorption systems is also a limiting factor that generally prevents them from being used to treat building air from enclosed composting facilities.

#### 4.17.6 Operational Controls

Every composting facility operator should know and understand the sources of odour at their facility, and develop proactive strategies to manage them. This would include the types of odours, conditions that lead to odour release, practices that reduce odour potential, and the potential for impact to neighbouring land uses.



**Photo 4.32. Carbon adsorption systems can be used to treat odours on sumps and tanks**

*Source: Scott Gamble*

Preventing odours requires consistent management, starting with immediate attention to incoming feedstocks. Feedstocks should be pre-processed and moved to the active composting piles as quickly as possible after they are received at the site; ideally by the end of the day they are received, and certainly with 48 hours.

Appropriate feedstock recipes need to be used. There needs to be enough moisture to sustain microbes, but not too much or the free air spaces in the material will be filled, and oxygen transfer will suffer. Nitrogen-rich materials need to be mixed with carbon-rich amendments to arrive at a mixture with a C:N ratio in the range of 25:1 or 35:1. Excess nitrogen in the material (indicated by a lower C:N ratio) can lead to release of the ammonia, which has a pungent smell.

A recipe resulting in a C:N ratio that is too low may also result in accelerated microbial growth. This can increase the oxygen demand of the composting pile, and if enough air cannot be provided (through passive or active aeration), anaerobic conditions can set in. An over-active pile can also become too hot, which can lead to more rapid moisture loss.

Regular monitoring of conditions in composting piles and good record keeping are important elements within a process management plan, and can help to make decisions that will avoid odours. Once feedstocks and bulking agents are incorporated into the composting pile, odour problems are often the result of oxygen levels being too low. The compost pile must have sufficient free air space to allow for the movement of air through the pile. As the material in the pile degrades, it may also be necessary to agitate or turn the pile to fluff it up and re-establish pore spaces that were lost as the material consolidated.

It is very important that composting piles not be over-sized. If the pile is too high, its weight can compress materials in the base of the pile, and reduce the amount of free air space. For the same reason, equipment should never be driven onto a composting pile, and operators should take care to not let the front tires of their front-end loaders touch the pile when building or turning it. If a passively aerated composting pile is too wide, air may not be able to reach the core of the pile.

The recommended temperature for active composting is between 50°C and 60°C, and the process should be managed within these ranges (except during PFRP when temperatures need to be greater than 55°C). At higher temperatures, microbe activity may be impaired, and the



**Photo 4.33. Compost piles that are too large or which do not have enough free air space are likely to create offensive odours**

*Source: Scott Gamble*

degradation process can slow. Anecdotally, higher temperatures have also been observed to result in the generation and release of more odour compounds.

As mentioned, excessive moisture in a composting pile can reduce free air space and limit the movement of air through the pile. When adding water to piles during the compost and curing processes, care must be taken by operators to not add too much, since removing excess water can be difficult. Excess water can also seep through the pile and accumulate around the outside bottom edges, where it can become a source of odours, as well as an attractant to flies.

If large amounts of water are required, it is recommended that the operator add it in two stages over a 2- or 3-day period. This will reduce the impact of a mistake made in calculating water addition rates, and provide the operator with an opportunity to make a correction during the second watering event.

Operators should be flexible and consider weather conditions and activities on adjacent sites. For example, turning immature compost piles on a hot, calm day should be postponed to avoid the possibility that odours released will linger and impact neighbours. Similarly, if neighbours have scheduled large outdoor events and have invited guests to their site, operators should take extra precautions to prevent impacts that might disrupt the event.

Cleanliness and implementing good housekeeping practices around the facility are also important. On their own, the material spilled around mixing and screening equipment, material that spills from overfull loader buckets around the site, residual piles, and standing water may not be significant odour sources. But added together, the cumulative odour impacts can be noticeable.

## 4.18 Process Water Management

Process water is the broad term adopted by AEP that describes liquids from compost sites that contain contaminants and could cause environmental impacts if they are released. The main sources of process water at composting facilities are stormwater runoff and leachate, but equipment washdown water and wastewater may also be contributors.

Stormwater runoff is any rainwater or meltwater that drains as surface flow from the composting facility. If runoff does not come in contact with feedstocks or compost piles, it may technically be



**Photo 4.34. Portable mist sprayer for masking agents used at a composting facility.**

*Source: Scott Gamble*

clean enough to be released offsite without treatment. However, when contact does occur, various contaminants can be picked up by the runoff, making it unsuitable for release. To provide the necessary level of environmental protection and compliance with regulations, it should be assumed that the runoff from receiving, processing, and curing areas is contaminated until sampling and testing proves otherwise.

Leachate refers to process water that seeps from unprocessed feedstocks, or materials being composted or cured. It includes:

- Precipitation that falls on and percolates through outdoor composting piles and biofilters
- Water that is released from feedstocks during storage, preparation, composting, and curing
- Excess water that leaches from compost during moisture addition

Precipitation that falls on and drains through finished compost in storage areas at the composting facility and runoff from compost storage areas are not considered to be process water.

Wastewater is defined broadly enough by AEP to include many sources at the site, including:

- Condensate from aeration systems
- Centrate from onsite dewatering of feedstocks
- Blowdown and effluent from scrubbers and heat exchangers
- Domestic sewage from washrooms

#### 4.18.1 Process Water Characteristics

Leachate and runoff from composting activities can be very strong in terms of biochemical oxygen demand (BOD) and chemical oxygen demand (COD). BOD is a measure of the amount of dissolved oxygen (DO) required to biochemically oxidize the degradable organics in the leachate. A high BOD leachate released to receiving water has a higher risk of causing an impact due to oxygen depletion in the stream (river, creek, lake, ocean) than one with a low BOD (either naturally or after treatment).

COD measures all the organic and inorganic materials present that can be oxidized by heat and acid. Since it includes organic materials that are not normally



**Photo 4.35. Runoff and leachate from composting facilities can have high BOD and contain other contaminants, and should be contained**

*Source: CH2M*



biodegradable, the COD of a leachate will always be higher than its BOD. The ratio of BOD to COD provides an indicator as to the biodegradability of the leachate.

Composting facility leachate may contain other contaminants, such ammonia-nitrogen, phosphorous, and suspended solids. If these contaminants make their way into streams, lakes, and other surface water bodies, they can be toxic to aquatic life and plants.

Leachate can also contain high levels of pathogens, as well as resin and fatty acids. Resin and fatty acids result from water leaching through stockpiles of wood waste, including ground yard waste and woodchip amendments. These leachates often have a noticeable black or brown colour, and when discharged to surface waters, can cause white foam to develop on the water's surface.

#### 4.18.2 Process Water Reduction

Due the costs and logistical implications associated with treating or disposing of process waters, site design and operating practices should emphasize reduction and re-use. Treatment or disposal should be considered once reduction and re-use opportunities have been implemented.

Provided it is not contaminated by other site activities, the precipitation that falls within the boundaries of the composting facility, but not within the receiving, processing, and curing areas, does not need to be managed as process water. The site should be graded to keep this runoff from draining into feedstock storage, composting and curing areas, and product storage areas. Constructing berms around processing areas is another common practice used to prevent runoff from adjacent areas from entering the active processing areas and contributing to runoff volumes.

Within the processing areas, buildings, pole barns, and other types of covered enclosures can be used to prevent precipitation from coming in contact with feedstocks and compost. The runoff from the roof gutters and downspouts on these structures can be collected in tanks, diverted to stormwater sewers, or diverted to the perimeter of the processing areas using downspouts or buried drainage pipes.

Roof drains and downspouts should also be directed away from biofilters that might be near the building. This minimizes the amount of biofilter leachate that needs to be managed,



**Photo 4.36. Enclosing composting activities inside a fabric-type structure can significantly reduce runoff volumes and treatment costs**

*Source: CH2M*

and prevents the drainage water from saturating the biofilter media and affecting its odour treatment performance.

Operators need to develop and follow appropriate feedstock recipes. If enough amendments are not added to wet feedstocks, or too much water is added to composting piles, the excess water will seep from the compost pile as leachate. To minimize leaching, the moisture content in initial feedstock mixtures and in composting piles should be maintained below the maximum recommended moisture content of 65%. Moisture contents of 55 to 60% are more typical.

The shape of compost piles can have a considerable influence on the amount of precipitation retained in a pile. Piles with flat or concave tops retain water, while a convex or peaked shape is better at shedding water. These effects are most noticed when the composting process is just starting or after a period of dry weather.

In the early stages of composting, a peaked windrow shape can act like a thatched roof or haystack, effectively shedding water. Part of this effect is due to the large initial particle size, and part is due to waxes and oils on the surfaces of particles. Both of these initial effects will diminish over time as the material decomposes. During dry weather, the outer surface of evenly stabilized organic material can become somewhat water-resistant, limiting absorption and encouraging runoff.

### **4.18.3 Process Water Collection**

The contaminated precipitation that runs off outdoor processing areas, and the leachate that seeps from composting piles, needs to be collected and managed to prevent negative environmental impacts. Working surfaces in processing and product storage areas are generally constructed with a slight slope to encourage drainage. Sloped pads are also intended to prevent puddles and standing water, which can be a source of odours and can attract flies and mosquitos.

The runoff and leachate from outdoor working pads is generally captured and held in a retention pond. If the composting site is large, it might be more cost-effective to construct two smaller ponds rather than grade the entire site to drain into a single pond.

To prevent the contents of the ponds from leaching out and impacting groundwater, ponds are normally lined with a compacted clay or a synthetic liner. To avoid damaging these liners, mobile equipment should never be driven into ponds unless there are features in place (for example, concrete slabs) that have been specifically designed for this purpose.

Retention ponds must be designed to hold, at a minimum, all of the runoff generated during a 1 in 25-year, 24-hour rainfall event. The site designer calculates this runoff volume based on historical

rainfall records for the geographic area where the compost site is located, and the size of the catchment areas that drain into the pond.

If a pond is designed to hold the minimum runoff volume and is already partially filled when a large storm occurs, the pond can overflow. Overflows from retention ponds are a reportable release as discussed in Section 6.3.7, and depending on the situation, may trigger the need for soil or groundwater investigations and remediation work.

Operators need to regularly check the levels in retention ponds, and take the necessary steps to test and remove extra water.



**Photo 4.37. Water levels in retention ponds need to be checked regularly to prevent overflows and releases**

*Source: CH2M*

To provide operators with some flexibility in managing pond water volumes, engineers often over-design the capacity of the pond. This means the pond can always have some amount of water stored in it (that is, dead storage), but still have enough unused capacity to handle storm events (that is, live storage). Not only does dead storage provide flexibility, it means that there is always a source of water onsite to moisten compost piles and to use for extinguishing fires.

Depending on the site layout and size, ditches or swales might be needed to transfer the runoff from working pads to retention ponds. To minimize erosion and reduce deposition of sediments further downstream, ditches and swales are normally grassed. In areas where water velocities are particularly high, it may be necessary to reinforce the ditch with riprap or culverts.

In high-precipitation areas like the West Coast of British Columbia, it is common to see outdoor working pads with trench drains, gutters, or catch basins. The amount of precipitation in Alberta does not normally warrant these design features.

Leachate produced in forced aeration systems or within the vessels of some composting systems are normally collected using underground drainage pipes designed into the system. This leachate often drains to an underground holding tank or to a sump, from which it can be pumped to an aboveground holding tank or into a truck for offsite disposal.

Operators at sites that use ditches and swales to convey runoff need to regularly inspect them to make sure there is not sediment buildup or blockages impeding flow. Similarly, any underground drainage lines and tanks need to be cleaned and inspected regularly. Cleaning usually requires the use of high-pressure water hoses and vacuum trucks. Inspection of underground tanks and pipes can be done using sewer cameras.

Operators also need to be mindful of sediments that accumulate in retention ponds. Over a period of 3 to 5 years, the amount of material that accumulates can be significant, and the sediments can affect the ability to pump or re-use the pond water. Concrete sedimentation basins or filter berms can be installed upstream of retention ponds to allow for capture and easy clean-out of sediments before they enter the pond.



**Photo 4.38. Basins and intercepts can be used to keep sediments out of retention ponds**

*Source: Scott Gamble*

The amount of sediments should be checked and removed as necessary. If they cannot be blended into fresh feedstocks and composted, sediments from ditches and retention ponds will need to be disposed of at an approved waste management facility. It might also be possible to land-apply the sediments; however, it is recommended that operators discuss this option with AEP staff before proceeding.

At facilities that operate in the winter, it is often necessary to remove snow from access roadways and processing areas to allow for continued operations. Operators should consider locations where the cleared snow will be stockpiled, as this will be a significant source of runoff in the spring. For example, piling snow on the upslope side of processing areas means that the snowmelt will run through the processing area for several weeks in the spring, contributing to runoff and poor working conditions.

#### **4.18.4 Process Water Re-Use**

Runoff and leachate that is collected in tanks and retention ponds can often be recirculated back into the composting process. This lets operators avoid having to use potable water to replace the moisture lost during the composting process, and avoids having to treat or dispose of extra runoff and leachate.

However, operators must be mindful that the runoff and leachate may contain enough pathogens to re-contaminate the compost and curing piles. It is important that runoff or leachate that contains pathogens only be recycled back onto compost piles that have not started the pathogen reduction stage.

Engineers sometimes design composting sites so that various working pads drain into different ponds. Often, this is done to reduce the amount of earthwork cuts and fills (and construction costs) required to slope large pads to a single location. This is also done intentionally to allow for better management of runoff and leachate.

For example, the runoff from the receiving and active composting area might be drained into one pond, while the runoff from the curing pad is drained to a second pond. The runoff from the curing pad should have a lower BOD and should not contain pathogens, and can be recycling back onto composting and curing piles with no treatment. Runoff from the receiving and active composting area is more likely to contain high BOD levels and pathogens, and can only be used to water piles before the start of the pathogen reduction stage.

Another consideration with re-use of leachate is odours. Leachate, particularly if it has a high BOD, can have an offensive smell. Handling and spraying the leachate on composting piles releases these odours, and the smells might be strong enough to impact neighbours.

#### 4.18.5 Onsite Treatment of Leachate and Runoff

There are a variety of methods and technologies that can be integrated into composting sites to treat or reduce the volume of leachate and runoff. Many of these technologies employ natural biological processes, while others rely on chemical or physical changes. The choice of treatment method used is a function of the strength and characteristics of the process water. The choice also depends on what will happen to the process water after it is treated: will it be discharged to the environment, re-used onsite in the composting process, or transferred to a WWTP for further treatment.

Natural treatment methods are becoming a more popular option for composting sites. These methods include the use of constructed wetlands and bioswales, either individually or in combination. The vegetation used in these systems cleanses runoff water by absorbing and incorporating excess nutrients, especially nitrates and phosphates, into their own tissue. Moreover, plant roots, stems, and leaves provide additional surface area upon which bacteria, fungi, and, in some cases, algae can flourish. These microbes not only remove dissolved nutrients, but also feed on carbon compounds that are suspended

Discharges to WWTPs sometimes needs to be scheduled during off-peak hours, which can complicate logistics and increase costs.



**Photo 4.39. Wetlands can be designed to treat runoff from composting facilities**

*Source: CH2M*

as solids or dissolved in the water. Plants and associated microorganisms in these systems can also help reduce concentrations of heavy metals.

Filter strips can be implemented to help remove fine suspended solids from process water before being discharged. Filter strips use native grasses and other surface vegetation to trap particles. Runoff is directed over the filter strip in a thin, even layer. Captured particles settle out of the water and into the soil or are physically filtered and adsorbed by the plants. Suspended particles flowing slowly through the grass attach to plants and settle to the soil surface.

Sediment basins and filter berms can be used to remove suspended particles out of runoff water. In a sediment basin, particles settle by gravity as water slowly moves through the basin. Filter berms constructed from coarse compost are placed across ditches and swales, usually in series, to intersect the flow; water flows through the compost material while sediments are retained in the compost. These approaches can be particularly effective for removing phosphorous associated with sediment. This will help limit sediment movement offsite, and can be a useful addition to either a vegetative filter strip or a treatment pond, enhancing the effectiveness of each.

Installing aeration equipment in retention ponds can treat leachates with higher BOD levels.

Types of equipment used in these applications include:

- Fountains
- Floating surface aerators
- Venture aerators
- Subsurface micro-bubble diffusers and tubing

Process water can be allowed to evaporate to reduce volume, particularly in southern Alberta. Process water is sprayed back over the retention pond or the composting pad using mist cannons; the fine droplets created will increase the amount of water that evaporates into the atmosphere.

Shock chlorination is a method of treating pathogens in leachate and runoff water. Shock chlorination can be done using the same calcium hypochlorite granules used in swimming pools; this is generally safer than transporting and handling liquid chlorination products. The amount of calcium hypochlorite required will vary based on the volume of process water being



**Photo 4.40. Aeration systems can be installed in retention ponds to reduce BOD and treat odours**

*Source: Scott Gamble*

treated, and the amount of suspended and dissolved organic matter in the water. Trials are usually required to determine the appropriate calcium hypochlorite dosage.

#### 4.18.6 Offsite Disposal of Leachate and Runoff

At some point, an operator may be faced with extra runoff or leachate in their retention pond that cannot be re-used or treated. Offsite disposal of the material may be the only option.

It may be possible to dispose of surplus process water at an approved wastewater treatment facility. Generally, the process water needs to meet the treatment plant's acceptance criteria, and a permit to discharge needs to be obtained from the municipality that owns the facility. Receiving permission to discharge to a treatment plant requires sampling and analysis of the process water, and usually takes several weeks to obtain. Special handling fees, or surcharge fees for over-strength wastewater (for example, high BOD levels), might also be charged by the municipality in addition to their regular disposal charges.

At facilities in rural areas, it may be possible to dispose of process water with lower levels of contamination through spray irrigation on nearby agricultural land. Irrigation must be done in accordance with AEP's [Guidelines for Municipal Wastewater Irrigation](#). Local AEP representatives should be consulted to confirm whether special approvals are required for this disposal method.

Another option for process water disposal is by deep well injection. Deep wells are approved by the Alberta Energy Regulator according to [Directive 051: Injection and Disposal Wells](#).

### 4.19 Equipment Maintenance and Replacement

Poor maintenance of facilities and equipment can lead to breakdowns, increased site hazards, and the inability to process feedstocks or manage the compost process. Ultimately, this can result in odours or other nuisance conditions. Downtime due to unscheduled maintenance can also have implications on a facility's operating costs and revenues. The cost of downtime not only includes the cost of repair, but also includes the cost of lost production and the need to hire temporary replacement equipment.

There are three types of equipment maintenance:

1. **Reactive:** Repair when something breaks
2. **Preventative:** Scheduled maintenance according to hours operated
3. **Predictive:** Using predictive indicators to plan repairs

Reactive maintenance will result in unplanned equipment downtime and a shorter operating life cycle for the equipment. Preventative maintenance is typically carried out on time-based intervals according to the manufacturer's recommendations.

Predictive maintenance involves measuring the performance of a piece of equipment along with other indicators (for example, contaminant levels in oil and hydraulic fluid, fuel consumption, temperature of bearings). This information is used to predict whether routine servicing and maintenance activities need to be accelerated or can be deferred, compared to the normal time-based schedule. Predictive maintenance is more involved, as it requires time and effort to monitor, record, and analyze indicators. However, it can result in cost savings over the life of the equipment because maintenance tasks are performed only when needed.

Most composting facilities rely heavily on mobile equipment, such as front-end loaders, windrow turners, and potable screens. Maintenance of this equipment is relatively straight forward and can be done using in-house or local resources, although some spare parts (for example, grinder teeth, windrow turner flails) may have to be ordered from out-of-province suppliers. Preventative maintenance programs are appropriate and are the most convenient for the mobile equipment commonly used at composting sites.

Larger facilities tend to also use pre-engineered composting systems that involve aeration fans and automated systems, and are powered by electricity. Maintenance of these systems is more complex, and may require hiring industrial electricians, instrumentation technicians, or a specialized mechanical maintenance contractor.

Every machine will reach a point where rising maintenance costs and increased downtime dictate that it be replaced. The life cycle for mobile equipment and processing equipment varies with the application it is put to. For example, a front-end loader working inside a large, enclosed composting facility might only operate reliably for 7,500 hours. The same unit operating in a less-challenging application, such as a gravel pit, can likely be operated for considerably longer. Some manufacturers of front-end loaders offer add-on packages (for example, more guarding, heavier duty components, reversing fans on radiators) aimed at extending the service life of their equipment.

When it comes time to replace a unit, the facility's owner can decide to purchase a new machine, or may consider replacing it with a used or rebuilt unit. A complete rebuild may give another 10,000 hours of equipment operating life at less expense than a new machine purchase. A disadvantage of a rebuild is that it will not bring the machine up to the latest technologies that may have evolved since its manufacture.

The facility operator or manager will need to also manage supplies and inventories for the site. This includes spare parts for equipment, shop supplies, oils, greases, filters, and fuel. This may require a tracking system so that supplies are ordered and delivered before there are shortages.



Fuel storage supplies will need to be monitored. Maintaining a record of supplies delivered and fuel used can help determine fuel demand and delivery frequency. With consistent fuel usage, delivery of fuel supplies can be scheduled with vendors.

## 4.20 Liner Protection and Working Surface Maintenance

Some form of containment liner is required below the operating areas of a composting facility. A liner constructed from clay soils is most commonly used, but synthetic liners, concrete, and asphalt are also acceptable. Synthetic liners are typically made from high-density polyethylene (HDPE), low-density polyethylene (LDPE), or polyvinyl chloride (PVC).

Liners (particularly clay liners) are the barrier that prevents the leachate produced by composting activities from impacting the groundwater. Great care and attention must be taken when operating a composting facility to avoid damaging the liner.

In many cases, a working surface of soil, gravel, or crushed concrete is laid overtop of clay or synthetic liners to protect them from damage and to provide a working surface that is accessible in all weather conditions. Asphalt and concrete surfaces require no overlying protective layer: they can easily withstand the weight of equipment and vehicles, and the heat from composting piles.

At some facilities, a protective layer is not installed on top of the engineered clay liner. In this case, the operator must be diligent in making sure the liner is not damaged by loaders or other equipment as compost piles are being moved and turned. Any damage to the liner, including wheel ruts, needs to be repaired.

Retention ponds are normally lined with clay or with a synthetic material. Since there is no vehicle traffic in these areas, protective layers are not normally installed. However, carelessness when

Synthetic liners used in retention ponds can be very slippery when they are wet. In some cases, it may be impossible for a person to scramble back up the sloped side of a pond if they slip and fall in.

For this reason, many facilities anchor knotted ropes at several locations around the top edge of ponds, and drape the ropes down the ponds' side into the water. The ropes help a person pull themselves out of the pond if they fall in.

handling pumps and hoses used to remove water from the ponds can result in punctures or tears to synthetic pond liners.

Working surfaces and roads should be inspected on a regular basis for damage, settlement, or rutting. Areas below and near composting piles and product storage piles should be inspected each time a pile is moved. Concrete and asphalt surfaces should be checked for cracking, and differential settlement that might lead to cracking in the future. Asphalt surfaces should also be checked for wear as repeated scraping in the same area by the bucket on a front-end loader will eventually wear through the asphalt.

Any damage to liners needs to be repaired as quickly as possible; it may be necessary to close the area off so it cannot be used until the repairs are completed. Inspections and any repairs that are completed should be noted in the facility's operating records.

## 4.21 Weather-Related Considerations

Not all composting facilities receive and process feedstocks on a year-round basis. Many yard waste processing facilities only operate during the spring and summer months, thereby avoiding many of the problems associated with composting during the winter. While seasonal facilities generally have a more simplistic design, climatic conditions cannot be ignored.

Precipitation, whether it results from rain or snow fall, is a key consideration during the facility and process design stage. Not only must precipitation be managed to control run-on and runoff, but it can also lead to other problems:

- Excessive rain can increase the moisture content of uncovered stockpiles of amendments, reducing their effectiveness for balancing moisture in wet feedstocks
- Excessive rain can saturate outdoor composting piles, possibly leading to nuisance conditions
- Concentrated runoff from roof gutters and downspouts can erode working surfaces or flood processing areas, biofilters, or storage piles
- Snow that melts from the heat of the composting process can refreeze on working surfaces, creating slip hazards or problems with vehicle traction

High and low temperatures can similarly lead to problems. If temperatures are too low, it can affect or stop the composting process. In extreme cases, windrows and piles will freeze. Operation of outdoor facilities on a year-round basis is possible in Alberta with proper operational and management practices. However, in some cases, it may be preferable to resort to an enclosed facility design for year-round operation.



**Photo 4.41. Composting in the winter**

*Source: Scott Gamble*

Hot weather can be equally problematic. High temperatures can lead to high rates of evaporation, resulting in outdoor windrows becoming overly dry. Through the combination of warm, outdoor temperatures and a hot composting process, indoor facilities can become virtual saunas during the summer months, which can lead to heat exhaustion and heat stroke for site personnel.

## 4.22 Product Sampling, Testing, and Quality Assurance

One of the keys to satisfying customers and ensuring continued success of your marketing and sales programs is to produce a product that is consistent and meets all end-product quality criteria. Inconsistent products, or distributing poor quality products, can limit the demand for compost products.

Implementation of a quality assurance and quality control (QA/QC) program is one of the main ways manufacturing industries maintain the desired level of quality in their products. A QA/QC program is simply the combination of various tools, measures, and proactive management methods that allow control of inputs, processes, and outputs to meet customer requirements. A typical QA/QC program at a composting facility starts with the process control system implemented during the composting processes, and ends with finished product testing.

Finished compost should not be removed from the composting facility until all QA/QC steps have been completed, and compliance with regulatory criteria has been verified.

### 4.22.1 Process Controls

Process controls are the combination of tools and procedures used to monitor and document the critical control points during the feedstock preparation, active composting, and curing stages. Its purpose is to control the composting process to verify consistent manufacturing process, to minimize defects, and to make products that can be guaranteed to customers.

Control methods will vary with the size of operation, level of technology, and end-product goals. For small composting facilities that do not market final products offsite, control points might be limited to one or two process variables (for example, temperature, bulk density, moisture content); and monitoring might be done every 1 to 3 weeks. At larger composting facilities and those that use actively aerated technologies, more variables are generally measured, and measurements are done more frequently.

Table 4.5 provides an example of a process control plan. The key components include:

- Identifying the critical variables and the upper and lower limits of each
- Selecting suitable instruments to measure the key variables
- Maintaining and calibrating instruments
- Developing and following documented procedures
- Providing training to operators
- Maintaining records
- Building in checks on results and data quality where possible
- Reviewing, understanding, and acting on the data

**Table 4.5. Example of a process control plan showing Monitoring Parameters and Frequency**

Control Parameter	Active Composting		Curing	
	Control Limits	Monitoring Frequency	Control Limits	Monitoring Frequency
Moisture Content	55 to 60%	At the start, and once per week	55 to 60%	Biweekly
Bulk Density	300 to 475 kg/m <sup>3</sup>	At start and completion of active composting stage	300 to 475 kg/m <sup>3</sup>	At start and completion of the active composting stage
Temperature	> 55°C 55 to 65°C	Daily during Pathogen Reduction Stage Weekly following Pathogen Reduction Stage	< 55°C	Biweekly
Pore Space Oxygen Concentration	12 to 18%	As required for troubleshooting	12 to 18%	As required

## 4.22.2 Finished Product Sampling

Compost is waste until it has been fully composted and meets the required end-product quality criteria. As explained in Chapter 6, AEP has adopted the criteria contained within the CCME's Guidelines for Compost Quality. As part of the QA/QC program, and to document compliance with the CCME guidelines, it is necessary for operators to regularly sample and analyze the compost they produce.

Specific guidance on finished compost sampling methods is not provided in the CCME document or in other AEP codes, standards, or guidelines. However, the CCME guideline does reference the sampling methods outlined in a voluntary national standard published by the Bureau de Normalisation du Quebec (BNQ). The sample methods outlined in the Test Methods for the Examination of Composting and Composts (TMECC) (US Composting Council, 2002) can also be used.

Representative samples from a batch of compost are normally collected using composite sampling practices, where a number of identically sized samples are taken from various random locations in the batch, combined and mixed, and then subsampled. The recommended number of random samples from which the composite sample is prepared varies slightly depending on the size of the compost pile(s) being sampled, as shown in Table 4.6. However, the practices for obtaining each random sample are the same, and are well-documented in the voluntary BNQ standard and in TMECC. These practices normally involve excavating into the pile between 25 to 50 cm to avoid surface contamination, and obtaining from 500 to 1,000 mL of material using clean sampling tools and non-metal sample containers.

When sampling materials for pathogens, the diligence needed regarding sampling procedures increases due to the higher potential for cross-contamination of samples and false-positive results. Cleaning of sampling tools between use, wearing of clean disposal gloves, and use of individual sample containers are required practices. Operators sometimes submit two or more grab samples from a pile to the laboratory for pathogen analysis, instead of preparing a single composite sample and risking cross-contamination.

Once obtained, samples must be preserved and handled in a manner that prevents contamination and minimizes further chemical or biological changes to the sample. This normally involves cooling samples to 4°C to limit biological activity, and transporting them in sealed coolers

**Table 4.6. Recommended Number of Subsamples Needed in a Composite Sample**

Volume of Pile of Batch	Number of Subsamples
≤ 5,000 m <sup>3</sup>	10
5,000 to 10,000 m <sup>3</sup>	20
>10,000 m <sup>3</sup>	40

to the laboratory. Most analytical procedures, particularly pathogen analysis, must be completed within certain time limits for the data to be reliable. It is critical that samples are submitted to the laboratory as quickly as possible. It is recommended that sampling is done in the morning and earlier in the week, so the samples can be delivered or couriered to the laboratory in a timely manner.

### 4.22.3 Sampling Frequency

In the composting industry, sampling frequency is generally determined based on the amount of product produced. There are no current regulatory requirements, and guidance from AEP and Canadian Food Inspection Agency (CFIA) is minimal.

Annual sampling is generally accepted as the minimum standard for smaller facilities producing less than 1,000 tonnes of product per year. Sampling frequency for larger facilities is influenced by processing and finishing technologies, but testing of individual product batches or lots ranging in size from 1,000 to 5,000 tonnes is typical.

Participants in the Compost Council of Canada's Compost Quality Alliance (CQA) program are required to obtain at least four samples during the production season at smaller sites (less than 5,000 tonnes), and as many as 12 samples at larger sites (more than 15,000 tonnes), as shown in Table 4.7.

**Table 4.7. CQA Sampling Frequency Requirements**

Annual Compost Production	Number of Samples
≤ 5,000 tonnes	4
5,000 to 15,000 tonnes	6
>15,000 tonnes	12

### 4.22.4 Finished Compost Testing

Results from the analysis of representative compost product samples can be compared to the Category B criteria contained in the CCME's Guideline for Compost Quality to demonstrate compliance with regulatory requirements. Some of the analysis results will also be needed for product labelling, to determine application rates in agricultural uses, and to assure customers that the compost meets their needs.

AEP requires that laboratories that test the compost samples be accredited. This ensures that the laboratory has a valid QA/QC program that increases the reliability of the resulting analytical results.

AEP also requires that testing must be completed using recognized analytical methods. Typically, AEP specifies analytical methods from one of the following references be used:

- Standard Methods for the Examination of Water and Wastewater (Greenberg, 1992)
- Methods Manual for Chemical Analysis of Water and Wastes (EPA, 1983)
- Determination of Foreign Matter Content – Sieving Method (CAN/BNQ 0413-210)
- Determination of Respiration Rate – Respirometric Method (CAN/BNQ 0413-220)
- Test Methods for the Examination of Compost and Composting (USCC, 2002)

One of the challenges faced by the composting industry is the inconsistency in analytical results that occurs using testing methods developed for soils. Compost has several unique characteristics that can cause interferences in traditional soil analytical methods. As a result, use of these methods can cause confusion among end-users.

As a means of addressing this issue, the composting industry, with support from the United States Department of Agriculture (USDA), developed an analytical methods manual that is specific to composting and compost products. The TMECC contains detailed protocols to measure a range of physical, chemical, and biological parameters of composting feedstocks, material in process, and finished products. The format of the TMECC manual was based on ASTM standards, and the specific methods it contains are based on standardized methods from the following sources:

- Report SW-846, Test Methods for Evaluating Solid Waste (EPA, 1990)
- Official Methods of Analysis (AOAC, 1990)
- Methods of Soil Analysis (Soil Science Society of America, 1996)
- Recommended Test Procedures for Greenhouse Growth Media (Warnke, 1988)
- Standard Methods for the Examination of Water and Wastewater (Greenberg, 1992)
- Standard Test Methods (ASTM, 1988)

Within Alberta, the methods outlined in TMECC are accepted by AEP and are commonly used by compost operators and commercial labs that offer compost analytical services. However, some other Canadian regulatory agencies, including the CFIA, have shown some reluctance in allowing the use of TMECC methods.

### 4.22.5 Analytical Parameters

Most commercial labs that provide compost testing services offer a basic suite that covers all the parameters needed to determine compliance with the CCME guideline. This package includes:

- Trace elements (arsenic, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, selenium, zinc)
- Pathogens (fecal coliform, salmonella, or both)
- Foreign matter and sharp foreign matter
- Maturity and stability (oxygen respiration, carbon dioxide evolution, or Dewar reheat test)

In addition to these regulatory criteria, there are several additional parameters that could be of interest to certain end-users, and which might need to be measured and reported. These additional parameters include:

- Ammonia-nitrogen
- Available phosphate-phosphorous
- Available potassium
- Bulk density
- Calcium
- Chloride
- Electrical conductivity
- Hot water extractable boron
- Magnesium
- Nitrate-nitrogen
- Particle size
- pH
- Phosphorous (as  $P_2O_5$ )
- Potassium
- Potassium (as  $K_2O$ )
- Sodium
- Sulphate
- Total Kjeldahl nitrogen (TKN)

### 4.22.6 Onsite vs. Offsite Testing

It is common for larger manufacturing facilities, particularly in the chemical industry, to conduct product testing at accredited labs located within the production facility itself. This approach is also common within the wastewater industry; many treatment plants have small, onsite labs to measure key process control criteria.

In the composting industry, onsite labs are much less common. Large-scale composting facilities may have a small lab area for completing basic process monitoring (for example, bulk density, particle size, moisture content, pH), but few are set up to measure more than these basic parameters. Final product testing is usually outsourced to a commercial laboratory due to the need for specialized analytical equipment and technicians trained in their use and maintenance.



In large part, this has to do with the costs involved with purchasing, operating, and maintaining the testing equipment and finding and retaining staff; when compared to the services offered by commercial laboratories, it is rarely cost-effective for a composting facility to internalize this service. Another reason for outsourcing final product testing is the cost of setting up and running the laboratory QA/QC programs that are mandated by regulatory agencies. Self-declaration of compost product quality based on onsite testing may also not be enough to provide consumer confidence.

## 4.23 Labelling of Compost Products

AEP has not specified any requirements for labelling of finished compost products. This is intentional, since labelling requirements for compost already exist in federal legislation and are enforced by the CFIA.

The Fertilizer Regulations specify labelling requirements for compost products that are sold. These requirements are summarized in CFIA's Trade Memorandum T-4-120. The labelling requirements include:

- Guaranteed analysis for minimum organic matter and maximum moisture content
- Instructions for use
- Lot number
- Producer information

There are protocols for label sizes and fonts, as well as rules about what claims can and cannot be made on the label. While the CFIA's labelling requirements are extensive, they are not well documented or publicized. As a result, many compost operators are unaware of the requirements or do not fully follow them.

The CFIA's requirements for compost technically only apply to products that are sold or imported into Canada. Thus, if an operator gives their compost away, they do not have to meet any of the requirements for testing and labelling. In recent years, the CFIA has broadened the application of the concept of "sold" to include any transaction where money changes hands. This eliminates the potential for a producer to circumvent the requirements by giving the compost away to a user, but charging them a fee for loading the product or an inflated amount for transportation.

## 4.24 Finished Compost Uses

Traditionally, compost has been used as a soil amendment in:

- Residential and commercial landscaping (for example, flower, vegetable and shrub beds, turf establishment, tree planting)

- Turf top dressing (for example, residential lawns, sports fields, parks)
- Reclamation of industrial sites and mines
- Incorporation into manufactured topsoils (for example, triple mix)

Compost is also used in agricultural applications and, to a lesser extent, in horticulture and silviculture. Compost used in these applications is typically screened so that it has a particle size of 0.5 inch or less. There is a significant volume of literature available outlining the use of compost in these applications, and the performance results from differing application rates and methods.

One area of research that has received a lot of attention in the scientific and industry literature <sup>2</sup> is the use of compost to control or eliminate certain types of plant pathogens. The beneficial microbes present in compost are thought to not only outcompete the pathogens in these situations, but actually assist the plants in fighting them off. Current thinking is that the plant disease suppressive abilities of a compost are related to the fungal content (or the fungal to bacterial ratio, by mass) of that compost.

Over the past two decades, a number of new uses for compost products have been researched and developed. These compost products are used in erosion control and slope stabilization applications, where the product is pneumatically applied either on its own or as a mixture with seed or fertilizer.

Some of the compost products use compost berms and compost-filled socks for stormwater treatment and sediment management applications. The compost used in these types of applications is a coarser-grained product, typically with a particle size that ranges up to 38 mm.



**Photo 4.42. Compost being pneumatically applied to a slope from blower truck**

*Source: CH2M*

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<sup>2</sup> [http://www.compost.org/CCC\\_Science\\_Web\\_Site/disease\\_suppression.htm](http://www.compost.org/CCC_Science_Web_Site/disease_suppression.htm)

Other uses for compost include landfill capping systems to passively treat landfill gas, and as a component of the media used in green roofs. These uses have been proven in a small number of projects, but are generally not widely publicized.

In addition to being used as a soil supplement, compost also has several alternative uses. One of the more common is as bedding material for cattle and poultry. Another alternative is to intentionally dry the compost product so it contains less than 25% moisture, and use it instead of sawdust or peat to absorb spills and clean up sludge pits.

## 4.25 Handling Off-Specification Compost Product

If good judgement is used and steps are followed to establish due diligence, it would be unusual for a composting facility to produce compost that does not meet AEP's finished compost quality criteria. If such material is generated, it is most likely a result of too much foreign matter content or the presence of sharp foreign matter. High pathogen levels, (either because PFRP criteria were not met or the material was re-contaminated after the active compost stage) is another possibility.

A compost product might also be produced that does not meet the specifications set by a particular customer. For example, the customer might require a compost for top dressing uses that meets a very rigid particle size specification, or need a product for greenhouse use that has a very low electrical conductivity or low boron levels.

If compost is produced that does not meet end-user specifications, it may be possible to divert the material to another customer or use, blend it with other products, or rescreen the material. Similarly, product that contains more foreign matter or sharp foreign matter than the amounts allowed by the CCME guidelines can be rescreened.

It may also be possible to blend the off-specification compost into incoming feedstocks and re-compost it. Alternatively, the compost could be used as the insulating layer on active composting piles. In this case, the compost would eventually be mixed into the compost pile and effectively be reprocessed.

Material that fails to meet pathogen criteria should be blended with incoming feedstocks and re-composted. It should not be used as an insulating layer, since the temperatures it is exposed to on the outside of the pile may not be high enough to treat the pathogens.

## 4.26 Routine Inspections

Operators should conduct an inspection of the composting facility at the start of each working day. During the inspection, the site operator should assess conditions in composting and curing piles, as well as confirm that nuisance conditions (for example, odours, litter, and dust) are not occurring. The site operator should also confirm that:

- Ditches and swales are free of debris and are properly draining
- There is no standing water on the composting pads
- The integrity of groundwater monitoring wells has not been compromised
- There has been no erosion of perimeter berms

Site operators should also monitor composting piles and raw material storage piles for indications of excessive generation of leachate.

## 4.27 Environmental Monitoring

Leachate and process water from composting activities can cause impacts if it escapes into watercourses or the groundwater. As part of permitting processes or enforcement actions, AEP may require a composting facility to develop a site-specific environmental monitoring program to check for impacts on water resources in the vicinity. This program typically includes surface water and groundwater sampling and analysis.

Indicator parameters are used to assess whether composting activities have impacted groundwater or surface water. An indicator parameter is a chemical or biological contaminant that would normally be found in the leachate or runoff from the compost site, but would not normally be found in high concentration in the natural environment. Chloride, nitrate-nitrogen, and pH are the indicator parameters specified by AEP for composting facilities. Other indicator parameters include:

- Ammonia
- Electrical conductivity
- Suspended and dissolved solids
- TKN
- Total phosphorus

### 4.27.1 Surface Water Monitoring

The objective of a surface water-monitoring program is to detect changes in surface water quality and movement of affected water off the property.

Surface watering sampling is typically done by taking grab samples from surface water bodies (for example, ponds) located on or next to composting facilities, or in streams or creeks running through or near the site. Where a stream or creek runs through the site, typically, two samples are taken: one upstream (before) of the compost operation (which represents background or unimpacted water conditions), and one downstream of the operation. The laboratory results from the two samples can be compared to see if the water has been affected.



**Photo 4.43. Surface water sampling**

*Source: JLTechical Services*

Sampling is normally done by an environmental technician who is trained in proper sampling collection and handling methods. Some analytical methods also require that special containers and preservation methods be used during the sampling process. The samples are placed in sealed bottles and submitted to a laboratory for analysis.

The presence of indicator parameters, such as chlorides or nitrates, may indicate that runoff from the composting operation has impacted the water body. If water has been affected, further investigation is required to both confirm and develop a plan to correct the mechanism that has let that happen.

### 4.27.2 Groundwater Monitoring

The objective of groundwater monitoring is to demonstrate that there have been no impacts on groundwater from composting activities, or to provide an early detection of impacts so that remedial actions can be taken.

A groundwater monitoring program requires that wells be installed in water-bearing geological formations at the composting site. At a minimum, one monitoring well must be installed upgradient (upstream), and two wells installed downgradient (downstream) of the composting operation. Additional wells may be required depending on the size of the facility and the hydrogeology of the site.

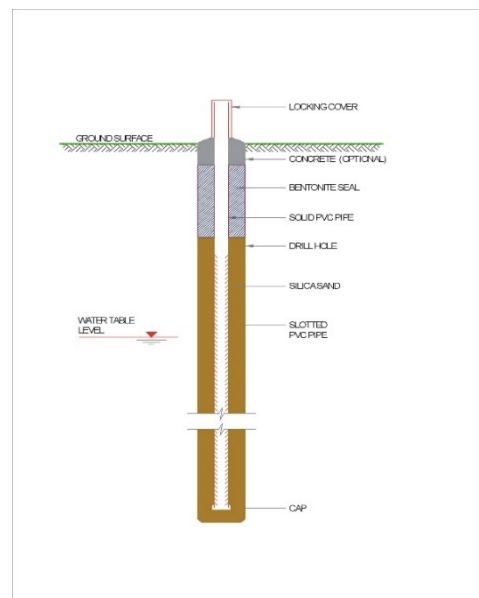
Monitoring wells are installed in a very specific manner. A portion of the monitoring well's casing is perforated so that only groundwater from the geological formation of concern can get into the well. Above this level (and below, if the well is deeper), the borehole in which the well has been installed must be sealed with an impermeable material (such as bentonite clay) to prevent potential contamination of the well water with surface water or groundwater from another formation. Typically, monitoring wells extend about 1 m above the ground surface and are protected by a lockable metal casing protector.

Groundwater monitoring wells are sampled using a strict protocol that includes the following steps:

- Inspecting the groundwater monitoring well for damage or other evidence of vandalism or tampering (groundwater monitoring wells should always be equipped with locks)
- Purging of stagnant water in the well by removing the equivalent of three well volumes of water from it
- After the well has recharged, extracting a groundwater sample, which is placed directly into laboratory sample bottles

Both purging and collection of the sample is done by trained technicians with specialized equipment.

The laboratory results for the upgradient (upstream) samples are compared to the downgradient (downstream) results to see if leachate indicators are present. The presence of elevated leachate indicators may mean that leachate is entering the surrounding environment, and should be further investigated to both confirm the findings and develop a remediation plan.



**Figure 4.7. Typical Groundwater Monitoring Well Construction**  
*Source: JL Technical Services*

## 4.28 Record Keeping and Reporting

Records related to compost production and sales are required by the CFIA as part of complying with the Fertilizer Regulations. Collection and self-reporting of data is also a cornerstone of AEP's regulatory approach. Maintaining accurate records of activities at

Due diligence means, that a person has established that he or she took all reasonable steps in a timely manner to avoid harm or prevent an event.

the composting facility is necessary to show the site is being operated in accordance with the facility design plan and the operations plan. Thorough records are the operator's best way of establishing due diligence and showing they have complied with regulatory requirements. In addition to complying with regulatory requirements, recording and reviewing of program and process information is important for operators. It allows them to measure program performance against goals and optimize the composting process.

The Operating Record is a broad term that refers to the collection of records that, together, provide the details of the facility's approval status, design, and operating history. At a minimum, the Operating Record should include:

- A copy of the facility's approval document
- Current design and operating plans
- Data showing the amounts of incoming feedstocks and amendments, and outgoing compost products
- Temperature monitoring data
- Data from surface water and groundwater monitoring programs
- Results from testing of finished compost products

The records can be paper-based, electronic, or a combination of the two. Original paper-based records are often stored at the facility, and duplicate copies (or electronic copies) are kept in a secure offsite location. However, in cases where there are no buildings at the facility, it may be necessary to keep the original records in an offsite location. When this is the case, the records must be easily retrievable in the event of an inspection by AEP or CFIA.

Original paper-based records should never be removed from the Operating Record, except as required under subpoena or for evidentiary purposes. If an original document is temporarily removed for these reasons, it should be replaced with a copy of the original.

If electronic records are used, operators should put data backup procedures in place to prevent loss of the records. Electronic records also need to be accessible to AEP and CFIA during inspections and upon request.

### **4.28.1 Annual Report**

An annual report needs to be prepared and entered into the facility's operating record by March 31 of the following year. Facilities operating under an [Alberta Environmental Protection and Enhancement Act](#) (EPEA) approval (as opposed to a notification or registration) also need to submit a copy of their annual report to AEP.

In addition to a summary of inbound feedstocks and amendments and a summary of the amount of compost produced, stored, and shipped from the facility, the annual report must also note the following:

- Temperatures and other process monitoring records
- An analysis of the compost if it is intended for an unrestricted use
- Surface water monitoring data
- Groundwater monitoring data as required by AEP
- Any remedial actions taken in response to impacts identified by surface water or groundwater monitoring



**Photo 4.44. At mid and large-sized sites, it is useful to have a map showing windrow and product stockpile locations**

Composting facilities operating under an approval from AEP may be subject to additional reporting requirements.

## **4.28.2 Additional Records**

For mid-sized and large facilities, the minimal records required by AEP are not likely to provide a complete picture of site activities, or be enough to establish the operator exercised due diligence.

Operators should consider keeping records of day-to-day activities at the site related to handling, mixing, composting, curing, and post-processing of feedstocks. In the event of odours or nuisance impacts, these records can be used to show that best practices were being followed, or to troubleshoot process conditions and plan corrective actions. A more complete Operating Record would include the following information in addition to the minimum requirements outline by AEP:

- Types and quantities of unacceptable wastes delivered to the site
- Types and quantities of contaminants removed from feedstocks
- Date that compost piles are constructed or added to, and their location within the site
- Approximate amounts of feedstock and amendments added to each compost pile
- Date that compost piles are turned
- Date, source, and approximate amount of water added to each compost pile
- Date that compost piles are moved, and their new location within the site
- Date that two or more compost piles are combined, and their new location



- Approximate quantity of finished compost produced from each lot
- Lot number, quantity, trucking company, and end-user of each bulk load of finished compost removed from the site

A record of measurements of the key process parameters (for example, temperature, oxygen level, moisture content, bulk density) should be kept. A rolling history of these measurements over the life of each compost batch or pile can be used to optimize the compost process and troubleshoot problems. Storing this information electronically in a spreadsheet or a commercial software package can make managing and using the data much easier. It also allows for process measurements to be graphed over time, which is often a more useful way of evaluating the data.

Recording the amounts of amendments used provides valuable insight that can help improve composting conditions in the future. Similar benefits can be obtained from logging dates and amount of water added to composting piles.

Weekly summaries of inbound and outbound materials can be prepared if material flow in and out of the composting facility is rapid or highly variable. These summaries will identify and quantify monthly or seasonal changes in material type and flow; tracking these patterns can be helpful for scheduling equipment, labour, and space more efficiently. If there is significant variation in feedstock quality or type during specific times of the year, this information can also be used to plan amendment needs and optimize feedstock blending recipes.

All the routine inspections completed by operators as part of their daily duties should be documented. Simple forms can be used to reduce the amount of writing required. The information in the inspection forms can be supplemented with time-stamped photographs showing conditions at the site.

Any complaints regarding the operation of the composting facility, including the time, date, nature of the complaint, and the person lodging the complaint, should be recorded. Along with this information, findings from inspections and any corrective actions taken in response to the complaints should be documented.

It is recommended that any changes to persons responsible for the site (for example, Certified Operators), changes to operation plans and procedures, and a summary of complaints and corrective actions also be included in the annual report.

## 4.29 Reporting Releases and Contraventions

Upon discovering or being notified that a spill or release has occurred that is causing (or is suspected of causing) an adverse environmental impact, the compost site's owner or operator must verbally notify AEP at the first available opportunity. Initial reports are normally made by

calling the AEP's toll-free reporting telephone line at 1-800-222-6514. This reporting line is staffed 24 hours per day.

## **24-Hour Response Line**

### **1-800-222-6514**

Contraventions of the conditions contained in operating approvals or the requirements of regulations or codes of practice must also be reported to AEP. The toll-free reporting line can be used for these notifications, as well. In some situations, an option for electronic reporting may be available.

**Figure 4.8. Releases must be reported at the first available opportunity**

Following the initial notification, the owners or operators must file a written report that provides further information on the releases or contravention. The specific information requirements for contravention reports are contained in the Release Reporting Regulation and its supporting guidelines. Generally, these reports need to include the date, location, and nature of the contravention, in addition to the cause, actions taken to mitigate impacts, and actions to prevent the contravention from re-occurring in the future.

The written reports are intended to supplement the initial verbal notification made to AEP following a contravention. **Written reports must be submitted within 7 days of the initial verbal report.**

# Chapter 5 – Math for Compost Operators

## 5.1 Learning Objectives

This chapter focusses on the mathematical formulas that composting facility operators can use to calculate areas and volumes of:

- Amendment and product stockpiles
- Compost piles
- Retention ponds
- Truck boxes
- Tanks and sumps

Formulas for calculating bulk density, and moisture and solids content are also presented, along with the formulas used to calculate feedstock and amendment recipes.

## 5.2 Metric and US Customary Units

Officially, units of measurement in Canada are based on the International System of Units, otherwise known as the SI system or the metric system. The metric system uses base units and different prefixes (that is, the beginnings of words) to indicate larger or smaller multiples of the base unit. Prefixes used in the metric system are based on multipliers of 10.

For example, the base unit of length is a metre. A kilometre (km) is 1,000 times the base unit, or 1,000 metres. Similarly, a millimetre (mm) is 1/1000 of a metre (or 0.001 m), and a centimetre (cm) is 1/100 of a metre (or 0.01 m). Alternatively, 1 m is equal to 1,000 mm or 100 cm. There are 10 mm in 1 cm.

In the metric system, the base unit for volume is a cubic metre (m<sup>3</sup>). Volume is also measured in litres (L) and millilitres (mL). A litre is equivalent to 1,000 cubic centimetres (cm<sup>3</sup>), and there are

### Common Metric Base Units

Measurement	Unit
Length	Metre (m)
Mass	Gram (g)
Volume	Cubic metre (m <sup>3</sup> )
Temperature	Celsius degrees

1,000 L in 1 m<sup>3</sup>. A millilitre is equivalent to 1 cm<sup>3</sup>. Other than millilitres, prefixes are not commonly applied to litres.

The base unit of weight is a gram (g). A kilogram (kg) is equivalent to 1,000 g. Large weights (e.g. trucks, compost shipments) are measured in tonnes. There are 1,000 kg in 1 tonne. To avoid confusion, a tonne is often pronounced as “tone” or is verbally referred to as “metric tonne”.

Converting from larger to smaller metric units involves multiplying by 10 for each step up in prefix. To convert from smaller to larger metric units, divide by 10 for each step up in prefix. Another way to convert units is to move the decimal one space to the right for each step down, or one place to the left for each step up.

Metric Prefix	Multiplier
Kilo	1,000
Hecto	100
Deca	10
Base unit	1
Deci	0.1
Centi	0.01
Milli	0.001

**Q: How many centimetres (cm) are in 12 metres?**

$$12 \text{ m} \times 10 \text{ decimetres (dm) per metre} \times 10 \text{ cm per dm} = 1,200 \text{ cm}$$

**Q: How many grams (g) are in 5 kilograms (kg)?**

$$5 \text{ kg} \times 10 \times 10 \times 10 = 5,000 \text{ g}$$

**Q: How many millilitres (mL) are in 3 litres (L)?**

$$3.000 \text{ L} = 3,000 \text{ mL}$$

**Q: How many metres are in 25,000 mm?**

$$25,000 \text{ mm} \div 10 \text{ mm per cm} \div 10 \text{ cm per dm} \div 10 \text{ dm per m} = 25 \text{ m}$$

**Q: How many grams are in 7,500 milligrams?**

$$7,500 \text{ mg} \div 10 \div 10 \div 10 = 7.5 \text{ g}$$

**Q: How many litres are in 5,800 millilitres?**

$$5,800.0 \text{ mL} = 5.800 \text{ L}$$

In the compost industry, much of the equipment used originates from the United States (US), where sizes and capacities are expressed in United States Customary (USC) units. Weight is measured in pounds (lb) and tons, and length is measured in inches (in) and feet (ft). Front-end loader buckets are sized in cubic yards (yd<sup>3</sup>) instead of cubic metres (m<sup>3</sup>). Flow rates of aeration fans are measured in cubic feet per minute (cfm) instead of cubic metres per second (m<sup>3</sup>/s). Capacities of screen systems are described in cubic yards per hour (yd<sup>3</sup>/h) instead of cubic metres per hour (m<sup>3</sup>/h).

#### Common Conversion Factors

$$1 \text{ m} = 3.28 \text{ feet (ft)}$$

$$1 \text{ kg} = 2.20 \text{ pound (lb)}$$

$$1 \text{ m}^3 = 1.31 \text{ yd}^3$$

$$1 \text{ L} = 0.26 \text{ USC gallon}$$

Because of this, operators may sometimes need to convert between metric and USC units. A pocket calculator with conversion functions, or a smart phone app, is the easiest way to do these conversions. There are some conversion factors that are easy and might be worth remembering, such as converting metres to feet, and cubic metres to cubic yards.

**Q: How many feet are in 12 metres?**

$$12 \text{ m} \times 3.28 \text{ ft per m} = 39.4 \text{ ft}$$

**Q: How many cubic yards are in 5 cubic metres?**

$$5 \text{ m}^3 \times 1.31 \text{ yd}^3 \text{ per m}^3 = 6.6 \text{ yd}^3$$

**Q: How many pounds are in 2 kilograms?**

$$2 \text{ kg} \times 2.2 \text{ lb per kg} = 4.4 \text{ lb}$$

**Q: How many metres are in 20 feet?**

$$20 \text{ ft} \div 3.28 \text{ ft per m} = 6.1 \text{ m}$$

**Q: How many cubic metres are in 2 cubic yards?**

$$2 \text{ yd}^3 \div 1.31 \text{ yd}^3 \text{ per m}^3 = 1.5 \text{ m}^3$$

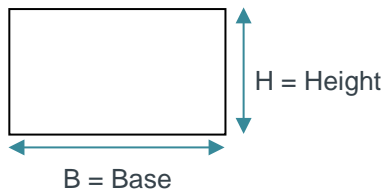
**Q: How many kilograms are in 20 pounds?**

$$20 \text{ lb} \div 2.2 \text{ lb per kg} = 9.1 \text{ kg}$$

## 5.3 Areas of Common Shapes

Operators need to know how to calculate the area of squares, rectangles, circles, triangles, and trapezoids. These may be needed to plan and lay out windrows and stockpile locations. They are also used to calculate volume. Common units are square metres (m<sup>2</sup>) and square feet (ft<sup>2</sup>). Land areas are normally expressed in hectares (ha) or acres.

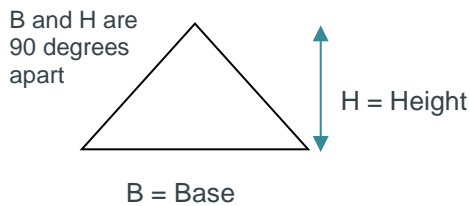
Area of a Square or Rectangle = Base x Height



**Q: If B = 8 m, and W = 12 m, what is the area?**

$$\begin{aligned}\text{Area} &= 8 \text{ m} \times 12 \text{ m} \\ &= 96 \text{ m}^2\end{aligned}$$

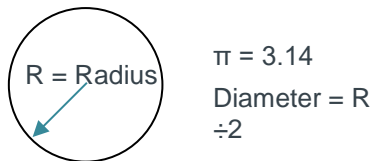
Area of a Triangle =  $\frac{1}{2}$  x Base x Height



**Q: If B = 6 m, and H = 3 m, what is the area?**

$$\begin{aligned}\text{Area} &= \frac{1}{2} \times 6 \text{ m} \times 3 \text{ m} \\ &= 3 \text{ m} \times 3 \text{ m} \\ &= 9 \text{ m}^2\end{aligned}$$

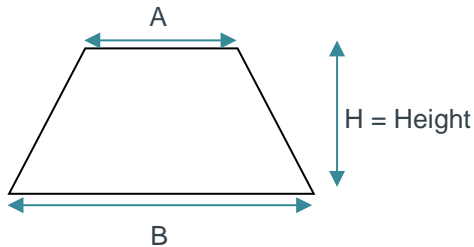
Area of a Circle =  $\pi$  x Radius <sup>2</sup>



**Q: If the radius is 2 m, what is the area?**

$$\begin{aligned}\text{Area} &= 3.14 \times 2 \text{ m} \times 2 \text{ m} \\ &= 12.6 \text{ m}^2\end{aligned}$$

Area of a Trapezoid =  $\frac{1}{2} \times (A + B) \times \text{Height}$



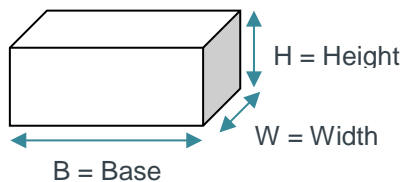
**Q: If A = 4 m, B = 8 m and H = 2 m, what is the area?**

$$\begin{aligned}\text{Area} &= \frac{1}{2} \times (4 \text{ m} + 8 \text{ m}) \times 2 \text{ m} \\ &= \frac{1}{2} \times 12 \text{ m} \times 2 \text{ m} \\ &= 12 \text{ m}^2\end{aligned}$$

## 5.4 Volume of Common Shapes

Calculating volumes of tanks and trucks is a skill needed by compost operators as part of day-to-day operations. Operators commonly use formulas for cubes and boxes or cylinders for these calculations. Volumes are expressed in cubic metres ( $\text{m}^3$ ), litres (L), cubic feet ( $\text{ft}^3$ ), and cubic yards ( $\text{yd}^3$ ).

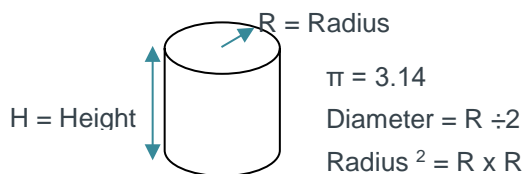
Volume of a cube or box = Base x Width x Height



**Q: What is the capacity of a dump truck box that is 3 m long (B), 2.4 m wide (W), and 1.5 m high (H)?**

$$\begin{aligned}\text{Volume} &= 3 \text{ m} \times 2.4 \text{ m} \times 1.5 \text{ m} \\ &= 10.8 \text{ m}^3\end{aligned}$$

Volume of a cylinder =  $\pi \times \text{Radius}^2 \times \text{Height}$



**Q: What is the volume of a tank that has a radius of 2 m and a height of 3 m?**

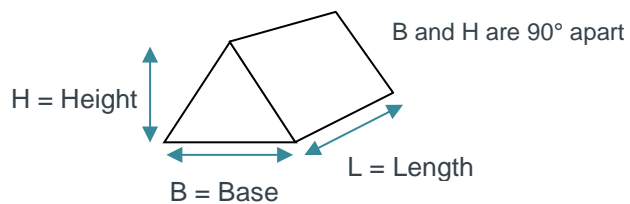
$$\begin{aligned}\text{Volume} &= 3.14 \times 2 \text{ m} \times 2 \text{ m} \times 3 \text{ m} \\ &= 37.7 \text{ m}^3\end{aligned}$$

## 5.5 Volumes of Windrows

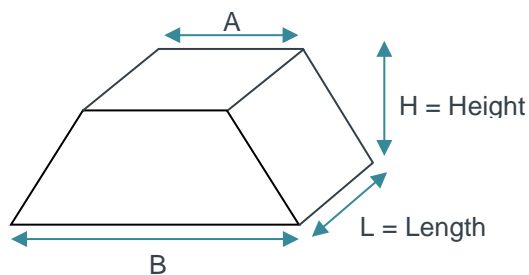
Calculating volumes of triangular and trapezoidal windrows is needed for water addition calculations, as well as for operational planning (for example, how long will it take to screen a windrow). Volumes of windrows are usually measured in cubic metres (m<sup>3</sup>) or cubic yards (yd<sup>3</sup>).

The volume of a windrow is calculated by multiplying the cross-sectional area of the windrow (triangle or trapezoid) by its length. The inward taper at the top of the windrow at each end is normally ignored in the calculation.

Volume of a triangular windrow =  $\frac{1}{2} \times \text{Base} \times \text{Height} \times \text{Length}$



Volume of a trapezoidal windrow =  $\frac{1}{2} \times (A + B) \times \text{Height} \times \text{Length}$



**Q: What is the volume of a triangular windrow that is 6 m wide, 3 m high, and 20 m long?**

$$\begin{aligned} \text{Volume} &= \frac{1}{2} \times 6 \text{ m} \times 3 \text{ m} \times 20 \text{ m} \\ &= 180 \text{ m}^3 \end{aligned}$$

**Q: What is the volume of a trapezoidal windrow that is 8 m wide at the base (B) and 4 m wide at the top (A), 2 m high (H), and 10 m long (L)?**

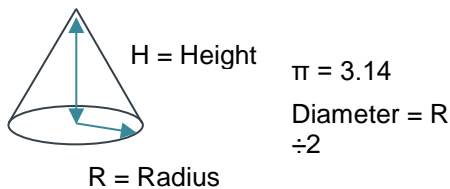
$$\begin{aligned} \text{Volume} &= \frac{1}{2} \times (4 \text{ m} + 8 \text{ m}) \times 2 \text{ m} \times 10 \text{ m} \\ &= \frac{1}{2} \times 12 \text{ m} \times 2 \text{ m} \times 10 \text{ m} \\ &= 120 \text{ m}^3 \end{aligned}$$



## 5.6 Volumes of Stockpiles

Volumes of stockpiles are calculated for operational planning. Stockpiles often take the form of a cone (for example, made with a stacking conveyor) or a trapezoidal pile (for example, made with a front-end loader). Volumes of stockpiles are usually measured in cubic metres (m<sup>3</sup>) or cubic yards (yd<sup>3</sup>).

Volume of a cone =  $\frac{1}{3} \times \pi \times \text{Radius}^2 \times \text{Height}$

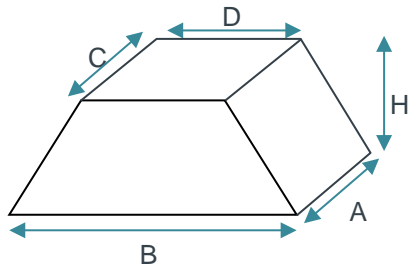


**Q: What is the volume of a conical stockpile of compost with a diameter of 10 m and a height of 10 m?**

Radius = diameter ÷ 2 = 10 m ÷ 2 = 5 m  
 Volume =  $\frac{1}{3} \times 3.14 \times 5 \text{ m} \times 5 \text{ m} \times 10 \text{ m}$   
 = 261.7 m<sup>3</sup>

Volume of a rectangular stockpile with sloped sides =  $H \div 6 \times [A_B + [(A+C) \times (B+D)] + A_T]$

Where A<sub>B</sub> (area of base of pile) = A x B, and A<sub>T</sub> (area of top of pile) = C x D



**Q: What is the volume of a trapezoidal stockpile of compost that measures 10 m (A) by 9 m (B) at the base, 4 m (C) by 3 m (D) at the top, and is 3 m (H) high?**

A = 10 m, B = 9 m  
 A<sub>B</sub> = 9 x 10 = 90 m<sup>2</sup>  
 C = 4 m, D = 3 m  
 A<sub>T</sub> = 3 x 4 = 12 m<sup>2</sup>  
 H = 3 m  
 Volume =  $3 \div 6 \times [(90 + [(10+4) \times (9+3)] + 12]$   
 = 0.5 x [90 + [14 x 12] + 12]  
 = 0.5 x [90 + 168 + 12]  
 = 0.5 x (270)  
 = 135 m<sup>3</sup>

## 5.7 Calculating Density

Density is a measure of the weight of a material per unit volume. The formula for calculating density is:

$$\text{Density} = \frac{\text{Weight of material}}{\text{Volume}}$$

---

### Volume the material occupies

Composting systems and equipment capabilities are often quoted on a weight basis (for example, tonnes per day), but operators often deal in volumes. If the operator knows (or measures) the density of a material, they can convert back and forth between weight and volume. Density is also used as a surrogate measure of free air space.

Common metric units of density are kilograms per litre (kg/L), kilograms per cubic metre (kg/m<sup>3</sup>), tonnes per cubic metre (t/m<sup>3</sup>). In USC units density is expressed in pounds per cubic foot (lb/ft<sup>3</sup>) and pounds per cubic yard (lb/yd<sup>3</sup>).

**Q: A 20-L bucket is filled with compost. The weight of the empty bucket is 1 kg. The weight of the full bucket is 13 kg. What is the density of the compost?**

$$\begin{aligned}\text{Density} &= (13 \text{ kg} - 1 \text{ kg}) \div 20 \text{ L} \\ &= 12 \text{ kg} \div 20 \text{ L} \\ &= 0.6 \text{ kg/L}\end{aligned}$$

**Q: A triangular windrow is 6 m wide, 3 m high, and 20 m long. The compost has a density of 0.6 kg/L. What is the weight of the compost in the windrow?**

$$\begin{aligned}\text{From previous examples, volume} &= 180 \text{ m}^3 \text{ and density} = 600 \text{ kg/m}^3 \\ \text{Weight} &= \text{Density} \times \text{Volume (re-arrange the formula to solve for weight)} \\ &= 600 \text{ kg/m}^3 \times 180 \text{ m}^3 \\ &= 108,000 \text{ kg}\end{aligned}$$

There are 1,000 kg in 1 tonne, so 108,000 kg = 108 tonnes

**Q: A truck can hold 5,000 kg of compost, which has a density of 0.6 kg/L. What is the volume of compost the truck can hold?**

There are 1,000 L in 1 m<sup>3</sup>, so 0.6 kg/L x 1,000 L = 600 kg/m<sup>3</sup>

Density = Weight ÷ Volume

Volume = Weight ÷ Density (re-arrange the formula to solve for volume)

$$= 5,000 \text{ kg} \div 600 \text{ kg/m}^3$$

$$= 8.3 \text{ m}^3$$

## 5.8 Calculating Moisture Content of a Single Material

Moisture content (MC) is a key control parameter in the compost process. Measuring the moisture content of a feedstock requires laboratory measurements (for example, oven drying)

and calculations. Moisture content is measured on a percent by weight basis.

$$\text{MC} = \frac{\text{Weight of water in the material}}{\text{Total weight of the material}} \times 100\%$$

**Q: A sample of compost is placed in a drying oven for 24 hours. The sample weighed 80 g before it was put in the oven, and 35 g when it was removed. The sample container weighs 5 g. What is the moisture content of the compost in the windrow?**

MC = Weight of water ÷ total weight

$$= (80 \text{ g} - 5 \text{ g}) - (35 \text{ g} - 5 \text{ g}) \div (80 \text{ g} - 5 \text{ g}) \times 100\%$$

$$= (75 \text{ g} - 30 \text{ g}) \div 75 \text{ g} \times 100\%$$

$$= 45 \text{ g} \div 75 \text{ g} \times 100\%$$

$$= 0.6 \times 100\%$$

$$= 60\%$$

**Q: A triangular windrow is 6 m wide, 3 m high, and 20 m long. The compost has a density of 0.6 kg/L, and a moisture content of 30%. How much water is in the windrow?**

From previous examples, volume =  $\frac{1}{2} \times 6 \text{ m} \times 3 \text{ m} \times 20 \text{ m} = 180 \text{ m}^3$ , its density is  $600 \text{ kg/m}^3$ , and the weight of the compost in the windrow is 108 tonnes.

MC = Weight of water  $\div$  total weight  
Weight of water = MC x total weight (re-arrange the formula to solve for water weight)  
= 30% x 108 tonnes  
= 32.4 tonnes

## 5.9 Calculating Moisture Content of a Mixture of Materials

Moisture content is also part of the feedstock recipe design process. The basic moisture content formula can be modified to calculate the moisture content of a mixture of two (or more) materials.

$$\text{MC} = \frac{\text{Weight of water in material A} + \text{Weight of water in material B}}{\text{Total weight of the material A} + \text{Total weight of the material B}} \times 100\%$$

**Q: A 10-tonne load of food waste is mixed with 5 tonnes of woodchips. The food waste has a moisture content of 65%, and the woodchips a moisture content of 20%. What is the moisture content of the materials after mixing?**

MC =  $\frac{\text{Weight of water in food waste and chips}}{\text{Total weight of food waste and chips}} \times 100\%$   
=  $[(10 \text{ tonnes} \times 65\%) + (5 \text{ tonnes} \times 20\%)] \div [10 \text{ tonnes} + 5 \text{ tonnes}] \times 100\%$   
=  $[6.5 \text{ tonnes} + 1 \text{ tonne}] \div 15 \text{ tonnes} \times 100\%$   
=  $7.5 \text{ tonnes} \div 15 \text{ tonnes} \times 100\%$   
= 50%

## 5.10 Solids Content

Solids content is a common measurement used in the wastewater treatment industry. The solids content of biosolids are usually referred to instead of the moisture content.

$$\text{Solids Content (SC)} = 100\% - \text{Moisture Content (MC)}$$

$$\text{Moisture Content (MC)} = 100\% - \text{Solids Content (SC)}$$

$$\text{Moisture Content (MC)} + \text{Solids Content (SC)} = 100\%$$

**Q: A 10-tonne load of biosolids is mixed with 5 tonnes of woodchips. The biosolids have a solids content of 20%, and the woodchips a moisture content of 20%. What is the moisture content of the materials after mixing?**

$$\text{Moisture Content of biosolids} = 100\% - \text{Solids Content} = 100\% - 20\% = 80\%$$

$$\begin{aligned} \text{MC} &= \frac{\text{Weight of water in biosolids and chips}}{\text{Total weight of biosolids and chips}} \times 100\% \\ &= \frac{[(10 \text{ tonnes} \times 80\%) + (5 \text{ tonnes} \times 20\%)]}{[10 \text{ tonnes} + 5 \text{ tonnes}]} \times 100\% \\ &= \frac{[8 \text{ tonnes} + 1 \text{ tonne}]}{15 \text{ tonnes}} \times 100\% \\ &= \frac{9 \text{ tonnes}}{15 \text{ tonnes}} \times 100\% \\ &= 60\% \end{aligned}$$

## 5.11 Water Addition Calculations

The basic moisture content formula can be used to determine how much water needs to be added to a compost pile.

### INCORRECT CALCULATION METHOD

**Q: A triangular windrow is 6 m wide, 3 m high, and 20 m long, and contains 108 tonnes of compost (density = 600 kg/m<sup>3</sup>). The moisture content of the compost is 30%, but needs to be raised to 45%. How much water should be added to the windrow?**

From the previous example, we know the windrow contains 32.4 tonnes of water beforehand.

Once the moisture content is adjusted, the windrow should have 45% x 108 tonnes = 48.6 tonnes of water. The difference, and the amount of water that needs to be added, is 48.6 tonnes – 32.4 tonnes = 16.2 tonnes.

If you check your results, you can see that this answer is incorrect:

$$\begin{aligned} \text{MC} &= \text{Weight of water} \div \text{total weight} \times 100\% \\ &= (32.4 \text{ tonnes} + 16.2 \text{ tonnes}) \div (108 \text{ tonnes} + 16.2 \text{ tonnes}) \\ &= 48.6 \text{ tonnes} \div 124.2 \text{ tonnes} \times 100\% \\ &= 39.1\% \end{aligned}$$

The correct way to do this calculation is complicated. It involves the moisture content formula for two materials:

$$\text{MC} = \frac{\text{Weight of water in material A} + \text{Weight of water in material B}}{\text{Total weight of the material A} + \text{Total weight of the material B}} \times 100\%$$

Many operators make a mistake doing this calculation because they do not factor in the weight of the water added to the pile.

In this case, material A is the material before extra water is added, material B is the water added to material A, and MC is the desired moisture content of material A *after* the water (material B) is added. Since material B is water and has a moisture content of 100%, the weight of water in material B is the same as the total weight of material B.

Also, remember that the amount of water in material A is the product of its weight (for example, starting weight before water is added) and its initial moisture content.

We can simplify this formula:

$$\text{Desired MC} = \frac{[\text{Weight of Material} \times \text{Initial Moisture Content}] + \text{Weight of water added}}{\text{Weight of material} + \text{Weight of water added}} \times 100\%$$

If we use variables for the various weights and moisture contents, and use algebra to re-arrange the formula and solve for the unknown weight of water that needs to be added, we get the following equation:

$$M_W = \frac{(MC_F - MC_I)}{(1 - MC_F)} \times M_I$$

Where:

$M_W$  is the amount of water to be added

$MC_F$  is the desired final moisture content

$MC_I$  is the initial moisture content of the material

$M_I$  is the initial weight of the material

## CORRECT CALCULATION METHOD

**Q: A triangular windrow is 6 m wide, 3 m high, and 20 m long, and contains 108 tonnes of compost (density = 600 kg/m<sup>3</sup>). The moisture content of the compost is 30%, but needs to be raised to 45%. How much water should be added to the windrow?**

$$M_W = \frac{(MC_F - MC_I)}{(1 - MC_F)} \times M_I$$

From the previous example, we know the windrow contains 32.4 tonnes of water beforehand.

$$\begin{aligned} M_W &= \frac{(MC_F - MC_I)}{(1 - MC_F)} \times M_I \\ &= \frac{(45\% - 30\%)}{(1 - 45\%)} \times 108 \\ &= \frac{(0.15)}{(0.55)} \times 108 \\ &= 0.27 \times 108 \\ &= 29.5 \end{aligned}$$

If you check your results, you can see that this answer is correct:

$$\begin{aligned} MC &= \text{Weight of water} \div \text{total weight} \times 100\% \\ &= [(108 \text{ tonnes} \times 30\%) + 29.5 \text{ tonnes}] \div [108 \text{ tonnes} + 29.5 \text{ tonnes}] \\ &= [32.4 + 29.5] \div 137.5 \times 100\% \\ &= 61.9 \div 137.5 \times 100\% \\ &= 45\% \end{aligned}$$



## 5.12 Calculating Carbon to Nitrogen Ratio

Carbon and nitrogen are both needed by the microbes in the composting pile. The ratio of carbon to nitrogen, or the C:N ratio, needs to be between 25:1 and 35:1 for optimal composting.

The C:N ratio of a material is calculated based on the dry weight of carbon and nitrogen in the material. It is assumed that any carbon and nitrogen in the water in the material is insignificant. Laboratories normally report carbon and nitrogen as a percentage of the total dry weight (dw).

$$\text{C:N Ratio} = \frac{\text{Dry weight of C in the material}}{\text{Dry weight of N in the material}} = \frac{\% \text{ Carbon (dw)}}{\% \text{ Nitrogen (dw)}}$$

$$\text{C:N Ratio} = \frac{\text{Total weight the material} \times \text{Solids Content} \times \% \text{ Carbon}}{\text{Total weight the material} \times \text{Solids Content} \times \% \text{ Nitrogen}}$$

**Q: Our lab report tells us that a sample of biosolids contains 2% nitrogen on a dry weight basis and 20% carbon on a dry weight basis. What is the C:N ratio of this material?**

$$\begin{aligned} \text{C:N Ratio} &= \text{Dry weight of carbon} \div \text{Dry weight of nitrogen} \\ &= 20\% \div 2\% \\ &= 10 \text{ (or 10:1)} \end{aligned}$$

**Q: The C:N ratio of a biosolids feedstock is 10:1. The nitrogen content of the biosolids is 2% dw and its solids content is 25%. How much carbon and nitrogen is in a 1,000 g sample of the biosolids?**

$$\begin{aligned} \text{Dry weight of nitrogen} &= \text{Wet weight} \times \text{solids content} \times \% \text{ Nitrogen} \\ &= 1,000 \text{ g} \times 25\% \times 2\% \\ &= 5 \text{ g} \end{aligned}$$

$$\text{C:N Ratio} = \text{Dry weight of carbon} \div \text{Dry weight of nitrogen}$$

$$\begin{aligned} \text{Dry weight of carbon} &= \text{Dry weight of nitrogen} \times \text{C:N Ratio (re-arrange formula)} \\ &= 2\% \times 10 \\ &= 20\% \end{aligned}$$

$$\begin{aligned} \text{Dry weight of carbon} &= \text{Wet weight} \times \text{solids content} \times \% \text{ Carbon} \\ &= 1,000 \text{ g} \times 25\% \times 20\% \\ &= 50 \text{ g} \end{aligned}$$

## 5.13 Recipe Design

Recipe design is the process of determining the amounts of feedstocks and amendments that need to be blended together to create the best mixture for composting.

Recipe design is an iterative process. It involves making an initial guess at the weights of each material, and then calculating the moisture content, bulk density, and C:N ratio of the blended materials.

$$\text{MC} = \frac{\text{Weight of water in material A} + \text{Weight of water in material B}}{\text{Total weight of the material A} + \text{Total weight of the material B}} \times 100\%$$

$$\text{C:N Ratio} = \frac{\text{Dry weight of C in material A} + \text{Dry weight of C in material B}}{\text{Dry weight of N in material A} + \text{Dry weight of N in material B}}$$

$$\text{Bulk Density} = \frac{\text{Weight of material A} + \text{Weight of material B}}{\text{Volume of material A} + \text{Volume of material B}}$$

When feedstocks and amendments are combined, the volume after mixing is often less than the sum of the volume of the two materials before mixing. This is because of the void spaces in the materials and how the particles of materials re-pack together when mixed. To account for this, operators sometimes apply a volume reduction factor of between 2% and 10% to the bulk density formula. The factor used is based on the operator's experience and historical field measurements.

The recipe design formulas can also be used to calculate the amount of amendments needed to add during later stages of the process to correct a problem (for example, too wet, not enough free air space, too much nitrogen).

**Q: Biosolids contain 2% dw of nitrogen and 20% dw of carbon, and have a solids content of 25% (MC=75%). The bulk density of the biosolids is 1,000 kg/m<sup>3</sup>.**

**Woodchips contain 0.1% dw of nitrogen and 20% dw of carbon, and have a moisture content of 20%. Their bulk density is 250 kg/m<sup>3</sup>.**

**If 100 kg of biosolids (material A) is combined with 100 kg of woodchips (material B), what is the C:N ratio, moisture, and bulk density of the resulting mixture?**

$$\begin{aligned} \text{MC} &= \text{Weight of water in biosolids and chips} \div \text{total weight of biosolids and chips} \times 100\% \\ &= [(100 \text{ kg} \times 75\%) + (100 \text{ kg} \times 20\%)] \div [100 \text{ kg} + 100 \text{ kg}] \times 100\% \\ &= [75 \text{ kg} + 20 \text{ kg}] \div 200 \text{ kg} \times 100\% \\ &= 95 \text{ kg} \div 200 \text{ kg} \times 100\% \\ &= 47.5\% \end{aligned}$$

$$\begin{aligned} \text{C:N} &= \frac{\text{Dry weight of carbon in biosolids and chips}}{\text{Dry weight of nitrogen in biosolids and chips}} \\ &= \frac{(100 \text{ kg} \times 25\% \times 20\% \text{C}) + (100 \text{ kg} \times 80\% \times 20\% \text{C})}{(100 \text{ kg} \times 25\% \times 2\% \text{N}) + (100 \text{ kg} \times 80\% \times 0.1\% \text{N})} \\ &= \frac{5 \text{ kg} + 16 \text{ kg}}{0.5 \text{ kg} + 0.08 \text{ kg}} \\ &= 21 \text{ kg} \div 0.58 \text{ kg} \\ &= 36.2 \end{aligned}$$

$$\begin{aligned} \text{Density} &= \text{Weight of materials A and B} \div \text{Volume of materials A and B} \\ &= [100 \text{ kg} + 100 \text{ kg}] \div [(100 \text{ kg} \div 1,000 \text{ kg/m}^3) + (100 \text{ kg} \div 250 \text{ kg/m}^3)] \\ &= 200 \text{ kg} \div [0.1 \text{ m}^3 + 0.4 \text{ m}^3] \\ &= 200 \text{ kg} \div 0.5 \text{ m}^3 \\ &= 400 \text{ kg/m}^3 \end{aligned}$$

# Chapter 6 – Regulation for Environmental Protection

## 6.1 Introduction and Learning Objectives

This chapter is about the Province of Alberta and Government of Canada's rules for managing waste in Alberta, including at composting facilities. These rules protect the air, water, and land (the environment); and the health and safety of people, fish, wildlife, and plants.

Composting facility operators need to know what rules to follow to do their jobs. While the authors have tried to identify all the relevant legislation and rules about waste, the discussion in this manual is only a summary. This manual also shares what the authors believe is most important for composting facility operators to know. Since this manual only provides a summary, facility owners and operators are encouraged to refer to the full versions of documents, which are obtained from original sources. For example:

- Alberta documents are available at the [Alberta Queen's Printer](#) or at the [AEP website](#)
- Federal documents are available at the [Government of Canada's website](#)

Municipal bylaws may also apply to waste management facilities. Local authorities can give you more information.

Learning objectives for this chapter include:

- Understanding why rules are needed to control composting facility operations
- Understanding how government puts those rules in place
- Understanding the relationships between the different regulatory tools used by government
- Getting familiar with the most important parts of the laws as they apply to Alberta composting facilities
- Gaining an awareness of the variety of rules, provincial and federal, that apply to different operations, depending on the specific site and activities
- Understanding the legislation and rules that apply to each composting facility from site-specific provincial approvals
- Understanding why monitoring and record-keeping is important

It is important that operators recognize that legislation, codes of practice, guidelines, and bylaws are periodically updated. The information contained in this chapter is current at the time of writing,

but Operators should confirm requirements by reviewing the source documents that are referenced.

## 6.2 Alberta Regulatory Framework

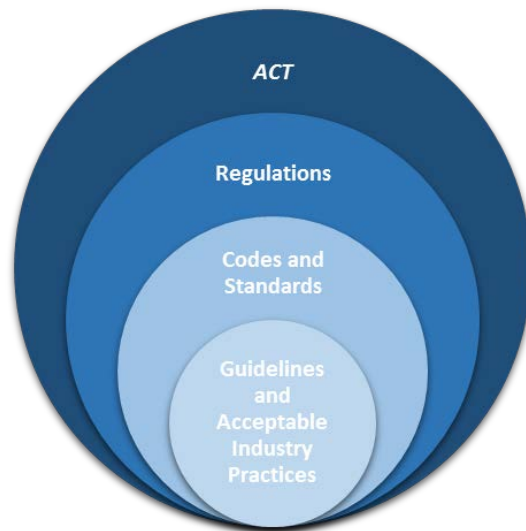
Acts give governments the authority to create regulations and other rules to support the goals described in acts. In general, Figure 6.1 shows the order of the different types of rules about how non-agricultural composting facilities are designed and operated.

For more information on how the government develops rules, see the [Citizen's Guide to the Alberta Legislature](#).

**Alberta Environment and Parks (AEP)** is the **lead regulator of non-agricultural composting facilities** in Alberta. However, there are other provincial and federal agencies that indirectly regulate composting facilities in Alberta, including:

- Agriculture and Forestry
- Health Services
- Labour
- Municipal Affairs

The **Natural Resources Conservation Board (NRCB)** is the **lead regulator of agricultural composting facilities** in Alberta. Agricultural composting facilities are on-farm sites that only accept manures or other waste from the farm. If an on-farm composting operation accepts materials from somewhere else, AEP would be the lead regulator.



**Figure 6.1. Hierarchy of rules that govern composting facilities**

Table 6.1 summarizes the different regulatory bodies and the legislation, regulations, guidelines, and directives that apply to Alberta composting facility operators. They are discussed in more detail later in this chapter.

## 6.3 Alberta Environmental Protection and Enhancement Act

[\*Alberta Environmental Protection and Enhancement Act\*](#) (EPEA) is the most important law for non-agricultural composting facilities in Alberta. EPEA is not just about waste and composting facilities. It is about protecting the environment – air, land, and water – from all activities that happen in the province. EPEA gives government the authority to write regulations to manage waste. Table 6.1 lists the rules that fall under EPEA for composting facility owners and operators. From the length of the list, you can see there is much for owners and operators to know about this important law. The most important documents are discussed later in this chapter. Owners and operators should become familiar with all the rules that apply to their particular operations.

EPEA also describes the powers of AEP inspectors and investigators. These government workers can audit, inspect, and enforce the Act and regulations. EPEA lets them make orders and apply penalties (from fines to facility closure) when orders are not followed.

**Table 6.1. Overview of Regulatory Documents Relevant to Composting facilities in Alberta**

<i>ALBERTA ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT</i>
<ul style="list-style-type: none"><li>• Activities Designation Regulation</li><li>• Waste Control Regulation<ul style="list-style-type: none"><li>○ Code of Practice for Compost Facilities</li><li>○ Alberta Landfill and Composting Facility Operator Certification Guideline</li><li>○ Best Management Practices: Managing Waste Management Facilities for Bears and Wildlife</li><li>○ Canadian Council of Ministers of the Environment (CCME) Guidelines for Compost Quality</li><li>○ Acceptable Industry Practices</li></ul></li><li>• Substance Release Regulation</li><li>• Release Reporting Regulation</li></ul>

**Table 6.1. Overview of Regulatory Documents Relevant to Composting facilities in Alberta**

OTHER ALBERTA ACTS AND REGULATIONS
<ul style="list-style-type: none"> <li>• <i>Water Act</i> and Water (Ministerial) Regulation</li> <li>• <i>Climate Change and Emissions Management Act</i> and Carbon Competitiveness Incentive Regulation (previously Specified Gas Emitters Regulation)</li> <li>• <i>Public Health Act</i> and the Nuisance and General Sanitation Regulation</li> <li>• <i>Weed Control Act</i> and Regulation</li> <li>• <i>Municipal Government Act</i> and the Subdivision and Development Regulation</li> <li>• <i>Occupational Health and Safety Act</i></li> <li>• <i>Agricultural Operation Practices Act</i></li> <li>• <i>Animal Health Act</i> and the Destruction and Disposal of Dead Animals Regulation</li> </ul>
FEDERAL LEGISLATION APPLICABLE TO COMPOSTING IN ALBERTA
<ul style="list-style-type: none"> <li>• <i>Canadian Weights and Measures Act</i></li> <li>• <i>Fertilizers Act</i> and Fertilizer Regulations               <ul style="list-style-type: none"> <li>○ T-4-93 – Standards for Metals in Fertilizers and Supplements</li> <li>○ T-4-120 – Regulation of Compost under the Fertilizers Act and Regulations</li> <li>○ International Waste Directive</li> <li>○ Enhanced Feed Ban and Specified Risk Material</li> </ul> </li> <li>• <i>Migratory Birds Convention Act</i> and Regulation</li> <li>• <i>Fisheries Act</i></li> </ul>

### 6.3.1 Activities Designation Regulation

In Alberta, there are three different authorization processes for composting facilities under EPEA:

1. An **approval** sets strict rules to develop and operate different facilities, which go beyond the minimum requirements in the Codes of Practice which are discussed in Section 6.3.3.
2. A **registration** is simpler. It only requires that the facility follow the **Waste Control Regulation’s Code of Practice for Compost Facilities**.
3. A **notification** applies to activities or facilities that will probably not impact the environment.

The [Activities Designation Regulation](#) (ADR) explains which activities need **approval**, **registration**, or **notification**. For composting and other solid waste facilities, the quantity or amount of waste, type of waste handled, and the environmental sensitivity of the location where the facility is built are used to determine requirements.



The ADR defines two different types of composting facilities:

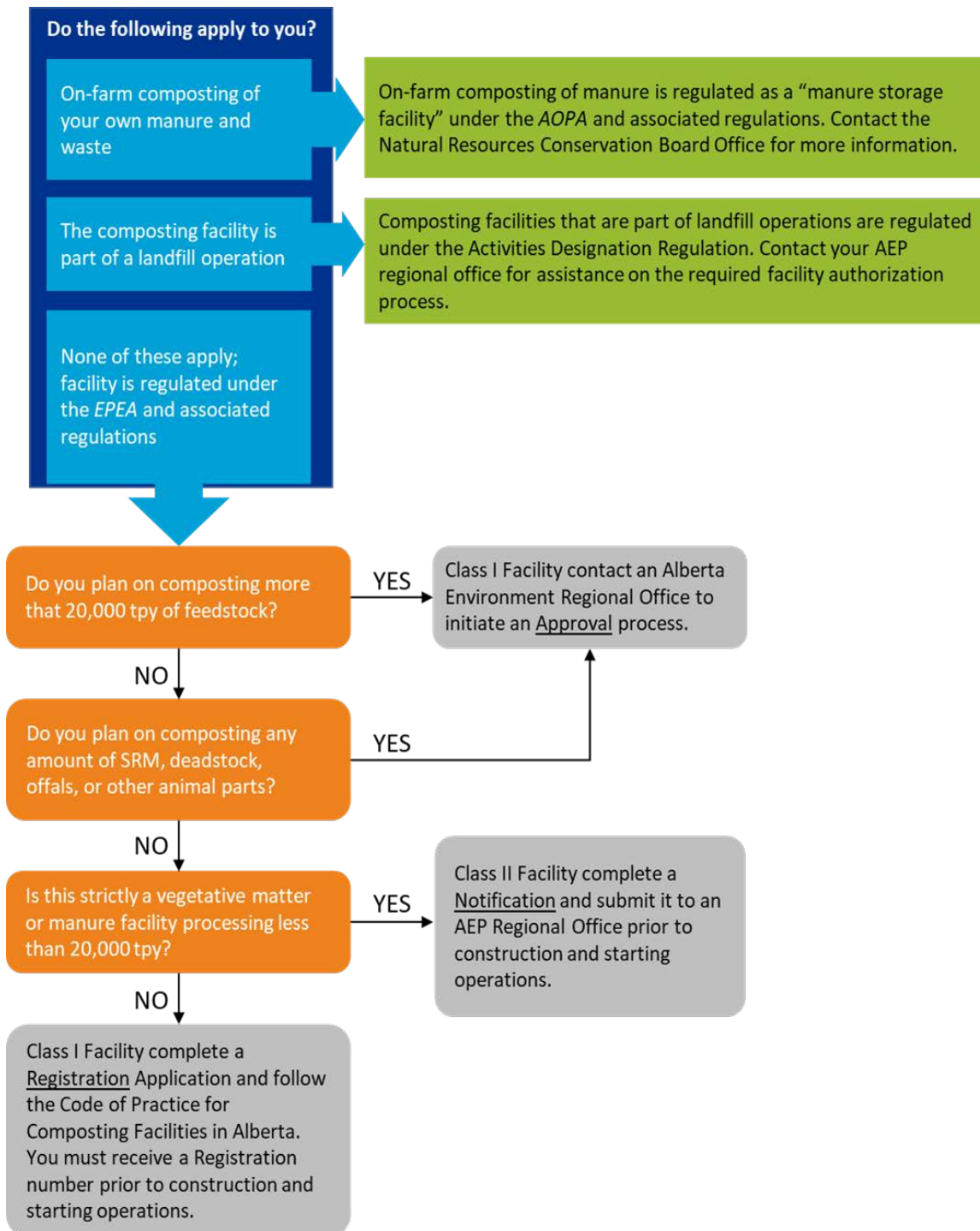
- Class II facilities accept only manure or vegetative matter.
- Class I facilities accept feedstocks not covered by Class II facilities (typical Class I facilities accept food waste, food and yard waste mixtures, municipal biosolids, and by-products from food processing plants)

Most composting facilities in Alberta are Class II. There are a few Class I facilities in Alberta, and they tend to be larger.

In terms of authorization processes, ADR requires:

- **Class II composting facilities** accepting **less than 20,000 tonnes per year (tpy)** of allowable feedstocks go through a **notification process**
- **Class I composting facilities** accepting **less than 20,000 tpy** of feedstocks obtain a **registration**
- **Class I or Class II** facilities accepting **more than 20,000 tpy** of feedstocks obtain an **approval**

Sites that would normally need a notification or registration may also have to apply for an approval, if AEP decides the facility is in a sensitive location or handles special kinds of feedstocks. Figure 6.2 shows how the decision process works according to the Activities Designation Regulation.



**Figure 6.2. Activities Designation Regulation Decision Process**

## 6.3.2 Waste Control Regulation

[Waste Control Regulation](#) (WCR) is the most important rule for managing waste, and building and operating non-agricultural composting facilities in Alberta. It:

- Regulates the handling, storage, recycling, and disposal of hazardous and non-hazardous wastes
- Defines what hazardous waste is
- Requires privately-owned waste management facilities to put aside funds (financial security) to pay for the cleanup and closure of the facility if the company goes bankrupt or otherwise defaults on their obligations
- Requires operators of composting facilities to be supervised by a Certified Operator
- Establishes the various codes, standards, guidelines, and Acceptable Industry Practices listed in Figure 6.1 – the most important of these are discussed in the following sections

## 6.3.3 Codes of Practice

A Code of Practice is a list of rules for different types of activities. Codes are often the relevant set of rules for small operations. The codes under the Waste Control Regulation provide rules for:

- Small landfills
- Composting facilities
- Small incinerators
- Land treatment of soil that has become contaminated with hydrocarbons (such as diesel, gasoline, and other refined fuels)

If a site does different types of activities, the operator may have to follow more than one code.

All codes provide rules for:

- The type of operation
- How much and the type of material that can be accepted
- Monitoring and record-keeping

Operators need to be able to easily find the records for activities that follow codes. The government may ask to see records in writing or during a facility inspection.

The [Code of Practice for Compost Facilities](#) describes the design and operating rules for Class I composting facilities that receive less than 20,000 tpy. It also defines monitoring requirements and compost product quality standards.

### Composting Facilities Located on Federal Lands

In Alberta, there are some waste facilities that do not have to follow Alberta waste laws. These are compost sites and other waste management facilities located on federal lands, including First Nations reserves and National Parks.

Composting sites on First Nations reserves need permits from the Federal Government. They must follow rules listed in those permits. Some reserves belong to regional landfill authorities. They may have waste transfer stations that are operated and managed by the rules in the authority's contracts.

Most National Parks in Alberta follow AEP policies, and some apply for EPEA approvals.

## 6.3.4 Guidelines

Guidelines explain how to manage different materials or run tests. AEP has published several guidelines that may apply to composting and other waste management facilities. Guidelines provide best management practices (BMPs). Guidelines do not use legal language, and make suggestions using softer terms, such as “should” and “may.” It is recommended, though, that composting facility owners and operators follow guidelines when they apply to help protect people and the environment. Some guidelines do become rules if they are included in a regulation or code, or in an approval.

Following all rules in a Code of Practice helps a facility avoid non-compliance reports or environmental protection orders, or enforcement orders for not following the code.

A summary of guidelines that apply to composting facilities in Alberta is provided in the following sections.

### 6.3.4.1 Alberta Landfill and Composting Facility Operator Certification Guideline

Composting facilities can cause harm to people and the environment. It is very important that operators understand how important their work is and what can happen if their site is not operated properly. The Government of Alberta requires every operating composting facility to have one or more certified operators. These operators must be trained to understand how best to operate their facilities to protect people and the environment.

The [Alberta Landfill and Composting Facility Operator Certification Guideline](#) describes the framework and requirements for composting facility operator certification. The AEP website has more information.

#### **6.3.4.2 Standards for Composting Facilities**

In 2007, AEP completed a multi-year review of the rules about agricultural and non-agricultural composting facilities. AEP's review was supported by other government departments, a committee of municipal and private sector industry representatives, and composting experts.

The review resulted in the development of the Standards for Composting Facilities in Alberta (the Standards) for Class II and III composting facilities. These Standards were intended to replace the Code of Practice for Compost Facilities. The Standards further clarified rules contained in the Code of Practice, including liner requirements, surface water controls, odour controls, and record keeping. The Standards also updated some Code of Practice requirements to reflect the accepted best practices for facility operations.

The Standards were published by AEP, but were not formally adopted under the Waste Control Regulation. Therefore, the Standards have no regulatory authority, except when it is specifically referenced in a composting facility's approval.

#### **6.3.4.3 Best Management Practice: Managing Waste Management Facilities for Bears and Wildlife**

Managing Waste Management Facilities for Bears and Wildlife is a guidance document for areas surrounded by wildlife. It describes BMPs to avoid conflicts with bears and other wildlife. The document describes how to fence and manage a site, and how to secure dumpsters.

#### **6.3.4.4 Acceptable Industry Practices**

Acceptable Industry Practices (AIPs) describe how to handle, dispose of, or recycle different types of waste. Both waste facility operators and waste generators use AIPs to properly manage wastes that may have environmental or safety concerns.

[Acceptable Industry Practices](#) fact sheets are available on AEP's website.

#### **6.3.4.5 Substance Release Regulation**

The [Substance Release Regulation](#) defines acceptable and prohibited substance releases to air. The rules in this regulation about burning materials are important to waste management operations. Burning anything other than clean wood results in a substance release that must be reported to AEP. Burning clean wood waste must also follow the regulation and cannot create thick smoke, odours, or visibility issues, or cause a nuisance to neighbours.

Section 26 of the Waste Control Regulation prohibits burning at waste management facilities including composting facilities unless it is conducted in accordance with the Substance Release Regulation.

The person responsible for the compost facility must notify AEP, local authorities, all adjoining property owners, the local fire department at least 7 days prior to the date of the burning,

informing them of the proposed burning and the date on which the proposed burning is to take place.

A **Fact Sheet** on burning waste is available on AEP's website.

#### 6.3.4.6 Release Reporting Regulation

A composting site has the potential to spill or release substances that might harm the environment, including:

- Leaks of hydraulic fluid, oil, antifreeze, and fuels from vehicles and heavy equipment
- Spills from onsite tanks
- Leachate spills or releases to surface water or groundwater
- Litter spreading to surrounding properties
- Fires with prohibited debris

Any release or spill that might create an unwanted effect (such as damage to the environment) must be reported to AEP. The [Release Reporting Regulation](#) explains when to report a release or spill, and to whom. Not reporting releases can result in fines or an order to shut down a facility.

## 6.4 EPEA Approvals

### 6.4.1 Understanding Approvals

Approvals issued by AEP are **site-specific**. Waste management facility staff must review, understand, and follow approvals. Approvals explain the minimum rules the site and its operators have to follow. The site manager and operators should create programs, policies, and procedures and train staff so they know what they need to do to follow the approval. Many facility owners hire engineers to update documents and recommend changes to site operations to help meet approvals. A site's management team should also review the approval with AEP to be sure they understand all the rules listed.

Approvals describe site-specific requirements. An approval may also include additional rules from those in the Codes of Practice, guidelines, or AIPs. This depends on site-specific conditions and concerns from the public or other stakeholders while the Approval is being issued.

An approval for a waste management facility in Alberta is a long and complex document. An Approval is important and helpful to owners and operators because it clearly spells out many important obligations and expectations.

## 6.4.2 Understanding Registrations

A registration is part of the Code of Practice for Compost Facilities. It explains rules for small to medium sized facilities when AEP decides a full Approval is not needed. A composting facility operating under a Registration must meet the general rules set out in the Code. **The Code takes the place of a site approval** and explains the rules the site and its operators have to follow. Site managers need to train all workers to follow the Code. Site managers should review the Code with AEP to be sure they understand the rules.

While not site-specific like an approval, the Code's general rules require that workers follow an Operations Plan. The Code also says that any groundwater and surface water monitoring must be explained in a written document called a record. Operating records for the facility must be kept safe, and an annual report must be written. In some cases, an engineer will help write the Operations Plan so that it follows the Code. The engineer may have also written process and nuisance monitoring plans that site staff follow.

Many Operations Plans include standard forms for the operators to use. Examples include:

- Daily, weekly, and monthly inspection
- Compost process monitoring logs
- Visitor log
- Complaint log
- Surface water reuse log
- Finished compost shipping record
- Residual disposal logs

During an inspection, good records can help prove intent, demonstrate due diligence and prevent fines.

## 6.4.3 Understanding Notifications

Notification is the simplest approach under EPEA, and is used for Class II composting facilities that accept less than 20,000 tpy of feedstock. The facility must notify AEP that they want to build a composting facility. The notification (which is usually a letter) must at least include:

- The name and address of the person in charge of the facility
- The location and description of the facility
- The dates when construction should start and end, and when the facility will open

Additional information may be requested by AEP.

## 6.4.4 Checking Compliance

Training staff so they know and understand the rules contained in their site's Approval or Registration (and the Code of Practice) is an important part of complying with the laws.

AEP inspectors will visit sites from time to time, and will hand out instructions and environmental protection orders if they find anything that does not follow the rules. Many site owners and operators hire a consultant to audit (check) that rules are being followed. Audits are usually once every 3 years so that owners and operators can fix problems, if they exist, beforehand instead of after an AEP inspection. This approach also shows AEP and other stakeholders, such as the community, that the site is well-operated. Of course, an important benefit is knowing about problems that could lead to environmental harm and dealing with them, hopefully, before they happen.

## 6.5 Water Act

The [Water Act](#) supports saving and managing water. For example, a *Water Act* licence is needed to use or divert (change) the flow of surface water or groundwater.

The *Water Act* applies to composting facilities where water is redirected or removed, or where offsite drainage is impacted. The act explains what a water body is and it provides rules for building a compost site near a water body.

Alberta also has the [Wetland Policy](#), which is important to review if a composting facility is being built or operated near a designated wetland.

The [Water \(Ministerial\) Regulation](#) includes rules for drilling, monitoring well construction, and borehole and monitoring well reclamation during compost site investigations and groundwater monitoring programs.

Some sites that use water for activities like dust control may have to report how much water they use onsite, based on the water licence.

## 6.6 Climate Change and Emissions Management Act

The [Climate Change and Emissions Management Act](#) explains how Alberta works to reduce greenhouse gas (GHG) emissions. Regulations and standards under the Act explain the rules that must be followed.

The main sources of GHG emissions in composting operations are:



- Release of methane gas from feedstocks when they break down under anaerobic conditions
- Burning of fossil fuels in equipment

Emissions need to be measured and reported for larger operations. If they are above a certain level, the facility will be classified as a “large emitter” under the Act. The [Carbon Competitiveness Incentive Regulation](#) (which replaced the Specified Gas Emitters Regulation in January of 2018) of the *Climate Change and Emissions Management Act* has defined large emitters as facilities that send out more than 100,000 tonnes per year of GHG expressed in carbon dioxide equivalents (CO<sub>2</sub>-e).

Large emitters are required to reduce GHG emissions. Large emitters, including landfills, can also pay into the Emission Reduction Alberta Fund or buy GHG reduction credits. These credits can be bought from facilities or projects that have extra credits to sell.

The Emission Reduction Alberta Fund is run by the [Emission Reduction Alberta \(ERA\)](#). ERA must use the fund to support new projects that will reduce GHG emissions in Alberta. Some waste management facility operators in Alberta have benefitted from the fund’s financial support for new projects, such as landfill gas collection and use.

This Act and its regulations and standards describe how voluntary projects can calculate GHG reductions, so they can sell credits to large emitters. Quantification protocols guide various projects that have an overall GHG reduction in Alberta. These protocols explain how to measure GHG offsets for certain projects. For example, composting organics instead of disposing in landfills can reduce GHG. The composting protocol explains how to measure a reduction that can be used for a credit.

Some projects that can reduce GHG on waste management sites in Alberta include:

- Composting
- Solar energy projects
- Wind power generation

The [Carbon Competitiveness Incentive Regulation](#) also explains the rules for reporting by emitters of GHG. Any facility that releases more than 10,000 tpy of GHG is required to file a report. For this Regulation and Act, GHG is reported as tonnes of carbon dioxide equivalent (CO<sub>2</sub>e). Different gases have different Global Warming Potential (GWP) factors. For example, carbon dioxide (CO<sub>2</sub>) has a GWP of 1, and methane in LFG has a GWP of 25. That means that the release of 1 tonne of methane will be reported as the release of 25 tonnes CO<sub>2</sub>e.

## 6.7 Public Health Act

In terms of importance, the [Public Health Act](#) (PHA) prevails over all other Alberta Government legislation, except for the Alberta Bill of Rights. Among other things, the PHA gives government officials powers to deal with epidemics and other health emergencies, and prevent conditions that could spread a disease.

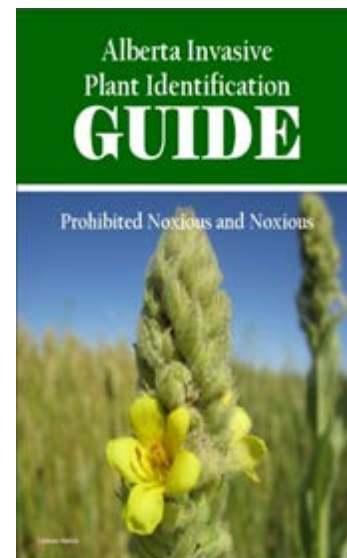
The [Nuisance and General Sanitation Regulation \(AR 243/2003\)](#) allows public health officials to order that conditions posing a danger to human health or that are a “nuisance” be fixed, or removed. They can also decide the site of the nuisance is unfit and require it be closed or changed. Many conditions can be considered nuisances, and public health officials have the power to decide what a nuisance is. This means that if a composting facility or other waste management site may cause or is causing a nuisance, Alberta Health can decide what actions are required to fix the situation.

## 6.8 Weed Control Act and Regulation

The [Weed Control Act](#) and its companion [regulation](#) regulate noxious (harmful) weeds, prohibited noxious weeds, and weed seeds through various controls, such as inspection and enforcement. These laws also require provisions for recovery of costs if laws are not followed.

Composting sites can be infested by weeds. There are usually finished product stockpiles and large areas of exposed soils exposed to wind, birds, and other ways seed can be spread. The rules list plants that are noxious weeds and others that are prohibited noxious weeds. Both provincial and local municipal officials can issue clean-up orders under these laws.

The [Alberta invasive plant identification guide: prohibited noxious and noxious](#) was written to help identify noxious weeds.



**Photo 6.1. Alberta Invasive Plant Identification Guide product stockpile locations**

## 6.9 Municipal Government Act

The [Municipal Government Act](#) makes municipalities responsible for checking that waste is properly managed within their boundaries. It also lets local governments (county, town, municipality) make rules about how a composting facility can be operated within their boundaries. Every composting facility will have to follow the land use bylaw or development permit from their local government. There may be rules for things like:

- Setbacks (including distance from town, houses, or parks)
- Litter control
- Hours of operation
- Appearance
- Any other matter that government feels is important

## 6.10 Occupational Health and Safety Act

Rules for health and safety in workplaces are listed in the [Occupational Health and Safety Act](#), Occupational Health and Safety Regulation, and Occupational Health and Safety Code. Site health and safety is discussed in Chapter 7.

## 6.11 Agricultural Operation and Practices Act

The *Agricultural Operation Practices Act* (AOPA) explains how to resolve conflicts between agricultural producers and the public about disturbances from agricultural operations. An agricultural disturbance includes things like odour, dust, noise, and smoke. AOPA makes sure that the province's livestock industry can keep growing in an environmentally sustainable way to serve local and world markets. More information is available on the [Alberta Agriculture and Forestry website](#).

AOPA also regulates confined feeding operations (CFOs), and manure storage and handling. AOPA rules about manures apply to any operation that produces, transports, or receives and applies livestock manure and manure compost, including:

- Crop producers using manure as fertilizer
- Custom manure applicators
- Livestock producers
- Existing, expanding, or new CFOs

Composting facilities regulated by AEP under EPEA are not subject to AOPA requirements.

## 6.12 *Animal Health Act* and the Destruction and Disposal of Dead Animals Regulation

Livestock producers produce meat to sell. This means every livestock producer must dispose of animal bones and other parts (carcasses) that are not sold. In Alberta, this type of disposal must follow the rules in the *Animal Health Act* generally, and the Dead Animals Regulation specifically.

Proper disposal of carcasses helps prevent livestock diseases, and protect air and water quality. Dead animals must be disposed of correctly within seven days of death. Mortalities can be composted, incinerated, buried, rendered, or naturally disposed. Giving scavengers access to carcasses is only allowed under the rules for natural disposal.

If an animal is known or suspected to have died from an infectious or reportable disease, the owner must report this to authorities, and dispose of the animal following the rules in the Act.

Very specific and strict rules are also in place for handling cattle carcasses. These are discussed in detail in Section 6.14.4.

## 6.13 Canadian Council of Ministers of the Environment – Guidelines for Compost Quality

The Guidelines for Compost Quality (the Guidelines) were first published by the CCME in 1996 after discussions between the provinces, Environment Canada, and Agriculture Canada. An updated version of the guidelines was published in 2005.

As shown in Table 6.2, the Guidelines include criteria for trace elements, pathogen levels, maturity, foreign matter (including “sharps”), and organic compounds. There are two sets of criteria within the Guidelines, which allow compost to be classified as

### The Canadian Council of Ministers of the Environment

CCME is an “intergovernmental forum” of federal and provincial/territorial government representatives.

CCME committees are formed to discuss and take joint action on environmental issues that have national implications. The CCME’s goal is to encourage consistent standards, practices, and laws across Canada.

either Category A or B<sup>3</sup>. The difference is different rules for trace elements and sharp foreign matter. Rules for pathogens levels, maturity, and organic compounds are the same for both categories.

The trace element and sharps criteria for Category A are more stringent than Category B. The trace element rules for Category B come from (and are in line with) the rules required by the federal Fertilizer Regulations discussed in Section 6.14.2. The Guidelines are adopted by AEP via the Code of Practice for Compost Facilities.

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<sup>3</sup> The terms “Category A” and “Category B” are specifically used in the CCME documentation. They should not be confused with, or used interchangeably with the terms “Class A” or “Class B,” which are used to describe pathogen treatment levels for biosolids.

**Table 6.2. Summary of CCME Guidelines for Compost Quality**

Parameter	Category A	Category B	
	Maximum Concentration within Product (mg/kg dry weight)	Maximum Concentration within Product (mg/kg dry weight)	Maximum Cumulative Additions to Soil (kg/ha)
<b>Trace Elements</b>			
Arsenic	13	75	15
Cobalt	34	150	30
Chromium	210	NL <sup>a</sup>	NL <sup>c</sup>
Copper	400	NL <sup>b</sup>	NL <sup>d</sup>
Molybdenum	5	20	4
Nickel	62	180	36
Selenium	2	14	2.8
Zinc	700	1,850	370
Cadmium	3	20	4
Mercury	0.8	5	1
Lead	150	500	100
<b>Pathogens<sup>e</sup></b>			
Salmonella	<3 MPN/4 g (dw)		
Fecal coliform	<1000 MPN/g (dw)		
<b>Foreign Matter and Sharp Foreign Matter</b>			
Foreign Matter	≤1 piece larger than 25 mm in any dimension per 500 mL	≤2 pieces larger than 25 mm in any dimension per 500 mL	
Sharp Foreign Matter	None greater than 3 mm in any dimension per 500 mL	≤3 pieces per 500 mL, 12.5 mm maximum dimension	
<b>Maturity and Stability</b>	Compost will be mature and stable at the time of sale and distribution, shall be cured for a minimum of 21 days and shall meet one of the following requirements: <ul style="list-style-type: none"> <li>- Respiration rate ≤ 400 mg O<sub>2</sub> per kg VS (or OM) per hour</li> <li>- Carbon dioxide evolution rate ≤ 4 mg C-CO<sub>2</sub> per kg OM per day</li> <li>- Temperature rise above ambient &lt; 8°C</li> </ul>		
<b>Organic Compounds</b>	Composting of feedstocks with high concentrations of persistent, bio-accumulating organic contaminants should be avoided.		

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<sup>a</sup>Not listed in Guideline, but can be calculated as 1060 mg/kg.

<sup>b</sup>Not listed in Guideline, but can be calculated as 757 mg/kg.

<sup>c</sup>Not listed in Guideline, but can be calculated as 210 kg/ha.

<sup>d</sup>Not listed in Guideline, but can be calculated as 150 kg/ha

<sup>e</sup> Compost produced only from yard waste must meet PFRP rules OR pathogen content limits. Compost produced from all other feedstocks must meet PFRP rules AND pathogen content limits

Notes:

kg/ha = kilogram(s) per hectare

mg/kg = milligram(s) per kilogram

MPN = most probable number

NL = not listed

OM = organic matter

VS = volatile solids

## 6.14 Compost Quality Alliance

The Compost Quality Alliance (CQA) is a voluntary program established by the Compost Council of Canada and compost producers interested in marketing their compost to the best possible use.

The primary goal of the program is to improve consumer confidence in compost products.

Open to all compost facilities and producers, the program utilizes standardized testing methodologies and product attribute declarations, which have relevance to a broad range of end use markets such as landscaping, agriculture, erosion control, home gardening, among others.

The laboratories participating in the Compost Quality Alliance program undergo testing calibration to ensure reporting accuracy and consistency. Included among the laboratory reports provided through the testing procedure are regulatory compliance attributes, agronomic parameters and nutritional values provided within the compost produced.

The program is managed through The Compost Council of Canada and an Advisory Board of Compost Producers charged with the ongoing advancement of compost market development across the country.



**Photo 6.2. Compost Quality Alliance (CQA) logo**

## 6.15 Federal Legislation Applicable to Waste Management in Alberta

### 6.15.1 *Canada Weights and Measures Act*

At many composting facilities, scales are used to weigh organic wastes that come in, and compost products that go out. The weights determine the charges to customers. Under the [Weights and Measures Act](#), when fees are based on scale readings, the scale must be re-

calibrated and certified on a set frequency. An accredited service provider must perform the calibration and certification.

### **6.15.2 Canadian Food Inspection Agency Fertilizer Act and Regulation**

The CFIA is a federal government agency that enforces Health Canada's food safety and nutritional quality standards. It also sets standards, and inspects facilities and enforces rules and inspections related to animal and plant health. The CFIA manages and enforces the *Fertilizer Act*, Fertilizer Regulations, and associated trade documents.

CFIA staff routinely sample fertilizers, fertilizer-pesticides, and soil supplements to check that products meet safety standards. This is done through random inspections and product sampling at blending, manufacturing, and processing plants; retail outlets; and warehouses. The samples are tested for contaminants including heavy metals, pesticides, and pathogens, such as *Salmonella*.

Per the Fertilizer Regulations, the CFIA calls compost a "soil supplement." All compost products sold have to follow quality rules. The quality rules are outlined in CFIA trade memoranda. T-4-93, for example, sets loading rates for trace element in soils. T-4-120 sets rules for organic matter, moisture content, pathogens, and compost maturity.

The Fertilizer Regulations also lists labelling rules for compost products that will be sold. The labelling rules include "guaranteed analyses" for minimum organic matter and maximum moisture content, instructions for use, lot number and producer information. There are rules about label sizes and the kind of lettering that can be used. There is also a long list of rules about what the label can say.

While there are a lot of CFIA labelling rules, they are not well-documented or known, so they are not always followed. Also, the rules are not fully enforced by CFIA across all soil supplement industries, which leads to more confusion for compost producers and consumers.

The CFIA's rules only apply to composts that are sold or imported into Canada. So, if a producer gives their compost away, they do not have to meet any of the Fertilizer Regulations requirements for testing and labelling. In recent years, the CFIA has changed what the word "sold" means to include any time that money changes hands. This reduces the chance a producer will not follow the rules by giving the compost away to a user, but charging them a fee for "loading" or "handling."



### **6.15.3 Canadian Food Inspection Agency International Waste Directive**

Waste from other countries can contain diseases and invasive species of plants that can hurt people or the environment. Under the [International Waste Directive](#), a composting facility taking international waste must have a special CFIA permit to accept these wastes. Waste removed from flights arriving from other countries is an example. This means that composting facilities that accept organic wastes from airports should check whether the wastes include materials removed from international flights.

### **6.15.4 Canadian Food Inspection Agency Specified Risk Material Guidance**

In 2007, the CFIA passed the enhanced feed ban. It controls the handling, transporting, and disposal of specified risk material (SRM) that could cause bovine spongiform encephalopathy (BSE). SRM includes the skull, brain, trigeminal ganglia (nerves attached to the brain), eyes, tonsils, spinal cord, and dorsal root ganglia (nerves attached to the spinal cord) of cattle 30 months or older, and the distal ileum (a portion of the small intestine) of all cattle.

Under the CFIA's rules, permits are required to remove from any site, convey (other than from area to area within the same site), receive, treat, store, export, sell, distribute, or destroy any type of SRM. This includes any dead stock that SRM has not been removed from.

The CFIA recognizes composting only as a way to reduce SRM volumes. Composting has not been accepted as a method to inactivate the disease agent in these materials that causes BSE. Composting facilities should take steps to check that the feedstocks they accept do not contain whole cattle carcasses or SRM, as this can lead to regulatory problems as well as difficulties using the finished compost products. Compost containing any form of SRM is considered SRM itself, and may not be sold as a fertilizer or supplement.

### **6.15.5 *Migratory Birds Convention Act* and Regulation**

Many birds are protected under the [Migratory Birds Convention Act](#). Some of these protected species, such as gulls, are attracted to composting facilities.

Nesting habitat for migratory birds must also be protected. If there is nesting habitat at or near a facility, care must be taken. As an example, Canadian geese nesting pairs often find a habitat near or along runoff control ditches or in compost piles. The Act requires they not be disturbed or moved without a permit.

The regulation sets the process through which facility operators can obtain permits to manage birds at their site. Some types of bird control programs also require a permit from Alberta Fish and Wildlife. Operators should always check with the local office.

### **6.15.6 Fisheries Act**

The [Fisheries Act](#) protects fish and fish habitat. If a composting facility allows contaminated groundwater or surface water to enter into water bodies with fish, the penalties of the Act may apply because:

*“No person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions ...”*

# Chapter 7 – Communication, and Health and Safety

## 7.1 Learning Objectives

Effective communication is important for the safe and orderly operation of composting sites. Communication and site safety go hand-in-hand. In this chapter, you will learn about:

- How to communicate effectively with the public, customers, employees, contractors, and site visitors
- The importance of open communication with site neighbours
- How to use effective signs to convey information, directions, and safety rules
- The value of public support and acceptance
- The need to communicate complex information clearly
- The importance of occupational health and safety regulations
- Common incidents at compost sites and how to prevent them
- Your responsibility for the safety of employees, customers, and visitors
- The importance of hazard assessments and controls
- Reporting and documentation of incidents and near-misses
- What personal protective equipment (PPE) is for and how to use it
- The importance of effective emergency response plans (ERPs)

## 7.2 Overview

Operators need to be prepared to communicate regularly with other employees at the facility, customers, and neighbours. Depending on the size and structure of the municipality or company that owns the site, operators may also need to communicate with:

- Elected officials
- The media
- The public at large
- Tour groups

A communications strategy will help staff when engaging with these various groups. If your employer has a communications or public relations department, they should be involved in

developing and delivering communications for different situations and audiences. Regular communications with the public and customers might be required to introduce new waste management programs, or inform about changes in site operations or disposal fees. Staff can communicate with a variety of tools, including:

- Call lines for inquiries
- Hand-outs to customers at the scale
- Media news releases and advertising
- Open house meetings and facility tours
- Personal communication
- Web pages and social media

Similar tools can be used for non-routine situations – usually events such as a fire, opening of a significant new facility, or a significant accident at the site.

Site employees may be asked for media interviews. It is best to assign a designated spokesperson who is trained and has experience in media interviews. Employees who are asked to conduct interviews should refer the media to the assigned spokesperson. This is important to maintain a consistent message and provide key information, particularly for non-routine events.

### Media Communication

- Assign a designated spokesperson
- Be prepared – know the purpose of the interview
- Answer questions honestly
- Stay on point with your message
- Speak in common (not technical) language
- Remember there is no such thing as “off the record”

## 7.3 Communicating Safety and Site Use

Important communications address health and safety, and site operational procedures and rules. All employees at the facility need to be part of the conversation between:

- Customers
- Employees
- Contractors working at the site
- Site visitors and tour groups
- Regulatory inspectors

### Safety Messages

- No smoking
- No scavenging
- Children and pets remain in vehicle
- Watch for vehicles and equipment
- Obey speed limits

### 7.3.1 Communicating with Customers

A customer may be a resident with a small load of yard waste, or a driver of a residential collection truck or large commercial truck.

Repeat customers, such as the residential and commercial collection truck drivers, will know the procedures. Site staff may need to explain the procedures to new drivers with regular hauling companies. The operator should work with the hauling companies to train their drivers. This can involve communication with the hauling company (which may be a municipal waste collection branch) through:

- Written procedures to follow at a composting facility
- Face-to-face meetings to review procedures
- Communicating observed unsafe practices with drivers
- Reporting unsafe practices to company or branch supervisors

The more challenging customers are those who do not come to the site frequently or are otherwise unaware of procedures and safety risks. Site staff may need to take additional time to explain where the customer needs to go and some basic safety rules of the site.

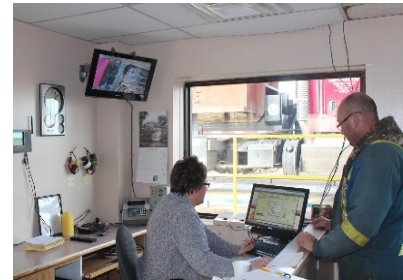
Communication with customers at the site begins at the site gate, with information signs and thorough communication with the scale or gate attendant. The attendant will collect information about customer and the load, provide direction to the correct tipping area, and relay safety information.

### 7.3.2 Communicating with Employees

Communication with site employees is key to the proper and safe operation of the site. This includes training on site operating and safety policies and procedures. Daily communications with employees can include:

- Emails if staff have access
- Memorandums
- Radio or phone conversations
- Tailgate meetings
- Verbal discussions and explanations

It is important to have contact with employees who are working alone. An employee who is working alone must be able to contact someone in case of an emergency. It is also important to have scheduled phone or radio checks with an employee who is working alone. There are technologies available that will send alert notifications if, for example, an



**Photo 7.1. First point of contact**  
Source: JLTechical Services



**visits with staff is an effective way to keep communications lines open**  
Source: CH2M

employee does not check in within a prescribed time or does not move within a certain time interval – indications of a possible medical emergency or accident.

Radio or cell phone communication between employees is important to maintain site control and site safety. In cases where there is anything out of the ordinary, such as a waste load that requires special handling, a bear was seen in the area, or vehicle or equipment breakdowns, there needs to be a reliable communication system.

In the event of an emergency onsite, the communication plan needs to include how to notify employees and customers, and contact emergency services. All employees must be aware of the communications procedures when an emergency occurs, and their individual roles and responsibilities. This is described in a site ERP.

### **7.3.3 Communicating with Contractors**

Contractors may be working on the site for construction projects, environmental monitoring programs, or other site works. Contractors need to be informed of site hazards and the safety requirements they must follow. They need to know the location of site utilities, of electric fences if used, and of features such as monitoring wells that must not be damaged. They also need to be made aware of new hazards as they arise.

Before a contractor begins work at the site, the operator should conduct a site safety orientation that informs the contractor of general safety policies and procedures, and highlights specific hazards and procedures for the work area.

Contract agreements should be very clear on a Prime Contractor's responsibility for safety. The Prime Contractor rules are also discussed in Section 7.7.34. If the contractor is the Prime Contractor, site staff will need to be informed about contractor safety procedures that must be followed in their work area. There must be an established communications process between the contractor and the facility management and staff, regardless of which party is the designated as Prime Contractor.

### **7.3.4 Communicating with Visitors and Managing Tours**

An operator may have site visitors, such as neighbours, community leaders, regulators, or operators from other facilities who are interested in the site. At times, the operator may be requested to lead tours for school groups, community social groups, or even conference tours and training course students. Accommodating such visits can be an important way to be seen as a positive asset to the community and the industry.

There should be advance notice for site visits, but sometimes, single visitors or small groups arrive at the site unannounced. The site owner should establish a policy on whether this will be allowed or not. If policy allows, the operator should always be prepared, but if the operator's judgment is that a visit or tour cannot be accommodated safely or adequately, they should be empowered to say "no."

Visitors should sign in at the site office or scale house and be escorted by a site employee. The operator should begin a site visit by asking questions about what they would like to see. The operator should be courteous when answering questions. If the operator does not know the answer to a question, they should say so and offer the contact information for someone who can provide an answer.

Tours by large groups are typically pre-arranged. It is best to schedule tours in low traffic periods of the day when site employees are more available, or to bring extra staff in. All site employees should be informed of a tour schedule so they are aware and can take proper safety precautions. Before starting on the tour, a site orientation should be given, including an overview of the site, what they will see on the tour, and safety procedures during the tour. If required, PPE must be worn. The site should keep a supply of high-visibility vests and other PPE available for visitors.



**Photo 7.3. Site orientation**

*Source: JLTechical Services*

Tour groups should remain in vehicles when in high traffic areas and where equipment is working. If a tour group views a part of the operation on foot for a demonstration or to see a specific piece of equipment, the group should remain with the tour guide. Site employees should always remain friendly and helpful to tour groups.

## 7.4 Signs

Signs are important communication tools at waste management sites.

Signs are posted to:

- Give general information, such as fees
- Give directions to various facilities and tipping areas
- Communicate safety rules



**Photo 7.4. Entrance sign**

*Source: Scott Gamble*

Too much signing can be confusing, and many people will then not bother to read them. Signs should be short, clear, and to the point. Signs and the text on them needs to be larger than one might expect. Signs that are too wordy or too small will not likely be read.

Alberta legislation requires that information signs at composting facility gates provide at least the following information:

- Name of the approval holder
- Any waste restrictions
- Phone numbers of:
  - ✓ Person responsible
  - ✓ Local fire department
  - ✓ AEP (1.800.222.6514)
  - ✓ Local police department

Other information typically provided on entrance signs includes the hours and days of operation and a schedule of disposal fees.

Information signs may also be posted at specific unloading areas.

Direction signs are used to guide customers to specific areas of the site. This may include signs posted along roads directing users to recycling areas or the working face. Additional direction signs are sometimes posted at the tipping locations to give customers instructions or safety information.

Because customers may not pay attention to signs, staff must watch for customer mistakes, and stop and speak to them to explain the rules in person if necessary. Signs support the staff in giving directions or conveying a message.



**Photo 7.5. Example of a public information sign**

*Source: Scott Gamble*



## 7.5 Value of Public Support and Acceptance

From a public relations perspective, a waste management facility can be a significant asset or a liability, depending on how it is managed and how well communication with the public and others is managed. When the relationship between the operators and the public is positive, there is more support and trust in the operations. Losing public support can lead to more regulatory oversight, legal issues, and difficulty gaining support for proposed solid waste management programs. It is best to involve the public at all stages of a facility's life, from initial siting through operations, and into closure activities.

Members of the public will become involved when they choose to. When there is poor communication, residents may feel the need to speak to the media or their elected officials. The goal for owners and operators should be to engage the public in positive ways.

Public involvement requires a two-way dialogue. This involves getting information out to the public, while also listening to the concerns and issues they have. Then it is important to address their concerns.

If a problem arises at the site, be honest about it, explain what actions are being taken, and give realistic timelines as to when the problem will be corrected. For example, if a neighbour calls to report litter blowing onto their property, arrange for clean-up as soon as possible. The operator may also review site operations to see if litter controls are working effectively.

Neighbours, residents, or businesses that are adjacent to or nearby the site are important stakeholder groups. Waste management sites are generally not a preferred neighbour. Concerns of neighbours typically include traffic, noise, dust, litter, and odours. Odour monitoring and management, as well as limiting certain activities (such as outdoor mixing) to periods with low wind conditions help to avoid complaints from neighbours.

An open communication process helps to build public trust and reduce opposition to the site.

The most effective way to build public support is to manage the facility and waste diversion programs to a high standard and protect the environment.



**Photo 7.6. Open and honest communication is recommended**

*Source: JL Technical Services*

Keeping on good terms with neighbours is key to broader acceptance of the facility within the community. It is best to communicate with the public, and neighbours frequently, openly, and honestly. Tools used for communication with neighbours might include:

- Newsletters
- A community liaison committee, meeting on a regular basis to discuss concerns, if any
- A call-out system so that, should there be an event, such as a fire, neighbours can quickly be given the facts and have their questions answered

Keeping an open dialogue with neighbours and the public in general can be helpful to keep them informed and quickly resolve concerns. People who are uninformed or misinformed can mistrust site operations. Once trust is lost, it is very difficult to gain it back.

## 7.6 Communicating Technical Information

At times, it may be necessary to provide the public with technical design information or an interpretation of testing result, such as groundwater or surface water quality analysis, or an analysis of a waste material.

Data interpretation and explanation is best left to professionals in the relevant field of study. This may be professionals employed by the composting facility, but it is often wise to use the third-party consultant who generated the data to provide the interpretation. This can add credibility to the information. Operators should not try to communicate information or answer questions on matters beyond their expertise. It is fine to explain that you will have to connect an individual with someone else for such discussions.

When explaining data to regulatory agencies and other scientific groups, using technical language is acceptable, as it is normally understood. When explaining scientific data to the general public, it is best to use non-technical language as much as possible. Use graphics or visual aids to help explain

### Community Liaison Committees

- Committees bring together interested or concerned community members (about 4 to 10 members) with facility representatives and operators.
- Committees may have regular scheduled meetings where they discuss:
  - Activities and events since the last meeting
  - Planned upcoming activities
  - Community concerns, if any
  - Action plans to address concerns

It is important that the facility representative commit to, and follow up on, communicating back to members the progress on action plans.

the data when possible. Be sure to address specific concerns that have been raised.

When explaining test results, take the time to explain how results relate to regulatory limits and impact the environment. For example, when explaining the results of a groundwater monitoring program, explain whether groundwater is being impacted or not. It is also important to explain the significance of any impact.

If a problem arises, have a strategy for communicating to the public. Explain:

- What the issue is
- The significance of the issue
- The corrective action plan
- A timeline for the corrective action

Provide regular updates on the progress and results of the corrective action until the situation is resolved.

## 7.7 Health and Safety at Composting Facilities

Composting sites can be dangerous places. Consider that at a site:

- Any manner of material can be in the incoming waste loads, including things that are sharp, dusty, heavy, explosive, combustible, and toxic
- Heavy equipment may operate close to staff and customers
- Many vehicles of different sizes and with drivers of varying skills are maneuvering in the same space – and there are no lines painted on the surface for them to stay within
- The ground surface may be irregular and strewn with waste materials, creating many opportunities for people on foot to trip, fall, or injure themselves
- It may be necessary to enter vessels, sumps, or other confined spaces to complete maintenance work

Incidents can involve employees, contractors, and the public. Common hazards and incidents at composting facilities include:

- Accidents or injuries caused by moving bulky, hard to handle materials
- Conflicts with wildlife
- Contact with heavy equipment working at the site (for example, front-end loader)
- Grinders and Shredders
- Moving Equipment (for example belts, conveyors, fans among others)
- Contact with or between customer vehicles

- Contact with sharp objects (glass, metal)
- Exposure to chemicals, dusts, moulds, pathogens, bioaerosols, particulate matter (PM<sub>10</sub>), process gases (for example: NH<sub>3</sub>, H<sub>2</sub>S, CO, CH<sub>4</sub> and CO<sub>2</sub>)
- Vehicle and Machinery Noise
- Fires
- Medical emergencies (such as heart attack, stroke, or asthma)
- Slips, trips, and falls
- Workplace violence incidents

Serious incidents have occurred at compost and other waste management sites across North America that have caused severe injuries and deaths. Such incidents have included customers and employees run over by equipment or vehicles, falls into transfer containers, explosions, and inhalation of dangerous gases.

Because of the nature of a compost site, use of best practices in applying established safety conventions and adhering to safety legislation is very important.



**Photo 7.7. Customers dropping off materials in tight quarters and around heavy equipment**

Source: CH2M

## **7.7.1 Occupational Health and Safety Act, Regulation and Codes**

The *Occupational Health and Safety (OH&S) Act*, Regulations, and Codes protect people working at and visiting composting facilities. Compost site operators should keep a copy of these documents at the site for reference. The [OH&S Act](#) can be found online at the [Queen's Printer](#). More information and tools that can be used to develop and maintain a safety culture at a work place can be found at [Work Safe Alberta](#).

The *OH&S Act* describes the minimum requirements for health and safety in Alberta workplaces. Officers enforce the legislation by issuing orders to employers.

The site's operating policies and procedures cannot conflict with the *OH&S Act* or Regulations.

### **7.7.1.1 Occupational Health & Safety Regulation**

The OH&S Regulation describes how to monitor and enforce the *OH&S Act*. Regulations are legally enforceable.

As of the publication of this study guide, the current version is Alberta Regulation 62/2003, with amendments up to and including Alberta Regulation 182/2013. The [OH&S Regulation](#) is available online at the [Queen's Printer](#).

### 7.7.1.2 Occupational Health & Safety Code

The OH&S Code is a guideline to assist employers and employees implement and follow the *OH&S Act* and Regulation. The OH&S Code provides specific and detailed information on how to meet the regulatory requirements.

The [OH&S Code](#) is available online through Work Safe Alberta. An [explanation guide](#) may be purchased from Alberta Queen's Printer or viewed online at Work Safe Alberta.

## 7.7.2 Responsibility for Safety

Vehicle traffic, heavy equipment, conveyors, and exposure to pathogens and moulds are just some of the risks that composting facility operators must deal with every day. Everyone at the site, including workers, contractors, and customers, needs to be aware of their surroundings to avoid accidents or injury.

The site owner is responsible for making sure a comprehensive safety program is developed and implemented. Site managers, supervisors, and operators have a responsibility to check that safety procedures are followed. Operating staff have a responsibility to work safely. Customers have a responsibility to follow safety rules for the site. ***Everyone is Responsible for Safety.***

### 7.7.2.1 Employee Safety

All composting facility employees are responsible for their own safety, as well as the safety of their co-workers, contractors, and the general public using the site. Employees are required to follow safe work practices and procedures that have been developed for the site and put in place by management. A safety program needs to include ongoing training of all site employees. Employees must wear PPE required by their employer's safe work practices and procedures.

### 7.7.2.2 Customer and Visitor Safety

Many customers are not trained or knowledgeable about the dangers at a compost site and need to be informed of site rules and procedures. Regular customers, such as waste truck drivers, may be more aware, but they, too, must be informed and reminded of site-specific procedures. Waste management facilities must have policies and procedures in place to handle customer and visitor health and safety risks. Common policies and procedures include:

- All loads must be secured
- All visitors (including tours and inspectors) and contractors must sign in and sign out of the facility

- Children and pets must remain in vehicles at all times
- Follow procedures to enter confined spaces safely (this is relevant, for example, to a technician who may be entering a manhole to collect samples, or maintenance staff entering a sump to work on a pump).
- Follow the 3 m rule - it is recommended that all customer vehicles have at least 3 m between each other when unloading (Staff should be trained and expected to require more separation when safety dictates. For example, end dump trailers require more separation because they are unstable when dumping).
- No loitering
- No scavenging
- No smoking
- No speeding
- Separate tipping areas for residential and commercial customers if possible

Sites should also have emergency response procedures in place.

Commercial and municipal waste truck drivers should be required to wear appropriate PPE while onsite, including:

- CSA-approved footwear
- Gloves
- High-visibility clothing

Some sites also require truck drivers to wear hard hats.

Visitors at the site may include tour groups, consultants, regulators, media, or other company or municipal employees. Visitors should be given a site orientation including safety during their visit. If they are going to be outside vehicles, they should wear appropriate PPE.

### 7.7.3 Partnerships in Injury Reduction

Partnerships in Injury Reduction (PIR) is a voluntary program through which employer and worker representatives work together with government to build an effective health and safety management system. By improving health and safety, the social and financial costs of workplace injury and illness are reduced.

This program promotes health and safety through partnerships with safety associations, industry groups, educational institutions, and labour organizations.



**Photo 7.8. Visitors wearing PPE**

*Source: JLTechical Services*

In Alberta, a PIR is an association, corporation, or organization that commits to taking a leadership role in health and safety by entering into a formal agreement with the Alberta government. The government and each partner sign a Memorandum of Understanding describing the specific commitments to health and safety each organization makes.

### 7.7.3.1 Certificate of Recognition

The PIR program awards Certificates of Recognition (CORs) to employers that have developed a health and safety management system and that have met established standards. Participating employers must complete annual safety audits of their health and safety program.



**Photo 7.9. Prevent injuries**

*Source: JL Technical Services*

Basic facts about CORs:

- Employers must acquire and maintain a valid COR to earn a financial incentive through the Workers Compensation Board (WCB) (rates can be reduced by as much as 20%)
- Alberta municipalities and corporations may require bidding contractors to hold a valid COR
- CORs are issued by the Government of Alberta

### 7.7.3.2 Small Employer Certificate of Recognition

The Small Employer Certificate of Recognition (SECOR) program provides an option for small employers to develop a health and safety management system identical to the PIR program and receive a COR. To be eligible under the SECOR program, the employer cannot have more than 10 employees and contractors in total.

### 7.7.3.3 Benefit of the COR and SECOR Programs

COR and SECOR participation can benefit the employer through:

- Reduced lost time due to an accident or injury
- Reduced equipment and property damage
- Reduced WCB premiums

Benefits to the employee and contractor include additional safety training, minor pain and

suffering due to accidents and injuries, and a safe and positive work environment.

Site owners may require contractors that are bidding on jobs or projects to have a valid COR or SECOR. Not having a valid COR may eliminate them from the bidding process.

#### 7.7.3.4 Working with Contractors

When a contractor is hired to operate the facility or for a construction project at the site, it must be clearly identified who the Prime Contractor is. There must be a Prime Contractor when there are two or more contractors at a work site. A Prime Contractor has the overall responsibility for safety at a work site.

By default, the owner is the Prime Contractor. In some cases, the owner can transfer this responsibility to a contractor. Conditions set out in the *OH&S Act* and Regulation must be met. The transfer must be in writing. There cannot be two Prime Contractors responsible for one work site. However, a site can be divided up into more than one work site.

For example, when a contractor is hired to construct a new processing area, if the work site for construction can be isolated from the rest of the site, it may be possible to assign Prime Contractor responsibility for that work site to the contractor. Even so, there must be communication between the owner and the contractors to avoid conflicts. Each situation is unique, and a composting facility owner or operator should carefully review the requirements of the *OH&S Act* and Regulation to see that all requirements for assignment of responsibility are met.

#### Prime Contractor

Multiple employers carrying out interrelated work activities, or whose activities may have a health and safety impact on each other, must understand who the Prime Contractor is for the site.

The owner of the work site is the Prime Contractor. The owner can decide if a hired contractor will take on the responsibility as prime.

The Prime Contractor has the overall responsibility for complying with health and safety legislation at the work site.



## 7.7.4 Hazard Assessment and Control

Hazard assessment and control is a foundational principle of workplace safety.

### 7.7.4.1 Identifying Hazards

A hazard is any situation, condition, or thing that may be dangerous to the safety or health of employees, customers, and visitors at a site. A hazard has the potential to cause an injury, illness, or loss.

There can be both safety and health hazards:

- **Safety hazards** may include substances, processes, actions, or conditions that can endanger the safety of anyone at the work site. This can include such things as potential for chemical burns, pinch points, slips and falls, electrical shocks, and more.
- **Health hazards** include chemical, biological, or psychological hazards that can cause health issues to exposed individuals. This can include hearing loss, lung damage, heat stroke, death or other problems.

There are a number of biological and chemical hazards could occur at compost facilities.

- **Biological hazards:** The turning and handling of compost materials at the compost facilities may result in the generation of microbial aerosol also referred to as bio-aerosols. Compost facility operators may be at risk of being exposed with bio-aerosols, which could lead to respiratory issues such as asthma and other lung-related illnesses.
- **Chemical hazards:** Ammonia (NH<sub>3</sub>), methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), hydrogen sulphide (H<sub>2</sub>S) are among the primary chemical exposures at compost sites depending on the nature of the composting and feedstock being composted. Notable among the chemical exposures is hydrogen sulphide (H<sub>2</sub>S), a very poisonous gas that is colorless, flammable, and smells like rotten eggs. The generation H<sub>2</sub>S gas often occurs at compost facilities when a composting pile turns anaerobic. As the concentration of H<sub>2</sub>S produced increases, it incapacitates the odor the smelling senses of nose and makes the odor of the gas undetectable. High concentrations of H<sub>2</sub>S can cause



**Photo 7.10. Involve employees in hazard assessments**

*Source: JL Technical Services*

In 2008, three workers at a British Columbia Mushroom Composting facility tragically died and two other workers suffered severe brain injuries after being exposed to H<sub>2</sub>S and Ammonia while trying to unclog a pipe inside the composting shed.

health issues such as shock, convulsions, breathing difficulties, unconsciousness, coma and even death. These health effects can occur within a few breaths.

Alberta's OH&S legislation requires employers to assess their work sites and identify existing or potential hazards prior to any work on a site. This is done by conducting a hazard assessment. A hazard assessment is written documentation of the hazards and methods to be used to control or eliminate the hazard. The recommendations for elimination or control of a hazard should include specific actions required to correct the problem.

The employer is expected to involve employees in assessing, controlling, and eliminating potential hazards. Injuries and ill health can ruin lives and result in additional costs to employees and employers because of impaired ability to work, lost production, machinery and equipment damage, and insurance cost increases. The *OH&S Act* and Regulation also include provisions for owners and their employees to be fined and prosecuted in court for serious non-compliance with legislation.

After the initial hazard assessment has been completed, further assessments should be conducted periodically so that employees are continuing to follow the correct procedures and that the equipment is in proper working condition. Additional hazard assessments are required:

- When a new work process is introduced
- When a work process or operation changes
- Before the construction of any significant additions or alterations to the work site

Once completed, how the hazards will be controlled must be explained to the employees. The employees need to know what their responsibilities are in relation to the hazard assessment. The communication method may include briefing workers on a one-to-one basis, discussing the results at safety meetings, and posting the results in a location accessible to workers. When an employee is assigned a task they are unfamiliar with, they should be given an orientation on the task that includes identification of hazards and the safety procedures involved.

There are two types of hazard assessments:

1. A **formal hazard assessment** is conducted on the task itself. An example would be fuelling a piece of equipment. The site must assess all hazards associated with the task and implement control methods to eliminate hazards identified.
2. A **site specific** or **field level hazard assessment** is done at the beginning of a work day or when a new job is started and considers where the task is taking place. At work locations where the activities and conditions change frequently, employers and workers often rely on field level hazard assessments that are done on-the-spot. Field level hazard assessments are often important at construction sites, during road building or brush

control activities, and where outdoor work activities are affected by changing weather conditions.

#### 7.7.4.2 Controls

If practical, hazards should be eliminated or controlled as close to where the problem is created as possible. If this is not possible, controls should be placed between the source and the employee. The closer a control is to the source of the hazard, the better. For example, if a hazard is identified where clothing could become entangled in a drive shaft, the closest solution would be an effective guard placed immediately over or around the shaft. If a solution like this is not possible, hazards must be controlled at the level of the worker by using PPE and safe work procedures.

The three levels of control in order of preference include:

1. **Engineering Controls:** The preferred method of control if elimination is not possible; physical controls implemented at the design, installation, or engineering stages (including guards and automatic shutoff switches).
2. **Administrative Controls:** Processes developed by the employer to control hazards (including safe work practices, procedures to minimize hazard potentials, job scheduling and rotation, training, and signage). These processes control the activities of employees.
3. **PPE:** Equipment used or clothing worn by a person for protection from health or safety hazards associated with conditions at a work site. Common PPE includes gloves, safety glasses, hard hats, steel-toed boots, and high-visibility clothing. Some tasks require more advanced training and equipment, such as the use of fall protection harnesses and rigging. PPE must be used when engineering or administrative methods cannot fully control the hazards, and must be used in conjunction with engineering or administrative controls, or both. PPE does not eliminate the hazard, but will protect employees from the hazard.



**Photo 7.11. Employee wearing PPE and Respiratory Protective Equipment in an enclosed composting building**

*Source: CH2M*

An excellent reference for employers and employees developing hazard assessment and control procedures for their work site is Work Safe Alberta's [Hazard Assessment and Control: a handbook for Alberta employers and workers](#). This best practice guidance document includes examples of completed formal and site-specific hazard assessment and control forms. The blank templates developed by Work Safe Alberta are included in Appendix 7-1.

The control of some hazards requires combining all three control methods to reduce the hazard to the lowest hazard level practicable or achievable. Employers should use the combination of methods that achieves the most worker safety.

#### 7.7.4.3 Safe Work Plans

There should be a safe work plan developed for every task and activity at a composting site. Safe work plans are developed from hazard assessments or incident investigations. The plan describes the hazards involved and the work procedures required to be followed to minimize the risk of injury. Required PPE will be listed. Safe work plans should be reviewed and updated regularly, and always when an operational change is introduced. Front line staff, especially those regularly involved in the task or activity, should be involved in the plan's development and trained in its use.

### 7.7.5 Incident Reporting and Investigation

An incident is an event or dangerous situation that either could have resulted in property damage or injury (for example, a near-miss), or an event that did result in damage or personal injury.

Employers need to have a process in place for reporting and investigating incidents and near-misses. It is important that incidents be both reported and investigated so that steps can be taken to prevent a repeat in the future. Involving front line staff in the reporting and investigation process can be an effective training tool.

Employers participating in the PIR program are required to document all incidents, accidents, and near-misses, and have a process for reviewing incidents to identify the actions necessary to avoid repetition.

A **near-miss** is an unplanned event that did not result in injury, illness, or damage; however, it could have. Only a fortunate break in the chain of events prevented an injury, fatality, or damage; in other words: a miss, but, nonetheless, very near.

All injuries, near-misses, and dangerous situations should be reported to a supervisor. All should be investigated to identify cause and corrective measures to prevent an accident from occurring or re-occurring.

More serious incidents must be reported to Alberta OH&S. The OH&S legislation in Alberta requires that an employer contact Alberta OH&S immediately if an injury or incident results in the following:

- A death
- A worker having to stay in hospital for more than 2 days
- An unplanned or uncontrolled explosion, fire, or flood that causes or may cause a serious injury
- The collapse or upset of a crane, derrick, or hoist
- The collapse or failure of any component of a building or structure

Incidents do not just happen - they are caused. They can be prevented if causes are eliminated. Causes can be eliminated if all incidents, including near misses, are investigated. Unless the cause is eliminated, the same situation could happen again.

An incident investigation should determine what happened and what the cause of the incident was. An investigation should consider unsafe conditions, acts, or procedures, and help to identify practical corrective measures. The purpose of an investigation should not be to find fault or lay blame. Rather, the investigation should identify the basic causes of the incident so that controls can be put in place to prevent it from happening again.

When investigating, look for the root cause: the main reason the incident took place. There may be more than one factor that caused the incident. What may, at first, appear to be the obvious cause may, in fact, be the result of other factors, such as:

- Application of policies and procedures
- Inadequate or ineffective policies or procedures
- Material, equipment, or tools and their condition
- Weather conditions or other factors
- Work procedure used
- Worker experience, skills, abilities, or physical and emotional state

Documentation of incidents, the investigations that result, and action plans arising from them is important. A composting facility should have standard templates for conducting and documenting each step. A sample template from Work Safe Alberta is included in Appendix 7-1.

## 7.7.6 Personal Protective Equipment

If a hazard assessment identifies that PPE is required, the site manager must make sure that staff, contractors, and visitors are wearing and using their PPE properly. PPE must be kept in good condition to serve the purpose it was intended for, and should be replaced if it is damaged. For example, cracked eye protection, worn safety footwear, or excessively dirty high-visibility clothing should be replaced.

Staff should be trained in the proper use and maintenance of PPE, such as hearing protection, respirators, or eye protection. Where respirators are required, a fit testing program needs to be implemented. Fit testing must be conducted by properly trained individuals.

It is common practice for employees at composting sites to wear:

- Coveralls or clothing that covers their legs and body
- High-visibility vests or clothing
- CSA-approved steel-toed footwear
- Eye protection
- Gloves

Some composting facilities also require that staff and visitors wear hard hats, respiratory protection equipment (RPE), and hearing protection throughout the site or in designated areas.

## 7.7.7 Emergency Response

Operators need to be prepared for a variety of emergencies, including:

- Environmental releases
- Fires or explosions
- Medical emergencies
- Severe weather
- Vehicle or equipment accidents
- Violent behaviour of customers or employees



**Photo 7.12. Employee wearing typical PPE in a composting facility**

*Source: CH2M*

The site operating plans should include an ERP. This plan should identify appropriate responses to emergency situations and who takes responsibility for managing the situation. An important part of an ERP is to document communication protocols during an emergency.

The ERP should identify evacuation procedures for customers and staff from buildings, site facilities, and the site itself. A pre-identified place for everyone to meet, a muster point, should be identified. Also, there should be a procedure for a roll call to confirm that no one has been left behind.

Emergency numbers should be posted and readily available to all staff. In the event of an emergency, the roles of each individual need to be identified and known. Employees should conduct regular emergency drills so that when an emergency occurs, the staff is well-practiced. Drills also provide opportunities to identify issues with response actions and allow for refining the response procedures.

In case of severe weather, such as tornado warnings, there should be a plan for warning employees and for shelter of employees and customers.

An example of a detailed ERP is available on the web page of [SWANA Northern Lights](#).

# Appendix 7-1

## Templates:

**Formal Hazard Assessment and Control Form**

**Site-specific (field level) Hazard Assessment and Control Form**

**Sample Incident Reporting and Investigation Form**

Source: Work Safe Alberta



### Formal hazard assessment and control (template)

Job/position/work type:				Date of assessment:		
Assessment performed by: (names)				Reviewed/revised:		
<b>Tasks</b>  (List <b>all</b> tasks/activities of the job/position)	<b>Hazards</b>  (List <b>all</b> existing and potential health and safety hazards)	Severity	Likelihood	Risk	<b>Controls</b>  (List the controls for each hazard:  Elimination, Engineering, Administrative, Personal Protective Equipment)	Date implemented:
		<b>S x L = R</b>				
<b>Severity:</b>  How serious could the consequences be?  <b>3</b> – It could kill you or cause a permanent disability, today or over time.  <b>2</b> – It could send you to the hospital.  <b>1</b> – It could make you uncomfortable.		<b>Likelihood:</b>  How likely is it going to happen?  <b>3</b> – It is highly likely.  <b>2</b> – It might happen.  <b>1</b> – It is unlikely.			<b>Risk:</b>  Calculate the risk of hazards to prioritize preventive actions.  Severity x Likelihood = Risk	

This form is for example only. Completing this form alone will not necessarily put you in compliance with the legislation. It is important and necessary that you customize this document to meet the unique circumstances of your work site. Further, it is essential that this document is not only completed, but is used, communicated, and implemented in accordance with the legislation. The Crown, its agents, employees, or contractors will not be liable to you for any damages, direct or indirect, from your use of this form.

**Site-specific hazard assessment and control (template)**

Company name:	
Work to be done:	Date of assessment:
Task location:	Emergency meeting location:

Identify the tasks and hazards below, and the plans to eliminate or control those hazards

Tasks (List <b>all</b> tasks/activities)	Hazards (List both health and safety hazards, and consider surrounding area)	Plans to eliminate/control (List the controls for each hazard: Eliminate, Engineering, Administrative, Personal Protective Equipment)

Please print and sign below (all members of the crew) prior to commencing work

Worker's name (Print)	Signature	Worker's name (Print)	Signature
Supervisor's name (Print)		Supervisor's signature	

By signing this form, you acknowledge that you understand the hazards and how to apply the methods to eliminate or control the hazards.

This form is for example only. Completing this form alone will not necessarily put you in compliance with the legislation. It is important and necessary that you customize this document to meet the unique circumstances of your work site. Further, it is essential that this document is not only completed, but is used, communicated, and implemented in accordance with the legislation. The Crown, its agents, employees, or contractors will not be liable to you for any damages, direct or indirect, from your use of this form.

### Sample Incident Reporting and Investigation Form

Name of worker: \_\_\_\_\_

Position: \_\_\_\_\_ Department: \_\_\_\_\_

Location of incident: \_\_\_\_\_

Date of incident: \_\_\_\_\_ Time: \_\_\_\_\_ a.m. p.m.

Type of incident: Near-miss  Minor injury  Serious injury

Date incident reported: \_\_\_\_\_ Time : \_\_\_\_\_ a.m. p.m.

Reported to: \_\_\_\_\_

Nature of injury (if any): \_\_\_\_\_

Witnesses: \_\_\_\_\_

Damage to equipment or property: \_\_\_\_\_

<b>Description of incident:</b>  
---

Identified causes (direct, indirect, root)  
--

Recommended Preventative Action:  
--

To be completed by:	Date:
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Follow-up:

By:	Date of follow-up:
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Name of person investigating: \_\_\_\_\_

Signature: \_\_\_\_\_

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