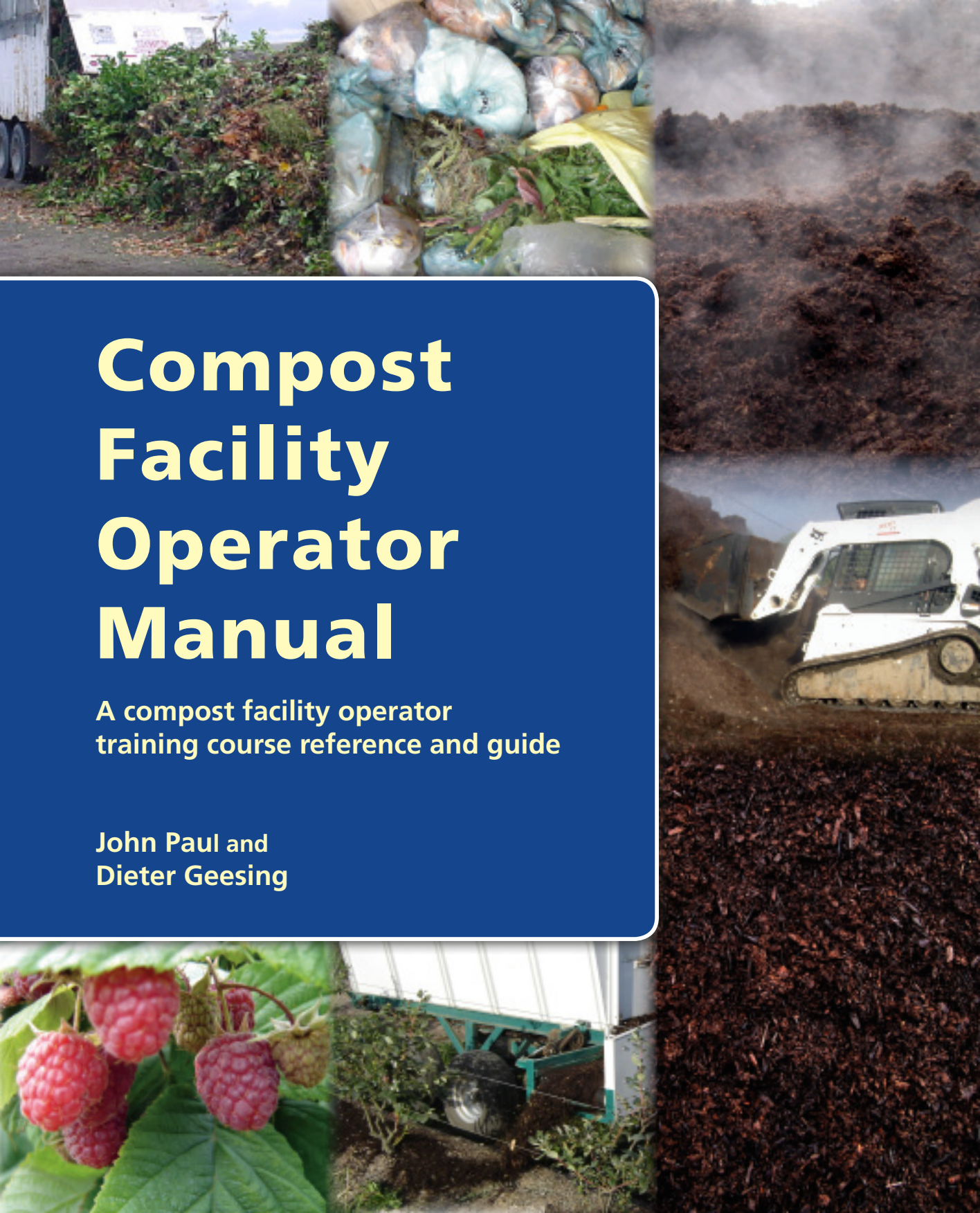
Compost Facility Operator Manual

A compost facility operator training course reference and guide

John Paul and
Dieter Geesing



Dedication

This book is dedicated to our children and youth, who have a passion for recycling and taking care of our world, and a simple trust that we will do the same.

This book is also dedicated to Jose, and the men and women like him who live from moment to moment, with the dream that perhaps their children and grandchildren can have an education and a future in a world that we have the responsibility to take care of.

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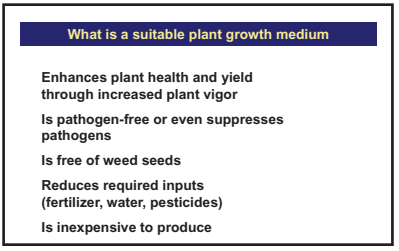
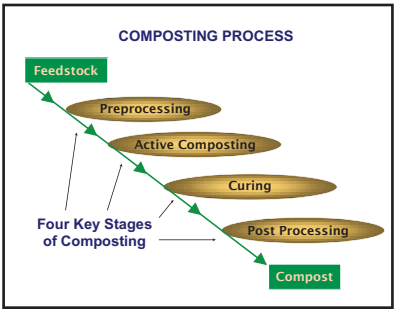
microorganisms. The benefits for plants include increased plant growth and vigor and reduced requirements for fertilizer, water and pesticides.



There are four key steps during the typical composting process. These include: feedstock pre-pocessing where the feedstock is treated and blended to achieve a mix with desired overall characteristics, the active composting important for pathogen kill, the curing necessary to obtain a mature and stable product, and the post-processing required to meet quality criteria for sale and distribution of the product.



This composting manual is organized in such a way as to follow the steps of the composting process. Chapter 2 provides a basic understanding of composting. The types of feedstocks, bulking agent and compost blend preparation is discussed in Chapter 3. The composting process and the various composting methods is outlined in Chapter 4. Chapter 4 includes curing and post processing. Chapter 5 discusses environmental impacts such as odor, water quality and noice. (to be continued).

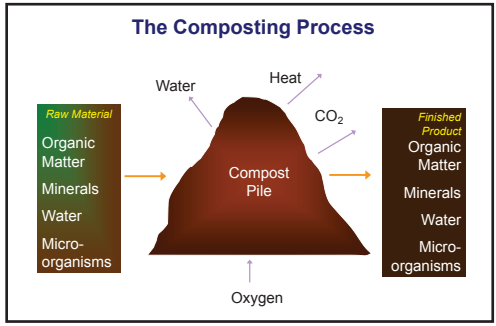
2 ELEMENTS OF COMPOSTING

2.1 The Composting Process

A simplified chemical equation for **aerobic respiration** which takes place during composting is as follows:

$$H_2O + C_6H_{12}O_6 + micro\text{-}organisms + O_2 \Rightarrow CO_2 + H_2O + heat\ energy + micro\text{-}organisms$$

where $C_6H_{12}O_6$ represent carbonaceous material that with addition of microbes and the presence of oxygen yield carbon dioxide, water vapor and heat energy.



The carbonaceous material is added to a composting system in the form of feedstock. Feedstock is a mix of various organic compounds and the type of feedstock used will alter the general equation for composting described above. Using municipal sludge for example, Haug (1993) determined the carbonaceous oxygen demand as follows:

$$C_{10}H_{19}O_3N + 12.5\ O_2 \Rightarrow 10\ CO_2 + 8\ H_2O + NH_3$$

Where $C_{10}H_{19}O_3N$ represents the sewage sludge. In reality, composting cannot be summarized with one single equation: The organic material feedstock contains a large variety of organic and inorganic compounds, and the compost process produces a multitude of intermediate compounds and final products.

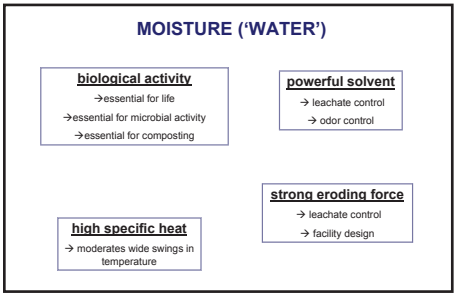
2.2 Actors of the Composting Process

Composting involves a succession of microbial activities where the environment created by one group of microorganism invites the activity of successive groups. Different types of microorganisms are active at different times in the composting pile. A compost pile is a complex ecosystem containing a wide variety of organisms. These organisms are integral to the composting process and can be classified in a variety of ways.

and animals. Above 70°C (158 °C), the diversity of microbes becomes limited to only a few species that can operate above these temperatures and the efficiency of the composting process may be compromised. Temperature monitoring should be part of the daily routine of the compost facility operator.

Rule of Thumb: ***Temperature Requirements***

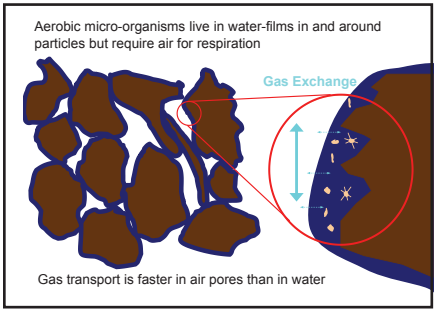
Temperature should be maintained for at least 10 days between 55°C (131°F) and 70°C (158°F) as a prerequisite for a pathogen-free high-quality final product



2.4.3 Moisture

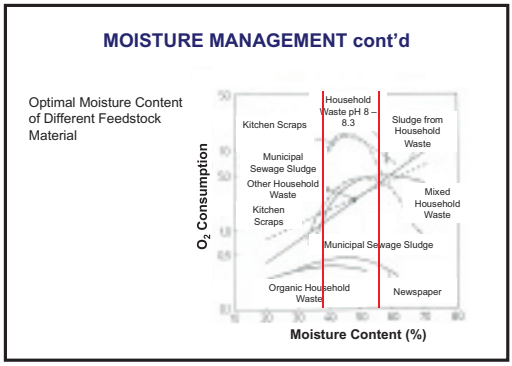
Water plays a number of important roles within a composting system. It is essential to all life forms including decomposer organisms. Water is also a powerful solvent and leachate (water that have been in contact with organic material) may sometimes contain trace elements, organic compounds, pesticides, salts and pathogens.

Water also plays a role in regulating temperature in compost systems. Water has a high specific heat, meaning it takes a large amount of energy to raise a mass of water by one degree Celsius. If too much water is present within a compost pile it will take longer for the temperature of the pile to increase.



Micro-organisms of the composting process live predominantly in the water films around and in particles, and water is also the key ingredient that transports substances within a composting mass. Oxygen reaches aerobic micro-organism in water films via gas exchange at the film surface. Gas exchange through water is slower than through air, and high moisture content will therefore cause anaerobic conditions because the speed of oxygen supply cannot meet the oxygen demand by the micro-organisms.

Liquid ingredients such as manure slurries, dairy wastes or some fish processing wastes pose special handling challenges because they need to be incorporated into the composting mix without making it soggy. Many liquids also present a potential odor problem.



As a rule, the higher the moisture content of the organic material, the greater the need to maintain a large void volume to ensure adequate aeration and to avoid compaction. For example, biosolids lack porosity and require mixing with bulking material such as wood chips and/or straw.

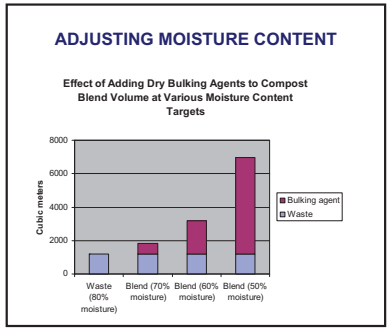
The moisture content of a wet material can be adjusted with dry bulking agents only to a limited extent. It is important to understand that the addition of drier bulking agent to a wet composting substrate substantially increases the space requirements for composting.

Case Study

One thousand tonnes (1,103 tons) of a waste containing 80% moisture and a bulk density of 850 kg m^3 (1400 lb yd^3) has a volume of 1,176 m^3 (1,569 yd^3). Adding bulking agent to bring the moisture content to 60% requires 1,000 tonnes of a material that is 40% moisture and a bulk density of 500 kg m^3 (827 lb yd^3). The resulting blend would have a moisture content of 60% and a bulk density of 630 kg m^3 (1041 lb yd^3) and a volume of 3,175 m^3 (4,155 yd^3). Moisture content goal of 65% moisture would require only 600 tonnes of bulking agent resulting in a total volume of 3,108 m^3 (2,376 yd^3).

In some cases, the use of forced aeration and turning may be a more efficient composting strategy to allow composting at a higher moisture content in order to reduce compost facility size.

Liquids can be added during the initial mixing process if a feedstock mix is below 45%. Liquid wastes may be further added during the composting process if the material is losing moisture drying during composting.



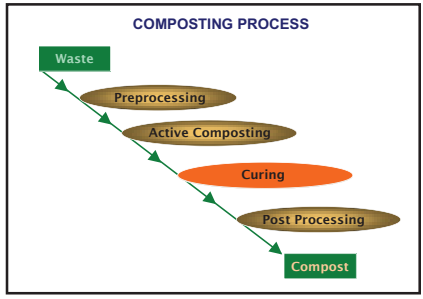
5 CURING AND POSTPROCESSING

5.1 Curing

The composting process is not complete until the compost has been properly cured. The curing stage of the composting process occurs after readily available organic matter has been degraded by the microbes during the active composting process. During the curing process the degradation of more complex molecules such as lignin continues and biologically stable humic substances are formed from intermediate metabolic products.

The active composting process is generally between 3 – 8 weeks, and includes the time required for pathogen kill. The end of the active composting process and the beginning of the curing stage is gradual and often determined by the system or the operator. A steady decline in temperature often indicates the transition between the two stages, although the temperature may rise again when the material is remixed to build the curing pile.

A curing period of *at least* four weeks is recommended after the active composting process to achieve a high-quality compost product. As in the case of active composting without forced aeration and/or with low turning frequency, the curing period can be six months or longer. Often, curing piles are also compost storage piles. The sale of compost is usually seasonal with peak periods in the spring and fall. This requires that most facilities will require a minimum of six months of storage for compost.



CURING

Why do we need curing ?

Immature/unstable compost may be the cause of

- N immobilization in soil
- Phytotoxicity (fatty acids, trace elements, ammonia)
- Odor

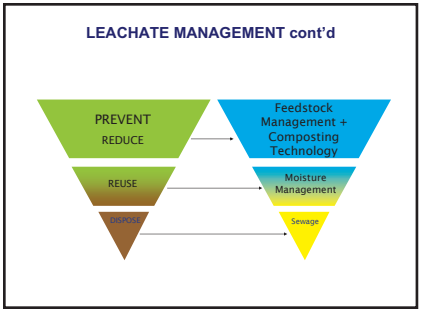
Compost will not be mature unless it has been properly cured

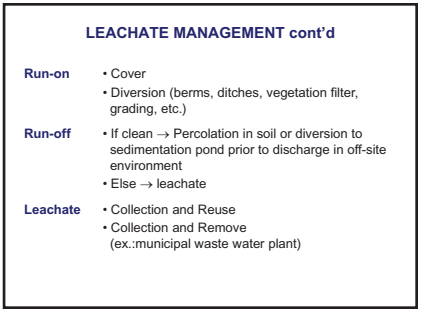
Curing: OPERATIONAL CONSIDERATIONS

- There is no specific point at which curing should begin
  - Windrows: No reheating after turning
  - Forced aeration: Steady temperature decrease
  - Minimum one month of curing
  - Time requirement dependents on intended use of compost
- During the curing phase the need for turning is greatly reduced
- Decreased risk of odor development
- Still a need for low levels of oxygen for microbial activity
  - construction of curing piles and/or windrows has to allow for passive airflow through the windrow
  - recommended size for a curing pile is 3-5 meters (10 -15 ft) high and 5 – 10 meters (15 – 30 ft) wide

Curing: OPERATIONAL CONSIDERATIONS cont'd

- Windrows should be kept in dry areas, away from excess moisture to avoid piles becoming anaerobic
- Pile shape should avoid water ponding (anaerobic conditions, vectors)
- Curing area should be well drained with surface runoff channeled away from piles on impermeable surface
- Avoid contaminating compost in the curing area (clean equipment after handling feedstock/actively composting material)
- Inexpensive breathable cover conserves quality by protecting from airborne seeds, by keeping the compost moist in dry climates, and by keeping the compost dryer in wet climates.

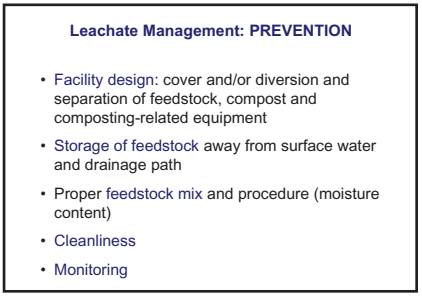




The principles of leachate management include leachate prevention and reduction, reuse and removal or treatment. Removal or treatment of leachate can be costly.

6.4.1.1 Leachate Prevention and Reduction

One goal is to minimize entry of run-on water (eg. precipitation, snowmelt) onto the site. Roof water and other clean water can be diverted away from any organic material. Leachate can be minimized by:



- Design of a proper feedstock mix. A proper mix should not generate leachate on its own, otherwise the mix is too wet and the mix must be revised. Maintain windrows and piles at a **moisture content** below the maximum recommended level of 60%. Proper carbon/nitrogen ratio (C/N ratio) balancing will also help to minimize the loss of nitrogen into the leachate.

Adding too much water at the beginning of the process results in leachate and odor.

- Protecting (**covering**) feedstock and material during storage, processing and curing.
- Construction of storage, processing and curing areas with **impervious ground surface**. The material should also withstand the machinery activity.

lowing a thorough decomposition and humification, it has stabilized and matured, providing valuable soil organic matter.

Compost is an excellent growing media ingredient as it provides beneficial microorganisms and nutrients, and balances pH.

For **potting mixes**, the amount of compost that can be added typically ranges from 1/10 to 1/3 (by volume), depending primarily on the nutrient content and the EC of the compost. A common blend for growing vegetables, for example, is 1/3 greenwaste compost, 1/3 perlite and 1/3 peat moss. For woody plants, a mix can be 1/3 greenwaste compost, 1/3 coarse sand and 1/3 milled bark. With this amount of compost in the blend, fertilizing is generally not required for the first weeks as the compost will supply all of the nutrition required for plant growth.

N immobilization with high C/N ratio compost

The practical significance of the C/N ratio becomes apparent when we understand the implication of adding high C/N ratio compost to soil.

Consider when material with a high C/N ratio of 55 (for example corn stalks), is added to the soil.

The microbial community responds to the new food supply. Heterotrophic microorganisms become active, and multiply rapidly. Because of the high C/N ratio, relatively little nitrogen is available from the new food source, and the soil microorganisms have to 'steal' the nitrogen from the nitrogen already available in the soil which reduces the nitrogen available to higher plants.

This condition can persist for weeks until the activities of the decay organisms subside. Plants growing in media amended with improperly composted material may become stunted or die. First symptoms on the plants are yellowing of the new leaves. Treating the symptoms after they appear is generally too late.

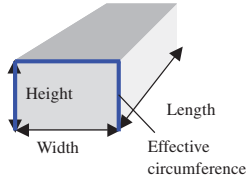
Compost can also be used as **amendment to garden and field soils**. When making repeated applications, it is important to remember that about 8-12% of the nitrogen is released annually. This nitrogen release results from further decomposition of organic matter by microbes, resulting in the release of ammonium, which oxidizes to nitrate rapidly in a field soil. With repeated applications of compost, the release of nitrogen can

SOME COMPOST APPLICATIONS

- **SOIL REMEDIATION:**
  - Compost binds heavy metals and other contaminants, reducing leachability and bioabsorption
  - Compost contributes to the degradation of petroleum contaminants in soils
- **WETLAND RESTORATION:** Compost enhances wetland restoration by simulating characteristics of wetland soils
- **EROSION CONTROL:** Coarser composts used as mulch provide erosion control
- **STORMWATER MANAGEMENT:** Compost can provide filtration and contaminant removal of stormwater pollutants
- **AIR POLLUTION CONTROL:** Compost as biofilter to control VOC's in exhaust gases

10 Calculations

10.1 Windrow Sizing

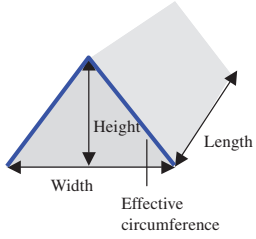


Rectangle

Volume = Height x Width x Length

Effective circumference= 2x height + width

Mass = Volume x Bulk Density

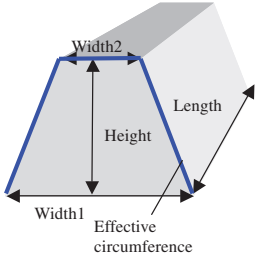


Triangle

Volume = Height x Width x Length x 0.5

Effective circumference= $2x\sqrt{height^2 + (width/2)^2}$

Mass = Volume x Bulk Density



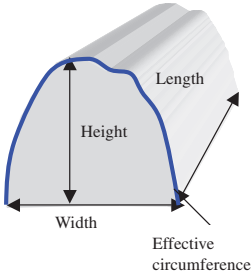
Trapezoid

Volume= Height x (Width1+Width2) x Length x 0.5 *[1]

Effective circumference =

$2 \times \left(\sqrt{((width2-width1)/2))^2 + height^2}\right) + width2$

Mass = Volume x Bulk Density



Oval

Approximations:

Volume = Height x Width x Length x 0.75 *[1]

Effective circumference= $2.3 \times \sqrt{height^2 + (width/2)^2}$

Mass = Volume x Bulk Density

*[1] In general, as the average windrow shape is between an oval and trapezoid, a **factor 0.66** is assumed to estimate windrow volumes and so the equation for volume becomes:

Volume = Height x Width x Length x 0.66

About the Authors

John Paul obtained a Ph.D. in Biochemistry and Soil Fertility from the University of Guelph. He worked as a waste management research scientist with Agriculture and Agri-Food Canada, and he has published numerous scientific articles on composting. John has been president of Transform Compost Systems since 1998 and has designed composting facilities in Canada, the US and overseas.

Dieter Geesing has worked for many years as scientist and lecturer at universities in Europe, Africa, Asia and the US. He has a long experience as consultant and manager of environmental and rural development projects for European and United Nation agencies, NGOs and communities. Dieter holds a M.Sc. in Forestry, a M.Sc. in Plant and Soil Science and a Ph.D. in Natural Sciences.

Some Comments from Course Participants

"the material is relevant – I could relate the information to our current operation and could see areas for improvement and upgrades"

"good mix of technical and practical information. Excellent knowledge base of presenters."

"approachable instructors. Life experience scenarios"

"answered many questions I had, appropriate for any compost technology overall"

"good mix of theory and practice; great presentation, and I appreciate the course book for further reference"

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