This handbook (binder) consists of seventeen Composting Factsheets, which introduce the reader to the composting process, how composting may fit into a farming operation, and some associated environmental concerns. All seventeen individual Factsheets are on our website in the Publications and Conceptual Plans (composting section). Included for producers looking for more detailed information are references and suggested reading (Factsheet No. 16). To obtain a copy of the binder version, please contact:

**Resource Management Branch**  
BC Ministry of Agriculture, Food and Fisheries  
1767 Angus Campbell Road  
Abbotsford, BC  V3G 2M3

Phone: (604) 556-3100  
Fax: (604) 556-3099
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This manual is approximately 70 pages in length.
Composting

THE COMPOSTING PROCESS

Composting is the biological decomposition of organic matter under controlled conditions brought about by the growth of microorganisms and invertebrates. While decomposition occurs naturally, it can be accelerated and improved by human intervention. Composting stabilizes organic matter, yielding an end product that contains humus, and has a uniform crumbly texture. An understanding of the composting process is important for producing a high-quality product and preventing operating problems. Figure 1 illustrates the basic composting process. The microorganisms and invertebrates that decompose manure and other farm wastes require oxygen and water, and produce compost, carbon dioxide, heat and water. The organic wastes provide nutrients (nitrogen and carbon) necessary for microorganisms to carry out decomposition efficiently.

The heat produced increases the temperature in the compost pile from near-ambient air temperature to as high as 70°C (160°F). The temperature rise results in increased water evaporation. As the process nears completion (after one month to one year), the compost pile once again approaches ambient air temperature.

Composting leads to a volume reduction. Much of this reduction results from the loss of carbon dioxide, water and other minor gases to the atmosphere.

Further reduction occurs as loose bulky materials are rendered into crumbly, fine-textured composts without any of the recognizable structure of the starting materials. Finished compost is comprised of microorganisms and invertebrates, their skeletons and decomposition products, and organic matter that is not readily degradable by these organisms. Finished compost takes on many of the characteristics of humus, the organic fraction of soil.

The rate at which the final product (compost) is generated and the magnitude of temperature rise during the composting process depend upon factors discussed on the following pages. Once composting is complete, the pile will have been reduced in volume by 20 percent to 60 percent, the moisture content to less than 40 percent, and the weight reduced by up to 50 percent. The finished compost pH is near neutral, and the carbon to nitrogen ratio should be below 20:1. Undesirable odours that typically emanate from the starting material are generally replaced by an earthy smell.

DECOMPOSERS

Naturally occurring microorganisms and invertebrates are the primary decomposers that accomplish composting. These microorganisms include bacteria, mould or fungi, actinomycetes and protozoa. Tiny invertebrate animals such as mites, millipedes, insects, sowbugs, earthworms and snails are the primary agents of physical decay. They break up waste debris and transport microorganisms from one site to another.

The ease with which organic materials are composted depends on the type of decomposers, the type of organic material being composted and the composting method used. For example, many decomposition organisms can utilize the carbon in sugar found in straw, while fewer decomposers can use the carbon in cellulose or lignin fibres found in paper or wood. As carbon compounds decompose,
part of the carbon is converted to microbial and invertebrate cell structure, while most is converted to carbon dioxide, which is lost to the atmosphere.

Different decomposers prefer different organic materials and temperatures; therefore, the more diverse the microbial populations, the better. If the environment becomes unsuitable for a decomposer, that organism will become dormant, die or move to a more hospitable area of the pile. Changing conditions during the composting process lead to an ever-changing ecosystem of decomposition organisms. Decomposer activity diminishes when the microorganisms cannot readily consume the remaining organic material.

Microorganisms in Composting
Microorganisms such as bacteria, fungi and actinomycetes account for most of the decomposition, as well as the rise in temperature that occurs in the compost process. Some microbes require oxygen to function, others do not. Those requiring oxygen are preferred in composting. Also, different microorganisms thrive in different temperature ranges. The goal in constructing and managing compost is to create an environment suitable for the desired microorganisms.

Aerobic Versus Anaerobic Microorganisms
Aerobic organisms thrive at oxygen levels greater than five percent (fresh air is approximately 21 percent oxygen). They are the preferred microorganisms, since they provide the most rapid and effective composting. Anaerobic organisms thrive when the compost pile is oxygen deficient. Decomposition by anaerobic micro-organisms is referred to as fermentation. Anaerobic conditions are undesirable in a compost pile. Some of the products of anaerobic decomposition are hydrogen sulfide, cadaverine and putrescine, which cause offensive odours. In addition, anaerobic processes can generate acids and alcohols that are harmful to plants.

Aerobic Microorganisms and Temperature
Among all microorganisms, aerobic bacteria are the most important initiators of decomposition and temperature increase within the compost pile. Psychrophilic bacteria work in the lowest temperature range and have an optimum temperature lower than 5°C (40°F). Mesophilic bacteria do best at temperatures between 10°and 45°C (50° and 110°F). Thermophilic bacteria are heat-loving and thrive above 50°C (120°F). Each category includes many strains of bacteria.

The initial temperature of the compost pile usually is related to the ambient air temperature. If the initial pile temperature is less than 21°C (70°F), psychrophilic bacteria begin decomposition. Their activity generates a small amount of heat and causes an increase in pile temperature that changes the environment for dominance by mesophilic bacteria. In turn, the more rapid decomposition by mesophilic bacteria can further increase the pile temperature to create an environment where the thermophile can thrive. Later, as the thermophilic bacteria in the pile decline in number and temperature decreases, mesophilic bacteria again become dominant.

While high temperatures have the advantage of killing pathogenic organisms and weed seeds, moderate temperatures encourage the growth of mesophilic bacteria, the most effective decomposers. If the material being composted is not diseased and does not contain seeds, there is no need to be concerned about achieving high temperatures. Many decomposers are killed or become inactive if temperatures rise above 60°C (140°F). The rise and fall of temperature during the process will depend on the material being composted, the composting method used and the water available for evaporative cooling.

Food Web of the Compost Pile
The food web of the compost pile is illustrated in Figure 2. The waste in the compost pile provides food for the first level of decomposers. Cellulose decomposition by microorganisms begins soon after the compost pile is established. Fungal mycelia quickly penetrate all parts of the heap, and early fruiting bodies of mesophilic fungi grow on the surface. Later, if the temperature rises enough, thermophilic actinomycete colonies can give the surface a grey appearance.
The availability of readily digestible food results in maximum microorganism growth and a temperature increase. During the heating period, soil invertebrates either die, become dormant, or migrate to cooler parts of the pile. These organisms return when the temperature declines. First-level consumers are attracted and become food for second-level consumers. Third-level consumers, such as centipedes, rove beetles, ground beetles, and ants prey on second-level consumers. Mites, millipedes, sow bugs, snails and slugs ingest plant tissue. Soft tissues of decaying plants and animals support the growth of worms. Earthworms ingest, digest and reshape organic matter. These activities of invertebrates tend to mix material, break larger particles into smaller ones and transform organic material into more digestible forms for microorganisms.

**FACTORS AFFECTING THE COMPOSTING PROCESS**

All natural organic material eventually decomposes. Under natural conditions, the decomposition process can extend over a period of months or even years, depending on climatic conditions. However, the natural process can be accelerated by controlling the process factors. Each of these factors has the potential to significantly affect the composting process.

Some of the more important factors in the composting operation are listed as follows:

- Carbon:Nitrogen Ratio (C:N)
- Surface Area and Particle Size
- Aeration
- Porosity
- Moisture Content
- Temperature
- pH of Materials
- Nutrients
- Toxic Substances

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**Figure 2** The Organisms in the Food Web of the Compost Pile

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Source: NRAES - Composting Reduce the Waste Stream
Carbon-to-Nitrogen Ratio

Carbon (C) and nitrogen (N) compounds are the components most likely to seriously limit the composting process if present in either excessive or insufficient amounts, or when the carbon-to-nitrogen (C:N) ratio is incorrect. Microorganisms in compost digest (oxidize) carbon as an energy source, and ingest nitrogen for protein synthesis. The proportion of these two elements should approximate 30 parts carbon to 1 part nitrogen by weight. C:N ratios within the range of 25:1 to 40:1 result in an efficient process. Softwood shavings, sawdust and straw are good sources of carbon. Other inexpensive sources of carbon include municipal waste and shredded newsprint or cardboard. Most manures are a good source of nitrogen. Table 1 lists carbon-to-nitrogen ratios for materials commonly included in farm compost piles.

Given a steady diet at a 30:1 ratio, microorganisms can decompose organic material quickly. When the C:N ratio is too high, there is too little nitrogen and decomposition slows. When the C:N ratio is too low, there is too much nitrogen and it will likely be lost to the atmosphere in the form of ammonia gas. This can lead to odour problems.

Most materials available for composting do not fit this ideal 30:1 ratio, so different materials must be blended to meet the ratio. In general, coarse, dried-out material contains very little nitrogen. For example, woody materials are very high in carbon. However, green wastes, such as foliage and manure, contain relatively high proportions of nitrogen. Proper blending of carbon and nitrogen helps ensure that composting temperatures will be high enough for the process to work efficiently.

Although proper blending is necessary, it can be difficult to blend materials to achieve this ratio exactly. Without knowing the moisture content of the materials being used, neither the dry weight nor the final C:N ratio of the combined material can be estimated. The typical C:N ratio, moisture content and bulk density for products commonly used for on-farm composting are given in Characteristics of On-Farm Composting Materials, Factsheet No. 382.500-3.

Blending of materials to achieve a workable C:N ratio is part of the art of composting. If a high-nitrogen material such as manure is being composted, it should be blended with a high-carbon material such as sawdust or paper. With experience, composters will develop procedures that result in workable mixtures for the materials being composted. Blending Materials for the Composting Process, Factsheet No. 382.500-4, is provided as a guide.

### TABLE 1

<table>
<thead>
<tr>
<th>Materials with High Nitrogen Values</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry manure with litter</td>
<td>13-18:1</td>
</tr>
<tr>
<td>Vegetable waste</td>
<td>12-20:1</td>
</tr>
<tr>
<td>Pig manure solids</td>
<td>15-25:1</td>
</tr>
<tr>
<td>Dairy manure</td>
<td>20:1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material with High Carbon Values</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood chips and sawdust</td>
<td>100-500:1</td>
</tr>
<tr>
<td>Paper</td>
<td>150-200:1</td>
</tr>
<tr>
<td>Straw</td>
<td>40-100:1</td>
</tr>
<tr>
<td>Foliage (green)</td>
<td>30-80:1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material with Neutral C:N Ratios</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat moss</td>
<td>18-36:1</td>
</tr>
<tr>
<td>Horse manure with litter</td>
<td>30-60:1</td>
</tr>
</tbody>
</table>

Surface Area and Particle Size

Microbial activity occurs at the interface of particle surfaces and air. The surface area of material to be composted can be increased by breaking it into smaller pieces, or by other means. Increased surface area allows the microorganisms to digest more material, multiply faster and generate more heat. Generally, the smaller the size and the more fragile the particle, the greater the biological activity and rate of composting. Chopped crop residues, softwood shavings and sawdust, for example, require no further size reduction. Materials can be chopped, shredded, split or bruised to increase their surface areas. A wide range of shredders and chippers are available, from large models used by tree services to small gas engine types.

Aeration

Aeration replaces oxygen-deficient air in the centre of the compost pile with fresh air. Rapid aerobic decomposition can only occur in the presence of sufficient oxygen. Aeration occurs naturally when air warmed by the compost rises through the pile, drawing in fresh air from the surroundings. Wind also stimulates aeration. Initial mixing of materials usually introduces enough air to start composting. Oxygen requirements are greatest during the initial weeks of most vigorous activity. Air movement through the compost pile is affected by porosity and moisture.
content. Regular mixing of the pile, referred to as turning, enhances aeration in a compost pile.

**Porosity**

Porosity refers to the spaces between particles in the compost pile, and is calculated by taking the volume of spaces or pores, and dividing by the total volume of the pile. If the material is not saturated with water, these spaces are partially filled with air that can supply oxygen to decomposers and provide a path for air circulation. As the material becomes water saturated, the space available for air decreases.

Compacting the compost pile reduces its porosity. Excessive shredding can also impede air circulation by creating smaller particles and pores. Turning fluffs up the material and increases its porosity. Adding coarse materials, such as straw or woodchips, can increase the pile porosity, although some coarse materials will be slow to decompose. As the compost process proceeds, the porosity decreases, restricting aeration.

**Moisture Content**

Moisture plays an essential role in the metabolism of microorganisms and indirectly in the supply of oxygen. Microorganisms can utilize only those organic molecules that are dissolved in water. A moisture content of 40 to 60 percent provides adequate moisture without limiting aeration. If moisture content falls below 40 percent, bacterial activity will slow down, and will cease entirely below 15 percent. When the moisture content exceeds 60 percent, nutrients are leached, air volume is reduced, odours are produced (due to anaerobic conditions), and decomposition is slowed. If the pile becomes too wet, it should be turned and restacked. This allows air to circulate back into it and loosens the materials for better draining and air drying. Adding dry material, such as straw, sawdust or finished compost can also remedy an excess moisture problem.

If the pile is too dry, water can be added. A more effective practice is to turn the pile and rewet materials in the process. Certain materials will shed water or absorb it only on their surface. Sawdust, hay, straw and vegetables must gradually be moistened until they glisten, then the squeeze test should be used to evaluate the moisture content. Optimum moisture content of raw materials should be in the range of 50 to 60 percent (wet basis), depending on particle size, available nutrients and physical characteristics.

**Temperature**

Heat generated by microorganisms, as they decompose organic material, increases compost pile temperatures. There is a direct relation between temperature and rate of oxygen consumption. The higher the temperature, the greater the oxygen uptake and the faster the rate of decomposition. Temperature increases, resulting from microbial activity, may be noticeable within a few hours of forming a pile. Pile temperatures between 32° and 60°C (90° and 140°F) indicate rapid composting. Temperatures greater than 60°C (140°F) reduce the activity of many of the most active organisms. Therefore, the optimum temperature range is between 32° and 60°C. Large volumes of organic matter provide both critical mass and insulating properties that allow interior temperatures to rise to 55° to 60°C (130° to 140°F) within a few days of compost start-up. Temperatures of composting materials characteristically follow a pattern of rapid increase to 55° to 60°C (130° to 140°F) and remain near this thermophilic level for several weeks. Temperatures gradually drop to 38°C (100°F) and finally drop to ambient air temperature. This characteristic pattern of temperature change over time reflects the types of decomposition and stabilization as composting proceeds, and is shown in Figure 3. Stabilized, finished compost products should have a very low rate of decomposition and will, therefore, not generate much heat. A temperature probe or soil thermometer should be used to keep track of pile temperatures.

![Figure 3: Compost Temperature and pH Variation with Time](image-url)
pH of Materials

Composting may proceed effectively over a range of pHs without seriously limiting the process. The optimum pH for microorganisms involved in composting lies between 6.5 and 7.5. The pH of most animal manures is approximately 6.8 to 7.4. Composting itself leads to major changes in materials and their pH, as decomposition occurs. For example, release of organic acids may, temporarily or locally, lower the pH (increase acidity), and production of ammonia from nitrogenous compounds may raise the pH (increase alkalinity) during early stages of composting. Whatever the pH measured in the starting materials, composting will always yield an end product with a stable pH usually near neutral. Figure 3 shows how pH typically changes over the composting process. Little heating will occur with a pH below 6.0 since bacteria work sluggishly until the pH rises to a more desirable level.

Nutrients

Adequate levels of phosphorus and potassium are also important in the composting process and are normally present in farm organic material such as manure, or poultry or pork mortalities.

Toxic Substances

Some organic materials may contain substances that are toxic to aerobic thermophilic bacteria. Heavy metals such as manganese, copper, zinc, nickel, chromium and lead may fall into this category. Heavy metals may be immobilized chemically prior to composting. In some manures, heavy metals are present in appreciable concentrations.

SUMMARY

The compost process depends on many factors as discussed, especially carbon-to-nitrogen ratios, surface area, aeration, moisture content, and temperature. The art of composting is balancing these factors to achieve the final product quality in the desired time frame. Composting will survive most forms of neglect, however, non-optimal conditions, caused by neglect, will simply slow down the process.
## CHARACTERISTICS OF ON-FARM COMPOSTING MATERIALS

Characteristics for materials marked with an asterisk (*) are values typically found for B.C. materials. All other characteristics are summarized literature values.

<table>
<thead>
<tr>
<th>Material</th>
<th>Nitrogen (Dry Weight) (%)</th>
<th>Carbon:Nitrogen Ratio (Dry Weight)</th>
<th>Typical Moisture Content (%)</th>
<th>Bulk Density at Moisture Content (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Beef (*)</strong>&lt;br&gt;- Feedlot c/w bedding</td>
<td>1.3</td>
<td>-</td>
<td>68</td>
<td>-</td>
</tr>
<tr>
<td><strong>2. Dairy (*)</strong>&lt;br&gt;- Solid Manure Handling</td>
<td>1.7</td>
<td>18.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>- Liquid Slurry</td>
<td>2.4 - 3.6</td>
<td>-</td>
<td>8 - 12</td>
<td>-</td>
</tr>
<tr>
<td>- Solids Separated from Slurry</td>
<td>1.45</td>
<td>-</td>
<td>23</td>
<td>-</td>
</tr>
<tr>
<td><strong>3. Pig (*)</strong>&lt;br&gt;- Liquid Slurry</td>
<td>0.15 - 5.0</td>
<td>20</td>
<td>93 - 99</td>
<td>1000</td>
</tr>
<tr>
<td>- Solids Separated from Slurry</td>
<td>0.35 - 5.0</td>
<td>-</td>
<td>75 - 80</td>
<td>270 - 860</td>
</tr>
<tr>
<td><strong>4. Poultry (*)</strong>&lt;br&gt;- Broiler Breeder Layer</td>
<td>3.6</td>
<td>10</td>
<td>46</td>
<td>470</td>
</tr>
<tr>
<td>- Broiler Litter</td>
<td>4.7</td>
<td>15</td>
<td>25</td>
<td>330</td>
</tr>
<tr>
<td>- Turkey Litter</td>
<td>4.2</td>
<td>14</td>
<td>33</td>
<td>380</td>
</tr>
<tr>
<td><strong>5. Horse Manure c/w Bedding</strong>&lt;br&gt;- c/w Straw Bedding (*)</td>
<td>1.4 - 2.3</td>
<td>22 - 50</td>
<td>59 - 79</td>
<td>725 - 960</td>
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<tr>
<td>- c/w Shavings (*)</td>
<td>1.5</td>
<td>27</td>
<td>67</td>
<td>-</td>
</tr>
<tr>
<td>0.9</td>
<td>65</td>
<td>72</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>6. Sheep Manure</strong></td>
<td>1.3 - 3.9</td>
<td>13 - 20</td>
<td>60 - 75</td>
<td>-</td>
</tr>
<tr>
<td><strong>7. Oat Straw</strong></td>
<td>0.6 - 1.1</td>
<td>48 - 98</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>8. Wheat Straw</strong></td>
<td>0.3 - 0.5</td>
<td>100 - 150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>9. Legume Grass Hay</strong></td>
<td>1.8 - 3.6</td>
<td>15 - 19</td>
<td>10 - 30</td>
<td>-</td>
</tr>
<tr>
<td><strong>10. Straw</strong></td>
<td>0.3 - 1.1</td>
<td>48 - 150</td>
<td>4 - 27</td>
<td>58 - 357</td>
</tr>
<tr>
<td><strong>11. Non-Legume Vegetable</strong></td>
<td>2.5 - 4.0</td>
<td>11 - 12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>12. Fruit Waste</strong></td>
<td>0.9 - 2.6</td>
<td>20 - 49</td>
<td>62 - 88</td>
<td>-</td>
</tr>
<tr>
<td>Material</td>
<td>Nitrogen (Dry Weight) (%)</td>
<td>Carbon:Nitrogen Ratio (Dry Weight)</td>
<td>Typical Moisture Content (%)</td>
<td>Bulk Density at Moisture Content (kg/m³)</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>----------------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>13. Fish Scraps &amp; Mortalities</td>
<td>6.5 - 14.2</td>
<td>2.6 - 5.0</td>
<td>50 - 81</td>
<td>-</td>
</tr>
<tr>
<td>14. Poultry Mortalities</td>
<td>2.4</td>
<td>5</td>
<td>65</td>
<td>-</td>
</tr>
<tr>
<td>15. Potato Tops</td>
<td>1.5</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16. Mixed Slaughter-House W</td>
<td>7 - 10</td>
<td>2 - 4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>17. Grass Clippings</td>
<td>2.0 - 6.0</td>
<td>9 - 25</td>
<td>82</td>
<td>180 - 260</td>
</tr>
<tr>
<td>18. Grass Clipping &amp; Other Gardening Waste</td>
<td>2.0</td>
<td>19.3</td>
<td>15</td>
<td>250</td>
</tr>
<tr>
<td>19. Leaves (freshly fallen)</td>
<td>0.5 - 1.3</td>
<td>40 - 80</td>
<td>38</td>
<td>60 - 80</td>
</tr>
<tr>
<td>20. Paper</td>
<td>0.2 - 0.25</td>
<td>127 - 178</td>
<td>18 - 20</td>
<td>-</td>
</tr>
<tr>
<td>21. Sawdust</td>
<td>0.06 - 0.8</td>
<td>200 - 750</td>
<td>19 - 65</td>
<td>350 - 450</td>
</tr>
<tr>
<td>22. Woodwaste (chips)</td>
<td>0.04 - 0.23</td>
<td>212 - 1313</td>
<td>-</td>
<td>445 - 620</td>
</tr>
</tbody>
</table>

To convert to Imperial units: $1000 \text{ Kg/m}^3 = 62 \text{ lb/ft}^3$

Some waste materials, especially from industrial and municipal sources, can contain toxic substances that would make the compost unsuitable for its intended use. Thus, it is important that the compost operator obtain copies of any analysis that may be required for disposal of the waste by pollution control authorities, and that metal concentrations be kept to levels acceptable to pollution control authorities for land application. If questionable materials are used, the compost must be analyzed.
BLENDING MATERIALS FOR THE COMPOSTING PROCESS

The ingredients for composting are organic by-products or waste materials. On-farm materials include animal manures, bedding, crop residues and, possibly, some processing wastes. In order to blend these materials in suitable proportions (sometimes referred to as the recipe), several factors must be taken into consideration, particularly the C:N ratio, moisture content, and porosity.

<table>
<thead>
<tr>
<th>SYMBOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a = total weight of ingredient a</td>
</tr>
<tr>
<td>b = total weight of ingredient b</td>
</tr>
<tr>
<td>c = total weight of ingredient c</td>
</tr>
<tr>
<td>M = desired Mix Moisture Content</td>
</tr>
<tr>
<td>Ma, Mb, Mc... = moisture content of ingredients a, b, c, ...</td>
</tr>
<tr>
<td>%Ca, %Cb, %Cc... = % carbon of ingredients a, b, c, ... (on dry weight basis)</td>
</tr>
<tr>
<td>%Na, %Nb, %Nc... = % nitrogen of ingredients a, b, c, ... (on dry weight basis)</td>
</tr>
<tr>
<td>R = desired C:N ratio of mix</td>
</tr>
<tr>
<td>Ra, Rb = C:N ratio of ingredients a, b</td>
</tr>
</tbody>
</table>

| FORMULAS FOR ONLY TWO INGREDIENTS |

Required amount of ingredient a per kg of b

To obtain desired C:N ratio:

\[
a = \frac{\% Na \times (Ra - R) \times (1 - Ma)}{\% Nb \times (Rb - Rb) \times (1 - Mb)}
\]

To obtain desired moisture content:

\[
a = Mb - M \times \frac{M - Ma}{M - Ma}
\]

| FORMULAS FOR A MIX OF MATERIALS |

C:N ratio = weight of C in ingredient a + weight of C in b + weight of C in c + ... / weight of N in a + weight of N in b + weight of N in c + ...

= \[
\frac{[\% Ca \times a \times (1 - Ma)] + [\% Cb \times b \times (1 - Mb)] + [\% Cc \times c \times (1 - Mc)]...}{[\% Na \times a \times (1 - Ma)] + [\% Nb \times b \times (1 - Mb)] + [\% Nc \times c \times (1 - Mc)]...}
\]

Moisture Content = weight of water in ingredient a + weight of water in b + weight of water in c + ... / total weight of all ingredients

= \[
\frac{(a \times Ma) + (b \times Mb) + (c \times Mc)...}{a + b + c + ...}
\]
EXAMPLE

Assume a broiler breeder farm has manure to compost, and that sawdust will be used as a bulking agent. How much sawdust and water needs to be added to the manure, to have a good compost mix.

Using values from *Characteristics of On-Farm Composting Materials*, Factsheet No. 382.505-3, assume:

<table>
<thead>
<tr>
<th></th>
<th>% Nitrogen (Dry wt)</th>
<th>Carbon:Nitrogen Ratio</th>
<th>Moisture Content (%)</th>
<th>Bulk Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broiler Breeder Manure</td>
<td>3.6</td>
<td>10</td>
<td>46</td>
<td>470</td>
</tr>
<tr>
<td>Sawdust</td>
<td>0.1</td>
<td>500</td>
<td>20</td>
<td>350</td>
</tr>
</tbody>
</table>

1. Using the formula for two ingredients from page 1, determine the amount of sawdust (a) needed for each kg of manure (b), to give a desired C:N ratio (R) of 30.

   Given:  
   b = 1 kg of broiler breeder manure  
   Ma = 0.20 (20% moisture content of sawdust)  
   Mb = 0.46 (46% moisture content of manure)  
   Ra = 500 (C:N ratio of sawdust)  
   Rb = 10 (C:N ratio of manure)  
   %Na = 0.1 (% nitrogen in sawdust)  
   %Nb = 3.6 (% nitrogen in manure)

   Determine: a (weight of sawdust needed) for a desired C:N ratio of R = 30

   \[ a = \frac{%Nb \times (R - Rb) \times (1 - Mb)}{%Na \times (Ra - R) \times (1 - Ma)} \]

   Calculation:  
   \[ a = \frac{3.6 \times (30 - 10) \times (1 - 0.46)}{0.1 \times (500 - 30) \times (1 - 0.20)} = \frac{3.6 \times 20 \times 0.54}{0.1 \times 470 \times 0.80} = 1.0 \]

   Answer: For each kg of manure, add 1.0 kg of sawdust to obtain a C:N ratio of 30.

2. Check the mix moisture content (M.C.) using the moisture content formula on page 1.

   Given:  
   a = 1.0 kg wt of sawdust from step 1  
   b = 1.0 kg wt of manure  
   Ma = 0.20 (20% moisture content of sawdust)  
   Mb = 0.46 (46% moisture content of manure)

   Determine: mix moisture content  
   \[ M.C. = \frac{(a \times Ma) + (b \times Mb)}{a + b} \]

   Calculation:  
   \[ M.C. = \frac{(1 \times 0.20) + (1 \times 0.46)}{1 + 1} = \frac{0.20 + 0.46}{2} = 0.33 \text{ or } 33\% \]

   Answer: This starting moisture content of 33% is too low, since ideal moisture content runs from 50 to 60%.
3. Adjust moisture content to 55% using the two ingredient formula on page 1.

Given:  
\[ b = 1 \text{ kg of manure/sawdust mix} \]
\[ M = 0.55 \] (55% desired moisture content)
\[ Ma = 1.0 \] (100% moisture content of water)
\[ Mb = 0.33 \] (33% moisture content of manure/sawdust mix)

Determine: ‘a’ quantity of water required
\[ a = \frac{Mb - M}{M - Ma} \]

Calculation:
\[ a = \frac{0.33 - 0.55}{0.55 - 1.0} = \frac{-0.22}{-0.45} = 0.49 \]

Answer: Add 0.49 kg of water for every 1.0 kg of manure/sawdust mix.

4. Determine: the volumes of manure, sawdust and water to mix.

Given:  
Tractor bucket volume = 2.0 m³  
Manure bulk density = 470 kg/m³  
Sawdust bulk density = 350 kg/m³.

Calculation: One bucketful of manure weighs 2.0 m³ x 470 kg/m³ = 940 kg

Since an equal weight of manure and sawdust is wanted add 940 kg of sawdust
\[ \frac{940 \text{ kg}}{350 \text{ kg/m}^3} = 2.7 \text{ m}^3 \text{ of sawdust.} \]

This is equal to 2.7 m³/2.0 m³ per bucket = 1.35 buckets of sawdust.

For each bucket full of manure used there will be a total manure/sawdust mix weighing
\[ 940 \text{ kg} + 940 \text{ kg} = 1840 \text{ kg} \]

Similarly for each bucketful of manure used add; 0.49 kg x 1840 kg = 902 kg water
\[ \text{kg of mix} \]
\[ \text{equals 902 litres water} \]

Answer: For each bucketful of manure add
1.35 bucketful of sawdust, and
902 litres of water

5. Check porosity of mix.

Porosity cannot be predicted with accuracy from ingredient characteristics. However, porosities for materials having bulk densities less than 640 kg/m³ are usually adequate.

\[ \text{Bulk Density} = \frac{940 \text{ kg} + 940 \text{ kg} + 902 \text{ kg}}{2.0 \text{ m}^3 + 2.7 \text{ m}^3} = \frac{2782 \text{ kg}}{4.7 \text{ m}^3} = 591 \text{ kg/m}^3 \]

The porosity of the mix is therefore expected to be adequate.
Some basic composting methods which have been developed include those that use bins, passive windrows, turned windrows, aerated static piles and in-vessel channels. The proper approach depends on the time to complete composting, the materials and volume to be decomposed, space available, the availability of resources (labour, finances, etc.) and the quality of finished product required. The Table on page 6 summaries the interplay between these factors.

**Bin Composting** is the production of compost in a bin. The compost is produced by natural aeration, and through turning. The compost mix is turned using a tractor front-end loader. Bin composting represents a low technology, medium labour approach producing a medium quality product. This option is primarily used for mortality composting.

**Passive Windrow Composting** is the production of compost in piles or windrows. Compost is produced by natural aeration, over long periods of time. Passive windrow composting represents a low technology and labour approach. Attention to details such as the porosity of the initial mix, uniform product mixing and particle size greatly improves the speed of the process and product quality.

**Turned Windrow Composting** is the production of compost in windrows using mechanical aeration. The compost mix is aerated by a windrow turner, which can be powered by a farm tractor (PTO), self-powered or self-propelled. Turned windrow composting represents a low technology and medium labour approach and produces a uniform compost.

**Aerated Static Pile Composting** is the production of compost in piles or windrows with mechanical aeration. The windrow or pile is located above air ducts, and aeration is achieved by blowing or drawing air through the composting material. Aeration systems can be relatively simple, using electrical motors, fans and ducting, or sophisticated, incorporating various sensors and alarms. Aerated static pile composting offers a medium technology and low labour approach, sometimes resulting in a non-uniform product. In some systems, mechanical aeration may occur near the end of the active compost period.

**In-Vessel Composting** is the production of compost in drums, silos or channels using a high-rate controlled aeration system, designed to provide optimal conditions. Aeration of the material is accomplished by: continuous agitation using aerating machines which operate in concrete bays, and/or fans providing air flow from ducts built into concrete floors. In-vessel composting represents a high technology and low labour approach, producing a uniform product.

**BIN COMPOSTING**

Bin composting methods are commonly used for yard waste; smaller amounts of manure; and for poultry, or pork mortalities. Turning compost can reduce decomposition time to two months or less.

Wastes in bins must be mixed on a regular basis. Frequent turning speeds up the composting process by providing aerobic bacteria with the oxygen required need to break down materials. A set-up often includes a series of bins, as shown in Figure 1. High temperatures, from 32° to 60°C (90° to 140°F), are produced when piles are turned every five to ten days. These actions are necessary to kill disease organisms and fly larvae, to help kill weed seeds, and to provide an environment necessary for the most efficient decomposer organisms.
Figure 1  A Wooden Bin Unit, with Three Compartments

Materials to be composted should be added to bins in layers, rather than in small amounts over time. Materials should be stockpiled until enough accumulates to add approximately one cubic metre or yard in a bin.

Operation and management of poultry, and pork mortality compost systems are explained in Managing Poultry Mortality Composting Systems, Factsheet No. 382.500-8, and Managing Pork Mortality Composting Systems, Factsheet No. 382.500-9. A detailed design of a mortality composting bin is shown in Mortality Compost Bin Design, Factsheet No. 382.500-10.

PASSIVE WINDROW

Passive windrow composting is a very low-cost approach requiring more land, but less labour and capital than other composting methods. Generally, material to be composted is collected and promptly piled into windrows which remain untouched. The materials may be wetted before they are initially formed into windrows, but this is not essential.

A windrow is simply an elongated pile of material with a more or less triangular cross-section. As illustrated in Figure 2, a windrow should measure about 3 metres (10 feet) wide and 1.5 metres (5 feet) high; its length will vary depending upon the amount of materials used. Aeration occurs naturally. As hot air rises, fresh air is drawn into the pile. Materials can be added as they become available, or stockpiled until sufficient amounts are available to make a good-sized pile or windrow. Two windrows should be used. When the first one is large enough, it should be allowed to decompose undisturbed. Additional waste should then be added to the second windrow. Covering the windrow with a layer of finished compost will help prevent moisture loss, reduce odour problems, and produce a more uniform compost. Composting in these windrows can take from six months to two years.

Large passive windrows can be as wide as 7 metres (24 feet), and as high as 4 metres (12 feet) and of any length. The centre of a windrow this size will quickly become anaerobic and only by turning can it receive a new oxygen supply. An unpleasant odour will develop in the anaerobic region and may begin to emanate from the composting material; hence, a large land area is necessary to buffer residents and businesses from the odour. Since rapid composting can take place only in the presence of oxygen, the compost normally will require three years to stabilize.

With both the small and large windrows used in passive windrow composting, there is no ability for process control. Therefore only medium product quality is produced.

TURNED WINDROW

Aeration of the windrow can be achieved through mechanical turning. Turning can also be done manually, but is considered impractical with volumes larger than one or two cubic metres. Uniform
decomposition, as well as pathogen destruction, is best achieved by turning the outer edges into the centre of the pile at each turn. However, if this cannot be accomplished, the frequency of turning can be increased. Turning should also be more frequent than under a regular schedule when the moisture content of the pile is too high so as to minimize the development of anaerobic conditions. In areas that receive heavy rainfall, it may be necessary to cover the windrows so they do not become too wet; however, the cost of this may be prohibitive for certain operations. Alternatively, maintaining a triangular or dome shaped windrow is effective for shedding excess rain or preventing excess accumulation of snow in the winter. In windrow composting, the raw material is mixed and placed in rows, either directly on the ground or on paved or concrete surfaces. During the active compost period, the size of the windrow decreases. Following the active period, windrows at the same level of maturity can be combined into larger rows, making additional space for more raw materials or compost.

The equipment used for turning the windrow, varies from front-end loaders or bulldozers to specially designed turning machines. Loaders, although inexpensive compared to turners, have a tendency to compact the composting material, are comparatively inefficient, and can result in longer composting periods and less consistent quality. Figure 3 shows a pull-type, tractor driven power takeoff, compost turner.

There are two basic types of windrow turners. The most commonly used have a series of heavy tines that are placed along a rotating horizontal drum which, turns, mixes, aerates and reforms the windrow as the machine moves forward. A second type uses a moving, elevator table chain equipped with sharp teeth. These windrow turners are either self-contained units that straddle the row, or are powered by a tractor driven power takeoff.
Windrows should be turned frequently at first and then at longer intervals by the end of the first month. A recommended turning frequency is:

<table>
<thead>
<tr>
<th>Week</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Week</td>
<td>3 Turnings</td>
</tr>
<tr>
<td>2nd Week</td>
<td>2-3 Turnings</td>
</tr>
<tr>
<td>3rd Week</td>
<td>2 Turnings</td>
</tr>
<tr>
<td>4th and 5th Week</td>
<td>1 Turning each week</td>
</tr>
<tr>
<td>6th and above</td>
<td>1 Turning every 2 weeks if heating still occurs</td>
</tr>
</tbody>
</table>

Temperature measurements inside the windrow should be used to gauge the need for turning to stimulate or control heat production.

With efficient turning by using a windrow turner, a minimum composting time is one month, followed by at least two months in a curing pile. The compost may be ready to apply to land or be marketed.

Windrow composting can produce excellent compost, using a variety of diverse materials. Wastes such as manure solids, fish waste and poultry mortalities can be composted with bulking agents such as sawdust, straw and recycled paper products. Windrow composting efficiency and product quality are dependent primarily upon two major factors: 1. the initial compost mix, and 2. management practices.

**AERATED STATIC PILE**

The aerated static pile composting method was developed by the United States Department of Agriculture and can be a very efficient system. During recent years, this method has become popular at the municipal level in composting sewage sludge, but has not yet become popular on the farm.

The aerated static pile method does not mechanically agitate compost material to achieve the desired level of aeration. The pile is constructed above an air source such as, perforated plastic pipes, aeration cones or a perforated floor; and aeration is accomplished either by forcing or drawing air through the compost pile. This system of aeration requires electricity at the site and appropriate ventilation fans, ducts and monitoring equipment. The monitoring equipment determines the timing, duration and direction of air flow. The pile should be placed after the floors are first covered with a layer of bulking agent, such as wood chips or finished compost. The material to be composted is then added, and a topping layer of finished compost applied to provide insulation. The optimum size of pile is related to the materials composted, air flow capabilities and the type of handling equipment. In some facilities, the initial mix is piled between temporary fencing or movable highway dividers. This allows considerable flexibility with respect to the size and location of the pile within the working area or building. In aerated static pile operations, the timing, duration and uniform movement of air are important. Air flow requirements change depending upon the materials composted, the size of the pile, and age of the compost.

A major difficulty with the static pile system is the efficient diffusion of air through out the entire pile, especially with wastes characterized by a large particle size distribution, high moisture content, or a tendency to clump. Other problems include the formation of channels in the pile which allow forced air to short-circuit. This causes excessive drying due to evaporation of moisture near the channels. These situations may require more frequent turns of piles.

Aerated static piles can produce excellent compost, provided that two basic operating conditions are met:

- The initial material has adequate porosity; and
- The air flow system works properly and provides adequate air flows uniformly during the active compost period to all areas of the pile.

In comparison to windrow composting, aerated static piles require a different level of management and monitoring. Windrow composting is often regarded as a "normal" extension of an existing manure-
handling system, since some or all of the existing farm machinery can be used for windrow composting. Aerated static piles require additional equipment and infrastructure investment, and these assets are dedicated solely to the compost operation. In addition, **pre-compost product mixing** is a very important step in aerated static pile systems. In contrast, the mixing and blending is done throughout the active composting stage in windrow composting.

Odour is an operation problem that can affect any type of compost system; however, odour problems are often inherent within a windrowing system. In contrast, if odour problems develop in an aerated static pile system, they can be easily identified and corrective measures taken such as for example, changing air flows; improving air flow capacities; dispersion and filters; and increasing the insulative cover. With negative air pressure delivery, air is drawn through the pile and can be cleaned using a bio-filter before releasing it to the atmosphere; with positive air pressure, air is pushed through the pile and the exterior insulative cover of mature compost cleans the exhaust air. Figure 4 shows an aerated static pile set-up using bio-filters.

**IN-VEssel**

In-Vessel compost systems are **high rate controlled aeration systems** which are designed to provide optimal composting conditions involving mechanical mixing of compost under controlled environmental conditions. Although various designs are available, the different systems are similar in that they are both **capital and management intensive**. In-vessel, or enclosed-vessel systems fall under three main categories:

- rotating drum
- horizontal (rectangular/cylindrical) or vertical silos
- channels

The main advantages of the in-vessel system over others (windrows, aerated static piles etc.) are the shortening of the mesophyllic and thermophilic stages, a higher process efficiency, and a decreased number of pathogens, resulting in a safer and more valuable end product. As well, space requirements are generally less than that of other methods. However, it is important to note that all systems require final stabilization of the compost. Disadvantages of the enclosed vessel method include high capital and operational costs due to the use of computerized equipment and skilled labour. In-vessel composters are generally more automated than windrow or static pile systems, and can produce a top quality finished product on a consistent basis.

Common reasons for choosing in-vessel composting over other methods include:

- odour control
- space constraints at the site
- process and materials handling control
- better public acceptance due to the aesthetics/appearance of the composting site
- less manpower requirements
- more consistent product quality

Several existing in-vessel systems in British Columbia consist of a series of channels equipped with a turner mounted on wheels that move on tracks placed at the top of the channel. The turner serves as a mixing device. The channel contains a perforated bottom for continuous or intermittent forced aeration. Figure 5 shows a possible four channel in-vessel method of composting with under-floor aeration. Retention time is approximately three weeks before the composting material is cured. Capacities of operations range from a few tonnes to hundreds of tonnes per day.

![Four Channel In-Vessel Composting](image-url)
<table>
<thead>
<tr>
<th>Model</th>
<th>General</th>
<th>Labour</th>
<th>Site</th>
<th>Bulking Agent</th>
<th>Active Period</th>
<th>Curing</th>
<th>Size: Height</th>
<th>Width</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Windrow</td>
<td>Low technology</td>
<td>Low labour required</td>
<td>Requires large land areas</td>
<td>Less flexible, Must be porous</td>
<td>Range: 6-24 Months</td>
<td>Not applicable</td>
<td>1 - 4 metres</td>
<td>3 - 7 metres</td>
<td>Variable</td>
</tr>
<tr>
<td>2. Turned Windrow</td>
<td>Active systems most common on farms</td>
<td>Increases with aeration frequency and poor planning</td>
<td>Can require large land areas</td>
<td>Flexible</td>
<td>Range: 21-40 days</td>
<td>30+ days</td>
<td>1 - 2.8 metres</td>
<td>3 - 6 metres</td>
<td>Variable</td>
</tr>
<tr>
<td>3. Aerated Static Pile</td>
<td>Effective for farm and municipal use</td>
<td>System design and planning important. Monitoring needed.</td>
<td>Less land required given faster rates and effective pile volumes</td>
<td>Flexible</td>
<td>Range: 21-40 days</td>
<td>30+ days</td>
<td>3 - 4.5 metres</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td>4. In-Vessel Channel</td>
<td>Large-scale systems for commercial applications</td>
<td>Requires consistent level of management/product flow to be cost efficient.</td>
<td>Very limited land, due to rapid rates and continuous operations</td>
<td>Flexible</td>
<td>Range: 21-35 days</td>
<td>30+ days</td>
<td>Dependent on bay design</td>
<td>Variable</td>
<td>Variable</td>
</tr>
</tbody>
</table>

| Aeration System            | Natural convection only       | Mechanical turning and natural convection | Forced positive/negative air flow through pile | Extensive mechanical turning and aeration |
| Process Control            | Initial mix only              | Initial mix. Aeration, temperature and/or time control | Initial mix. Aeration, temperature and/or time control. Turning. |
| Odour Factors              | Odour from the windrow will occur. The larger the windrow the greater the odours. | From surface area of windrow. Turning can create odours during initial weeks. | Odour can occur, but controls can be used, such as pile insulation and filters on air system. | Odour can occur. Often due to equipment failure or system design limitations. |

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**Resource Management Branch**

[www.agf.gov.bc.ca/resmgmt](http://www.agf.gov.bc.ca/resmgmt)

Linking to our Publications and Conceptual Plans

This is one of a series of Factsheets on Composting. A list of references used in producing this series is included in the Composting Factsheet “Suggested Reading and References.”

**COMPOSTING FACTSHEET SERIES PREPARED BY**
Hog Producers Sustainable Farming Group; Pacific Agricultural Research Centre (Agassiz), Agriculture and Agri-Food Canada; and Resource Management Branch, BCMAF

**FOR MORE INFORMATION CONTACT**
RESOURCE MANAGEMENT BRANCH
Ministry of Agriculture, Food and Fisheries
1767 Angus Campbell Road
Abbotsford BC, CANADA V3G 2M3
Phone: (604) 556-3100 Fax: (604) 556-3099
SITE SELECTION FOR COMPOSTING

The site selected for the collection, storage and composting of agricultural wastes must be in full compliance with the Code of Agricultural Practice for Waste Management, (hereafter referred to as the Code), and in a manner that prevents pollution. **The Code should be consulted before selection of a composting site.** Figure 1 shows the setbacks required by the code.

Refer to *Regulations Affecting Composting*, Factsheet No. 382.505-12, and *Co-Composting With Off-Farm Wastes*, Factsheet No. 382.505-13, when non-agricultural wastes are brought onto the farm. The composting operation must meet B.C. Environment, Waste Management Requirements and may need to obtain a Waste Management Permit.

It is not feasible to transport low-value materials a long distance. Economic management of composting should minimize transportation cost. Transportation that may be involved in a composting operation include movement:

1. of raw composting material to the site, and
2. of compost to the final processing/storage area.

It is most convenient to set up the composting operation close to the source of the solid waste. Selection of the composting site is largely dependent on the existing layout of the farming operation.

Machines, such as a compost turner, front-end loader and trucking vehicle, are frequently used in composting operations and can take up considerable space. The composting site should also be selected in such a way that easy access of machinery does not interfere with existing operations and structures. Adequate space should be available for, to allow for future expansion.

SITE DESIGN

The area required for composting depends on the amount of waste to be received and the amount of bulking agents required. Generally, one cubic metre of raw composting material will require about 0.8 square metres of ground area for a windrow setup. Detailed dimensions for different types of windrow composting are illustrated in Figure 2.

The composting site should be paved with either concrete or asphalt to avoid groundwater contamination. Floors also provide a good environment for compost quality control by preventing foreign materials from entering into windrows. After heavy rain showers, it is easy to drain the water on a concrete floor. Concrete floors may be more expensive than asphalt; however, asphalt floors deteriorate faster.

Runoff and leachate collection must be considered when site grading. The grade should be designed in such a way that the liquid leachate from compost can flow freely to a centre point for collection, and be applied to the windrow when the windrow becomes too dry.

A roof over a compost windrow/pile is likely required in B.C.'s South Coastal area during the winter rainy season. Too much rain may slow the composting process by causing anaerobic zones to develop. A roof also reduces costs of building runoff storage basins.

If the composting material is too wet, nutrient-rich liquid may leach out. This liquid should be properly collected to avoid it entering watercourses. Figure I also shows a simple runoff and leachate collection system suitable for an uncovered facility in an area with rainfall less then 600 mm (24 in). The leachate collected can be applied back to the windrow as a nutrient source. A berm around the composting site will also prevent runoff from entering a watercourse.

Composted materials may become too dry due to evaporation and water will be required to adjust the moisture content back to a suitable range. Sprinklers can be used to spread water evenly onto the composting mass.
Approximately the same area required for the composting process should be available for curing. Curing should be done under a roof. The space required for packaging includes the area occupied by the packaging machines and temporary storage area. Space should also be assigned for storage of the finished compost. Roofed storage is not required for finished produce packaged in plastic bags. Site planning should also account for extra storage space needed in the eventuality of slow market conditions.
Example Layout

Size an outdoor turned windrow facility to handle 38 tonnes/week (2000 tonnes/yr) of manure

1. **Given:**
   - a bulk density for solid manure equals 700 kg/m³ (0.7 tonnes/m³)
   - an equal volume of bulking agent and manure used to achieve the correct C:N ratio
   - 50% shrinkage after active composting
   - 6 weeks required for the active composting phase
   - windrows have a 3.7 m (12 ft) base, 1.2 m (4 ft) height, and volume of 3 m³/m length (32 ft³/ft)
   - 4 weeks required for curing
   - curing piles have a 5.5 m (18 ft) base, 1.8 m (6 ft) height, and volume of 6.75 m³/m length (72 ft³/ft)
   - up to 9 weeks storage is expected with piles 2.4 m, (8 ft) high

2. **Calculate Size of Windrows:**

   Volume manure handled per week = 38 tonnes = 54.3 m³
   
   Volume bulking agent required equals volume manure = 54.3 m³
   
   Total volume of manure and bulking agents = 54.3 m³ + 54.3 m³ = 108.6 m³
   
   Windrow length required = \( \frac{108.6 \text{ m}^3}{3 \text{ m}^3/\text{m length}} \) = 36.2 m (120 ft)
   
   Answer: Since 6 weeks are required for the active composting phase, 6 windrows each 36.2 m long are necessary.

3. **Calculate: Size of Curing piles:**

   Volume to be cured = 108.6 m³ x 50% shrinkage = 54.3 m³/week
   
   Pile size: 4 wk. x 54.3 m³ = 217.2 m³ total
   
   Pile length: = \( \frac{217.2 \text{ m}^3}{6.75 \text{ m}^3/\text{m length}} \) = 32.2 m (for the full 4 week curing stage)
   
   Answer: A single curing pile 32.2 long or two, each 16.1 m long is adequate.

4. **Calculate: Size Storage Area:**

   Volume of compost requiring storage per week = 54.3 m³/wk
   
   Pile Volume: = 9 wk. x 54.3 m³/wk = 488.7 m³
   
   Pile Size: = \( \frac{488.7 \text{ m}^3}{2.4 \text{ m height}} \) = 204 m² or 10.2 m x 20 m
   
   Answer: A pile measuring 10.2 m by 20 m is necessary.

5. Figure 3 shows a possible layout for this size of outdoor composting facility. The total site area setbacks, work space, etc. covers 0.4 hectares.
6. Calculate: Size Runoff collection pond using the following assumptions:

- the six month rain in the worst 25 years is expected to be 500 mm (19.7 inches)
- 100% of the precipitation falling on the hard surface will run off
- about 25% of the precipitation falling on the windrows and other piles will run off

Runoff from hard surface = $1500 \text{ m}^2 \times 500 \text{ mm} \times 100\% = 750 \text{ m}^3$

Runoff from piles = $175 \text{ m}^2 \times 500 \text{ mm} \times 25\% = 147 \text{ m}^3$

Total = $897 \text{ m}^3$

Answer: A concrete runoff basin 10 m x 5.8 m x 3 m deep, with 1:1 sidewalls, will contain the 897 m$^3$ of runoff plus the 393 m$^3$ of precipitation that will fall into the basin during the worst winter six month period expected in a 25 year period. A possible layout is shown in Figure 3.

Figure 3  Outdoor Composting Facility as per Sample Calculation on Page 3
MANAGING AGRICULTURAL COMPOSTING SYSTEMS

PRECOMPOST

Determination of Carbon/Nitrogen Ratio

During composting, almost all of the nutrients in the organic material can be utilized by microbes. However, the most important nutrient balance is the ratio of carbon to nitrogen (C:N). Too much carbon compared to nitrogen (high C:N ratio) will slow down the composting process excessively. Too much nitrogen compared to carbon (low C:N ratio) will lead to higher ammonia emissions and odour problems. An efficient composting process must have ingredients in the proper C:N ratio. The optimum ratio is a function of the nature of the composting materials, i.e., the availability of the nutrients, particularly the carbonaceous components. A C:N ratio of about 25 to 30:1 (25 to 30 parts carbon to 1 part of nitrogen) has been shown to be optimum for most types of wastes. If woody bulking agents are used for composting, a C:N ratio of 35 to 40:1 may be used due to the low availability of carbon.

Selection of Bulking Agents

Bulking agents play two roles in composting:
- they provide an extra carbon source to increase the carbon to nitrogen ratio; and
- they increase the porosity of the composting material which improves air movement.

When selecting bulking agents consider the following:

1. **Economics:** Costs of materials should be assessed, including shipping and processing (sorting, grinding, etc.).

2. **Particle Size:** Particles should be 2 to 10 mm (0.08 to 0.40 in), in length, and fairly uniform.

3. **Availability of Carbon:** If a bulking agent is to be used to adjust the C:N ratio, the availability of carbon in the agent should be considered. Not all the carbon will be immediately available for the microbes to consume. Some woody materials, such as wood chips, are hard to break down, and more bulking agent may be required to compensate for this.

4. **Environment:** Some of the bulking agents being used today may contain toxic substances. For example, sawdust from treated wood and ground paper can contain various pollutants. These materials should not be used as bulking agents.

5. **Permits:** Non-agricultural wastes used as bulking agents may require a waste management permit from the Ministry of Environment, before they can be used on a farm.

Bulking agents currently available are:
- sawdust;
- woodchips;
- straw; and
- shredded or ground paper.

Large particles remaining after sawdust and woodchips are composted can be recycled after screening.

Grinding

If composting materials contain particles larger than 10 mm (0.40 in) in length, and constitute a large portion of the total volume, grinding will be required to mechanically reduce the pieces to 2 to 10 mm (0.08 to 0.40 in) in order to increase the efficiency of composting.
Weighing and Mixing

After weighing different composting materials, as explained in Blending Materials for the Compost Process, Factsheet No. 382.500-4, the composting materials should be mixed thoroughly by using either a front-end loader, a solid manure spreader, a compost turner or a specially-designed mixer. A sorting machine, such as a rotating screen belt may be used to separate the inerts from the biodegradable materials. When using agricultural wastes alone, these machines are not usually necessary. They may be needed if any bulking agents added contain inerts. Sorting and grinding equipment are all commercially available.

If a front-end loader is to be used for mixing, it is easier to form the windrow in layers. The windrows should then be turned two to four times. A specially-designed compost turner will provide far better mixing and aeration than a front-end loader, and save labour at the same time.

COMPOSTING PROCESS CONTROL

Dimension of Windrow/Pile

Windrow size depends on the turning method chosen. Small windrows are typically 3 to 3.6 m (10 to 12 ft) wide at the bottom with heights to 1.5 m (5 ft). Large windrows are typically 5.4 to 6.6 m (18 to 22 ft) wide at the bottom with heights to 2.1 m (7 ft) and up to 2.1 m (7 ft) wide at the top. See Site Selection for Composting, Factsheet No. 382.500-6 for information on a suggested layout of a composting facility.

Control of Moisture and Aeration

Moisture content and aeration are two critical interdependent factors in composting. The lower limit of moisture content in composting is normally about 45 to 50%. If the composting material is too dry, biological activity will be slow. The upper limit of the moisture content is largely a function of the nature of the composting materials. If the composting materials are porous as is the case for example, in hog manure mixed with sawdust, the upper limit of moisture content may be as high as 70%; if the compost cannot maintain well-defined pores within its mass, as is the case in for example, chicken layer manure mixed with shredded paper, the upper limit of moisture content should not be over 60%. If the materials are too wet, anaerobic conditions will dominate the composting process, slowing decomposition and generating foul odours.

Determination of moisture content can be made easily by using the following steps:

1. Weigh an empty container
2. Weigh the container with the compost sample in it
3. Dry the sample in an oven at 105°C (220°F) for six to eight hours
4. Weigh the container with the dried sample in it
5. Subtract the container weight (1) from both the wet (2) and dry (4) weights to obtain sample weights
6. Use the following equation to determine the moisture content of the sample

\[
\text{Moisture Content} = \frac{(\text{Weight of Wet Sample} - \text{Weight of Dry Sample}) \times 100\%}{\text{Weight of Wet Sample}}
\]

In the field, the “squeeze test” will give an indication of wetness. When the moisture content is about 60%, the material should feel damp to the touch, with just a drop or two of liquid expelled when the material is tightly squeezed in the hand, as shown in Figure 1.

When the composted materials are too wet (above the upper limit), windrows and piles should be turned more frequently. An alternative is to add drier material, such as dry compost or bulking agent, to absorb extra moisture. If the composting materials are too dry (below 45%), water should be added during turning or mixing until a suitable moisture level is achieved. Overwatering should be avoided.

Air requirement is determined by the nature of the composting materials and the stage of the composting process. Aeration also provides a means of cooling down the composting material when overheated. Air requirements can roughly be assessed by observing the colour and smell of the compost. Under the following conditions, more air is needed:
1. There is an objectionable odour from the windrow;
2. Colour is lighter in the inner section of the windrow; and
3. The composted materials are too wet.

During the first two weeks the windrows/piles should be turned every second day, if the temperature remains between 35º and 60ºC (95º and 140ºF). For the next two weeks (weeks 3 and 4), turn the windrows/piles twice a week. For the third two weeks (weeks 5 and 6), turn the windrows/piles should be turned once a week. Following these six weeks and until the process is complete, the composted materials should be turned once a month. Maturity will typically be achieved in a minimum of three months.

**Temperature**

Temperature needs to be monitored consistently during composting. The ideal temperature range for microbes to flourish is between 35º and 55ºC (95º and 130ºF). Temperatures over 60ºC (140ºF) will slow down the microbial activity and hence the composting process. However, for a significant reduction of weeds and pathogens, maintaining temperatures of over 55ºC (130ºF) is required for at least three days. Temperatures over 70ºC (170ºF) should be avoided by aeration or turning. Temperatures over 55ºC (130ºF) will usually be reached after two to six days of composting.

Daily reading of temperatures should be taken for the first four weeks; if temperatures move close to 60ºC (140ºF), more frequent readings are suggested to check for overheating. After composting for four to six weeks, less frequent readings of once or twice a week may be taken.

**Odour**

Eliminating odours completely during composting is not possible. However, odour can be minimized by following basic procedures. After five to six days of composting under favourable conditions, the composting materials begin to acquire a faintly earthy odour, indicating a healthy process. This earthy non-objectable odour becomes more pronounced as time progresses. Objectionable odours may appear under the following conditions:

1. Inadequate aeration, allowing anaerobic digestion to take place. **Solution:** Aerate the composting materials more frequently.
2. A low C:N ratio. **Solution:** Adjust the C:N ratio by adding more carbonaceous materials.
3. Wet composting materials. **Solution:** Aerate more or add dry materials to absorb the excess moisture.

**Runoff and Leachate**

If composting is in an uncovered area, all runoff must to be collected. This runoff can be reused in the composting system. In order to control and manage runoff, composting should be done on a hard surface such as concrete. No runoff may be discharged without a permit from the B.C. Ministry of Environment, Lands and Parks. Leachate is not likely to form if the process is controlled properly from the beginning. If leachate appears, it should be collected and pumped back to the windrows or piles during turning. See **Site Selection for Composting, Factsheet No. 382.500-6**, for an example sizing of a runoff and leachate holding pond.

**Maturity and Quality Control**

Although there is no fixed standard for compost maturity or quality, the CAN/BNQ 0413-200 National Standard of Canada: Organic Soil Conditioner - Composts, does provide a voluntary standard to the composting industry. Part of the standard are on the next page.

Additional parameters such as nutrient value, (ie nitrogen (N), phosphorus (P), and potassium (K)), cation exchange capacity, pH, soluble salt (E.C.) and particle size could be considered. In practice, the following method may apply to measure the maturity of compost.

After three months of composting and curing, collect about one to three cubic metres of compost from different locations of the windrow (close to the surface and deep inside), thoroughly mix the compost and
adjust the moisture content to about 50%, and pile the conditioned compost up, providing air. If there is no more than a 5°C, (10°F) rise or drop, the compost may have reached its maturity. If the temperature rises more than 5°C, a longer curing time is required.

The final composted material should have the following physical and odour qualities: unrecognizable original materials; dark brown to black; foreign matter/materials less than 1%; relatively porous, not compacted or hard; and no objectionable odours, but an ‘earthy’ smell.

See Using Compost, Factsheet, No. 382.500-15 for more information on using compost.

**POSTCOMPOST**

At this stage, compost has completely stabilized and characterized by the qualities described above. The compost is ready to market or use on farm.

**Screening**

If screening and grinding are not completed before composting, and the final product contains inerts such as plastic, glass, metal, gravels or big chunks of bulking agents, these produces should be screened out before marketing.

**Drying or Watering**

The final moisture content of the compost should be adjusted to about 50% by either drying or watering. Water in the final product should be evenly distributed by complete mixing.

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<table>
<thead>
<tr>
<th>Trace Element</th>
<th>Concentration mg/kg (air-dried)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>13</td>
</tr>
<tr>
<td>Cd</td>
<td>3</td>
</tr>
<tr>
<td>Co</td>
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<tr>
<td>Cr</td>
<td>210</td>
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<tr>
<td>Cu</td>
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<td>Mo</td>
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<tr>
<td>Ni</td>
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<td>Pb</td>
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</tr>
<tr>
<td>Se</td>
<td>2</td>
</tr>
<tr>
<td>Zn</td>
<td>500</td>
</tr>
</tbody>
</table>

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The CAN/BNQ 0413-200 National Standard Characteristic Standard

| Moisture Content: | not greater than 60% (as received) |
| Total Organic Matter Content: | not less than 40% (% of oven dried mass) |
| Foreign Matter Content: | ≤ 0.5% (oven dried) with maximum diameter 12.5 mm |
| Maturity: | based on meeting two of three requirements: (C/N ratio ≤ 25, or Oxygen uptake ≤ 150 kilogram oxygen per kilogram of volatile solids per hour, or Germination rate for cress or radish seeds in compost of at least 90% of germination rate of control and plant growth in compost-soil mix shall not differ by more than 50% in comparison to the control sample).

Faecal Coliform Content: < 1000 MPM/ g of total solids (oven dried mass)

Salmonella Content: No salmonella present in compost

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Hog Producers Sustainable Farming Group;
Pacific Agricultural Research Centre (Agassiz),
Agriculture and Agri-Food Canada; and
Resource Management Branch, BCMAF

FOR MORE INFORMATION CONTACT:
RESOURCE MANAGEMENT BRANCH
Ministry of Agriculture & Food
1767 Angus Campbell Road
Abbotsford BC, CANADA V3G 2M3
Phone: (604) 556-3100 Fax: (604) 556-3099

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Page 4 of 4
MANAGING POULTRY MORTALITY COMPOSTING SYSTEMS

Poultry composting can be accomplished by placing a 300 mm (12 in) layer of dry poultry litter in the bottom of a bin as shown in Figure 1. When carcasses release excess moisture, this absorptive base layer helps prevent release of highly odorous leachate.

Carcasses are placed on top of the base layer at least 300 mm (12 in) away from bin walls. Placement closer than this can lead to seepage of liquid through the walls. Keeping carcasses away from side walls also helps to maintain them at temperatures that speed decay and kill disease-causing microorganisms. Carcasses should not touch each other; too many carcasses in one spot leads to localized wet spots and poor composting.

After the carcasses are positioned inside the bin, they are covered with 100 to 150 mm (4 to 6 in) of poultry litter. Incomplete coverage can lead to fly problems.

Layering of carcasses and poultry litter continues until the bin is filled to a depth of about 1.2 in (4 ft), at which point it is capped with 300 mm (12 in) of dry poultry litter. In a properly operating compost operation, new material added to the bins reaches temperatures of 50 to 65 °C within 24 to 48 hours.

If dry broiler litter is not available, a mix of one part caged layer manure with 0.2 parts straw or sawdust by weight can be used as a substitute.

Two Stage Process

After a bin is completely filled, it must undergo a primary heating phase lasting 10-14 days. During this time, rapid microbial action depletes the oxygen within the bin, the rate of decay slows, and temperatures may begin to fall.

Following the first phase, the partially composted waste is removed from the primary bin and placed in a secondary bin. The mechanical action of moving the compost breaks up the pile, redistributes excess moisture, and introduces a new oxygen supply. Once this takes place, a secondary heating cycle occurs, accompanied by further decomposition.

By the end of the secondary heating phase, carcasses as large as 7 to 9 kg (15-20 lb) are normally reduced to bones that are reasonably clean and free of tissues that cause odors and attract insects and predators.
Large birds weighing 7 kg (15 lb) or more, may need a third heating phase to achieve complete decay, particularly if compost moisture content falls outside the optimal 50-60% range. If large birds constitute a major portion of daily flock losses, it is advantageous to compost large and small carcasses separately. This minimizes the amount of bin space tied up in a third heating cycle that is not needed for small carcasses.

**Composter Design**

In sizing a poultry composter, it is necessary to know, or estimate, the number and weight of birds in the enterprise, and the percent daily mortality expected. Maximum daily mortality on a weight basis usually occurs when birds are at or near market weight. Once the maximum daily mortality weight is known the number and size of composters can be calculated. See Mortality Compost Bin Design, Factsheet No. 382.500-10, for information.

**Monitoring the Composter**

Temperature is a good indicator of the "health" of the compost process. A probe-type dial thermometer with a 1 m (36 in) stem is a good instrument for monitoring temperatures in bins. Temperature should be checked daily to ascertain the condition of the compost. Normally, temperatures in the primary bins should rise to the 55-65 °C range in one or two days, and should peak in the 60-70 °C range in 7 to 10 days. Temperature is an important parameter in the control of fly larvae and pathogens. Typical temperature profiles for primary and secondary compost phases are shown in Figure 2.

Although experience indicates that temperatures above 75 °C are rare, a remote possibility exists that temperatures could rise to spontaneous combustion levels. Conditions conducive to spontaneous combustion occur in damp, deep-piled, compacted masses of organic matter. Experience indicates that compost piles limited to 1.5 m (5 ft) in depth, with the proper porosity and moisture levels, do not present a fire hazard. Nevertheless, the potential for spontaneous combustion should be kept in mind as temperatures are monitored. If temperatures appear to be rising towards the 75 °C level at a constant, or increasing rate, the compost should be removed from the bin and spread on the ground to cool.
MANAGING PORK MORTALITY
COMPOSTING SYSTEMS

COMPOSTING INGREDIENTS

The composting of dead swine requires the addition of a carbon source to ensure proper carbon/nitrogen ratios are present for the composting process.

Experience thus far suggests that sawdust is an ideal carbon source due to its small particle size, ease of handling, absorbency and high carbon content. The use of straw as the only carbon source has been less successful, with lower composting temperatures, leaching of fluids from the composting pile, and longer time required to complete the process. When sawdust is used as a carbon source, plan to provide about 6½ cubic metres of sawdust per 1000 kilograms of carcass (100 cubic feet per 1000 pounds) to be composted. For farrow-to-finish operations, total sawdust requirements are about one-quarter to one-third cubic metre annually per sow in the herd.

A precise carbon/nitrogen ratio does not seem to be necessary to obtain good composting, and most composting with sawdust as the carbon source has been done without adding supplemental nitrogen. However, if sawdust is used according to the above recommendations, some supplemental nitrogen may have to be added to obtain the ideal carbon/nitrogen ratio of 25. The addition of about 3 kilograms of ammonium nitrate (NH₄N0₃) in dry, granular form per 100 kilograms of swine carcass will provide the nitrogen necessary to achieve this carbon/nitrogen ratio. The ammonium nitrate should be mixed with the sawdust used to cover the carcass and can be applied by simply "hand-scattering". As noted previously, most composting is accomplished without the use of additional nitrogen, but this practice may help in starting up a new composting cycle and obtaining desired composting temperatures.

The type of sawdust used in composting can influence the success of the operation. Although a fine or small particle size sawdust is not absolutely necessary, large wood chips and shavings do not seem to work well. Sawdust or wood refuse material generated from bark and/or mulching operations may contain rocks, stones and other foreign material in addition to excessively large wood particles, and should not be used for composting.

Tests on fresh sawdust obtained from seasoned logs or kiln-dried lumber indicate a moisture content of 20 to 30 percent. Sawdust stored in piles tends to collect moisture, increasing its moisture content.

The ideal moisture content in a composting pile is 50 to 60 percent. Swine carcasses have a moisture content near this range. Since a large proportion of sawdust obtained from covered piles may be very dry, it may be necessary to adjust moisture content or add water to the composting recipe. If the sawdust is exceptionally dry or the composting pile becomes dry due to the internal heat generated, it will be necessary to add more water for optimal decomposition. The moisture content of sawdust or a composting mixture can be judged somewhat by its appearance and feel. Sawdust that has a damp appearance and feels damp is probably near the proper moisture content. If it appears wet, or free water can be squeezed out, it should be allowed to dry to a drier condition before being used. Fresh
sawdust taken directly from kiln-dried lumber or seasoned logs will probably be too dry necessitating the use of extra water. Water should be added as needed to obtain a damp feel and appearance. Very dry sawdust (20 percent or less moisture) may require the addition of up to 150 to 250 litres per cubic metre (1 to 1½ gallons of water per cubic foot) to obtain the proper moisture content. Water should be added by sprinkling or spraying as the sawdust is placed on the carcasses. The over-addition of water should be avoided, as excessively wet mixtures do not compost properly and may require removal and remixing with dry sawdust to recover the process. "Green" sawdust from fresh-cut, unseasoned logs may have a moisture content as high as 80 percent. Such sawdust may be too wet for optimum composting, and should be allowed to dry somewhat or should be mixed with drier sawdust or finished compost before use. A water line and hydrant installed at the composter will facilitate water addition and general cleanup activities.

Temperature is the best indicator that the composting process is proceeding properly. Temperatures in the composting pile should rise to the 55 to 70 °C range, indicating active microbial activity, and facilitating rapid breakdown of carcasses.

COMPOSTER MANAGEMENT

Although composters are simple and relatively easy to operate and manage, certain procedures are necessary to ensure that the process proceeds efficiently. The following steps should provide acceptable finished compost in a swine operation:

1. Start a primary composting bin by placing at least 300 mm (12 in) sawdust under and around the first carcasses. Carcasses placed directly on dirt or concrete floors, or against bin walls will not compost properly.

2. Place carcasses in the primary bin as necessary. It is very important to use sufficient sawdust so each carcass is covered on all sides with a minimum of 300 mm (12 in) of sawdust. Small pigs may be grouped or placed with somewhat less sawdust between them. A 300 mm (12 in) sawdust cover between carcasses and the pile surface should always be maintained to minimize odours and rodent problems. Hoofs, legs, ears, or snouts should never be left sticking out of the pile. Most problems in swine composting arise when insufficient sawdust is used as a top cover. A pointed rod or dowel can be used to measure the thickness of the cover. Large carcasses may need to be recovered after a day or two as sawdust settles. The compost pile should be roofed.

Carcasses placed in warm sawdust begin composting more quickly. This can be accomplished by placing more than the minimum 300 mm (12 in) sawdust cover over the previous carcasses. This allows the sawdust to heat up so that successive carcasses are then buried in this pre-warmed sawdust. A loader bucket can be used to dig out a cavity in the pre-warmed sawdust, before a fresh carcass is placed. If finished compost is available, it should be used to cover the carcass to provide additional heat and bacteria to initiate the composting process. Fresh sawdust should finally be used to provide the top cover thickness needed for a new cavity for the next carcass.

3. Monitor temperature of the composting pile with a long-stem, dial-type thermometer. When composting is proceeding properly, temperatures will reach 55 to 70 °C. Primary bins started during cold weather may not begin composting immediately. However, if carcasses are buried with the proper amounts of sawdust, composting should begin on its own as temperatures warm up gradually. There is usually enough heat in active (as opposed to newly started) compost piles to continue composting through cold weather. If sawdust is used as recommended, its insulation characteristics are sufficient to minimize the effects of cold ambient temperatures.

4. After the last carcasses placed in the primary bin have composted for three months or longer, move the contents to a secondary bin. This step provides mixing and re-aeration of the material so that the compost will "finish off" properly.

5. After the pile has composted another three months in a secondary bin, it should appear as a dark, granular, nearly black, humus-like material with very little odour. Some resistant ingredients such as teeth may still be identifiable, but should be soft and easily crumbled.
6. Use finished compost referenced above for “starter” material on new carcasses being composted in primary bins. This provides heat and bacteria to enhance startup of the composting process. Experience has shown that up to 50 percent of the sawdust requirement for composting can be met using "recycled" finished compost. However, plan to use fresh sawdust in the amounts described for starting up a new composting operation until sufficient finished compost becomes available. Haul and spread finished compost as needed using a conventional manure spreader. Apply finished compost at agronomic rates for the crop being grown. Obtain a laboratory analysis of the compost for nitrogen (N), phosphate (P₂O₅), and potash (K₂O) for precise fertilizer content.

7. Keep fresh sawdust as dry as possible because dry sawdust encourages a better composting process. In the Fraser Valley sawdust piles 8. should be covered to maximize dryness and minimize the generation of leachate. Fresh sawdust in a pile will shed some water if the pile is mounded, and has no pockets or depressions.

9. Keep the area around the composter mowed and free of tall weeds and brush. Watch for any leaching that might occur. Using more sawdust in the bottom of the bins can help eliminate leaching problems.

**COMPOSTER DESIGN**

In sizing a pork composter, it is necessary to know, or estimate, the number and weight of average daily mortalities expected. Actual past death loss data should be used in sizing composters for existing operations. For new operations having no history of average death loss see the data in Table 1 for information. Once the average daily mortality weight is known the number and size of composters can then be calculated. See Mortality Compost Bin Design, Factsheet No. 382.500-10 for more information.

<p>| TABLE 1 AVERAGE ANNUAL DEATH LOSS FOR SWINE IN CONFINEMENT |
|-----------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Weight Range (kg)</th>
<th>Average Weight (kg)</th>
<th>Annual Death Loss (%)</th>
<th>Annual Death Loss Per Animal Space (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sow Herd¹</td>
<td>160 - 180</td>
<td>170</td>
<td>6 - 8 %</td>
</tr>
<tr>
<td>Nursery²</td>
<td>6 - 25</td>
<td>15</td>
<td>22 - 26 %</td>
</tr>
<tr>
<td>Finishing</td>
<td>25 - 115</td>
<td>70</td>
<td>10 - 12 %</td>
</tr>
</tbody>
</table>

¹ Includes all mature animals, farrowing sows, gestating pigs, and boars
² Includes losses in farrowing house prior to weaning

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**FOR MORE INFORMATION CONTACT:**
RESOURCE MANAGEMENT BRANCH
Ministry of Agriculture & Food
1767 Angus Campbell Road
Abbotsford BC, CANADA  V3G 2M3
Phone: (604) 556-3100  Fax: (604) 556-3099
MORTALITY COMPOST BIN DESIGN

This factsheet covers composter sizing and design, with general information on each and special instruction on poultry and pig mortality composting. The last section deals with composter construction.

COMPOSTER SIZING
A composter should be sized to adequately process the mortalities typically expected on the farm.

**Poultry**
Bin systems constructed for composting poultry typically consist of bins having a total volume of 125 litres for each kilogram of average daily loss. Of this, 62 litres is required for primary composting and 62 litres for secondary. In imperial units this is equivalent to one cubic foot each of primary and secondary bin volume per pound of average daily loss. For example, a broiler farm averaging 100 kilograms of loss per day would need approximately 6.2 cubic metres of primary bin capacity and the same amount of secondary bin space. See Managing Pork Mortality Composting Systems, Factsheet No. 382.500-9, for information on estimating average daily losses.

**General**
While some producers find that they can manage with less capacity, the extra space costs little and provides valuable operating flexibility for contingencies such as short periods of higher than average mortality, busy times of the year when bins cannot be emptied on schedule, or occasional batches that require additional time to decompose completely.

Total bin volume recommendations suggested here assume only average daily death losses. Catastrophic losses due to disease, ventilation failures, or other unpredictable events would require considerably larger facilities.

COMPOSTER DESIGN
Composter design and layout can be determined once primary and secondary composting volumes have been estimated. Layout of a composter should be as flexible as necessary to accommodate existing features, restrictions, traffic patterns, equipment or other factors peculiar to a given operation. No specific layout is necessary or best in all cases. Following are some considerations in designing a mortality composter.

1. Provide primary and secondary composting volumes as calculated previously.
2. Depth of compost bins should not exceed 1.8 m (6 ft) so as to reduce compaction effects and the potential for spontaneous combustion. An ideal bin depth is 1.5 m (5 ft).

3. Since small carcasses are usually placed inside the primary composting bins by hand, the front of the bin should be designed so that carcasses need not be lifted over a five foot high door. This can be accomplished with removable dropboards that slide into a vertical channel on each side of the bin or with doors that split horizontally.

4. Width of compost bins is usually selected to accommodate the loading/unloading equipment to be used. Tractor front-end loaders, or skid-steer loaders are typically used to load and unload bins. Bin width should be at least 300 mm (12 in), and preferably 2/3 to 1 m (2-3 ft) wider than the bucket used for unloading, in order to prevent excessive mechanical damage to the bin or loader. If wheels on the loading/unloading equipment are wider than the bucket, the bin should be widened accordingly.

5. Length of compost bins is typically 1.5 m (5-6 ft) for poultry and 3 to 4.5 m (10-14 ft) for pork. Longer bins are more difficult to enter and exit, and composting proceeds more efficiently if the composting mass lies in a somewhat square configuration, rather than in a long rectangular bin.

6. Several, smaller primary composting bins work more efficiently than a few very large bins.

7. Even though calculations may indicate fewer, a minimum of two primary bins is required. This allows use of the second bin while the top layers of the first bin are still composting.

8. Secondary composting volume may be provided in bins which are duplicates of the primary bins, or may be provided in one bin equal to the total required secondary volume.

9. It may be desirable to add one or two extra primary composting bins in a composter design. These bins can be used for storage of ingredients such as litter, sawdust, etc. If unusually high mortalities occur during some period, these extra bins could be put into service to compost the extra mortalities. Experience has shown that some ingredient storage at the composter site greatly facilitates management of the process.

**Poultry**

The number of bins in a composting system will depend on individual bin dimensions and the total required bin volume. Bins with up to 7 to 8 cubic metres (250-300 cubic feet) of capacity are recommended for small carcasses. These bins would have floor areas of about 5 square metres (50 square feet). Extremely large bins that take a long time to fill are undesirable since they lead to unnecessarily long heating times for the first carcasses placed.

Example 1 illustrates the method of determining the number of primary bins needed for a poultry mortality composting system. Since fractional sized bins cannot be used, the calculations suggest that three primary bins be provided. Two bins might be adequate some of the time, but primary composting volume may be inadequate during periods of high death loss with only two bins. Three or four bins would provide some room for ingredient storage, with excess composting volume available in the event of expansion of bird numbers or higher than expected death loss. The primary bins may be arranged in any configuration suitable to the operator. Generally, it is most efficient to arrange bins so that primary compost can be easily and quickly moved to the secondary composting area.

Figure 1/Layout A, is a schematic of a composter layout using three primary bins, with secondary composting volume provided in bins opposite the primary bins. A litter/ingredient storage area is provided at one end of the unit to facilitate management of the system.

Figure 1/Layout B, is a schematic of a composter integrated within a litter storage unit. In this system, litter is available as needed from the litter storage area. This area also provides long term storage for finished compost and litter not used in the composting process. As environmental concerns increase, the need for a litter storage facility is likely to become more acute. Litter spreading (including finished compost) should be done when climatic conditions and crop nutrient needs are most favorable to minimize environmental impacts.
EXAMPLE 1

How many primary compost bins are needed for mortalities from a chicken broiler operation that has an average daily death loss of 160 kg (350 lb)?

1. Primary composting volume: $160 \text{ kg} \times 62 \text{ litres/kg} = 9920 \text{ litres} = 9.92 \text{ cubic metres}$
   or $350 \text{ lb} \times 1 \text{ cubic foot/lb} = 350 \text{ cubic feet}$

2. Primary bin depth: 1.5 metres (5 ft) recommended

3. Primary bin width: bucket width plus 2/3 to 1 m (2-3 ft) recommended
   if bucket is 1.2 metres (4 ft) wide then width should be about 1.9 metres (6 ft)

4. Primary bin length: 1.5 metres (5 ft) recommended

5. Primary bin volume (depth x width x length): $1.5 \text{ m} \times 1.9 \text{ m} \times 1.5 \text{ m} = 4.28 \text{ cubic metres}$
   or $5 \text{ ft} \times 6 \text{ ft} \times 5 \text{ ft} = 150 \text{ cubic feet}$

6. Number of primary bins (total primary volume / primary bin volume):
   $9.92 \text{ cubic metres} / 4.275 \text{ cubic metres per bin} = 2.32 \text{ bins}$
   or $350 \text{ cubic feet} / 150 \text{ cubic feet per bin} = 2.33 \text{ bins}$
Pork

The number of bins required in a composting system will depend on individual bin dimensions and the total required bin volume. Bins with 15 to 30 cubic metres (500 to 1,000 cubic feet) of capacity are recommended for large carcasses. Bins of this volume would have a floor area of about 10 to 20 square metres (100 to 200 square feet). Extremely large bins that take a long time to fill are undesirable since they lead to unnecessarily long heating times for the first carcasses.

Example 2 illustrates calculations and assumptions in determining the number of primary bins needed for a pork mortality composting system.

A minimum of three months composting time is needed in both the primary and secondary phases. It may be necessary to extend this period of time if an unusual number of large carcasses are composted, or if ambient temperatures are low.

In most cases a minimum of three bins will be required, two of which are used for primary composting and the third for secondary composting.

In a typical scenario, the first bin is filled with three months of death losses, at which time the second bin is started. At the end of the second three-month period, the second bin is full, and the last carcasses placed in the first bin have composted for three months. The contents of the first bin are then ready to move to the third bin for the secondary composting phase. After three months of secondary composting, the material can be moved out and applied to land, and the secondary bin (the third one) is available to receive the contents of the second bin. Larger operations will require more than the minimum three bins. Experience has also shown that having extra bins available for storage of fresh sawdust and finished compost is beneficial.

COMPOSTER CONSTRUCTION

Actual construction of a composter can be of many different forms, all producing good results. Some essential features to consider are location, type of structure, construction materials and ingredient storage. All good composters will include some or all of the following characteristics:

**EXAMPLE 2**

How many primary bins are needed for composting mortalities from a 200 sow farrow-to-finish operation that has an average daily death loss of 55 kg (120 lb)?

<table>
<thead>
<tr>
<th>Step</th>
<th>Calculation</th>
</tr>
</thead>
</table>
| 1.   | Primary composting volume: 55 kg x 1.25 cubic metres/kg = 68.75 cubic metres  
 or 125 lb x 20 cubic feet/lb = 2500 cubic feet |
| 2.   | Primary bin depth: 1.5 metres (5 ft) recommended |
| 3.   | Primary bin width: bucket width plus 2/3 to 1 m (2-3 ft) recommended  
 if bucket is 1.5 metres (5 ft) wide then width should be about 2.44 metres (8 ft) |
| 4.   | Primary bin length: 3 to 4.5 metres (10 to 14 ft) recommended  
 select a length of 3 metres (10 ft) |
| 5.   | Primary bin volume (depth x width x length): 1.5 m x 2.44 m x 3 m = 11 cubic metres  
 or 5 ft x 8 ft x 10 ft = 400 cubic feet |
| 6.   | Number of primary bins (total primary volume / primary bin volume):  
 68.75 cubic metres / 11 cubic metres per bin = 6.25 bins  
 or 2500 cubic feet / 400 cubic feet per bin = 6.25 bins |
**Location / Access**

Location of a composter should take into account any impact it may have on the farm residence and any nearby neighbor residences. While offensive odors are not usually generated in the composting process, the handling of dead birds and pigs, manure and litter on a daily basis may not be aesthetically pleasing. When locating a composter, consideration should be given to traffic patterns required in moving dead birds or pigs, moving the required ingredients and removing finished compost from the composter. The composter site should be well-drained and provide all-weather access roads and work areas.

**Foundation / Floor**

An impervious, weight-bearing foundation and floor should be provided for all primary and secondary composting areas. This feature ensures all-weather operation, helps secure the composter against rodent access and generally minimizes the potential for contamination of the surrounding area. In addition to providing concrete under the compost bins, themselves consideration should also be given to providing a similar concrete floor in traffic areas and work alleys. Experience has shown that, with the frequent loading and unloading activities associated with composting, dirt or even gravel areas tend to become rutted and potholed. This condition is worsened even more if the work alleys are not roofed.

**Construction Materials**

Any portion of the composter structure such as poles, and sidewalls which will be in contact with dirt or composting material should be constructed with pressure treated lumber or other rot-resistant materials.

**Roof**

Experience has shown that a roof covering the primary and secondary composting bins is necessary to control rain water and the moisture content of the composting mass. Roofing the working area as well facilitates all-weather activities. Additionally, any ingredient storage areas or bins should be roofed to preserve the ingredients at the desired moisture content. Roof heights must be adequate to ensure clearance for front end loaders; however, a high roof may allow too much direct rain or draining roof water to be blown into the composter. This problem can be minimized with the addition of partial sidewalls, and roof gutters.
**Ingredient Storage**

Experience has shown that having sufficient amounts of ingredients such as sawdust, and litter, present at the composter greatly facilitates day-to-day management of the process. Litter, however, may only be readily available during periods of partial or total building cleanout. Inclement weather can also hamper the handling and transfer of ingredients in a timely fashion. In determining the amount of storage needed, consideration should be given to the frequency with which ingredient transfer and restocking can be managed. Storage requirements may vary considerably among different operations. It has been suggested that providing a minimum of two bins (of primary bin size) for ingredient storage will sufficiently facilitate the operation of a four-primary bin composter. If more than four primary bins are required, ingredient storage may need to be increased according to the above ratio. Bins used for storage can double as primary composting bins if needed, during periods of high death loss, or may facilitate expansion of the composter if the farm is increased. Ingredient storage does not have to be in bins, but the ingredient storage area should be roofed.

If the composter can be constructed in conjunction with a litter storage facility, ingredient handling may be greatly simplified. Litter will be readily available from the litter storage area and other ingredients can be stored appropriately in the same location.

Although most poultry operations in British Columbia do not use litter storage facilities, experience has shown that such facilities can greatly enhance the management of building cleanout and field spreading operations. Since outside storage of litter in uncovered piles represents a potential environmental liability, litter storage facilities are required by regulation to be covered from October through April.

**Finished Compost Storage**

Secondary compost bins provide a place for compost to undergo a second heating cycle and further composting. However, as secondary bins become full, the compost must either be spread on the land or moved to a finished compost storage area. Any compost storage area should be covered to prevent rainfall from saturating the pile, which could cause leaching. A litter storage facility can also be used to store finished compost until land spreading can be conveniently carried out.

**Utilities**

A water line with freeze-proof hydrant at the composting facility will aid in adjusting the moisture content of the recipe if needed, and further facilitates cleanup and washdown of personnel, equipment and the composting area as needed. A minimum 20-amp electrical circuit will allow the use of power tools, lights or other appliances which may be needed at the compost facility.
Composting organic material has many benefits. Organic wastes are diverted from landfill or other disposal sites. Composted material can be used as a soil amendment or nutrient source. Composting stabilizes some of the nutrients in wastes so that they are not as readily leached out. This decreases the potential for ground and surface water contamination. The use of compost on low organic matter soils results in improved moisture and nutrient retention, decreased soil erosion, reduced surface crustling, suppression of plant diseases and improved soil tilth. Composting of organic wastes kills weed seeds, pathogenic bacteria and viruses.

There are environmental risks associated with composting and compost use. Some risks are inevitable, but others are related to improper compost production or improper use. Ground and surface water pollution can occur as a result of improper use of compost. Air pollution can also occur when composting. See Regulations Affecting Composting, Factsheet No. 382.500-12, for more information on regulation.

**ENVIRONMENTAL CONCERNS DURING PRODUCTION OF COMPOST**

**Water Quality**

Composting of organic wastes must be performed only in locations where leaching of pollutants from the operation is minimized. The leachable pollutants in agricultural waste include bacteria (some pathogenic), phenolic compounds, ammonium nitrogen, nitrate nitrogen, potassium, and water containing a high biochemical oxygen demand. Potential pollutants from composting municipal or industrial wastes include heavy metals and petrochemical compounds.

Composting wastes must be protected from rainfall that can leach pollutants. Composting should be performed on an impervious surface, such as a concrete pad. Facilities to contain runoff in order to prevent leaching and diffusion of pollutants into the soil and/or groundwater must be provided. No runoff can be discharged without a permit from the B.C. Ministry of Environment, Lands and Parks. See Site Selection for Composting, Factsheet No. 382.500-6, for an example of a runoff and leachate collection system.

**Air Quality**

Composting of organic wastes also results in the formation of products that affect air quality such as: ammonium; NOx; methane, and of other potential harmful organic compounds. Odours are typically generated as well.

**Odour:** Odour is often the most noticeable air quality concern. Most organic wastes will generate some foul odour during the composting process. Foul odour increases when the composting material is allowed to become anaerobic. Therefore, odours can be minimized with proper aeration. Prevailing wind direction and proximity to residential areas are important factors to take into consideration in selecting sites for composting. Biofilters are an option with aerated static pile composting, or if the compost facility is enclosed within a building.

**Ammonia (NH4):** Ammonia acidifies rain, contaminates surrounding areas with excess nitrogen (N) and causes foul odours.
Ammonia loss is inevitable in most composting facilities. However, those with low C:N ratios wastes will result in the greatest ammonia losses. Addition of wastes with high C:N ratios may reduce ammonia loss only if the carbon (C) is easily degradable. Thus, addition of high carbon woodwastes is not very effective because carbon in such products is released slowly.

**Nitrous Oxide and Other NOx Gases:** During intense microbial activity, as occurs in the compost process, there is significant loss of nitrogen as nitrous oxide and other NOx gases, particularly nitric oxide (NO). Nitrous oxide (N2O), for example, is 240 times more harmful than CO2 in contributing to global warming. It is a stable gas and diffuses to the stratosphere where it destroys ozone. At present, there is little research on the management of these gases during composting.

**Methane (CH4):** There is some indication that the diversion of organic wastes away from landfills will reduce the production of anthropogenic (produced by human activities) methane. While this diversion of wastes will reduce methane emissions, unfortunately there may be increased NOx emissions as a result.

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**ENIRONMENTAL CONCERNS ASSOCIATED WITH THE USE OF COMPOST**

**Water Quality**

Although many of the nutrients in compost have been stabilized during the composting process, they can contribute to leaching over the long term. Heavy applications of compost may release more nitrogen than can be utilized by the crop, with subsequent risk of groundwater pollution. Therefore applications of compost should be based on the availability of mineralizable nutrients such as nitrogen for crop requirements. See Using Compost, Factsheet No. 382.505-15, for discussion on proper use of compost.

**Disease and Weed Transmittance**

If composted properly, potentially harmful bacteria, viruses, and weed seeds, are destroyed by high temperatures of 55º to 60 ºC (130º to 140 ºF) for three days. Achieving these temperatures should therefore be a priority. Potential users will be reluctant to utilize compost if they have experienced disease or weed infestations resulting from improper management.
REGULATIONS AFFECTING COMPOSTING

AGRICULTURAL COMPOSTING, REGULATIONS

The ultimate goals of composting are to produce a good growing medium for plants and a stabilized source of nutrients in an organic form. Within British Columbia, composting and, to a lesser extent compost quality are regulated primarily by two acts. The Waste Management Act and the Agricultural Land Commission Act. Composting of other wastes, such as municipal solid waste, yard waste and biosolids or the co-composting of agricultural waste with other wastes is not considered to be agricultural composting and could be subject to regulation by several other Acts.

Waste Management Act

In British Columbia there are three kinds of composting which may occur on a farm that are considered agricultural composting as defined by the Code of Agricultural Practice for Waste Management, part of the Agricultural Waste Control Regulation, under the Waste Management Act:

1. Agricultural wastes produced on a farm that are composted and used on the same farm for various agricultural and horticultural purposes.
2. Agricultural wastes both produced and composted on a farm and sold off or distributed off the farm.
3. Agricultural wastes produced off the farm but brought to a farm and composted. The resulting compost must be used on the farm.

Composting operations which do not fall within the preceding three categories are not considered agricultural operations, and are subject to regulation under the Waste Management Act or the Production and Use of Compost Regulation.

Agricultural Waste is defined under the Agricultural Waste Control Regulation and includes manure, used mushroom media and agricultural vegetation waste. Woodwaste is the only non-agricultural waste that can be co-composted with agricultural waste, and the resulting compost may used on the farm or be sold off the farm. However, the woodwaste must have been previously used on the farm for one of the allowed uses described in the Code of Agricultural Practice for Waste Management. Note: Although the Code does not allow the direct use of woodwaste in composting, it is implied that this would be an allowed use.

Materials used to make compost include, but are not limited to, manure, straw, vegetative waste, wood waste, other sources of carbon and nitrogen, and bulking agents.

In some instances it may be necessary to add materials or wastes not produced on the farm to produce good quality, useful compost. For example, fish waste may be used to balance the carbon:nitrogen ratio of woody wastes from nurseries. Similarly, straw, woodwaste or ground paper may be blended with manure high in nitrogen and moisture. Non-agricultural wastes brought onto a farm for composting purposes requires a permit or approval from Ministry of Environment, Lands and Parks.

Farm practices must not cause pollution. If a farm operation does not comply with the Code, it may need to be operated under a waste management permit. The B.C. Ministry of Environment, Lands and Parks is authorized to take legal action anytime under the Waste Management Act should pollution occur.
**Agricultural Land Commission Act**

In addition to regulations under the Waste Management Act which govern composting, there are provisions under the *Agricultural Land Commission Act* and the *Soil Conservation Act* which allow the Agricultural Land Commission to set policies which control composting activities on lands within the Agricultural Land Reserve (ALR). Policy 014/86 deals with composting and divides such activities into three categories:

**Category 1: General Commercial Composting.** This includes general composting, including municipal solid waste, that may be part of a municipal or regional waste disposal program. A variety of materials may be composted from different sources and may or may not use agricultural waste as part of the process.

**Category 2: Agriculture Commercial Composting.** This includes facilities that have a strong agricultural orientation due to one or several forms of locally generated animal waste being a prime input into the operation.

**Category 3: Farm Composting.** This includes the composting of wastes originating on and off the farm for the purposes of the farm operation. Waste may be brought onto the property if the composting operation is for growing medium or a product to be used exclusively for the farm operation upon which the composting activity is taking place. Examples include mushroom farms, nurseries and greenhouses.

The third category above deals with the types of composting activities which are allowed for under the *Agricultural Waste Control Regulation*. The second category deals with composting operations which are not considered to be agricultural composting operations although they may be carried out on agricultural land with permission. The first category describes operations which would likely require exclusion of the land from the ALR.

**Farm Practices Protection (Right to Farm) Act**

This Act provides farmers with the fundamental right to farm in B.C.’s important agricultural areas, particularly in the Agricultural Land Reserve, provided “normal farm practices” are followed and other legislation is abided by, specifically the Waste Management Act, Pesticide Control Act and the Health Act. The Farm Practices Protection Act protects farmers from undue nuisance complaints regarding odour, dust and noise and provides a complaint resolution process.

**COMPOST QUALITY**

Although agricultural composting is not regulated by compost quality criteria, compost products, leaving a farm will enter a market where many products are governed by such criteria. The following discussion pertains to compost quality criteria and the parameters which are usually measured. See *Managing Agricultural Composting Systems, Factsheet No. 382.500-7*, for an example of compost quality criteria.

As previously mentioned, the goals of composting are to produce a good growing medium for plants or a stabilized source of nutrients in an organic form. Parameters such as moisture content, maturity, total organic matter content, porosity, water retention, particle size, pH, nutrient content and specific conductance (soluble salts) are factors which may be used to evaluate compost quality. Also of importance are the presence of unwanted items such as soluble salts, stones, glass, metal, plastic, pathogenic bacteria, viable weed seeds, pesticide residues and heavy metals. In general, compost containing these contaminants is not acceptable for any agricultural use.

Foreign material, in a compost product is defined as the presence of organic or inorganic material that is not readily decomposed, such as glass, metal, plastic, leather and bones, but does not include sand, grit or small stones. Some of these materials may not be a concern for certain agricultural applications or for a low grade use such as landfill cover, but if present in noticeable quantities, can make compost unacceptable for use in horticulture production, and landscape gardening. Compost is classified in the *Production and Use of Compost Regulation (Schedule 2 part 2(a))* by the proportion of foreign matter present as follows:

- **Class 1:** $\leq 1\%$
- **Class 2:** $> 1\%$ but $\leq 2\%$
- **Class 3:** $> 2\%$ but $\leq 10\%$
Pathogens

The current standard in Canada (CAN/BNQ 413-200) for pathogens in compost is that faecal coliforms concentration must be less than 1,000 MPM/g (oven dried mass) and that no salmonella are to be present. The factors that bring about the destruction of organisms pathogenic to humans, animals and plants in the compost process are mainly a function of heat, time and competition from other microorganisms.

Heat: Temperatures should be at sufficiently high levels for a period of time long enough to destroy all pathogenic organisms. For example, salmonella typhosa does not grow beyond 46°C (115°F), and dies within 30 minutes at 55°C to 60°C (130°F to 140°F) and within 20 minutes at 60°C (140°F). Some plant pathogens or fungi may require temperatures of 50°C (122°F) for up to 14 days for complete control. Most organisms are destroyed within a short time in the active phase of a well functioning compost.

Time: Pathogens do not die instantaneously; some time is usually required. Section 9(1)h of the Production and Use of Compost Regulation, (BC Reg 334/93), published by the B.C. Ministry of Environment, Lands and Parks describes specific time and temperature requirements. Generally, if all organic waste has been exposed to 55°C for 3 or more consecutive days, pathogens will be significantly reduced.

Weeds, Animal Health Products and Pesticides

As is the case for pathogen extermination, destruction of weed seeds generally occurs if the entire composting mass achieves a temperature of 55°C (130°F) or more for three consecutive days. Apart from this, note that under the Weed Control Act, it is illegal to sell noxious weed seeds, such as Canada Thistle at all.

Animal health products such as drugs and hormones are reported to be destroyed if the composting process remains thermophilic for a minimum of three days.

Metals

Metals will not normally be of concern if you use clean agricultural feedstocks. Feedstocks are described in Co-composting with Off-Farm Wastes, Factsheet No. 382.500-13. For these materials, guidelines for metal concentrations exist. High concentrations of heavy metals in soils can affect the health of humans and animals eating crops grown on these soils. Once applied, most metals remain in the crop rooting zone for many years. The Production and Use of Compost Regulations published by BCMELP details the allowable trace metal content of municipal solid waste compost, including those available "on an unrestricted basis". Some example of allowable limits are listed in Table 1.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Concentration (mg/kg dry wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>≤ 13</td>
</tr>
<tr>
<td>Cadmium</td>
<td>≤ 2.6</td>
</tr>
<tr>
<td>Chromium</td>
<td>≤ 210</td>
</tr>
<tr>
<td>Cobalt</td>
<td>≤ 26</td>
</tr>
<tr>
<td>Copper</td>
<td>≤ 100</td>
</tr>
<tr>
<td>Lead</td>
<td>≤ 150</td>
</tr>
<tr>
<td>Mercury</td>
<td>≤ 0.8</td>
</tr>
<tr>
<td>Molybdenum</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Selenium</td>
<td>≤ 50</td>
</tr>
<tr>
<td>Zinc</td>
<td>≤ 2</td>
</tr>
</tbody>
</table>

*From: Production and Use of Compost Regulations BC Reg 334/93.*

*Metal concentrations (Code 1) refer to compost classed as Types Y and A, i.e. compost which has unrestricted distribution.*
NON-AGRICULTURAL COMPOSTING, ANCILLARY REGULATIONS

A number of regulations relative to compost production relate to potential health hazards, while others are primarily concerned with the commercial production and sale of compost. There are three levels of government that establish legislative requirements for composting operations: local, provincial and federal. Each of these has jurisdiction over producers in aspects that legislate the prevention of pollution or nuisance. Compliance with one agency does not necessarily mean that requirements are satisfied for all agencies. Non-compliance with the legislation or regulation of any agency may result in fines, jail terms or regulated compliance, for example the requirement to operate under a permit.

Local Government

Local governments have the authority to enact and enforce a variety of land use plans and zoning bylaws that affect agricultural operations. Zoning bylaws delineate specific areas for agriculture within local government regions or districts, as well as establish specific setbacks for the siting of farm buildings. Specific setback distances from lot lines and watercourses are to help reduce conflicts with neighbours and to minimize pollution risk.

Local government authority to establish legislation affecting agriculture is given under the Municipal Act; however, all municipal planning and legislation within the Agricultural Land Reserve is subject to the Agricultural Land Commission Act, and the Farm Practices Protection (Right to Farm) Act.

When changes are made to a zoning bylaw, existing operations not in compliance with the new bylaw will be protected under the non-conforming section of the Municipal Act. This means that the operation would be considered "legally non-conforming" and could operate as previously, but would be limited to its present size. Expansion of a farm operation would require total conformance to any new bylaw.

Each local government varies in the number of bylaws affecting agriculture. Local government legislation can regulate such things as:

- specific setback distances from lot lines for buildings;
- building requirements in flood plains;
- nuisances, for example, excessive noise from machinery; and
- setback distances for facilities from watercourses.

With the enactment of the Farm Practices Protection Act, farm bylaws have been introduced into the Municipal Act that give local governments more flexibility in regulating the conduct of farm operations. Farm bylaws have to be approved by the Minister of Agriculture, Fisheries and Food.

Provincial Government

There are four provincial government ministries in British Columbia that administer Acts affecting farm practices on B.C. farming operations. When provincial and federal acts or regulations change, producers must meet such changes, since there is no "non-conforming status" as in local government legislation.

1. Ministry of Municipal Affairs, Recreation and Culture

   Municipal Act. This Act gives local governments the authority to write bylaws that control the use and development of land, including the regulation of farming operations. Control of land is achieved through community plans, land use bylaws and development permits. The Municipal Act also gives local government the authority to make bylaws that control nuisance. Any of these regulations could effectively control the method of composting, or in more extreme cases, prevent the existence of operations at all.

2. Ministry of Health

   Health Act. This Act regulates farm practices that could constitute a health hazard. A health hazard may occur, for example, if manure or other wastes are discharged to land, water or air to such an extent that nutrients or pathogens cause a health problem to the general public. Sanitary regulations for example, specifically address dead animal disposal. These regulations could affect the use of mortalities or off-farm wastes in composting operations.

3. Ministry of Environment, Lands and Parks

   Waste Management Act. This Act is the primary provincial legislation responsible for controlling waste within the agricultural industry. Pollution is defined under the Waste Management Act as "the presence in the environment of
substances or contaminants that substantially alter or impair the usefulness of the environment”.

The Agricultural Waste Control Regulation, part of the Waste Management Act, is supplemented by a set of farm practice standards called the Code of Agricultural Practice for Waste Management (Code). This Code deals with the application and composting of agricultural wastes, and does not address non-agricultural waste composting.

Farms that compost off-farm yard waste with livestock manures and produce less than 20,000 m³ of finished compost per annum must comply with Section 3 of the Production and Use of Compost Regulations part of the Waste Management Act, as well as the Code. However, operations that mix other off-farm feedstocks will likely need to comply with Section 15, Request For Individual Exemption.

The purpose of the Production and Use of Compost Regulation is to facilitate recycling and resource recovery, and to protect the Province’s land and water resources by regulating the production and use of compost made from municipal solid waste. This regulation does not cover the composting of on-farm wastes. This regulation does cover the composting of any municipal solid waste (MSW), and yard waste if the annual finished compost volume is greater than 20,000 m³. The regulation sets strict limits on the size and location of a site as well as on the composting processes to be followed. Operations that compost sewage sludge (biosolids) are dealt with separately under other regulations. The compost operations which have an annual production of less than 60 cubic meters.

4. Ministry of Agriculture, Fisheries and Food

Agricultural Land Commission Act. This Act establishes the Agricultural Land Reserve (ALR), a provincial land use authority which designates the primary use of lands within its boundaries. The Agricultural Land Commission, through the Act, can specify allowed uses such as composting operations.

The Soil Conservation Act deals strictly with the removal and placement of fill on a property within the ALR. This Act can pertain to the development of composting facilities.

Federal Government

Fisheries Act. At the present time, the Fisheries Act is the primary federal legislation that addresses pollution from farms. This Act prohibits any unauthorized deposit of a deleterious substance into water frequented by fish or into water that may eventually enter water frequented by fish. Environment Canada, in cooperation with Fisheries and Oceans Canada, has the lead role in the administration of pollution control provisions for the Fisheries Act. The Canadian Shellfish Sanitation Program monitors shellfish water quality, and is included in the Fisheries Act. Examples of deleterious substances are manure, compost, runoff from compost production areas, and woodwaste leachate. The Fisheries Act is considered to be the strongest legislation for pollution control in British Columbia.

Fertilizer Act. Since compost may be used as an organic fertilant, the Fertilizer Act must be abided by. Applicable sections in the Act are titled: Exemptions from Registration, Registration, Standards, Regulations, Guaranteed Analysis and Labelling. Depending on the operation, a permit may or may not be required. The Fertilizer Act also provides details on nutrient content criteria.

Canadian Environmental Protection Act. Section 8(1)(b) of this Act presents guidelines on compost labelling under the auspices of the Environmental Choice Program. Manufacturers or importers of compost wanting to identify their product with The Environmental Choice EcoLogo must conform to this guideline.

Organic Soil Conditioners - Compost National Standard Of Canada (CAN/BNQ 413-200). This national standard for compost quality was prepared by Le Bureau de normalisation du Québec and is a voluntary standard for the industry.
Co-composting: Is defined as the composting of a mixture of two or more types of wastes, for example manure and yard waste.

Composting is just one of several approaches that can turn both on-farm and off-farm waste materials into a resource. As an alternative to simply applying manure to land, more and more farmers are looking at the possibility of co-composting manure with other organic materials. The finished compost is then marketed off the farm.

It should be noted that a farm composting its own agricultural wastes, or bringing in agricultural waste from another farm for use on the farm, legislatively falls under the Waste Management Act and Code of Agricultural Practice For Waste Management (Code). Any other composting operation is subject to the Waste Management Act and possibly to the Production and Use of Compost Regulation, as described in Regulations Affecting Composting, Factsheet No. 382.500-12. Co-composting operations are regulated by the Waste Management Act, meaning that they may require a Waste Management Permit for any emissions to the air, or discharges of leachate or contaminated water. Municipal solid wastes and biosolids have a separate regulation governing their use. For clarification, in Bill 29-1992, Waste Management Amendment Act, 1992, Section (1)(b), municipal solid waste (MSW) means ",(a) refuse which originates from residential, commercial, institutional, demolition, land clearing or construction sources, or (b) refuse specified by a manager to be included in a waste management plan."

Co-composting livestock manure with clean organic agricultural and non-agricultural wastes offers a number of opportunities for farmers. It can generate revenue by converting livestock manure into a stable, marketable Soil conditioner. For some producers, it can solve manure handling and odour problems. Other recognized uses for compost are as bedding material, and as a fertilizer.

The primary advantage for using off-farm waste (for producers who have material to compost) is to aid in the creation of a proper starting mix. It is necessary to achieve a starting mixture with a Carbon to Nitrogen ratio of 20:1 to 30:1, a moisture of 40 to 60%, and a porosity of 50%. The blending and balancing sequence should satisfy the C:N ratio first, moisture second, and lastly, porosity. See Blending Materials for the Composting Process, Factsheet No. 382.500-4, for more information on mixing materials. Most farms have an abundant supply of nitrogen rich composting materials, but need an outside source of carbon to achieve the correct starting C:N ratio. For instance, a turf grower with wet, high nitrogen grass clippings, needs a dry carbon source. Pork producers with very fine and wet manure solids high in nitrogen need a porous carbon source.

Composting is not a new phenomenon, and is well suited to agricultural applications. Some sources of off-farm wastes suitable for composting include:

- Yard Waste (grass clippings, prunings,)
- Hatchery Waste (mortalities, egg shells,)
- Food-Processing Waste (cleanings, trimmings,)
- Woodwaste (sawdust, shavings,)
- Fish Waste (mortalities or cleanings)
- Paper and Cardboard Waste (non-waxed)

Operations co-composting non-agricultural waste with agricultural waste would not be considered agricultural composting operations (under the Waste Management Act).
Yard Waste

Yard waste is vegetative matter resulting from gardening, horticulture, landscaping or land clearing operations, and includes materials such as tree and shrub trimmings, plant remains, grass clippings and chipped trees. Depending on the season, these materials (other than grass clippings) are generally high in carbon and are comprised of large particle sizes, making them useful as a carbon source or bulking agent in the initial compost blend.

Yard waste can be combined with other farm generated wastes, such as manure, to accelerate the composting process and provide an environmentally sound means of farm waste management. Composted yard wastes are converted into soil amendments or mulches for use by residents, nurseries, park services, government and private landscapers and other groups. As with other composts, composted yard waste can improve the soil’s physical, chemical and biological properties. As a mulch, composted yard waste can modify soil temperatures, reduce erosion, control weeds and improve moisture retention.

Woody materials can also be ground or shredded and perhaps processed further to produce a mulch. Leaves can be incorporated directly into the soil to build up organic matter. However, since yard waste will compete with growing plants for nitrogen, composting is recommended before incorporating it into the soil.

The mass and volume of yard wastes can be considerably reduced by composting. See Composting Methods, Factsheet No. 382.500-5 to determine suitable methods for co-composting yard wastes with livestock manures.

The B.C. Ministry of Environment, Lands and Parks’ Production and Use of Compost Regulation applies to facilities that produce more than 20,000 m³ of yard waste compost per year, or facilities that compost any volume of municipal solid waste. This Regulation identifies criteria relating to materials, setbacks, site design and location, storm water and leachate management, and other design criteria. For operations producing less than 20,000 m³ per year, Sections 3 and 4, Yard Waste and Prohibitions, of the Regulation apply.

Broiler Hatchery Waste
Commercial hatchery waste can also be used as co-compost with livestock manures. There is a generous supply of hatchery waste in the Fraser Valley, and some producers are looking for alternative ways of handling their waste. The mechanics of composting are straightforward and easily carried out on any farm with a bucket loader. A covered area with a concrete floor is required for environmental reasons. A major concern with hatchery by-products is disease transmission from the waste to livestock. The composting of hatchery waste with poultry litter will produce a safe, rich organic product, at the same time removing waste from municipal landfills.

The composted end product will be free of pathogens that could jeopardize the health of humans or poultry as long as the moisture content in the compost piles is controlled and elevated temperatures are maintained.

A recent study found hatchery waste composted with poultry litter produced compost with 1% nitrogen, 2.5% phosphorus and 0.25% potassium on a dry weight basis. Additionally, a calcium concentration (CaCO₃) of 60% and a full compliment of micro-nutrients was produced. Values of calcium are generally three to six times higher than composted manures.

Food Processing Waste
Food-processing waste consist of such items as reject fruits and vegetables from canning or packing plants, offal from meat processing plants, winery tank cleanings and milk and cheese processing wastes. Approvals or permits may be required for using these types of wastes. Food-processing wastes are more suited to larger-scale composting operations.

These wastes will have variable characteristics depending upon the process used to generate them. Many of these wastes are wet, and generally have a moderate to low C:N ratio. The best way to utilize these products is to combine them with dry high carbon, bulking agents, such as woodwaste, clean paper waste or straw. Moisture control can be the most difficult challenge. The addition of drier, high-carbon materials, the turning of windrows and the covering the piles are practices that help to adjust moisture levels.

Woodwaste
Adding carbonaceous material, such as sawdust, wood shavings or woodchips, is often advantageous to the composting of high nitrogen materials such as livestock manure. These materials bring up the C:N ratio to a more desirable level. Prior to composting, wet organic materials should be mixed with a dry material or bulking agent to reduce initial moisture content. Woodwastes also have the ability to absorb moisture and odours.
Bulking agents are usually necessary to increase the porosity of fine-textured materials such as poultry manure, as well as to absorb excess moisture. The amount of bulking agent needed may range from less than 1:1 (parts by volume) to more than 5 bulking agent to 1 part manure, depending on particle size and initial moisture content.

High moisture livestock manure can be dried to below 60 percent moisture content by blending finished compost or bulking agents such as sawdust or woodchips. The end product usually has final moisture content of 20 to 40 percent. Which can be recycled as a bulking agent.

**Fish Waste**

Fish waste is a high nutrient resource. Any type and grade of fish, mixed with a carbon source, can be turned into a high grade compost. Fish wastes are generally received and handled as a wet slurry, therefore, a relatively dry, high carbon substrate or bulking agent is required. Odour management can be a serious issue with fish wastes. Since most of the nitrogen in fish wastes are readily available, such wastes require a readily available carbon additive. Without it, the composting process will tend to generate an objectionable smell due to the release of ammonia gas. The end product of composted fish waste will be a high quality organic soil conditioner/fertilizer suitable for agricultural or residential use.

**Paper and Cardboard Waste**

Paper has a high carbon content and is moderately degradable. It has the ability to absorb moisture well, but has poor porosity and structure. Black inks are generally non-toxic, but large quantities of coloured inks are best avoided because of possible heavy metal content. Paper products may need shredding and sorting for effective handling. Odours may be a problem with some paper products such as gypsum wall board. In general, paper is a good to moderate amendment depending on the original structure of the compost mix.

Cardboard is also a high carbon source with good degradability properties. Its structure provides for good moisture absorption. Some shredding, storage and sorting may be needed. Staples may need to be removed and glues in corrugated cardboard may contain high boron levels. Waxed cardboard is compostable; however, management of the compost and odours can be a challenge. Extra caution should be taken when selecting cardboard for a composting operation.

When using paper or cardboard products, other factors must be considered. Whether the pulping process uses chlorine or is mechanical may affect its co-composting properties. When wet, paper and cardboard are not friable, hence a proper moisture content and a larger particle sizes of other composting materials are required. More frequent turning may be required to break up paper ‘balls’. B.C. Ministry of Environment, Lands and Parks’ approval under the *Production and Use of Compost Regulation* is required to use paper and cardboard waste.

**Other Non-Agricultural Wastes**

At the present time there are no other wastes which are considered to be of value as co-composting materials.

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This is one of a series of Factsheets on Composting. A list of references used in producing this series is included in the composting factsheet “Suggested Reading and References.”

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**FOR MORE INFORMATION CONTACT:**
RESOURCE MANAGEMENT BRANCH
Ministry of Agriculture & Food
1767 Angus Campbell Road
Abbotsford BC, CANADA  V3G 2M3
Phone: (604) 556-3100  Fax: (604) 556-3099
ECONOMICS OF COMPOSTING

Note: This factsheet was produced in January 1993, and the information has not been updated with this printing.

In order to develop a cost-effective composting facility, a number of factors must be carefully analyzed. The cost of a facility is largely dependent on three factors:

- the compost system chosen;
- the amount and type of manure composted; and
- the buildings constructed.

Compost Systems

The size and sophistication of a composting system are the basic factors affecting total investment cost. Sophistication is generally defined in terms of efficiency (length of active composting period), monitoring systems (ability to measure temperature, oxygen, and leachate), odour control mechanisms, labour requirements, and quality of buildings. Capital costs for a passive windrow system can be very low if an existing loader-equipped farm tractor is available. For a turned windrow system, an appropriate tractor and turner could easily cost $50,000 to $60,000. For aerated static pile systems, the cost of the aeration system including ducting, motors, fans and monitoring equipment represents a major capital cost; however, little costs are incurred for turning machinery. In-vessel systems have relatively high capital costs, given a typical requirement for buildings, concrete, internal agitation/aeration systems, and monitoring equipment.

Manure Type and Quantity

The capital investment and annual operating costs of a compost facility are directly related to both the type and quantity of manure composted. As the dry matter content of the manure increases, the amount of bulking agent that is required decreases. As a result, both capital and operating costs decrease. Operating costs decrease due to reduced need for bulking agent, labour and fuel. Capital costs decrease because smaller work areas and building sizes are required. Since bulking agents such as sawdust, can cost $12.00 to $13.00 per tonne of manure composted, any reduction in the amount used or price paid will have a significant affect on compost production costs. In cases where the dry matter content of the manure is low as in liquid manure systems, an additional investment in solid/liquid separators will be necessary.

Buildings

Compost operations are characterized by four distinct activities: mixing, composting, curing and storage. In many cases, all compost-related activities are completed in the open. However, for environmental and quality considerations, concrete pads and/or simple pole-type buildings may be required. For example an operation composting 1,000 tonnes of manure annually needs a work area of approximately 1,900 square metres (15,000 square ft.). If buildings are constructed for all four activities, total construction costs could be $125,000 to $150,000 for an operation of this size.

COMPOST PRODUCTION COSTS

Compost production costs can vary considerably, depending upon the total capital investment, price of bulking agents and labour, and annual production levels. As indicated in Table 1, production costs can range from $18.86 to $39.14/m³ ($36.00 to $70.00 per tonne), for a facility composting 2,000 tonnes of manure annually.
**TABLE 1**

COMPOST PRODUCTION COSTS

<table>
<thead>
<tr>
<th>Windrow Composting System</th>
<th>Basic Windrow&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Deluxe Windrow&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure Composted (tonnes)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Sawdust Required (tonnes)</td>
<td>1,360</td>
<td>1,360</td>
</tr>
<tr>
<td>Compost Produced (tonnes)</td>
<td>1,800</td>
<td>1,800</td>
</tr>
<tr>
<td>Total Investment</td>
<td>$40,000</td>
<td>$190,000</td>
</tr>
<tr>
<td>Production Cost (per cubic metre)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Efficiency&lt;sup&gt;d&lt;/sup&gt;</td>
<td>$20.16</td>
<td>$39.14</td>
</tr>
<tr>
<td>Low Efficiency&lt;sup&gt;e&lt;/sup&gt;</td>
<td>$18.86</td>
<td>$31.72</td>
</tr>
</tbody>
</table>

<sup>a</sup> Basic windrow system consists of a tractor and turner only.

<sup>b</sup> Deluxe windrow system consists of a tractor, turner, hard surface area and buildings for composting, curing and storage.

<sup>c</sup> 20% dry matter.

<sup>d</sup> Active compost period is 49 days.

<sup>e</sup> Active compost period is 21 days.

Compost production costs and related sensitivity analysis is summarized in Table 2. Based upon various operational assumptions incorporated within a base case scenario, compost production costs for the different options range from $13.96/m³ to $24.56/m³.

**COMPOST MARKETING**

Significant potential appears to exist for a composted manure product positioned as an organic soil conditioner in the bulk and retail markets.

The strong market potential reflects a need for substitute products in several market segments including retail sales, (nurseries, department grocery and hardware stores), agriculture (including the potentially large organic producer sector) and other bulk sales such as landscape contractors, wholesale nurseries, silviculture operations, and golf courses. An increasing emphasis by society on non-synthetic, environment-friendly products suggests a favourable growth trend in the markets identified.

In terms of volume of soil conditioners purchased on an annual basis, the largest retail market is the nursery segment, while the largest bulk market is the landscape contracting sector. Both of these groups indicate an interest in trying or evaluating proposed products.

In terms of accessibility, the market with the greatest potential is the B.C. market, particularly the Lower Mainland region. Composting plants located in the Fraser Valley area could market approximately 27.8 million litres of product by 1997.

In order to penetrate the markets identified, the finished composted product would have to be priced competitively with the leading soil conditioners presently available. Therefore, prices of 6.3 cents per litre and 5.3 cents per litre can be charged in the retail and bulk markets, respectively.

The marketing costs of the compost product are significant. The largest cost item would be transportation and handling, which is expected to absorb about 35% of the sales revenue generated each year. Bagging costs would also be significant, totalling about 30% of sales revenue. Other charges include sales force, advertising, and promotion costs.

For more information on the economics and marketing of the finished product, copies of the following reports may be obtained from the Resource Management Branch.

## TABLE 2
**COST OF PRODUCTION AND SENSITIVITY ANALYSIS OF ON-FARM COMPOSTING METHODS**

<table>
<thead>
<tr>
<th>Base Case Scenario: (2050 tonnes/yr manure + 1400 tonnes/yr bulking agent)</th>
<th>Windrow</th>
<th>Aerated Static Pile</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational Coefficients and Values</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Compost Produced</strong></td>
<td>(m³/year)</td>
<td>3,254</td>
</tr>
<tr>
<td></td>
<td>(tonnes/year)</td>
<td>1,806</td>
</tr>
<tr>
<td><strong>Labour</strong></td>
<td>(hours/year)</td>
<td>271</td>
</tr>
<tr>
<td><strong>Investment Level:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Buildings</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Mixing</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Compost</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Curing</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Aeration System</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total Investment</strong></td>
<td></td>
<td>$50,000</td>
</tr>
<tr>
<td><strong>Annual Operating Expenses</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td>$45,423</td>
</tr>
<tr>
<td><strong>Compost Production Costs</strong></td>
<td>$/m³</td>
<td>$13.96</td>
</tr>
<tr>
<td></td>
<td>$/tonne</td>
<td>$25.15</td>
</tr>
</tbody>
</table>

### Sensitivity Analysis

<table>
<thead>
<tr>
<th>Sensitivity Analysis</th>
<th>Change</th>
<th>New Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bulk Prices</strong> (Sawdust)</td>
<td>+ 25%</td>
<td>$5.43 / m³</td>
</tr>
<tr>
<td></td>
<td>- 25%</td>
<td>$3.26 / m³</td>
</tr>
<tr>
<td><strong>Manure Volume</strong></td>
<td>+ 25%</td>
<td>3,125 t/year</td>
</tr>
<tr>
<td></td>
<td>- 25%</td>
<td>1,875 t/year</td>
</tr>
<tr>
<td><strong>Labour Rate</strong></td>
<td>+ 25%</td>
<td>$15.00 / hour</td>
</tr>
<tr>
<td></td>
<td>- 25%</td>
<td>$9.00 / hour</td>
</tr>
<tr>
<td><strong>Fuel Price</strong></td>
<td>+ 25%</td>
<td>$0.75 / litre</td>
</tr>
<tr>
<td></td>
<td>- 25%</td>
<td>$0.45 / litre</td>
</tr>
<tr>
<td><strong>Manure-Dry Matter Content</strong></td>
<td>30%</td>
<td>$14.20</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>$14.66</td>
</tr>
<tr>
<td><strong>Price Range</strong></td>
<td>High</td>
<td>$15.97</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>$14.06</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>$11.95</td>
</tr>
</tbody>
</table>

<sup>a</sup> Pole-type buildings with open walls/galvanized steel roof.

<sup>b</sup> Includes bulking material, labour, fuel, electricity and investment costs (interest, depreciation, repair, and maintenance.)

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**FOR MORE INFORMATION CONTACT:**
RESOURCE MANAGEMENT BRANCH
Ministry of Agriculture & Food
1767 Angus Campbell Road
Abbotsford BC, CANADA V3G 2M3
Phone: (604) 556-3100 Fax: (604) 556-3099
USING COMPOST

INTRODUCTION

Compost is a homogenous and friable mixture primarily composed of stabilized (no longer decaying) organic matter. Composting is the biological decomposition of natural organic materials by soil organisms into stable organic matter. Compost improves the water-holding capacity, and stability of soils and allows for easier root penetration by plants. It may also reduce the need for commercial fertilizer.

Benefits

While composting reduces landfill waste volumes, the primary objective of any operation is to produce a high quality product in as cost-effective a way as possible, without creating a hazard or nuisance. This compost should be a rich humus that will benefit the soil and promote health in future crops.

The major reasons for applying compost are to provide plants with a supply of nutrients in a stable organic form; to make soil more porous, allowing water, air and plant roots to penetrate more readily; and to improve the water retention capability of soil. Compost can assist in the breaking up of heavy clay soils or binding together large particles in sandy soils. Compost should be well stabilized before use. Incompletely composted material can contain organic acids and other organic compounds which may be toxic to plants. Compost attracts earthworms that aerate the soil, improve drainage and bring up minerals from the subsoil for plants use.

Cautions

The presence of unwanted materials such as stones, glass, plastics, pathogenic bacteria, weed seeds, toxic compounds and heavy metals, detracts from high compost quality. More information on this subject is contained in Regulations Affecting Composting, Factsheet No. 382.500-12.

When using compost, particularly in potting mixes, several factors must be considered. These include:

- Salt Content;
- Nutrient Concentrations;
- C:N Ratio of Compost and Soil;
- Porosity;
- Metals Concentrations; and
- Maturity of Compost.

In most instances, compost should constitute no more than 50% by volume of potting soils.

Elevated levels of salt in composts can be toxic to plants. Addition of compost with a high salt content such as found in spent mushroom compost, should be applied with caution especially, to salt-sensitive plants.

Concentrations of plant nutrients in compost will also affect plant growth. Major elements (nitrogen, phosphorus and potassium) and minor elements are found in compost, usually at a low concentration.

The C:N ratio expresses the relative proportion of carbon (C) and nitrogen (N) in compost. For comparison, soil organic matter or humus usually has a C:N ratio of around 10:1. Table 1 shows the C:N ratios for a few finished products. A finished compost having a C:N ratio greater than its surrounding soil may use nitrogen from the soil, making this nitrogen unavailable for growing plants.

Stable organic matter, as found in finished compost, enables soil to hold more water through the enhanced
formation of soil aggregates, which provides more space for air. Lack of porosity reduces germination and increases surface crusting.

Concerns about heavy metals in compost are addressed in Regulations Affecting Composting, Factsheet No. 382.500-12. Refer to this paper for proposed metals concentration limits.

Ideally, several characteristics should be identified in finished or mature compost. These include:

- Freedom from pathogens and weed seeds.
- An adequate supply of at least some of the major nutrients and a variety of minor nutrients.
- A crumbly texture that allows air to penetrate, holds moisture, and allows excess water to drain away.
- Brown to black in colour.
- A sweet earthy odour
- Freedom from mould and rotten smells.
- Temperatures at ambient conditions without rising when restacked.
- A C:N ratio less than 25:1.
- A content of at least 30 to 50% organic matter.
- A pH between 5.0 and 8.0.

### TABLE 1

<table>
<thead>
<tr>
<th>Type</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Manure Compost</td>
<td>7:1 to 10:1</td>
</tr>
<tr>
<td>Fish Mortality Compost</td>
<td>25:1 to 35:1</td>
</tr>
<tr>
<td>Municipal Solid Waste Compost</td>
<td>7:1 to 25:1</td>
</tr>
<tr>
<td>Mushroom Media Compost</td>
<td>8:1 to 27:1</td>
</tr>
<tr>
<td>Pig on Litter Compost</td>
<td>23:1 to 43:1</td>
</tr>
<tr>
<td>Pig Manure Compost</td>
<td>12:1 to 35:1</td>
</tr>
<tr>
<td>Poultry Manure Compost</td>
<td>7:1 to 10:1</td>
</tr>
</tbody>
</table>

FERTILIZER

Composts contain little nitrogen (N), phosphorus (P) or potassium (K), meaning that the dry weight percentages of these elements are very low. Since most nitrogen is in an organic form, it is released gradually. This decreases the risk of immediate leaching and extends its availability during the growing season.

The ability of compost to supply nitrogen to crops will vary depending on the initial composition of the raw wastes, as well as on the type and duration of the composting process. Stabilization of wastes through effective composting reduces the carbon to nitrogen ratio. One way to assess the energy potential of organic residues is by looking at the ratio of carbon to nitrogen present in the residue. The higher the ratio, the greater the energy the materials contain, and the longer it will take microorganisms to digest. Fresh hay, fresh manure and compost have C:N ratios in the range of about 10:1 to 30:1, ideal for balancing the energy needs of the soil organisms with the nitrogen needs of the plants. Materials with C:N ratios less than 20 are considered to be fertilizers, while materials with ratios more than 30 are considered soil amendments.

Most of the plant nutrients in compost are not immediately soluble in water, but are released gradually. Composts allow for nutrients to be used more efficiently, reducing the amount of fertilizer that needs to be applied and the potential loss of soluble nutrients such as nitrate to groundwater. A typical breakdown of nutrients in manure derived compost is shown in Table 2. The pH of most solid waste compost ranges from 7.0 to 8.0, and its introduction to soil will have little or no effect on soil pH.

SOIL AMENDMENT

The beneficial effects of organic wastes on soil physical properties are evidenced by increased water infiltration, water-holding capacity, water content, aeration and permeability, soil aggregation and rooting depth, and by decreased soil crusting, soil bulk density and runoff by erosion.

Without regular addition of organic material to soils, there is a potential for increased leaching, erosion and gradual deterioration of soil physical properties. Moreover, as soil degrades, there is an accompanying decrease in crop use efficiency of fertilizer nutrients, especially nitrogen.
TABLE 2  TYPICAL NUTRIENT BREAKDOWN OF FINISHED COMPOST

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Dry Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>&lt;1% up to 4.5%</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.5% to 1%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.8% to 1%</td>
</tr>
<tr>
<td>Calcium</td>
<td>2% to 3%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2% to 3%</td>
</tr>
</tbody>
</table>

The C:N ratio of soil organic matter generally range from 12:1 to 20:1. Any compost or other organic waste material which has a C:N ratio greater than 30:1 may cause a reduction in plant-available nitrogen, and will supply carbon to the soil. Compost with C:N ratios below 20:1 will supply nitrogen to the soil.

Composts provide a more stabilized form of organic matter than raw wastes and can greatly improve the physical properties of soils. Addition of compost to sandy soils will increase their ability to retain water and render them less prone to drought. In heavy-textured clay soils, the added organic matter will increase permeability to air and increase its water infiltration capabilities, thereby minimizing surface runoff and increasing water storage. The addition of compost to clay soils may reduce soil compaction, lower its bulk density and increase rooting depth.

## RATE OF APPLICATION

The amount of compost applied depends on crop nitrogen requirement, field topography, climatic region, soil type, and nutrient composition of the finished compost. Land application rates of compost must meet the *Code of Agricultural Practice for Waste Management*.

Farmers frequently apply organic wastes (including compost) to their fields at rates that are too low or too high for maximum economic returns. When the rate is too low, soil physical properties are not sufficiently improved and the plant nutrient level is inadequate to sustain optimum crop growth and yield. If applied at excessive rates, plant nutrients are not utilized efficiently and contribute to environmental pollution via runoff and leaching. Crop yield responses to additions of organic materials are highly variable and again, is dependent upon the crop, soil type, climatic conditions, management system and organic material used. For acceptable agronomic application rates, nitrogen application from compost should match crop nitrogen removal. Example 1 illustrates calculations and assumptions in determining the amount of nitrogen available in compost.

### EXAMPLE 1

**Determine:** Compost application rate to supplying 200 kg of nitrogen. Given the following compost analysis:

- Total nitrogen (TKN) 1.59% (or 15,900 ppm)
- Mineral nitrogen (NH₄) 1562 ppm
- (NO₃) 672 ppm
- Bulk density of compost is 400 kg/m³

**Assume:**
- 50% loss of ammonia (NH₄-N) (based on research with manures, composts and biosolids)
- 20% of organic nitrogen is available in year of application (based on a range of 10 to 30% from research on composts and biosolids)

**Calculation:**

Total available nitrogen in the first year is: available organic + remaining ammonia + nitrate.

Total organic nitrogen = (TKN - NH₄) = 15,900 ppm - 1562 ppm =13,666 ppm

Available organic nitrogen = 13,666 ppm x 20% = 2733 ppm

Remaining NH₄ = 1562 x 50% = 781 ppm

Total available nitrogen = 2733 ppm + 781 ppm + 672 ppm = 4186 ppm (or 4.18 kg/tonne)

To obtain 200 kg N per ha apply (200 kg N/ha / 4.18 kg N/t) 47.8 tonnes compost per hectare or 47.8 tonnes/ha x 1000 kg/tonne x 1 m³/400 kg = 120 m³/ha

**Answer:** Therefore, 120 m³/ha of compost can be applied to supply the 200 kg N/ha.
COMPOST IN A MIX

Finished compost is considered to be humus, and composts are often used as part of a standard potting soil media. Potting media should generally contain a maximum of 50% compost by volume. Compost will benefit soil and greenhouse media by increasing its moisture-holding capacity and buffering capacity, and by providing a small amount of nutrients and essential trace elements. Some potting mixes include equal proportions of compost, sand and soil.

Spent mushroom compost has been researched as a growing medium additive in nursery container culture for a wide assortment of woody species. Mushroom compost cannot be used alone because of its lack of stability, its low water availability, its high salinity level and its neutral pH. It can, however, be used as part of a total compost component in a mix.

EXAMPLES OF USE

Compost has many uses and provides a number of agronomic benefits. The demand for compost is a function of price, availability, quality and, to some extent, service, education and promotion on the part of the producer. In areas where compost has been produced and used for a period of time, various markets and applications naturally evolve. The potential uses for compost are primarily in agriculture, land development and horticulture.

Agricultural

Advantages of field applied compost include:
- its use as an organic fertilizer for organic farmers;
- increased aeration and organic matter content;
- improved moisture and nutrient retention;
- decreased soil erosion and soil crusting;
- plant disease suppression; and
- improved tilth.

Land Development

Compost in land development applications are mostly used for:
- landscaping and golf courses maintenance, renovation and establishment of turf; and
- land reclamation for landfills and gravel pits.

Horticulture

Horticultural enterprises making use of compost are:
- greenhouses and nurseries;
- field growers and sod producers; and
- home gardeners.

Compost has been used as a substitute for peat moss in the production of bedding plants in the greenhouse industry and has performed well in the production of woody ornamental plants.

Sod cultivated on compost is of greater strength, equal in density and quality to conventional sod, and weighs 20 to 25% less than soil-produced sod.

Compost can also be used as a mulch for ornamental plants. It conserves moisture, increases pH and nutrient levels, decreases soil temperature, resists packing or matting, and reduces weed growth. These effects can last for more than one year.

Compost can be also used with other media, such as soil, perlite, and vermiculite for potted plants, turf or home gardens.

Compost also serves as an excellent additive to soils that may be poorly suited for agriculture. The increase in organic matter improves the soil water-holding capacity and reduces erosion by increasing its structural strength.

Compost Use for "Organic Producers"

Compost use by organic producers is referred to in the B.C. Organic Agricultural Products Certification Regulation, Operation Policies and Farm Standards Manual, Sections 2.7 and 4.2.8. These standards require written documentation of sources of off-farm materials used in on-farm composting activities. Certain composts are regulated, particularly those containing organic waste material derived from an industrial process including: abattoir waste; yeast fermentation waste; whey; hatchery waste; fish farm waste; mushroom compost; and paper and wood products.

Producers participating in organic certification programs should consult with their respective Certification Committees to determine acceptable methods and materials.
Home Gardener Use
For home gardeners, compost can be used in flower and vegetable gardens. A layer up to 7.5 cm or 3 inches thick should be spread on and mix well with garden soil. For house plant media mixes, finished compost should be mixed with equal parts soil and sand to make a nutrient rich potting soil. Screened compost can be used as part of a seed-starting mix or lawn top-dressing.

Other benefits of compost include its use in:
- for forest fertilization. This provides beneficial solutions to two complementary problems by: 1) disposing of excess organic waste, such as woodwaste, and 2) sustaining and increasing the productivity of our forests;
- greenhouse vegetable and flower production;
- flower bulb production;
- city park, sports field and recreation maintenance;
- field and row crop production; and
- fruit farming.
COMPOSTING

SUGGESTED READING AND REFERENCES

SOURCE OF INFORMATION

Olds College Composting Technology Center
4500 - 50 Street,
Olds, Alberta, T4R 1R6
Phone: (403) 556-4745, or (403) 556-4644
Fax: (403) 556-4608

The Composting Council of Canada
Suite 300, 200 MacLean Street,
Ottawa, Ontario, K2P 0L6
Phone: (613) 238-4014,
Fax: (613) 238-7559
Email: ccc@compost.org

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**COMPOSTING FACTSHEET SERIES PREPARED BY:**
Hog Producers Sustainable Farming Group;
Pacific Agricultural Research Centre (Agassiz),
Agriculture and Agri-Food Canada; and
Resource Management Branch, BCMAF

**FOR MORE INFORMATION CONTACT:**
RESOURCE MANAGEMENT BRANCH
Ministry of Agriculture & Food
1767 Angus Campbell Road
Abbotsford BC, CANADA V3G 2M3
Phone: (604) 556-3100 Fax: (604) 556-3099
GLOSSARY OF COMPOSTING TERMS

**Actinomycetes**: A group of microorganisms, intermediate between bacteria and true fungi, that usually produce a characteristic branched mycelium. These organisms are responsible for the earthy smell of compost.

**Aeration**: The process by which oxygen-deficient air in compost is replaced by air from the atmosphere. Aeration can be enhanced by turning compost.

**Aerator**: A machine used to create new passages for air and moisture in a compost pile or windrow.

**Aerobic**: An adjective describing an organism that can live only in the presence of oxygen (i.e., an aerobic organism).

**Aggregate, soil**: Many soil particles held in a single mass or cluster such as a clod, crumb, block or prism.

**Agricultural Wastes**: Wastes normally associated with the production and processing of food and fibre products on farms, feedlots, ranches and ranges. May include animal manure, crop residues and dead animals.

**Ambient Air Temperature**: The temperature of the air in the vicinity of a compost pile.

**Amendment, soil**: Any substance such as lime, sulphur, gypsum or sawdust used to improve the productive properties of a soil. Fertilizers are one type of soil amendment. However, many soil amendments such as soil conditioners, do not have significant fertilizer value.

**Ammonia (NH3)**: A gaseous compound comprised of nitrogen and hydrogen. Ammonia, which has a pungent odour, is commonly formed from organic nitrogen compounds during composting.

**Amorphous**: Having no definite shape or structure.

**Anaerobic**: An adjective describing an organism that can live or function in the absence of air or free oxygen, or a zone in the compost mass that is without oxygen.

**Backyard Composting**: The composting of organic solid waste, such as grass clippings, leaves or food waste at a residential dwelling site, where the waste is generated by the residents of the dwelling and/or neighbouring units.

**Bacteria**: A group of microorganisms having single-celled or non-cellular bodies.

**Biochemical Oxygen Demand (BOD)**: The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions, normally five days at 20°C unless otherwise stated. A standard test used in assessing the biodegradable organic matter in municipal wastewater.

**Biodegradable**: Subject to degradation by biochemical processes.

**Buffering Capacity**: The ability of the soil to resist changes in pH. Commonly determined by the presence of clay, humus and other colloidal materials.

**Bulk Density, Soil**: The mass of dry soil per unit of bulk volume, including the air space. Bulk volume is determined before drying. Drying is accomplished at 105°C until no change in weight occurs over time.

**Bulking Agent**: An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix, e.g., sawdust.

**C**: Chemical symbol for carbon.

**Carbohydrate**: Any compound containing only carbon, hydrogen and oxygen such as sugars, starches and cellulose.

**Carbon Dioxide (CO2)**: An inorganic gaseous compound comprised of carbon and oxygen. Carbon dioxide is produced by the oxidation of organic carbon compounds during composting.

**Carbon-to-Nitrogen Ratio (C:N)**: The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.
**Cation Exchange Capacity:** The total amount of exchangeable cations that a soil can adsorb. It is expressed in milliequivalents per 100 g of soil or of other adsorbing materials such as clay.

**Cellulose:** A long chain of tightly bound sugar molecules that constitutes the chief part of the cell walls of plants.

**Chemical Persistence:** That property of a chemical to remain in the environment essentially unchanged.

**Co-composting:** The composting of a mixture of two or more types of wastes, e.g., manure and yardwaste.

**Compost:** A group of organic residues, or a mixture of organic residues and soil, that have been piled, moistened and allowed to undergo biological decomposition.

**Composting:** The biological degradation or breakdown of organic matter by a managed process.

**Curing Area:** An area where organic material that has undergone the rapid initial stage of composting is further stabilized into a humus-like material.

**Damping-Off Disease:** The wilting and early death of young seedlings caused by a variety of pathogens.

**Decomposers:** The microorganisms and invertebrates that cause the normal degradation of natural organic materials.

**Digested Sewage Sludge (Biosolids):** Solids arising from sewage treatment which have been held in a properly designed and operated biological sewage treatment system, for a period of time sufficient to achieve at least 35 per cent reduction by weight in total volatile residue, and which has been dewatered to contain at least 10% solid material.

**Enzyme:** A protein molecule which acts as a catalyst for specific biochemical reactions.

**Erosion:** Wearing away of the land surface by running water, wind, ice or other geological agents.

**Evaporative Cooling:** Cooling that occurs when heat from the air or compost pile material is used to evaporate water.

**Fast Composting:** An intensive composting method that produces finished compost in one to two months. This method requires frequent turning to maximize aeration. When temperatures of 60°C (140°F) are achieved, a "thermal kill" of pathogens, or "partial sterilization" occurs.

**Fertilizer:** Any organic or inorganic material of natural or synthetic origin added to a soil to supply certain elements essential to the growth of plants.

**Fungus:** (Plural: **Fungi**) A group of simple plants that lack a photosynthetic pigment. The individual cells have a nucleus surrounded by a membrane, and may be linked together in long filaments called hyphae. The individual hyphae can grow together to form a visible body.

**Green Compost:** Materials mixed together to be composted.

**Green Manure:** Green plant material incorporated into the soil, to improve the soil qualities.

**Heavy Metals:** A group of metallic elements that include lead, cadmium, zinc, copper, mercury and nickel. Can be found in considerable concentrations in sewage sludge and several other waste materials. High concentrations in the soil can lead to toxic effects in plants, animals and humans ingesting plants or soil particles.

**Herbicides:** Agents used to inhibit plant growth or kill specific plant types.

**Humic Acids:** Chemical or biological compounds composed of dark organic substances that are precipitated upon acidification of a basic extract from soil.

**Humus:** Stable organic fraction of the soil matter remaining after the major portion of added plant and animal residues have decomposed. Humus is usually dark in colour, amorphous and relatively resistant to further rapid degradation.

**Inoculant:** The dried or inactive microorganisms that become active when added to the compost pile.

**Invertebrates:** An animal without a backbone or spine.

**K:** Chemical symbol for potassium.

**Leachate:** The liquid that results when ground or surface water contacts solid waste, and extracts material, either dissolved or suspended, from the solid waste.

**Leaching:** The removal of materials in solution from the soil by percolating waters.

**Lignin:** A substance that, together with cellulose, forms the woody cell walls of plants and the cementing material between them. Lignin is resistant to decomposition.

**Macronutrient:** Essential nutrient needed in relatively large amounts, e.g., nitrogen and potassium.
Manure: The fecal and urinary excretion of livestock and poultry. Sometimes referred to as livestock waste. This material may also contain bedding, spilled feed, water or soil. It may also include wastes not associated with livestock excreta, such as milking centre wastewater, contaminated milk, hair, feathers or other debris.

Mesophyllc Range: Operationally, that temperature range most conducive to the maintenance of optimum digestion by mesophyllc bacteria, generally accepted as between 21º-38ºC (70º-100ºF).

Microbe: See Microorganism.

Micronutrient: An essential nutrient needed in small amounts, e.g., boron, molybdenum. Also called a trace or minor element.

Microorganism: An organism requiring magnification for observation, e.g., a bacterium.

Moisture Content: The fraction or percentage of a substance comprised of water. Moisture content equals the weight of the water portion divided by the total water plus dry matter weight.

Mulch: A material spread over the soil surface to conserve moisture and porosity in the underlying soil to suppress weed growth. Grass clippings, compost, woodchips, bark, sawdust and straw are common mulch materials.

Municipal Solid Waste (MSW): Discarded materials, substances or objects excluding special hazardous, or biomedical wastes, which are collected or originate from residential, commercial, demolition, land clearing, construction, institutional and industrial sources, and which typically are discharged to municipal landfills. Municipal solid waste may include agricultural manure, and "digested sewage sludge".

Mycelium: Collective term for fungus filaments or hyphae. (See Fungus).

N: Chemical symbol for nitrogen.

Noxious Weeds: A group of weeds that physically harm cultivated plants by crowding them out.

Nutrient: A chemical element taken into a plant that is essential for growth, development or reproduction.

Nutrient-Holding Capacity: The ability of a medium to absorb and retain nutrients so that they will be available to the roots of plants.

Offal: Parts removed as waste from a carcass meant for food.

Organic Fertilizer: By-product from the processing of animal or vegetable substances that contain sufficient plant nutrients to be of value as fertilizers.

Organic Matter: Matter derived from living or once-living organisms that gradually can be broken down to yield important plant nutrients.

Oxidize: To chemically combine with oxygen.

P: Chemical symbol for phosphorus.

Pathogen: Any organism capable of producing disease or infection. Often found in waste material, most pathogens are killed by high temperatures in the composting process.

Peat: The unconsolidated soil material consisting largely of undecomposed, or only slightly decomposed, organic matter accumulated under conditions of excessive moisture.

Permeability, Soil: The ease with which gases, liquids or plant roots penetrate or pass through a bulk mass or layer of soil.

pH: A measure of the concentration of hydrogen ions in a solution. pH is expressed as a negative exponent. Thus, something that has a pH of 8 has ten times fewer hydrogen ions than something with a pH of 7. The lower the pH, the more hydrogen ions are present, and the more acidic it is. A pH of 7 is considered neutral. Compost decomposes fastest with a pH of around 6.5 (slightly acidic).

Phytotoxic: An adjective describing a substance that has a toxic effect on plants. Immature or anaerobic compost may contain acids or alcohols that can harm seedlings or sensitive plants.

Pollution: The presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment.

Porosity, soil: The percentage volume of total soil bulk not occupied by solid particles.

PTO: Power take off. Drive shaft and coupling on a tractor which transmits power from the tractor engine to implements and secondary equipment, such as, pumps, grinders, windrow turners.

Recipe: The ingredients and proportions used in blending together several raw materials for composting.

Red Worms: Eisenia fetidae, commonly known as red worms, are deep maroon in colour. They thrive only in manure or garbage and are rarely found in ordinary soils.
**Slow Composting:** A minimal-effort composting method that produces finished compost in a year or more. Slow composting requires little maintenance.

**Soil Compaction:** The disruption and reduction of the large pores within the soil.

**Soil Conditioner:** A soil additive that stabilizes the soil, improves its resistance to erosion, increases its permeability to air and water, improves its texture and the resistance of its surface to crusting, makes it easier to cultivate, or otherwise improves its quality.

**Soil Structure:** The combination or arrangement of primary soil particles into secondary particles, units or peds. Compost helps bind soil primary particles to improve the structure of the soil.

**Soil Texture:** A characterization of soil type, based on the relative proportions of sand, silt and clay in a particular soil.

**Stabilized:** An adjective describing compost that has at least passed through the thermophilic stage, and to a point that biological decomposition of the waste has occurred to a sufficient degree that the compost has beneficial value to plant growth. Stabilized compost can be stored, handled and used without giving rise to odour or self-heating problems, even if it should become wet.

**Thatch:** Dead and drying grass plant parts such as roots, stems and shoots, that accumulate above the soil surface.

**Thermophilic:** An adjective describing microorganisms that thrive in, and generate, temperatures between 45º-68ºC (113º-155ºF).

**Topdressing:** A layer of compost, or other material, applied to the surface of soil.

**Vermicomposting:** The process by which worms convert organic waste into worm castings.

**Volatilization:** Evaporation or the release of compounds into gaseous form.

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

**Woodwaste:** Includes hog fuel, mill ends, wood chips, bark and sawdust, but does not include demolition waste, construction waste, tree stumps, branches, logs or log ends.

**Worm Castings:** The dark, fertile, granular excrement of a worm. Granules are rich in plant nutrients.

**Yardwaste:** Vegetative matter resulting from gardening, horticulture, landscaping or land clearing operations, and includes materials such as tree and shrub trimmings, plant remains, grass clippings, trees, stumps and uncontaminated lumber from demolition operations.